Energy efficiency: context-rich problems and a kettle practical

Name: Class: Date:

Page 1 has two context-rich problems. Work in a group of three if you can: a manager, a checker and recorder, and a sceptic who questions every step. Solve each problem in five steps. Page 2 is a practical that measures how much of an electric kettle's energy heats the water.

PROBLEM 1 Solar panels for the school hall

> You're on your school's energy team. The school wants solar panels on the hall roof to run the hall's lights and fans, which use 6 kW. The panels would cover 30 m^2 of the roof and come with a 25-year warranty, and the hall was built in 1962. On a clear day with the sun high, sunlight brings at most about 1.3 kW to each square metre (OpenStax). The panels are about 20% efficient, the top of the 15 to 20% that Your Home gives for monocrystalline cells. Will the panels supply enough power for the hall at midday on a clear day?

1 **Focus the problem:** What do you need to find? Which information do you need?

3 **Plan a solution:** Which calculations, in which order?

4 **Execute the plan:** Do the calculations. Show your working and units.

2 **Describe the physics:** Sketch a Sankey diagram: the energy in, the useful energy out and the wasted energy out.

energy in on the left

5 **Evaluate the answer:** does it make sense? When would the panels supply less?

PROBLEM 2 Heat from a spin class

> You're helping at a gym where 20 people ride exercise bikes in a 20-minute spin class, with the music turned up loud. The bikes' screens say each rider is putting out about 150 W of useful power. Cyclists turn about 20% of their food energy into useful work (OpenStax). The room is 12 m long, and the manager wants to know how much thermal energy the riders' bodies add to the room during the class, to check whether the air conditioner can cope.

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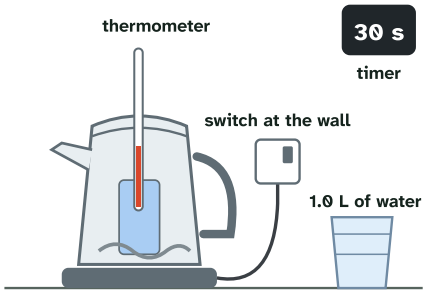
energy in on the left

5 **Evaluate the answer:** is all the energy accounted for? Where does the riders' useful work end up?

PRACTICAL How much of a kettle's energy heats the water?

Aim: To measure how much of the electrical energy an electric kettle uses ends up as thermal energy in the water, and to work out the kettle's efficiency.

Each group needs: an electric kettle with its power rating on its label, in watts; a measuring jug; cold tap water; a thermometer (a digital probe is best); a stopwatch or a phone timer.



Safety. Hot water and steam can scald. Your teacher may run this as a demonstration. Fill the kettle and use the thermometer only while it is switched off at the wall. Switch the kettle on and off at the wall, keep the cord away from the edge of the bench, don't lift the kettle while it is switched on, and stop heating at about 50 °C.

1. Write down the kettle's power rating from its label, in watts. If the label gives a range, such as 2000 to 2400 W, use the middle of the range.
2. Measure 1.0 L of cold tap water with the jug and pour it into the kettle. One litre of water has a mass of 1 kg (OpenStax).
3. Stir the water with the thermometer and record its starting temperature.
4. Close the lid, switch the kettle on at the wall and start the timer. Switch it off at the wall after exactly 30 s.
5. Open the lid, stir the water gently with the thermometer, and record the highest temperature it reaches.
6. Empty the kettle, let it cool for a few minutes, and repeat twice more with fresh cold water.

Trial	Starting temperature (°C)	Final temperature (°C)	Temperature rise (°C)	Energy supplied (J)	Energy to the water (J)	Efficiency (%)
1						
2						
3						
Average						

Energy supplied (J) = power rating (W) × time (s). Energy to the water (J) = 4186 × mass of water (kg) × temperature rise (°C), because it takes 4186 J to warm 1 kg of water by 1 °C (OpenStax). Efficiency = energy to the water ÷ energy supplied × 100%.

1. Work out the energy supplied, the energy to the water and the efficiency for each trial, and the average. Show your working for trial 1.

2. The law of conservation of energy says no energy was destroyed. Where did the rest of the electrical energy go? Name at least two places.

3. Sketch a Sankey diagram for your average trial, with the arrows' widths in proportion to the energies.

energy in on the left

4. Why might your three trials give different efficiencies? How could you make the measurement more reliable?