B.1 Thermal energy transfers

Practice Worksheet — name: ________________________ date: _____________

FORMULAS FOR THIS TOPIC

DENSITY $\rho = \frac{m}{V}$ AVERAGE PARTICLE KE $\bar{E}_k = \frac{3}{2} k_B T$ SPECIFIC HEAT CAPACITY $Q = mc\Delta T$

LATENT HEAT $Q = mL$ CONDUCTION RATE $\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$ STEFAN–BOLTZMANN LAW $L = \sigma A T^4$

APPARENT BRIGHTNESS $b = \frac{L}{4\pi d^2}$ WIEN'S DISPLACEMENT LAW $\lambda_{\max} T = 2.9 \times 10^{-3}$ m K

SECTION A — MULTIPLE CHOICE

A1. Ice at 0 °C melts to water at 0 °C. During melting, the thermal energy supplied goes to:

- A Increasing the average kinetic energy of the molecules
- B Increasing the potential energy of the molecules
- C Increasing both kinetic and potential energy equally
- D Increasing the temperature of the water

A2. Star X has twice the surface temperature and half the radius of star Y. The ratio of luminosities L_X/L_Y is:

- A 1
- B 2
- C 4
- D 8

A3. A metal spoon and a wooden spoon are both at room temperature. The metal one feels colder because:

- A Metal is at a lower temperature
- B Metal has a higher specific heat capacity
- C Metal conducts thermal energy away from the hand faster
- D Wood radiates more energy than metal

SECTION B — SHORT ANSWER

B1. A 0.50 kg block of ice at 0 °C is added to 2.0 kg of water at 25 °C. Determine whether all the ice melts. ($c_{water} =$ 4200 J kg^{-1}K^{-1}, $L_f = 3.3 \times 10^5$ J kg^{-1}) [4 marks]

B2. The spectrum of a star peaks at 290 nm. Calculate its surface temperature and state the assumption made. [3 marks]

B3. Explain, in terms of particles, how thermal energy is conducted along a metal rod heated at one end. [3 marks]

ANSWER KEY

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Section A

A1: Increasing the potential energy of the molecules — Temperature — and hence average kinetic energy — is constant during a phase change. The latent heat does work against intermolecular forces, raising the molecules' potential energy as the solid structure breaks.

A2: 4 — $L = \sigma A T^4 = 4\pi R^2 \sigma T^4$. Ratio: $(R_X/R_Y)^2 (T_X/T_Y)^4 = (1/2)^2 \times 2^4 = \frac{1}{4} \times 16 = 4$. The fourth-power temperature dependence dominates.

A3: Metal conducts thermal energy away from the hand faster — Both are at the same temperature; your skin senses the rate of energy loss, not temperature itself. Metal's much higher thermal conductivity k gives a larger $\Delta Q/\Delta t$ from your hand.

Section B

B1: Energy to melt all ice: $Q = mL = 0.50 \times 3.3 \times 10^5 = 1.65 \times 10^5$ J. Maximum energy available cooling water to 0 °C: $Q = 2.0 \times 4200 \times 25 = 2.1 \times 10^5$ J. Since $2.1 \times 10^5 > 1.65 \times 10^5$, all the ice melts, and the remaining 4.5×10^4 J warms the mixture slightly above 0 °C.

B2: Wien's law: $T = \frac{2.9 \times 10^{-3}}{290 \times 10^{-9}} = 1.0 \times 10^4$ K. Assumption: the star radiates as a black body (emissivity ≈ 1).

B3: Particles at the hot end gain kinetic energy and vibrate with larger amplitude; collisions pass this energy to neighbouring particles progressively along the rod. In metals, free electrons also migrate and transfer energy rapidly through collisions, which is why metals conduct far better than insulators.