Exercise walk-through

Transfer of thermal energy ▪ 2.3

eXercise

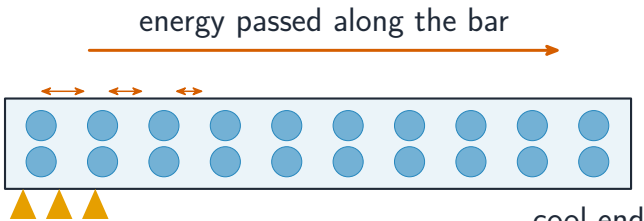
You must be able to

- explain conduction (and why metals are good conductors)
- explain convection currents in fluids
- describe thermal radiation and good/poor emitters

Method — Three transfer methods

- **conduction:** energy passed by vibrating particles; metals conduct best (free electrons).
- **radiation:** infrared waves, no material needed; dull-black surfaces emit/absorb best.

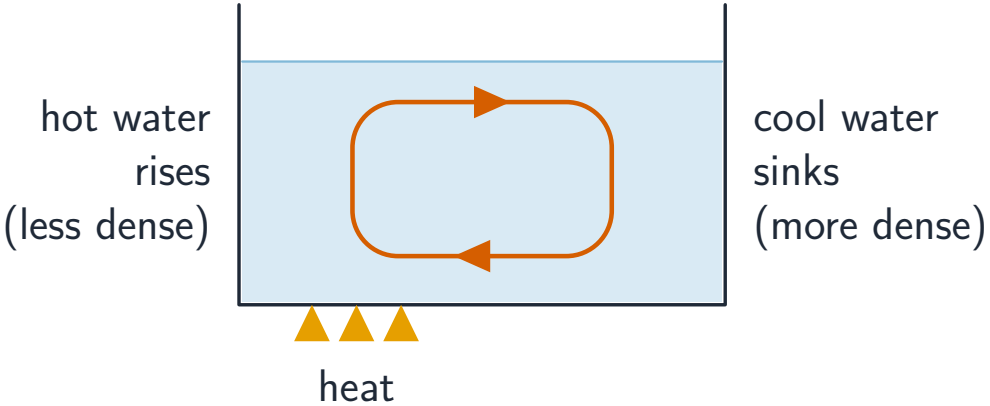
Method — Three transfer methods



particles vibrate more at the hot end and pass the energy to their neighbours

A heated metal bar passing energy from the hot end to the cool end

Method — Three transfer methods



A beaker heated from below: hot water rises, cool water sinks

Method — Doing the experiments, and the Earth's balance

Comparing conductors. Fix a drawing pin with a little wax to one end of rods of copper, iron, glass and wood and heat the other ends equally. The pin drops first from the copper, then the iron, and last or never from the glass and wood. Metals win because free electrons carry energy as well as the vibrating **lattice 晶格**; gases and most liquids conduct badly because their particles are far apart and exchange energy only when they collide.

Showing convection. Drop a crystal of purple potassium permanganate into a beaker of water and heat gently below it: a coloured stream rises above the heat, spreads across the top and sinks at the sides. Explain it by density: heated fluid expands, so the same mass fills a larger volume, its density falls and it rises; cooler, denser fluid sinks to replace it.

Comparing emitters and absorbers. Fill a dull black can and a shiny silver can with hot water at the same temperature: the black one cools faster, so it is the better

Method — Doing the experiments, and the Earth's balance

emitter. Fill both with cold water and place them equally far from a heater: the black one warms faster, so it is the better absorber. The rate of emission is greater when the surface is **hotter** and when it is **larger**.

The Earth's temperature. The Earth absorbs radiation from the Sun and emits infrared back into space. Its average temperature stays constant only while the two rates are equal: absorb faster and it warms, emit faster and it cools. Greenhouse gases in the atmosphere absorb some of the emitted infrared and send part back down, so more of them means a warmer Earth.

Everyday examples. A kitchen pan has a metal base (conduction into the food) and a plastic handle (an insulator). A radiator warms a room by convection. You feel a fire's radiation at once, because radiation needs no material. A vacuum flask blocks all three: the vacuum stops conduction and convection, the shiny surfaces stop radiation.

Practice 2.1 ▪ 1 mark

State why metals are good conductors of thermal energy.

Solution 2.1

Method: Doing the experiments, and the Earth's balance

Worked steps

they contain free (delocalised) electrons that carry energy quickly B1.

Practice 2.2 ▪ 1 mark

State which surface is the best emitter of infrared radiation.

Solution 2.2

Method: Doing the experiments, and the Earth's balance

Worked steps

a dull, black surface B1.

Practice 2.3 ▪ 3 marks

Describe an experiment to show which of two solids is the better thermal conductor.

Solution 2.3

Worked steps

Fix a drawing pin to one end of each rod with wax (B1); heat the other ends equally (B1); the pin on the better conductor falls first, because energy reaches its end sooner (B1).

Practice 2.4 ▪ 2 marks

Explain, in terms of density, why heated water rises in a beaker.

Solution 2.4

Method: Doing the experiments, and the Earth's balance

Worked steps

Heated water expands, so the same mass occupies a larger volume and its density falls B1; the less dense water floats up through the denser water around it B1.

Practice 2.5 ▪ 2 marks

State two factors that increase the rate at which a surface emits radiation.

Solution 2.5

Method: Doing the experiments, and the Earth's balance

Worked steps

A higher surface temperature B1 and a larger surface area B1. (A duller, blacker surface also emits faster.)

Exam-style 3.1 ▪ 1 mark

Convection cannot take place in a solid because:

A solids have no particles

B the particles cannot move from place to place

C solids are too cold

D solids do not conduct

Solution 3.1

Method: Doing the experiments, and the Earth's balance

A solids have no particles

B the particles cannot move from place to place ✓

C solids are too cold

D solids do not conduct

Worked steps

B. In a solid the particles vibrate in fixed positions and cannot move from place to place.

Exam-style 3.2 ▪ 3 marks

A beaker of water is heated at the bottom.
(a) Explain how a convection current forms.
(b) State why heating at the top would not set up a convection current.

Solution 3.2

Worked steps

(a) the water at the bottom is heated, expands and becomes less dense M1; it rises, and cooler, denser water sinks to replace it M1; this circulation is a convection current A1.

(b) hot (less dense) water would already be at the top, so there is nothing to make it rise — no current forms B1.

Exam-style 3.3 ▪ 2 marks

Two metal cans are filled with hot water; one is dull black and one is shiny silver. State and explain which cools faster.

Solution 3.3

Method: Doing the experiments, and the Earth's balance

Worked steps

(a) Conduction and convection both need particles B1; the vacuum has almost none, so neither can carry energy across the gap B1.
(b) Shiny silver surfaces are poor emitters, so little infrared leaves the inner wall B1, and they are good reflectors, so radiation crossing the gap is reflected back B1.
(c) Plastic is a poor conductor, so little energy is conducted out through the stopper B1; a metal stopper would conduct energy away quickly B1.
(d) Evaporation from the surface, or convection of the warm air above it B1; put a lid on the mug B1.

Exam-style 3.3 ▪ 2 marks

A vacuum flask keeps a hot drink hot. It has double glass walls with a vacuum between them, and both glass surfaces are silvered.
(a) Explain how the vacuum reduces the energy lost by conduction and by convection.
(b) Explain how the silvered surfaces reduce the energy lost by radiation.
(c) The stopper is plastic. Explain why plastic is used rather than metal.
(d) A student leaves the same drink in an open metal mug. State the main way energy leaves the surface of the drink, and one way to reduce it.

Solution 3.3

Method: Doing the experiments, and the Earth's balance

Worked steps

(a) Conduction and convection both need particles B1; the vacuum has almost none, so neither can carry energy across the gap B1.
(b) Shiny silver surfaces are poor emitters, so little infrared leaves the inner wall B1, and they are good reflectors, so radiation crossing the gap is reflected back B1.
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Exam-style 3.4 ▪ 1 mark

The Earth absorbs radiation from the Sun and emits infrared radiation into space.
(a) State the condition for the average temperature of the Earth to stay constant.
(b) Explain how an increase in greenhouse gases raises the average temperature.
(c) A dark tarmac road and the air above it both become hotter on a sunny day.
Explain how the road gets hot, and how the air above it then gets hot.

Solution 3.4

Method: Doing the experiments, and the Earth's balance

Worked steps

(a) It absorbs energy at the same rate as it emits it B1.
(b) Greenhouse gases absorb some of the infrared emitted by the Earth B1 and re-emit part of it back towards the surface, so less energy escapes and the Earth warms until the rates balance again B1.
(c) The road absorbs radiation from the Sun, and a dull black surface is a good absorber, so its temperature rises B1; the air touching the road is warmed by conduction B1; that warmed air expands, becomes less dense and rises, carrying energy upwards by convection while cooler air moves in B1.