Exercise walk-through

Thermal equilibrium ▪ 14.1

eXercise

You must be able to

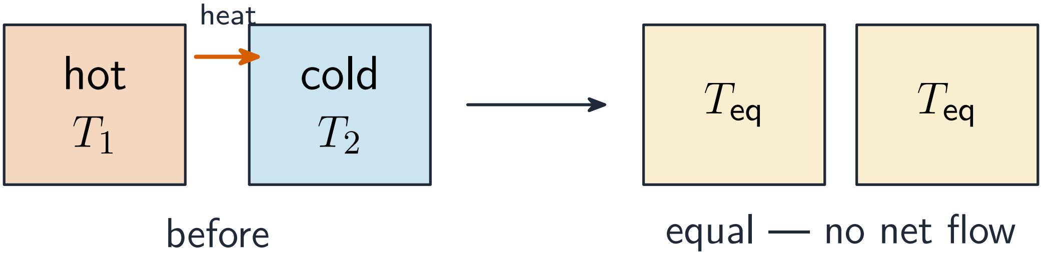
- state that thermal energy flows from **higher** to **lower** temperature
- explain **thermal equilibrium** and that temperature is not the same as thermal energy

Method — Heat flow and equilibrium

Thermal energy flows from **hot to cold**. When two bodies touch, energy moves until their temperatures are equal — **thermal equilibrium**, with **no net** energy flow:
Temperature decides the **direction** of flow — it is **not** how much thermal energy a body holds. A cup of boiling water holds far less energy than a warm swimming pool, but heat still flows **from** the cup **to** a cooler object.

energy flows hot $\to$ cold until T equal

Method — Heat flow and equilibrium



Heat flows until thermal equilibrium

Practice 2.1 ▪ 1 mark

State the direction in which thermal energy flows.

Solution 2.1

Method: Heat flow and equilibrium

Worked steps

From a region of **higher temperature** to a region of **lower temperature** B1.

Practice 2.2 ▪ 2 marks

State what is meant by **thermal equilibrium**.

Solution 2.2

Method: Heat flow and equilibrium

Worked steps

Two bodies are at the **same temperature** B1, so there is **no net flow** of thermal energy between them B1.

Practice 2.3 ▪ 1 mark

Two objects at the **same temperature** are in contact. State the **net** flow of energy between them.

Solution 2.3

Method: Heat flow and equilibrium

Worked steps

Zero (no net flow) **B1**.

Exam-style 3.1 ▪ 2 marks

State what is meant by two objects being in **thermal equilibrium**.

Solution 3.1

Method: Heat flow and equilibrium

Worked steps

They are at the **same temperature** **B1**, so there is **no net transfer** of thermal energy between them **B1**.

Exam-style 3.2 ▪ 2 marks

Explain why a small cup of boiling water ($100\ ^\circ$C) may hold **less** thermal energy than a swimming pool at $25\ ^\circ$C.

Solution 3.2

Method: Heat flow and equilibrium

Worked steps

Temperature shows the **direction** of heat flow, not the amount of energy stored B1; the pool has a far greater **mass**, so it can hold more total thermal energy despite its lower temperature B1.

Exam-style 3.3 ▪ 1 mark

Thermal energy flows from object A to object B. This tells you that:

- **A** A is at a higher temperature than B
- **B** B is at a higher temperature than A
- **C** A and B are at the same temperature
- **D** A contains more thermal energy than B

Solution 3.3

Method: Heat flow and equilibrium

A A is at a higher temperature than B ✓

B B is at a higher temperature than A

C A and B are at the same temperature

D A contains more thermal energy than B

Worked steps

A — A is at a higher temperature than B.

Exam-style 3.4 ▪ 2 marks

Two blocks, P and Q, are made of the same metal. P has mass 0.50 kg and is at 80 °C; Q has mass 1.5 kg and is at 20 °C. They are placed in contact inside a perfectly insulating box.

(a) **State**, with a reason, the direction of the net flow of thermal energy at the moment they touch.

(b) **Explain**, in terms of the molecules, what "thermal equilibrium" means for these two blocks, and what is true of their temperatures when it is reached.

(c) The specific heat capacity of the metal is 390 J kg^{-1} K^{-1}. **Determine** the final temperature of the two blocks.

(d) **State and explain** whether the two blocks hold equal amounts of internal energy once they are in thermal equilibrium.

Solution 3.4

Method: Heat flow and equilibrium

Worked steps

(a) From **P to Q** B1, because P is at the higher **temperature**, and thermal energy always flows from the hotter body to the colder one B1.
(b) Their molecules collide at the boundary and transfer energy, and on average energy passes from the block whose molecules have the greater mean kinetic energy B1. At thermal equilibrium there is **no net** flow of energy either way B1, and the two blocks are at the **same temperature** B1.
(c) Energy lost by P = energy gained by Q, so
$0.50 \times 390 \times (80 - \theta) = 1.5 \times 390 \times (\theta - 20)$ M1. The specific heat capacity cancels:

Solution 3.4

$0.50(80 - \theta) = 1.5(\theta - 20)$, so $40 - 0.5\theta = 1.5\theta - 30$ **M1** and $\theta = \dfrac{70}{2.0} = 35\ ^\circ\mathrm{C}$ **A1**.

(d) **No** **B1**. They are at the same temperature, so their molecules have the same **mean** kinetic energy, but Q has three times the mass and therefore three times as many molecules, so it holds about three times the internal energy **B1**.