4.2 Energy transfers by particles

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS convection • bimetallic strip

Objective

Build the skills to answer exam questions on **heat transfer and expansion** : conduction, convection, evaporation and condensation, what changes the rate of energy transfer, and expansion with the bimetallic strip.

You must be able to:

- explain conduction in metals and non-metals, and convection in fluids
- explain evaporation and condensation with particles
- explain how temperature difference, surface area and materials change the rate of energy transfer
- explain expansion and the bimetallic strip

1 Key knowledge and worked examples

■ Heat transfer

idea	equation or rule
conduction	vibrating particles pass energy to their neighbours; in metals, free electrons carry energy quickly; non-metals and gases are poor conductors (insulators)
convection	in liquids and gases: heated fluid expands, becomes less dense and rises; cooler, denser fluid sinks; this makes a convection current
evaporation	the fastest particles escape from the surface, so the liquid left behind cools; faster when warmer, with a larger surface area or with wind
condensation	a gas touching a cold surface cools and turns back into a liquid
rate of transfer	faster with a bigger temperature difference, a larger surface area (fins), and a thinner or better-conducting material
expansion	solids, liquids and gases expand when heated, because the particles move or vibrate more
bimetallic strip	two metals that expand by different amounts are joined; when heated, the strip bends with the metal that expands more on the outside

Worked example 1: temperature difference. A cup of tea at 80 °C cools by 3 °C a minute in a 20 °C room. Estimate how fast it cools at 50 °C.

1. Known: temperature difference 60 °C gives 3 °C per minute.
2. Rule: the rate of cooling is about proportional to the temperature difference.
3. Numbers: at 50 °C the difference is 30 °C, half as big.
4. Result: **about 1.5 °C per minute**.

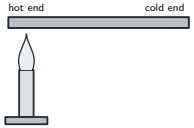
Worked example 2: a bimetallic strip. A strip of brass and steel is heated. Brass expands more than steel. Which way does it bend?

1. Known: brass expands more than steel.
2. Rule: the metal that expands more goes on the outside of the curve.
3. Apply: brass becomes longer than steel, so the strip curves away from the brass side.
4. Result: **it bends with brass on the outside**.

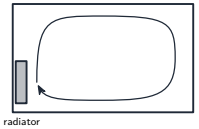
Answer shapes: in a particle explanation, say what the particles do and what that changes, e.g. “less dense, so it rises”.

2 Practice

2.1 Explain why metals are good thermal conductors. [2]



2.2 A radiator is fixed to the wall of a cold room. Explain how it heats the air in the whole room. [2]



2.3 An Arctic fox has small ears. A desert fox has very large ears. Explain how the size of the ears helps each fox. [2]



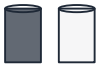
3 Exam-style questions

3.1 Wet clothes dry faster on a warm, windy day. Explain why, using ideas about particles. [3]



3.2 A student fills two cans with 0.30 kg of hot water each. One can is painted matt black and the other is shiny silver. She records the temperature of the water every 2 minutes.

(a) Calculate the average rate of cooling of each can over the 10 minutes. Which surface is the better emitter of infrared? [3]



time / min	0	2	4	6	8	10
black / °C	80	72	65	59	54	50
silver / °C	80	76	72	69	66	63

(b) Give two variables she must keep the same. [2]

(c) Calculate the energy transferred from the water in the black can in the 10 minutes. Calculate the average power. ($c = 4200$ J/kg °C) [3]

(d) Explain why each can cools more slowly as time goes on. Then describe how a hot-water tank can be designed to keep the water hot. [6]

Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- metals have free electrons
- the electrons move through the metal and carry energy quickly to the cold end

2.2

- air near the radiator is heated, expands, becomes less dense and rises
- cooler, denser air sinks to take its place, making a convection current round the room

2.3

- large ears have a large surface area, so the desert fox loses energy quickly and stays cool
- small ears have a small surface area, so the Arctic fox loses less energy and stays warm

3.1

- water evaporates when the fastest particles escape from the surface
- at a higher temperature, more particles have enough energy to escape
- wind carries away the water vapour, so fewer particles return to the clothes

3.2

(a) black: $30 \div 10 = \mathbf{3.0}\,^\circ\text{C/min}$; silver: $17 \div 10 = \mathbf{1.7}\,^\circ\text{C/min}$; **matt black** is the better emitter

(b) any two: starting temperature, volume or mass of water, size of can, room temperature, lid or no lid

(c) $E = 0.30 \times 4200 \times 30 = \mathbf{37\,800}$ J; $P = 37\,800 \div 600 = \mathbf{63}$ W

(d) points to include:

- the rate of cooling depends on the temperature difference with the room
- as the water cools, the difference gets smaller, so it cools more slowly
- a thick layer of insulation, e.g. foam that traps air, reduces conduction and convection
- a shiny outer surface emits less infrared
- a lid stops evaporation and convection from the top
- a small surface area for its volume reduces energy loss

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.