4.2 Thermal energy transfers (full B.1)

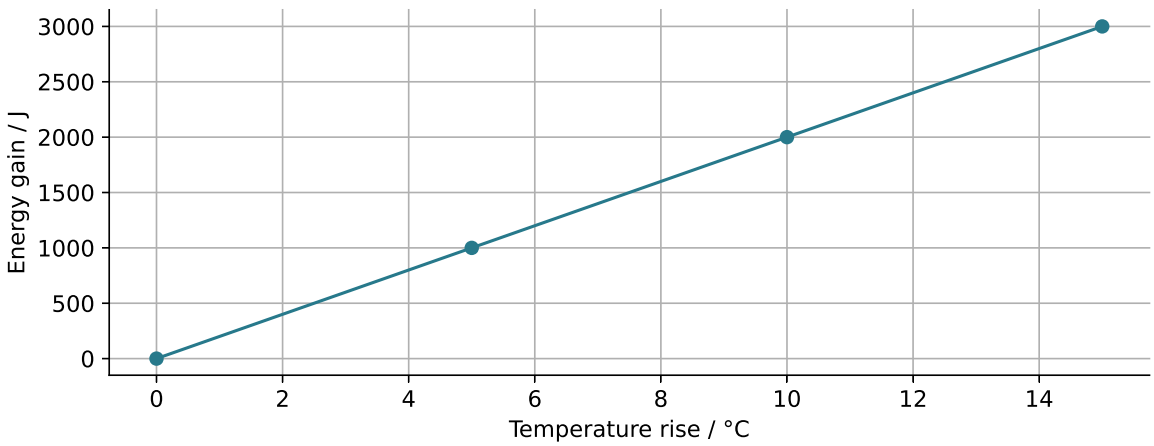
Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS internal energy • specific latent heat • emissivity

Objective

Practise the full guide B.1 toolkit: Kelvin temperature and mean kinetic energy (E_k = 3/2 k_B T), Q = mcΔT and Q = mL, the conduction rate ΔQ/Δt = kAΔT/Δx, Stefan–Boltzmann L = σAT^4 with apparent brightness b = L/4πd^2, Wien's λ_max T = 2.9×10^{-3} m · K, and emissivity. Original practice; not an official IB paper.

1 Key knowledge and worked examples



■ **The B.1 equation set**

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

$$L = \sigma A T^4 \qquad b = \frac{L}{4\pi d^2} \qquad \lambda_{\max} T = 2.9\times10^{-3}\ \mathrm{m\cdot K} \qquad \text{emissivity} = \frac{\text{power per unit area}}{\sigma T^4}$$

Worked check. A star radiates like a black body of radius 7.0×10^8 m at 5800 K: $L = 5.7\times10^{-8}\times4\pi(7.0\times10^8)^2\times5800^4 \approx 4\times10^{26}$ 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 = 2.0×10^{-4} m^2, 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 = 6.4×10^6 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]