OCR A A Level Thermal Physics 1 solutions

Matching solutions and teaching prompts for the class review

Specification points covered

- 5.1.1(a) Define thermal equilibrium.
- 5.1.1(b) Understand that the absolute thermodynamic scale is independent of the property of any particular substance.
- 5.1.1(c-d) Measure temperature in °C and K, and use T(K) = θ(°C) + 273.
- 5.1.2(a-c) Describe solids, liquids and gases using particle spacing, ordering and motion; use kinetic models; describe and explain Brownian motion.
- 5.1.2(d-g) Define internal energy; understand absolute zero; explain changes in internal energy during heating and phase change.
- 3.2.4(a) Define and use density, ρ = m / V. (Module 3 retrieval)

Teaching focus

Model the precise language throughout: quantities increase, decrease or stay constant; particles move, collide or vibrate.
For Brownian motion, pupils must link a random, haphazard visible path to unequal collisions from much smaller air molecules.

1. Absolute temperature and thermal equilibrium

1. The asteroid sample is initially at -43 °C. Convert this temperature to kelvin. [1 mark]

Answer / mark points: T = -43 + 273 = 230 K.

Teacher prompt / common error: Use T(K) = θ(°C) + 273; kelvin values do not use a degree symbol.

2. The coolant controller displays 315 K. Convert this temperature to °C. [1 mark]

Answer / mark points: θ = 315 - 273 = 42 °C.

Teacher prompt / common error: Subtract 273. Credit 42 °C, not 42 K.

3. A technician claims that 40 °C is twice 20 °C. Use absolute temperature to evaluate this claim. [2 marks]

Answer / mark points: 20 °C = 293 K and 40 °C = 313 K. The ratio is 313 / 293 = 1.07, not 2, so the claim is false.

Teacher prompt / common error: Temperature ratios must use kelvin. Comparing the Celsius numbers gives a meaningless ratio.

4. Define thermal equilibrium. [1 mark]

Answer / mark points: Two systems are in thermal equilibrium when they are at the same temperature and there is no net thermal energy transfer between them.

Teacher prompt / common error: Require both ideas in the definition: same temperature and no net transfer.

2. Energy transfer and the particle model

5. The outer chamber wall is at 320 K and the sample canister is at 250 K. State the direction of net thermal energy transfer and the condition needed for the net transfer to become zero. [2 marks]

Answer / mark points: Net thermal energy transfers from the hotter outer wall to the colder canister. The net transfer becomes zero when they reach the same temperature (thermal equilibrium).

Teacher prompt / common error: Thermal energy transfers from higher temperature to lower temperature; avoid saying that 'cold moves'.

6. The kelvin scale is an absolute thermodynamic scale. State what is meant by this. [1 mark]

Answer / mark points: Its temperatures do not depend on the thermometric property of any particular substance; the scale is referenced to absolute zero.

Teacher prompt / common error: The key idea is independence from any one material or thermometer property.

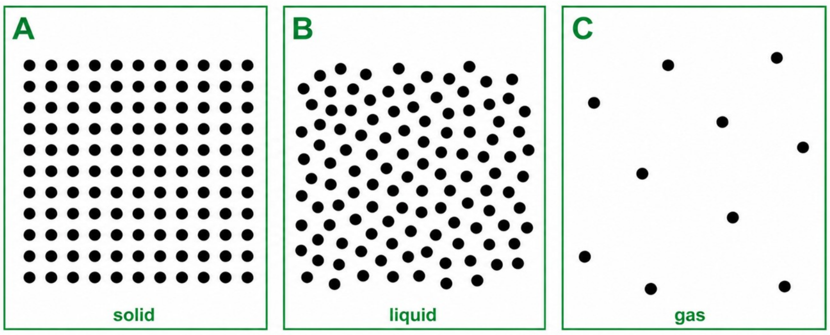

Figure 1: identified particle arrangements

7. Figure 1 shows three particle arrangements. Identify the state of matter represented by A, B and C. [3 marks]

Answer / mark points: A is a solid, B is a liquid and C is a gas.

Teacher prompt / common error: Use the spacing and ordering shown: close/ordered, close/disordered, widely spaced.

8. Describe the arrangement and motion of the particles in the solid asteroid sample. [2 marks]

Answer / mark points: The particles are closely packed in a regular ordered arrangement. They vibrate about fixed positions.

Teacher prompt / common error: Do not accept 'the particles are fixed'. Their positions are fixed, but the particles vibrate.

9. Describe the arrangement and motion of the particles in the liquid coolant. [2 marks]

Answer / mark points: The particles are close together but have no regular arrangement. They move randomly and can move past one another, so the liquid can flow.

Teacher prompt / common error: Liquid particles are still close together. They are not widely separated as in a gas.

10. Use the particle model to explain why the gas in a filled test chamber takes the shape and volume of the chamber, whereas the liquid coolant has a fixed volume. [2 marks]

Answer / mark points: Gas particles are far apart and move freely throughout the available space, so the gas fills the chamber. Liquid particles remain close together because of intermolecular attraction, so the liquid keeps a fixed volume even though its particles can move past one another.

Teacher prompt / common error: A complete explanation distinguishes both spacing and freedom of motion.

3. Heat transfer in the test chamber

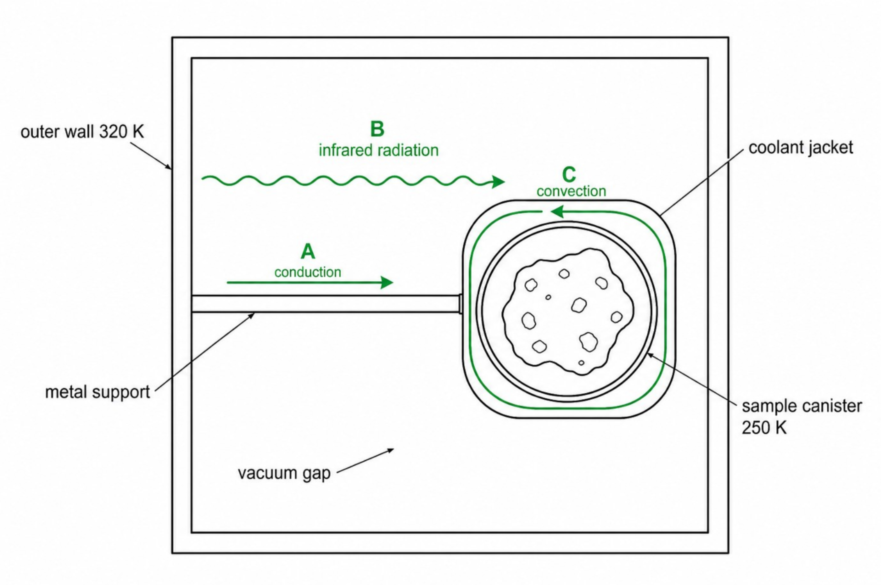

Figure 2: named energy-transfer processes

11. Figure 2 shows three energy-transfer processes in the test chamber. Name the process represented by A, B and C. [3 marks]

Answer / mark points: A: conduction through the metal support. B: infrared radiation across the vacuum. C: convection in the liquid coolant.	
Teacher prompt / common error: A acts through a solid, B crosses empty space and C is bulk circulation of a fluid.	

12. Explain why conduction and convection cannot transfer energy across the vacuum gap, but process B can. [2 marks]

Answer / mark points: Conduction and convection require particles, so they cannot occur through a vacuum. Infrared radiation is an electromagnetic wave and can travel through a vacuum.	
Teacher prompt / common error: Conduction and convection need matter. Infrared radiation does not.	

13. Explain how the circulating current shown by C can form in the liquid coolant. Use density in your answer. [3 marks]

Answer / mark points: Coolant warmed in one region expands and becomes less dense, so it rises. Cooler coolant is denser and sinks. The repeating rise and fall produces a convection current.	
Teacher prompt / common error: The causal chain must be clear: heating -> expansion -> lower density -> rise; cooling -> greater density -> sink.	

4. Density and evidence for the particle model

14. The asteroid sample has mass 1.84 kg and volume 6.80×10^{-4} m^3. Calculate its density. [2 marks]

Answer / mark points: $\rho = m / V = 1.84 / (6.80 \times 10^{-4}) = 2.71 \times 10^3$ kg m^{-3}.	
Teacher prompt / common error: Expect the equation, substitution and kg m^{-3}. The result is about 2710 kg m^{-3}.	

15. The coolant has density 1050 kg m^{-3}. A test uses 3.20 litres of coolant. Calculate the mass of coolant. 1 litre = 1.00×10^{-3} m^3. [2 marks]

Answer / mark points: $V = 3.20 \times 10^{-3}$ m^3. $m = \rho V = 1050 \times 3.20 \times 10^{-3} = 3.36$ kg.	
Teacher prompt / common error: The most common error is failing to convert litres to m^3 before using SI density.	

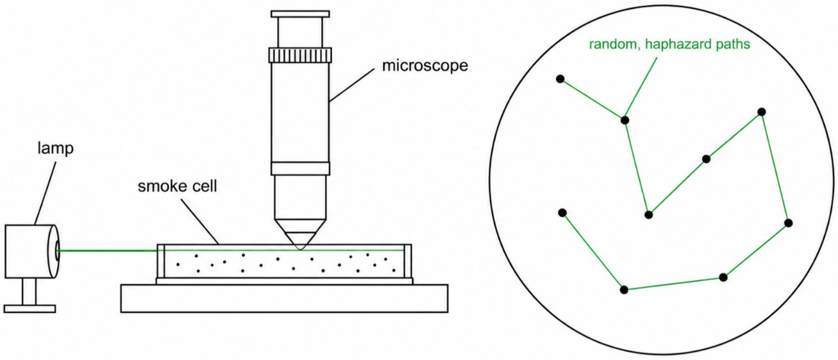

Figure 3: the observed paths are random and haphazard

16. Figure 3 shows the tracked paths of two smoke particles at equal time intervals. Describe the pattern of motion using two precise words. [1 mark]

Answer / mark points: The paths are random and haphazard.	
Teacher prompt / common error: Require both words: random and haphazard. Do not replace them with 'vibrating'.	

17. Explain what causes the observed motion of the smoke particles. [3 marks]

Answer / mark points: The visible smoke particles receive unequal collisions from different sides by much smaller, rapidly and randomly moving air molecules. The resultant impact changes the direction of each smoke particle, producing its random, haphazard path.	
Teacher prompt / common error: The observed objects are smoke particles, not air molecules. Require collisions with much smaller air molecules and unequal impacts from different sides.	

5. Internal energy and absolute zero

18. Define the internal energy of a system. **[2 marks]**

Answer / mark points: Internal energy is the sum of the random kinetic energies and intermolecular potential energies of the particles in the system.

Teacher prompt / common error: 'Thermal energy stored' is not a definition. Both random kinetic energy and potential energy are required.

19. The solid sample is first warmed from 250 K to 280 K without changing state. It is then heated while it melts at constant temperature. For each stage, describe the changes in the particles' average random kinetic energy and intermolecular potential energy, and hence the change in internal energy. **[4 marks]**

Answer / mark points: While the solid warms, the average random kinetic energy increases, the vibration amplitude increases and the internal energy increases; the intermolecular potential energy is approximately unchanged. During melting at constant temperature, the average random kinetic energy stays constant while intermolecular potential energy increases as particles separate and the ordered structure breaks down. Internal energy therefore increases during melting even though temperature stays constant.

Teacher prompt / common error: Model quantity language: kinetic energy increases or stays constant; potential energy increases; temperature stays constant. Do not say the temperature 'stops'.

20. What does absolute zero mean for internal energy? Give its value in K and °C. **[2 marks]**

Answer / mark points: Absolute zero is the lowest possible temperature and corresponds to the minimum internal energy of a system. It is 0 K, approximately -273 °C.

Teacher prompt / common error: Use the current specification wording: minimum internal energy. Do not overstate this as all particle motion necessarily ceasing.

Closing review

During a phase change, temperature and average random kinetic energy stay constant while potential energy and internal energy increase.
Absolute zero is the lower limit of temperature and corresponds to minimum internal energy.