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QUESTION WORKBOOK

Thermal energy transfer and specific heat capacity

Thermal physics · Year 13

AQA 3.6.2.1 · CIE 14.1.1, 14.1.2, 14.3.1, 14.3.2, 16.1.1, 16.1.2, 16.2.2
OCR A 5.1.1(a), 5.1.2(a), 5.1.2(b), 5.1.2(d), 5.1.2(f), 5.1.2(g), 5.1.3(a), 5.1.3(b)(i), 5.1.3(c), 5.1.3(d)(i)

20 questions · 64 marks

NAVY SCREEN EDITION

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SECTION A · Warm-up

A1 Define the internal energy of a substance. [2]

A2 Calculate the energy needed to raise the temperature of 0.50 kg of water by 20°C (specific heat capacity of water = 4200 J kg^{-1} K^{-1}). [2]

A3 Explain why the temperature of a substance stays constant while it changes state, even though energy is being supplied. [2]

A4 State what is meant by two objects being in thermal equilibrium. [1]

A5 The gas in a sealed cylinder gains 250 J of energy by heating. At the same time a piston does 90 J of work on the gas. Calculate the increase in the internal energy of the gas. [2]

A6 A baking tray warms from 18°C to 43°C in an oven. State the temperature rise of the tray in kelvin, and explain why no unit conversion is needed. [2]

SECTION B · Standard

B1 An aluminium block of mass 2.0 kg is heated from 20°C to 70°C. Calculate the energy supplied to the block (specific heat capacity of aluminium = 900 J kg^{-1} K^{-1}). Assume no energy is lost to the surroundings. [3]

B2 Calculate the energy needed to melt 0.30 kg of ice at its melting point (specific latent heat of fusion = 3.34 × 10^5 J kg^{-1}), and state why the temperature does not rise while the ice melts. [4]

B3 Supplying 5000 J of energy raises the temperature of a 0.20 kg block by 25°C. Calculate the specific heat capacity of the block. [3]

B4 A 2.0 kW heater warms 1.5 kg of water by 30°C ($c = 4200$ J kg^{-1} K^{-1}). Assuming no losses, calculate the time taken. [3]

B5 In a continuous-flow experiment, water flows at 8.0 g s^{-1} over a 1.50 kW electric heater. The water enters at 18.0°C and leaves at 58.0°C ($c_{water} = 4200$ J kg^{-1} K^{-1}). Calculate the rate at which energy is lost to the surroundings. [3]

B6 A camping stove transfers energy to a pan of water at 750 W. The pan holds 0.90 kg of water at 15°C (c = 4200 J kg^{-1} K^{-1}). Show that the water takes about 7 minutes to reach 100°C. Assume no energy is lost and that the heat capacity of the pan itself is negligible. [3]

B7 An overnight storage tank holds 140 kg of water, which an immersion heater warms from 12°C to 55°C (c = 4200 J kg^{-1} K^{-1}). Electricity costs 28p per kWh (1 kWh = 3.6 × 10^{6} J). Determine the cost of heating the tank. Assume no energy is lost. [4]

SECTION C · Stretch

C1 Calculate the total energy needed to turn 0.20 kg of ice at 0°C into water and then warm it to 20°C (latent heat of fusion = 3.34 × 10^{5} J kg^{-1}, c_{water} = 4200 J kg^{-1} K^{-1}). [4]

C2 0.10 kg of water at 80°C is mixed with 0.20 kg of water at 20°C. Assuming no energy is lost to the surroundings, calculate the final temperature. [4]

C3 Explain the difference between heating and doing work as ways of increasing the internal energy of a gas. [3]

C4 A manufacturer of storage heaters needs a solid core that stores 5.4 MJ of energy when its temperature rises from 20°C to 220°C. The core must fit inside a casing of internal volume 0.0090 m^3. Three materials are available. Material W: c = 880 J kg^{-1} K^{-1}, density 2300 kg m^{-3}, cost 15p per kg. Material X: c = 450 J kg^{-1} K^{-1}, density 7200 kg m^{-3}, cost 60p per kg. Material Y: c = 930 J kg^{-1} K^{-1}, density 5100 kg m^{-3}, cost 90p per kg. Deduce which material the manufacturer should choose. [5]

C5 A 2.4 kW kettle contains 0.50 kg of water at 100°C. The kettle is faulty and does not switch off (specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}). Show that the kettle boils dry in about 8 minutes. Assume all the energy supplied goes to the water. [3]

C6 A student heats a beaker of crushed ice, initially at -15°C, using an immersion heater that supplies energy at a constant rate, and continues until the melted water has boiled for some time. Describe and explain the shape of the temperature-time graph for the contents of the beaker. Refer in your answer to the kinetic and potential energies of the molecules and to the relative sizes of the quantities involved. [6]

C7 In a continuous-flow experiment a liquid passes a heater at 12.0 g s^{-1} while the heater delivers 1290 W, and the liquid leaves 25.0 K warmer than it entered. The flow rate is then changed to 8.0 g s^{-1} and the power adjusted to 870 W, giving the same inlet and outlet temperatures as before. Determine the specific heat capacity of the liquid and the rate at which energy is lost to the surroundings, and explain why a second run is needed. [5]