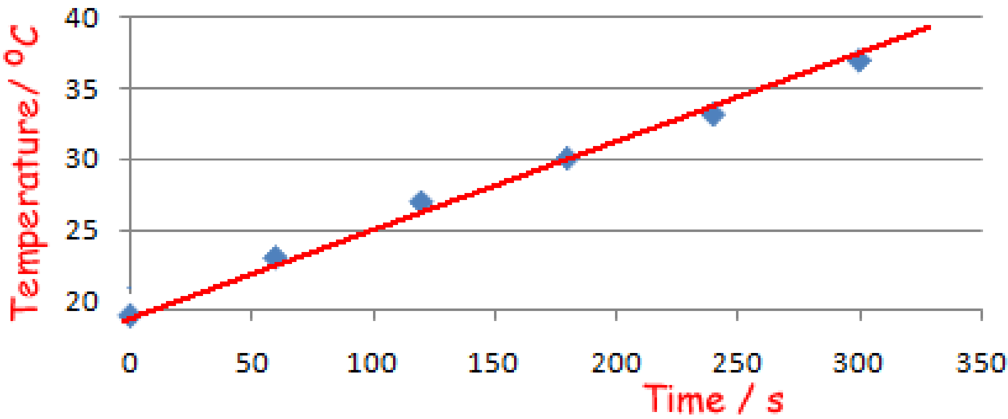
Specific Heat Capacity and Latent Heat Questions – A2 Physics

1. An electrical heater is used to heat a 1.0 kg block of metal, which is well lagged. The table shows how the temperature of the block increased with time.

temp/°C	20.1	23.0	26.9	30.0	33.1	36.9
time/s	0	60	120	180	240	300

(a) Plot a graph of temperature against time on the graph paper provided.



- adequate scale **(1 mark) – filling the paper**
- points plotted correctly **(1 mark)**
- best fit line (at least a point to right and left of line) **(1 mark)**

(3)

(b) Determine the gradient of the graph.

Clearly marked, use of triangle minimum size 8cm **(1 mark)**

gradient = 0.056 ± 0.004 (°C/s) **(1 mark)**

(2)

(c) The heater provides thermal energy at the rate of 48 W. Use your value for the gradient of the graph to determine a value for the specific heat capacity of the metal in the block.

$$mc\Delta\theta = \Delta Q = Pt$$

$$mc(\Delta\theta/t) = P$$

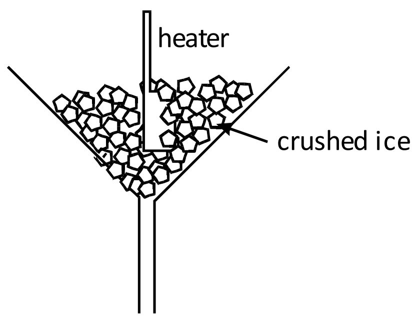
$$c = P/(m \times \text{gradient of the graph})$$

$$= 48/0.056$$

$c = 860 \pm 60\ \text{J kg}^{-1}\ \text{K}^{-1}$ (or $\text{J kg}^{-1}\ °\text{C}^{-1}$) **(1 mark)**

(2)

(d) The heater in part (c) is placed in some crushed ice that has been placed in a funnel as shown.
The heater is switched on for 200 s and 32 g of ice are found to have melted during this time. Use this information to calculate a value for the specific latent heat of fusion for water, stating **one** assumption made.



$Q = Pt = ml$

$48 \times 200 = 32 \times 10^{-3} \times l$ **(1 mark)**

$l = 3.0 \times 10^{5}\ \text{J kg}^{-1}$ **(1 mark)**

Any sensible assumption, e.g. no heat lost to surroundings **or** temperature does not change **or** all heat is transferred to ice **(1 mark)**

(3)

(Total 10 marks)

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Q2 (a) A student immerses a 2.0kW electric heater in an insulated beaker of water. The heater is switched on and after 120 s the water reaches boiling point. The data collected during the experiment is given below.

initial mass of beaker 25 g	**initial mass of beaker and water 750 g**
initial temperature of water 20 °C	**final temperature of water 100 °C**

Calculate the specific heat capacity of water if the thermal capacity of the beaker is negligible.

$mc\Delta\theta$ = Q = Pt

$0.725 \times c \times (100 - 20)$ **(1 mark)**

$= 2000 \times 120$ **(1 mark)**

c = 4100 **(1 mark)** J kg^{-1} **(1 mark)**

(4 marks)

(b) The student in part (a) continues to heat the water so that it boils for 105 s. When the mass ofthe beaker and water is measured again, it is found that it has decreased by 94 g.

(i) Calculate a value for the specific latent heat of vaporisation of water.

Q = ml = Pt

$94 \times 10^{-3} \times l = 2000 \times 105$ **(1 mark)**

$l = 2.2 \times 10^{6}$ J kg^{-1} **(1 mark)**

(ii) State **two** assumptions made in your calculation.

- no evaporation (before water heated to boiling point) **(1 mark)**
- no heat lost (to the surroundings) **(1 mark)**
- heater 100% efficient **(1 mark)** - any two

(4 marks)

[8 marks]

Q3 A tray containing 0.20 kg of water at 20 °C is placed in a freezer.

(a) The temperature of the water drops to 0 °C in 10 minutes.

specific heat capacity of water = 4200 J kg^{-1}K^{-1}

Calculate

(i) the energy lost by the water as it cools to 0 °C,

ΔQ = $mc\Delta\theta$

energy lost by water = $0.20 \times 4200 \times 20$ **(1 mark)**

$= 1.7 \times 10^{4}$ J **(1 mark)** [1.68×10^{4} J]

(ii) the average rate at which the water is losing energy, in J s^{-1}.

rate of loss of energy = $(1.68 \times 10^{4})/(10 \times 60)$ = 28W **(1 mark)**

(3 marks)

(b) (i) Estimate the time taken for the water at 0 °C to turn completely into ice.

specific latent heat of fusion of water = 3.3 x 10^{5}J kg^{-1}

ΔQ = ml = Pt

$(28 \times t) = 0.20 \times 3.3 \times 10^{5}$ **(1 mark)**

$t = 2.4 \times 10^{3}$ s **(1 mark)** (2.36×10^{3} s)

(ii) State any assumptions you make.

constant rate of heat loss **(1 mark)**

ice remains at 0oC **(1 mark)**

(3 marks)

[6 marks]

Q4 (a) A 2.0kW heater is used to heat a room from 5 °C to 20 °C. The mass of air in the room is 30 kg. Under these conditions the specific heat capacity of air = 1000 J kg^{-1}K^{-1}.

Calculate

(i) the gain in thermal energy of the air,

$\Delta Q = mc\Delta\theta$

$Q = 30 \times 1000 \times 15$

$= 4.5 \times 10^5$ J **(1 mark)**

(ii) the minimum time required to heat the room.

$P \times t = 4.5 \times 10^5$ **(1 mark)**

$t = 45 \times 10^5/2000 = 225$ s **(1 mark)**

(4 marks)

(b) State and explain **one** reason why the actual time taken to heat the room is longer than the value calculated in part (a)(ii).

Heat is lost to surroundings or other objects in room or to heater itself **(1 mark)** therefore more (thermal) energy is required from heater **(1 mark)**

[or because convection currents cause uneven heating **or** rate of heat transfer decreases as temperature increases]

(2 marks)

[6 marks]

Q5. A bicycle and its rider have a total mass of 95 kg. The bicycle is travelling along a horizontal road at a constant speed of 8.0ms^{-1}.

(a) Calculate the kinetic energy of the bicycle and rider.

$E_k = \frac{1}{2}mv^2$

$E_k = \frac{1}{2} \times 95 \times 8.0^2$ **(1 mark)**

$= 3040$ J **(1 mark)**

(2 marks)

(b) The brakes are applied until the bicycle and rider come to rest. During braking, 60% of the kinetic energy of the bicycle and rider is converted to thermal energy in the brake blocks. The brake blocks have a total mass of 0.12 kg and the material from which they are made has a specific heat capacity of 1200 J kg^{-1} K^{-1}.

(i) Calculate the maximum rise in temperature of the brake blocks.

60% of the KE = $0.60 \times 3040 = 1824$ (J) **(1 mark)**

$\Delta Q = mc\Delta\theta$

$1824 = 0.12 \times 1200 \times \Delta\theta$ **(1 mark)** $= 13$ K **(1 mark)** (12.7 K)

(ii) State an assumption you have made in part (b)(i).

No heat is lost to the surroundings **(1 mark)**

(4 marks)

[6 marks]

Q6. A female runner of mass 60 kg generates thermal energy at a rate of 800W.

(a) Assuming that she loses no energy to the surroundings and that the average specific heat capacity of her body is 3900 J kg^{-1}K^{-1}, calculate

(i) the thermal energy generated in one minute,

Energy in one minute = $800 \times 60 = 48 \times 10^3$ J **(1 mark)**

(ii) the temperature rise of her body in one minute.

$\Delta Q = mc\Delta\theta$

$48 \times 10^3 = 60 \times 3900 \times \Delta\theta$ **(1 mark)**

$\Delta\theta = 0.21$ K **(1 mark)** (0.205 K)

(3 marks)

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(b) In practice it is desirable for a runner to maintain a constant temperature. This may be achieved partly by the evaporation of sweat. The runner in part (a) loses energy at a rate of 500W by this process. Calculate the mass of sweat evaporated in one minute.

specific latent heat of vaporisation of water = 2.3 x 10^6 J kg^{-1}

(3 marks)

ΔQ = ml

Energy in one minute: 500 × 60 **(1 mark)**

= m × 2.3 × 10^6 **(1 mark)**

So m = 0.013 kg **(1 mark)**

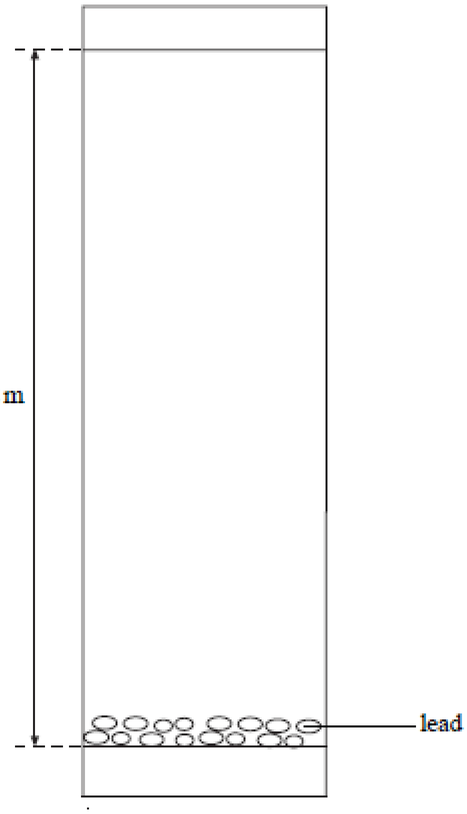
(c) Explain why, when she stops running, her temperature is likely to fall.

She is not generating as much heat internally **(1 mark)** but is still losing heat (at the same rate) [or still sweating] **(1 mark)** hence her temperature will drop **(1 mark)**

(2 marks)

[8 marks]

Q7. The diagram on the right shows a tube containing small particles of lead. When the tube is inverted the particles of lead fall freely through a vertical height equal to the length of the tube.



(a) Describe the energy changes that take place in the lead particles during one inversion of the tube.

Lead particles fall and lose potential energy (as tube is inverted) **(1 mark)**. This is converted to kinetic energy **(1 mark)**. Kinetic energy is converted into heat energy on impact **(1 mark)**

(3 marks)

(b) The tube is made from an insulating material and is used in an experiment to determine the specific heat capacity of lead.

The following results are obtained.

mass of lead:	**0.025 kg**
number of inversions:	**50**
length of tube:	**1.2m**
change in temperature of the lead:	**4.5K**

Calculate

(i) the change in potential energy of the lead as it falls after one inversion down the tube,

Ep = mgΔh = 0.025 × 9.81 × 1.2 = 0.29(4) J **(1 mark)**

(ii) the total change in potential energy after 50 inversions,

total change of energy (= 50 × 0.294) = 15 J **(1 mark)** (14.7 J)

(use of 0.29 gives 14.(5) J)

(iii) the specific heat capacity of the lead.

ΔQ = mc$\Delta\theta$

14.7 = 0.025 × c × 4.5 **(1 mark)**

c = 131 J kg^{-1} K^{-1} **(1 mark)** (130.7 J kg^{-1} K^{-1})

(use of 15 from (ii) gives 133 J kg^{-1} K^{-1})

(4 marks)

[7 marks]

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Q8. In an experiment to measure the temperature of the flame of a Bunsen burner, a lump of copper of mass 0.12 kg is heated in the flame for several minutes. The copper is then transferred quickly to a beaker, of negligible heat capacity, containing 0.45 kg of water, and the temperature rise of the water measured.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific heat capacity of copper = 390 J kg^{-1} K^{-1}

(a) If the temperature of the water rises from 15 °C to 35 °C, calculate the thermal energy gained by the water.

$\Delta Q = mc\Delta\theta$ **(1 mark)**
$\Delta Q = 0.45 \times 4200 \times (35 - 15)$
$= 3.8 \times 10^4$ J **(1 mark)** (3.78×10^4 J)

(2 marks)

(b) (i) State the thermal energy lost by the copper, assuming no heat is lost during its transfer.

3.8×10^4 J **(1 mark)**

(ii) Calculate the fall in temperature of the copper.

$mc\Delta T = \Delta Q$
$0.12 \times 390 \times \Delta T = 3.8 \times 10^4$ **(1 mark)**
$\Delta T = 812$ K **(1 mark)**
use of $\Delta Q = 3.78 \times 10^4$ J gives $\Delta T = 808$ K

(iii) Hence calculate the temperature reached by the copper while in the flame.

(812 + 35) = 847 °C **(1 mark)**
(use of 808 gives 843 °C)

(4 marks)
(6 marks)

Q9.

(a) Calculate the energy released when 1.5 kg of water at 18 °C cools to 0 °C and then freezes to form ice, also at 0 °C.

specific heat capacity of water = 4200 *J kg^{-1} K^{-1}*
specific latent heat of fusion of ice = 3.4 × 10^5 *J kg^{-1}*

Water cooling to zero

$\Delta Q = mcT$
$\Delta Q_1 = 1.5 \times 4200 \times 18$ **(1 mark)**
$= 1.1 \times 10^5$ (J) **(1 mark)**

Ice forming

$\Delta Q_2 = 1.5 \times 3.4 \times 10^5$
$= 5.1 \times 10^5$ (J) **(1 mark)**
total energy released ($= 1.1 \times 10^5 + 5.1 \times 10^5$)
$= 6.2 \times 10^5$ J **(1 mark)**

(4 marks)

(b) Explain why it is more effective to cool cans of drinks by placing them in a bucket full of melting ice rather than in a bucket of water at an initial temperature of 0 °C.

Ice requires an input of latent heat energy to melt (1 mark). It therefore takes this energy from the drink before the drink begins to take energy from the melted ice. It therefore stays at 0 °C for longer that it would in the cold water **(1 mark)**

(2 marks)
(6 marks)
(63 marks Total)