Year 11 Science: Thermal energy, heating and insulation

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How much energy is needed to heat 2.0 kg of water from 20 °C to 45 °C?

2. 9000 J of energy raises the temperature of a 0.5 kg metal block by 20 °C. Find its specific heat capacity and use the table to name the metal.

3. How much energy is needed to boil away 0.2 kg of water that is already at 100 °C?

4. 21 000 J is given to 0.25 kg of water. By how much does its temperature rise?

5. Explain why a puffer jacket keeps you warm, in terms of heat transfer.

Exam-style question: the hot water bottle

Sione fills a hot water bottle with 1.5 kg of water at 60 °C and puts it in his bed. Eight hours later the water is at 20 °C. The specific heat capacity of water is 4200 J kg^{-1} °C^{-1}.

6. Calculate the thermal energy the water gives out over the eight hours.

7. Calculate the average rate at which the bottle gives out energy, with a unit.

8. Sione's grandmother knits a thick woollen cover for the bottle. Discuss how the cover affects conduction, convection and radiation, and what this means for how long his bed stays warm.

Fix the mistake

9. Correct this statement: "Water heated from 20 °C to 70 °C: E = 0.5 × 4200 × 70."

10. Correct this statement: "Cold gets into the flask through the walls."

11. Correct this statement: "Hot air rises because heat rises."

12. Correct this statement: "While ice melts its temperature rises because energy is going in."

Answer key (for parents and tutors)

1. How much energy is needed to heat 2.0 kg of water from 20 °C to 45 °C?
   $\Delta T = 45 - 20 = 25$ °C; $E = mc\Delta T = 2.0 \times 4200 \times 25 = 210\,000$ J.
2. 9000 J of energy raises the temperature of a 0.5 kg metal block by 20 °C. Find its specific heat capacity and use the table to name the metal.
   $c = E \div (m\Delta T) = 9000 \div (0.5 \times 20) = 900$ J kg^{-1} °C^{-1}, so it is aluminium.
3. How much energy is needed to boil away 0.2 kg of water that is already at 100 °C?
   $E = mL = 0.2 \times 2\,260\,000 = 452\,000$ J.
4. 21 000 J is given to 0.25 kg of water. By how much does its temperature rise?
   $\Delta T = E \div (mc) = 21\,000 \div (0.25 \times 4200) = 20$ °C.
5. Explain why a puffer jacket keeps you warm, in terms of heat transfer.
   The filling traps lots of still air; air is a poor conductor because its particles are far apart, and trapped air cannot move to form convection currents, so heat leaves your body only slowly.
6. Calculate the thermal energy the water gives out over the eight hours.
   $\Delta T = 60 - 20 = 40$ °C; $E = mc\Delta T = 1.5 \times 4200 \times 40 = 252\,000$ J (Achieved for the right formula with numbers; Merit for the correct answer).
7. Calculate the average rate at which the bottle gives out energy, with a unit.
   8 hours = $8 \times 3600 = 28\,800$ s; $P = E \div t = 252\,000 \div 28\,800 = 8.75$ W, about 8.8 W (Excellence needs both calculations with units).
8. Sione's grandmother knits a thick woollen cover for the bottle. Discuss how the cover affects conduction, convection and radiation, and what this means for how long his bed stays warm.
   Achieved: the wool is an insulator so it keeps the heat in. Merit: wool traps air, which is a poor conductor, and the trapped air cannot move, so conduction and convection are reduced. Excellence: air particles are far apart, so they pass on kinetic energy slowly by collisions, and air held still in the fibres cannot rise and carry heat away; the cover's outer surface also stays cooler, so less infrared is radiated. The water still gives out about 252 000 J as it cools to 20 °C, but over a longer time, so the power is lower and the bed stays warm for longer.
9. Correct this statement: "Water heated from 20 °C to 70 °C: $E = 0.5 \times 4200 \times 70$."
   Use the change in temperature, $\Delta T = 70 - 20 = 50$ °C, not the final temperature.
10. Correct this statement: "Cold gets into the flask through the walls."
    There is no such thing as cold flowing; heat (thermal energy) always moves from the hotter object to the colder one.
11. Correct this statement: "Hot air rises because heat rises."
    Heated air particles move faster and spread apart, so the air becomes less dense than the air around it and rises.
12. Correct this statement: "While ice melts its temperature rises because energy is going in."
    The temperature stays at 0 °C while it melts; the energy goes into breaking the fixed arrangement of particles, not speeding them up.