A-LEVEL PHYSICS • EXERCISE SHEET

14.1 Thermal equilibrium

Name: ____________ Class: ________ Date: __________ **Total: 19 marks**

KEY WORDS temperature 温度 • thermal equilibrium 热平衡 • thermal energy 热能 • heat 热量 • energy 能量

Objective

Build the skills to answer exam questions on **thermal equilibrium**.

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

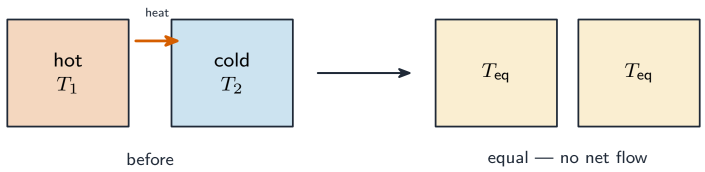
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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:

energy flows hot → cold until T equal



Heat flows until thermal equilibrium

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.

2 Practice

Now apply the methods above.

2.1 State the direction in which thermal energy flows. [1]

2.2 State what is meant by **thermal equilibrium**. [2]

2.3 Two objects at the **same temperature** are in contact. State the **net** flow of energy between them. [1]

3 Exam-style questions

3.1 State what is meant by two objects being in **thermal equilibrium**. [2]

3.2 Explain why a small cup of boiling water (100 °C) may hold **less** thermal energy than a swimming pool at 25 °C. [2]

3.3 Thermal energy flows from object A to object B. This tells you that: [1]

- **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

3.4 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. [2]

(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. [3]

(c) The specific heat capacity of the metal is 390 J kg^{-1} K^{-1}. **Determine** the final temperature of the two blocks. [3]

(d) **State and explain** whether the two blocks hold equal amounts of internal energy once they are in thermal equilibrium. [2]

Solutions

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

2.1

- from a region of **higher temperature** to a region of **lower temperature**

2.2

- two bodies are at the **same temperature**
- so there is **no net flow** of thermal energy between them

2.3

- **zero** (no net flow)

3.1

- they are at the **same temperature**
- so there is **no net transfer** of thermal energy between them

3.2

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

3.3 A

- A is at a higher temperature than B, so thermal energy flows **A → B**
- **B** would reverse the flow; **C** equal temperatures; **D** confuses energy stored with temperature

3.4

(a) from **P to Q**

- because P is at the higher **temperature**, and thermal energy always flows from the hotter body to the colder one

(b) their molecules collide at the boundary and transfer energy; on average energy passes from the block whose molecules have the greater mean kinetic energy

- at thermal equilibrium there is **no net** flow of energy either way
- the two blocks are at the **same temperature**

(c) energy lost by P = energy gained by Q

$$(0.50\ \text{kg})(390\ \text{J kg}^{-1}\,\text{K}^{-1})(80-\theta)\ {}^\circ\text{C} = (1.5\ \text{kg})(390\ \text{J kg}^{-1}\,\text{K}^{-1})(\theta-20)\ {}^\circ\text{C}$$

- c cancels: $0.50(80-\theta) = 1.5(\theta-20)$

$$40 - 0.5\theta = 1.5\theta - 30 \Rightarrow \theta = \frac{70}{2.0} = \mathbf{35}\ {}^\circ\text{C}$$

(d) **no**

- 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