

Energy Flow in Technological Systems

This worksheet reviews how energy is transformed and transferred in natural and technological systems, and how the laws of thermodynamics limit the amount of useful energy available after each conversion ([Outcome](#)). It also covers the mathematical description of mechanical energy, including kinetic energy, gravitational potential energy, and work ([Outcome](#)).

Exercises

1. Multiple Choice

Circle the best answer for each question.

a) Which statement best describes the first law of thermodynamics as applied to a technological device?

- A) Energy is created inside the device to perform work
- B) Energy is destroyed as it passes through the device
- C) Energy is conserved; it changes form but the total amount stays constant
- D) Energy only flows from cold objects to hot objects

b) Why is no real heat engine 100% efficient?

- A) Engines are always poorly built
- B) Some energy is always converted to non-useful thermal energy, consistent with the second law of thermodynamics
- C) Friction can be eliminated but engineers choose not to
- D) The first law of thermodynamics forbids full efficiency

c) Chemical energy stored in gasoline is an example of:

- A) Kinetic energy
- B) Potential energy
- C) Nuclear energy
- D) Radiant energy

2. Matching: Devices and Energy Transformations

Match each technological device on the left with the energy transformation it primarily performs, drawn from [Outcome](#) and [Outcome](#). Write the correct letter in the blank.

Device	Answer	Energy Transformation
1. Hydroelectric generator	_____	A) Chemical energy !' thermal energy !' mechanical energy
2. Solar heating panel	_____	B) Gravitational potential energy !' kinetic energy !' electrical energy
3. Automobile engine	_____	C) Radiant (solar) energy !' thermal energy
4. Fuel cell	_____	D) Chemical energy !' electrical energy

3. Mechanical Energy Calculations

Show all steps, including units, for each part ([Outcome](#)).

a) A 1200 kg car accelerates from rest to a velocity of 20 m/s. Calculate the kinetic energy of the car at 20 m/s.

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

Work space:

b) A 15 kg crate is lifted to a height of 4.0 m above the ground. Using $g = 9.81 \text{ m/s}^2$, calculate the gravitational potential energy gained by the crate.

$$E_p = mgh$$

Work space:

c) State, in one sentence, the relationship between the work done on an object and the change in its energy ([Outcome](#)).

4. Efficiency of a Thermal Power Plant

A thermal power plant supplies 5000 J of energy from burning fuel. Of this, 3200 J is converted into useful electrical energy; the rest is lost as waste heat ([Outcome](#)).

a) Calculate the efficiency of the plant, expressed as a percentage.

$$\text{Efficiency (\%)} = (\text{useful energy output} \div \text{total energy input}) \times 100$$

Work space:

b) Identify one reason, based on the second law of thermodynamics, why the efficiency cannot reach 100% ([Outcome](#)).

5. Short Answer: Historical Development of Thermodynamic Technology

Before the laws of thermodynamics were formally stated, engineers such as James Watt improved engine designs through trial and error ([Outcome](#)).

a) Explain how it was possible for engine technology to improve before the underlying scientific laws were understood.

b) Give one example of a pre-contact First Nations or Inuit technology that applied an understanding of thermal energy transfer, as described in [Outcome](#).

6. Tracing Energy Flow Through a System

Choose one technological system (for example: a bicycle coming to a stop, a refrigerator, or a heat pump) and describe the sequence of energy transformations that occur within it, from the initial energy input to the final useful output and waste losses ([Outcome](#), [Outcome](#)).

System chosen: _____

Energy flow (list each stage in order):

1. _____
2. _____
3. _____

4.

Identify which stage represents the greatest loss of "useful" energy, and explain why this loss occurs ([Outcome](#)).

Answer Key

1. a) C b) B c) B
2. 1-B, 2-C, 3-A, 4-D
3. a) $E_k = \frac{1}{2}(1200 \text{ kg})(20 \text{ m/s})^2 = 240\,000 \text{ J}$; b) $E_p = (15 \text{ kg})(9.81 \text{ m/s}^2)(4.0 \text{ m}) = 588.6 \text{ J}$; c) The change in energy of an object equals the work done on it ($\Delta E = W$).
4. a) Efficiency = $(3200 \text{ J} \div 5000 \text{ J}) \times 100 = 64\%$; b) Some energy is always converted to non-useful waste heat during energy conversion, as required by the second law of thermodynamics.
5. a) Answers will vary but should note that engineers used trial and error and practical observation to improve designs (e.g., valve improvements) without a formal theoretical understanding of thermodynamics; b) Answers will vary; accept any reasonable example such as pre-contact heating or food-storage technologies based on thermal energy transfer.
6. Answers will vary depending on the system chosen; responses should show a logical sequence of energy transformations, correctly identify the stage with the greatest useful-energy loss, and explain the loss in terms of the first and second laws of thermodynamics.