

Exercise walk-through

14.1

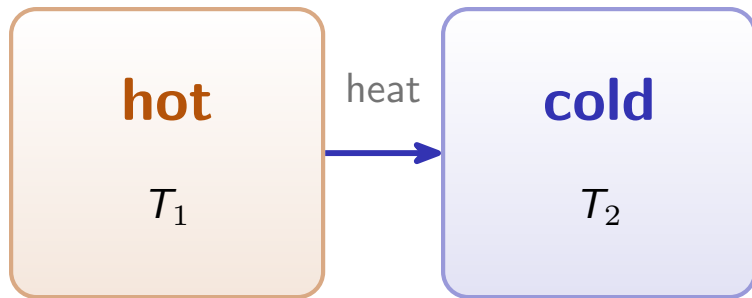
Thermal equilibrium

A-Level Physics

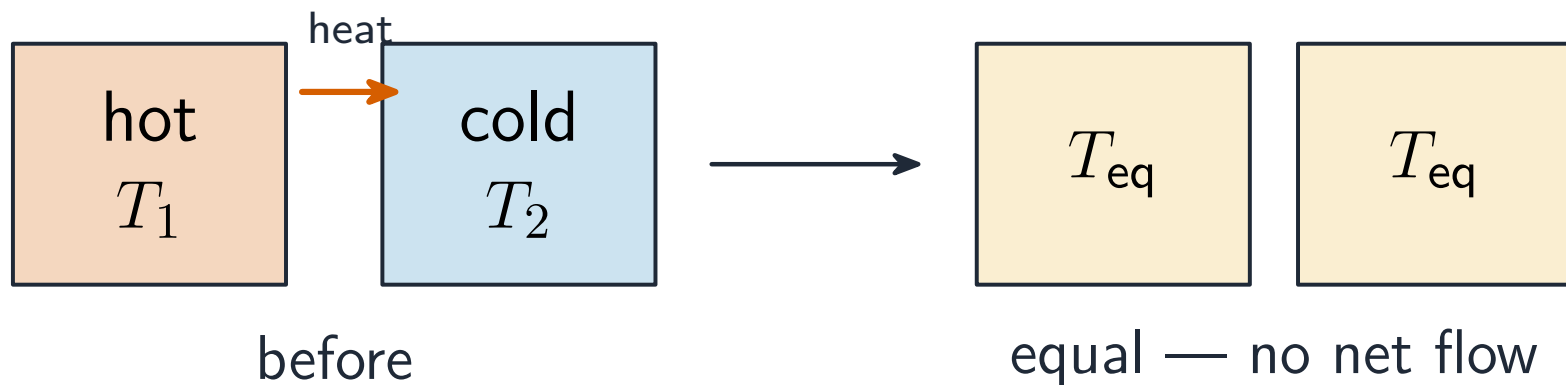
Thermal equilibrium

Two bodies in contact exchange energy until they reach the same **temperature** – **thermal equilibrium**. Heat flows from the hotter to the colder. Once they match, the net flow is zero.

A thermometer works because it comes to equilibrium with whatever it touches – so it must be small enough not to change that temperature.



What equilibrium means



Net energy flows from hot to cold until the two are at the **same temperature** – that is what a thermometer waits for before it reads.

At **thermal equilibrium** there is **no net** flow of energy between the bodies – they are at the same temperature, not necessarily holding the same energy.

Temperature is not energy

Temperature fixes the **direction** of heat flow.
It does **not** say how much **thermal energy** a body holds.

A cup of water at 100°C holds far **less** energy than a pool at 25°C – but metal dropped in the cup **gains** energy, and in the pool **loses** it.



hotter,
less energy



cooler,
far more energy

Exercises 2.1-2.3

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]

Exercises 2.1-2.3

2.1 State the direction in which thermal energy flows.

[1]

2.1

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

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

[2]

2.2

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

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

[1]

2.3

- **zero** (no net flow)

Exercises 3.1·3.2

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

[2]

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

[2]

Exercises 3.1·3.2

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

[2]

3.1

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

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

[2]

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

Exercise 3.3

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

Exercise 3.3

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

3.3 A

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

Exercise 3.4 (a)

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]

Exercise 3.4 (a)

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]

(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

Exercise 3.4 (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.

(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]

Exercise 3.4 (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.

(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]

(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**

Exercise 3.4 (c)

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.

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

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

(c) energy lost by P = energy gained by Q, i.e. $m_P c \Delta\theta_P = m_Q c \Delta\theta_Q$

$$m_P c \Delta\theta_P = m_Q c \Delta\theta_Q$$

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

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

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

Exercise 3.4 (d)

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.

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

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(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