

IB Physics – Theme B: The Particulate Nature of Matter

IB Physics SL & HL · Total marks: 39 · Answers on the last page

Practice questions covering thermal energy transfers, the gas laws, thermodynamics (some parts HL only, marked), and current and circuits from IB Physics Theme B. A calculator is required; take the specific heat capacity of water as $4180 \text{ J kg}^{-1}\text{K}^{-1}$, the specific latent heat of fusion of ice as 334000 J kg^{-1} , and the molar gas constant as $R = 8.31 \text{ J mol}^{-1}\text{K}^{-1}$.

Section A – Thermal Energy Transfers

1. A 0.50 kg sample of water is heated from 15°C to 40°C . Calculate the thermal energy required, in kJ . [3]
2. Calculate the energy required to melt 0.20 kg of ice at 0°C , giving your answer in kJ . [2]
3. 0.20 kg of ice at 0°C is converted completely into water at 20°C . Calculate the total thermal energy required, in kJ . [4]
4. Using the particle (kinetic) model of matter, explain why the temperature of a substance remains constant while it is melting, even though thermal energy is continuously being supplied. [3]

Section B – Gas Laws (Calculator required)

5. A gas sample of 2.0 mol occupies a volume of 0.050 m^3 at a temperature of 300 K . Use the ideal gas equation $pV = nRT$ to calculate the pressure of the gas. [3]
6. A fixed mass of gas at constant volume has pressure $1.0 \times 10^5 \text{ Pa}$ at a temperature of 300 K . The gas is heated to 450 K . Calculate the new pressure. [3]
7. Using the kinetic model of an ideal gas, explain why the pressure of a fixed mass of gas increases when its temperature is increased at constant volume. [3]
8. A gas occupies a volume of $2.0 \times 10^{-3} \text{ m}^3$ at a pressure of $1.5 \times 10^5 \text{ Pa}$. It is compressed at constant temperature until its volume is $1.2 \times 10^{-3} \text{ m}^3$. Calculate the new pressure. [3]

Section C – Thermodynamics (HL) and Circuits (Q9 and Q12 are HL only)

9. (HL) In one cycle, 500 J of thermal energy is added to a gas, and the gas does 200 J of work on its surroundings as it expands. Use the first law of thermodynamics to find the change in internal energy of the gas. [3]
10. Two resistors, $R_1 = 6 \Omega$ and $R_2 = 3 \Omega$, are available.
 - (a) Find the equivalent resistance when they are connected in series.
 - (b) Find the equivalent resistance when they are connected in parallel. [4]
11. A battery of EMF 12 V and internal resistance 0.5Ω is connected to an external resistor of 5.5Ω .
 - (a) Calculate the current in the circuit.
 - (b) Calculate the terminal potential difference of the battery. [4]
12. (HL) A heat engine takes in 800 J of thermal energy from a hot reservoir each cycle and expels 500 J to a cold reservoir.

- (a) Calculate the useful work done by the engine per cycle.
- (b) Calculate the efficiency of the engine, giving your answer as a percentage. [4]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

1. $Q = mc\Delta T = 0.50 \times 4180 \times 25 = 52250 \text{ J} = 52.3 \text{ kJ}$.
2. $Q = mL_f = 0.20 \times 334000 = 66800 \text{ J} = 66.8 \text{ kJ}$.
3. Energy to melt: 66800 J. Energy to heat water from 0°C to 20°C : $0.20 \times 4180 \times 20 = 16720 \text{ J}$.
Total = 83520 J = 83.5 kJ.
4. During melting, the energy supplied is used to break the intermolecular bonds holding particles in fixed positions in the solid lattice (increasing potential energy), rather than to increase the average kinetic energy of the particles, so the temperature (which depends on average kinetic energy) stays constant.
5. $p = \frac{nRT}{V} = \frac{2.0 \times 8.31 \times 300}{0.050} = 9.97 \times 10^4 \text{ Pa}$.
6. $\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow P_2 = 1.0 \times 10^5 \times \frac{450}{300} = 1.5 \times 10^5 \text{ Pa}$.
7. Increasing temperature increases the average kinetic energy (and hence speed) of the gas molecules. This means molecules collide with the container walls more frequently and with greater momentum change per collision, increasing the average force per unit area, i.e. the pressure.
8. By Boyle's law, $P_1 V_1 = P_2 V_2 \Rightarrow P_2 = \frac{1.5 \times 10^5 \times 2.0 \times 10^{-3}}{1.2 \times 10^{-3}} = 2.5 \times 10^5 \text{ Pa}$.
9. $\Delta U = Q - W = 500 - 200 = 300 \text{ J}$ (the internal energy increases by 300 J).
10. (a) $R_{\text{series}} = 6 + 3 = 9 \Omega$.
(b) $R_{\text{parallel}} = \frac{6 \times 3}{6 + 3} = 2.0 \Omega$.
11. (a) $I = \frac{\varepsilon}{R + r} = \frac{12}{5.5 + 0.5} = 2.0 \text{ A}$.
(b) $V = \varepsilon - Ir = 12 - (2.0)(0.5) = 11 \text{ V}$.
12. (a) $W = Q_H - Q_C = 800 - 500 = 300 \text{ J}$.
(b) Efficiency = $\frac{W}{Q_H} = \frac{300}{800} = 0.375 = 37.5\%$.

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