

4.2 Thermal energy transfers (full B.1)

Name: _____ Class: _____ Date: _____

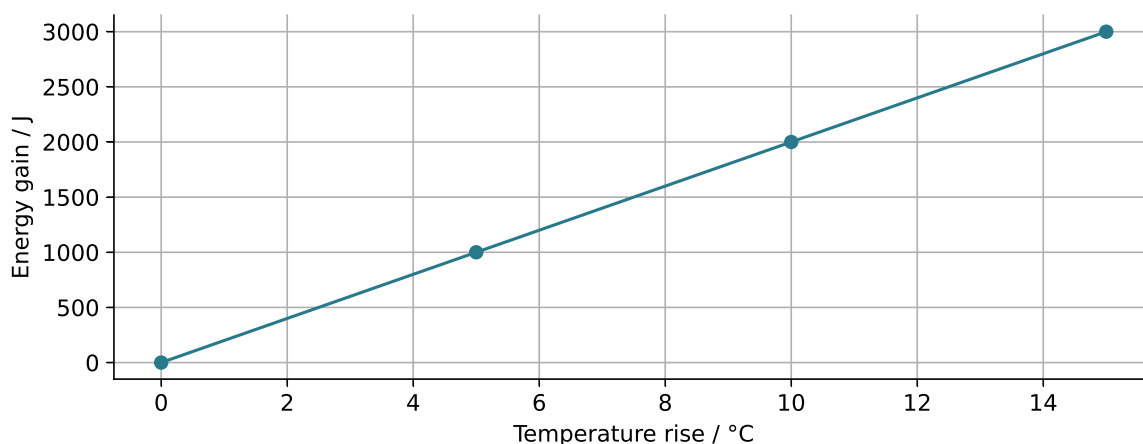
Total: 25 marks

KEY WORDS internal energy • specific latent heat • emissivity

Objective

Practise the full guide B.1 toolkit: Kelvin temperature and mean kinetic energy ($E_k = \frac{3}{2} k_B T$), $Q = mc\Delta T$ and $Q = mL$, the conduction rate $\Delta Q/\Delta t = kA\Delta T/\Delta x$, Stefan–Boltzmann $L = \sigma AT^4$ with apparent brightness $b = L/4\pi d^2$, Wien's $\lambda_{\max} T = 2.9 \times 10^{-3} \text{ m} \cdot \text{K}$, and emissivity. Original practice; not an official IB paper.

1 Key knowledge and worked examples



■ The B.1 equation set

$$E_k = \frac{3}{2} k_B T \quad Q = mc\Delta T \quad Q = mL \quad \frac{\Delta Q}{\Delta t} = \frac{kA\Delta T}{\Delta x}$$

$$L = \sigma AT^4 \quad b = \frac{L}{4\pi d^2} \quad \lambda_{\max} T = 2.9 \times 10^{-3} \text{ m} \cdot \text{K} \quad \text{emissivity} = \frac{\text{power per unit area}}{\sigma T^4}$$

Worked check. A star radiates like a black body of radius $7.0 \times 10^8 \text{ m}$ at 5800 K :
 $L = 5.7 \times 10^{-8} \times 4\pi(7.0 \times 10^8)^2 \times 5800^4 \approx 4 \times 10^{26} \text{ W}$.

2 Practice

2.1 Convert 27 °C to kelvin, and a change of 45 K to Celsius degrees. [2]

2.2 Calculate the mean kinetic energy of a gas molecule at 300 K ($k_B = 1.38 \times 10^{-23}$ J/K). [2]

2.3 0.50 kg of water cools from 80 °C to 30 °C ($c = 4186$ J/(kg · K)). Calculate Q. [2]

2.4 A metal rod ($k = 50$, $A = 2.0 \times 10^{-4}$ m², length 0.40 m) has ends 100 K apart. Calculate the conduction rate. [3]

2.5 A black body's spectrum peaks at 970 nm. Calculate its temperature. [2]

3 Exam-style questions

3.1 A 1.2 kW heater warms 2.0 kg of ice at 0 °C. Calculate the energy to melt the ice ($L_f = 3.34 \times 10^5$ J/kg), the further energy to reach 25 °C, and the minimum total heating time. [5]

3.2 A planet orbits a star of luminosity 4.0×10^{26} W at a distance of 1.5×10^{11} m. Calculate the apparent brightness, and the power incident on the planet's cross-section (πR^2 , $R = 6.4 \times 10^6$ m). [5]

3.3 A radiator surface (2.0 m^2 , 340 K) has emissivity 0.80 . Calculate the power radiated, and compare it with a black body at the same temperature. [4]
