Heat on the Move

Compare energy accounting, heat flow, and performance.

PHY.3.8 "Enrichment: Research to compare the first and second laws of thermodynamics as related to heat engines, refrigerators, and thermal efficiency."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline statements about where energy goes, circle limits on what each machine can do, and number the two different ways the passage measures performance. Use your marks to compare the first and second laws.

A Freezer at the Market

1 At a weekend food market, a small generator runs a freezer. Inside the generator's engine, burning fuel heats gas. The hot gas pushes a piston, turning a shaft that supplies electrical power. The **first law of thermodynamics** says energy is conserved: energy entering the engine as heat becomes useful work and heat released to the surroundings. If 100 joules of heat enter and 30 joules become work, 70 joules leave as heat. The engine does not create energy. Its **thermal efficiency**, useful work divided by heat input, is 30 percent in this example.

2 The **second law of thermodynamics** adds a limit that conservation alone cannot explain. In a repeating heat-engine cycle, not all incoming heat can become work; some must pass to a cooler place. Heat also tends to move naturally from warmer objects to cooler ones. The engine's 70 joules of released heat are therefore not missing energy, and the 30 percent efficiency is not simply a bookkeeping choice. Even a carefully built engine cannot reach 100 percent thermal efficiency while operating between a hot source and a cooler sink. Friction and other real-world losses can reduce its efficiency further.

3 The freezer reverses the usual direction of heat transfer: it moves heat from cold food to the warmer market air. This requires work from the generator. Under the first law, the heat delivered to the air equals the heat removed from the freezer plus the work supplied to its cooling system. Under the second law, cold-to-warm heat transfer cannot happen continuously without work or another compensating change. A freezer is usually rated by a **coefficient of performance**, heat removed from the cold space divided by work input, not by an engine's thermal efficiency. That ratio can exceed one without creating energy.

2 ANSWER WITH EVIDENCE

Use the passage

1. Suppose the engine turns 40 of every 100 joules of input heat into work instead of 30. How much heat must leave the engine, and which law accounts for it?

2. A vendor claims that removing friction would let the repeating engine turn all its input heat into work. Which law rules this out, and why?

3. How does the second law limit the engine differently from the freezer?

4. A freezer has a coefficient of performance of 2. What does it remove for each joule of work, and why is that not 200 percent engine thermal efficiency?

3 YOUR TURN

Your own words

At a skating rink, an engine powers equipment that keeps the ice cold. In 80 to 110 words, propose a way to use the system's heat, compare what the first and second laws say about both machines, distinguish engine thermal efficiency from the cooling equipment's coefficient of performance, and name one measurement you would investigate to test your proposal.

ANSWER KEY

Heat on the Move

HIGH SCHOOL · PHY.3.8

PART 1 · READ AND MARK

Underline statements about where energy goes, circle limits on what each machine can do, and number the two different ways the passage measures performance. Use your marks to compare the first and second laws. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Suppose the engine turns 40 of every 100 joules of input heat into work instead of 30. How much heat must leave the engine, and which law accounts for it?	**60 joules must leave as heat. The first law requires the energy output to equal the 100 joules of input.**
2	A vendor claims that removing friction would let the repeating engine turn all its input heat into work. Which law rules this out, and why?	**The second law rules it out. A repeating heat engine must release some heat to a cooler place, even without friction.**
3	How does the second law limit the engine differently from the freezer?	**The engine must release some heat to a cooler place. The freezer needs work or another compensating change to move heat from cold food to warmer air.**
4	A freezer has a coefficient of performance of 2. What does it remove for each joule of work, and why is that not 200 percent engine thermal efficiency?	**It removes 2 joules of heat for each joule of work. That is heat moved divided by work input; engine thermal efficiency is work output divided by heat input.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would use heat from the rink's cooling equipment to warm nearby changing rooms instead of releasing it outdoors. The first law says that heat delivered to the rooms comes from heat removed from the rink plus work supplied to the cooler. It also requires the engine's incoming heat to equal its work plus rejected heat. The second law still requires work to move heat from the cold rink to warmer rooms, and the engine must reject some heat. The cooler's coefficient of performance measures heat removed per unit of work, not the engine's thermal efficiency. I would measure the changing rooms' heater energy use before and after the change.

Accept other feasible uses of rejected heat. The response should conserve energy in both devices, state both second-law limits, distinguish the two performance ratios, and identify a relevant measurement.