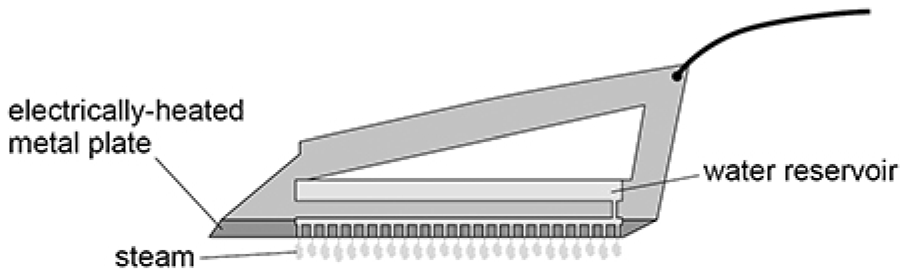
A-Level Physics

Thermal Energy Transfer

Question Paper

Time available: 61 minutes
Marks available: 47 marks

1. The figure below shows an electric steam iron.



Water from a reservoir drips onto an electrically-heated metal plate. The water boils and steam escapes through holes in the metal plate.

The electrical power of the heater inside the iron is 2.1 kW.

Assume that all the energy from the heater is transferred to the metal plate.

(a) The metal plate has a mass of 1.2 kg and is initially at a temperature of 20 °C.
The heater is switched on. After a time *t* the metal plate reaches its working temperature of 125 °C.

Calculate *t*.

specific heat capacity of the metal = 450 J kg^{-1} K^{-1}

t = ________________ s

(2)

(b) The metal plate is maintained at its working temperature.
Water at $20\ °C$ drips continuously onto the metal plate.
Steam at $100\ °C$ emerges continuously from the iron.

The maker claims that the iron can generate steam at a rate of $60\ g\ min^{-1}$.

Determine whether this claim is true.

specific latent heat of vaporisation of water = $2.3 \times 10^6\ J\ kg^{-1}$
specific heat capacity of water = $4200\ J\ kg^{-1}\ K^{-1}$

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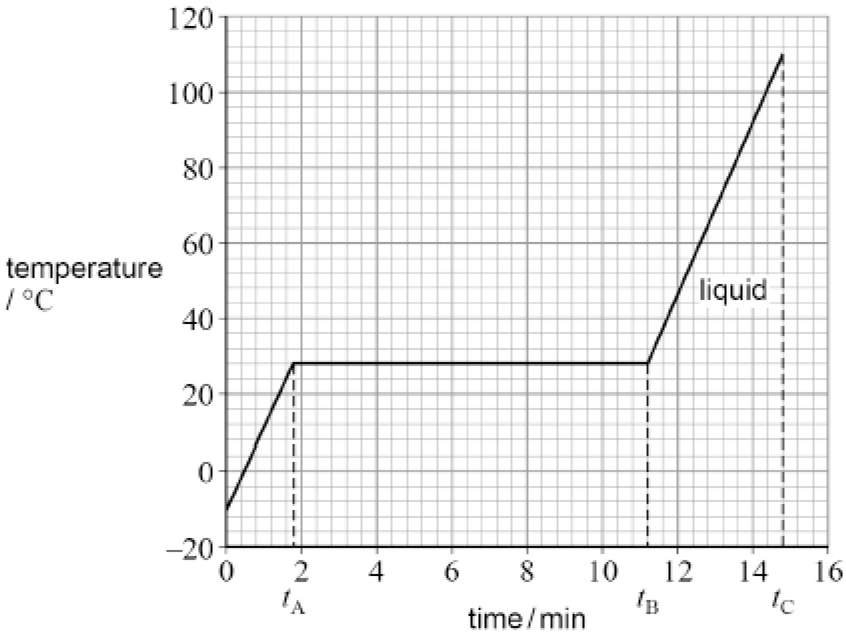
(3)
(Total 5 marks)

2. A perfectly insulated flask contains a sample of metal **M** at a temperature of –10 °C.

The figure shows how the temperature of the sample changes when energy is transferred to it at a constant rate of 35 W.



(a) State the melting temperature of **M**.

temperature = _______________ °C

(1)

(b) Explain how the energy transferred to the sample changes the arrangement of the atoms during the time interval t_A to t_B.

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(1)

(c) State what happens to the potential energy of the atoms and to the kinetic energy of the atoms during the time interval t_A to t_B.

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(2)

(d) Describe how the motion of the atoms changes during the time interval t_B to t_C.

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(1)

(e) The sample has a mass of 0.25 kg.

Determine the specific heat capacity of **M** when in the liquid state. State an appropriate SI unit for your answer.

specific heat capacity = ________________ unit = ___________

(3)

(f) The table shows the specific latent heats of fusion l for elements that are liquid at similar temperatures to **M**.

Element	Caesium	Gallium	Mercury	Rubidium
l **/ kJ kg^{-1}**	16	80	11	26

M is known to be one of the elements in the table above.

Identify **M**.

M = ________________

(2)

(Total 10 marks)

3. (a) Explain what is meant by specific latent heat of fusion.

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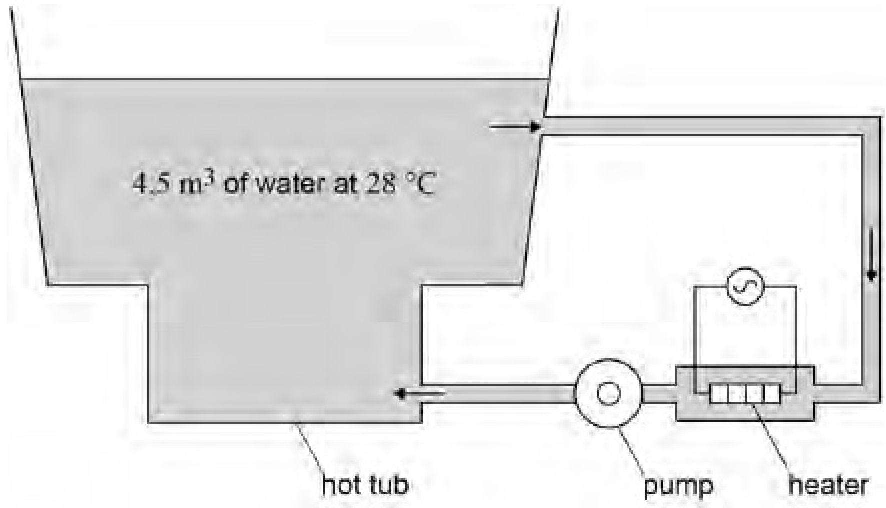
(2)

(b) The diagram shows how the temperature of the water is maintained in a hot tub.



The hot tub system has a volume of 4.5 m^3 and is filled with water at a temperature of 28 °C

The heater transfers thermal energy to the water at a rate of 2.7 kW while a pump circulates the water.

Assume that no heat is transferred to the surroundings.

Calculate the rise in water temperature that the heater could produce in 1.0 hour.

density of water = 1000 kg m^{-3}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}

temperature rise = ____________________ K

(3)

(c) The pump can circulate the water at different speeds.
When working at higher speeds the rise in temperature is greater.

Explain why.
Again assume that no heat is transferred to the surroundings.

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(2)
(Total 7 marks)

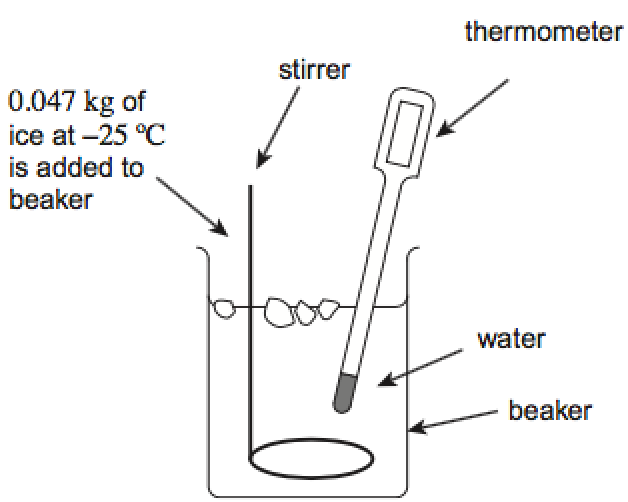
4. (a) Which statement explains why energy is needed to melt ice at 0°C to water at 0°C?

Place a tick (✓) in the right-hand column to show the correct answer.

	✓ if correct
It provides the water with energy for its molecules to move faster.	
It breaks all the intermolecular bonds.	
It allows the molecules to vibrate with more kinetic energy.	
It breaks some intermolecular bonds.	

(1)

(b) The diagram shows an experiment to measure the specific heat capacity of ice.



A student adds ice at a temperature of –25°C to water. The water is stirred continuously. Ice is added slowly until all the ice has melted and the temperature of the water decreases to 0°C. The mass of ice added during the experiment is 0.047 kg.

(i) Calculate the energy required to melt the ice at a temperature of 0°C.
The specific latent heat of fusion of water is 3.3×10^5 J kg^{-1}.

energy = ______________________ J

(1)

(ii) The water loses 1.8×10^4 J of energy to the ice during the experiment.
Calculate the energy given to the ice to raise its temperature to 0°C. Assume that no energy is transferred to or from the surroundings and beaker.

energy = ______________________ J

(1)

(iii) Calculate the specific heat capacity of the ice.
State an appropriate unit for your answer.

specific heat capacity = ______________________ unit = ___________

(2)

(Total 5 marks)

5. (a) Lead has a specific heat capacity of 130 J kg^{-1} K^{-1}.

Explain what is meant by this statement.

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(1)

(b) Lead of mass 0.75 kg is heated from 21 °C to its melting point and continues to be heated until it has all melted.

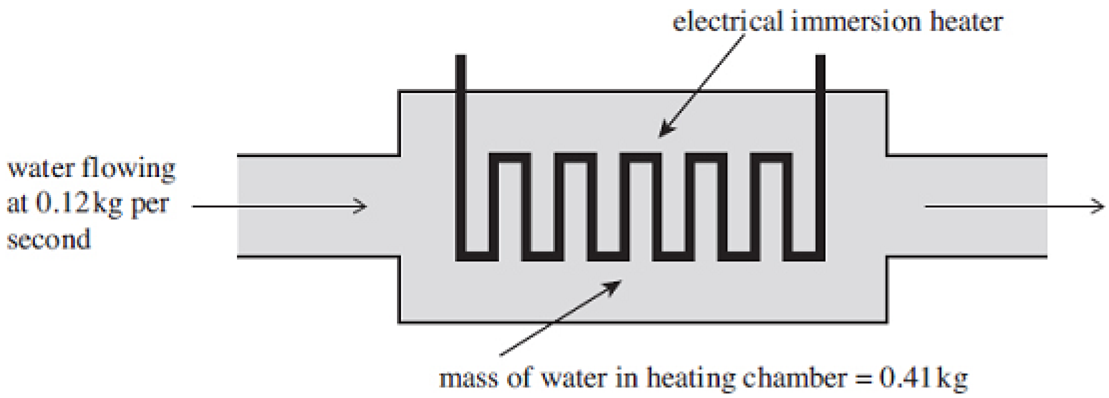
Calculate how much energy is supplied to the lead.
Give your answer to an appropriate number of significant figures.

melting point of lead = 327.5 °C
specific latent heat of fusion of lead = 23 000 J kg^{-1}

energy supplied ____________________ J

(3)
(Total 4 marks)

6. An electrical immersion heater supplies 8.5 kJ of energy every second. Water flows through the heater at a rate of 0.12 kg s^{-1} as shown in the figure below.



(a) Assuming all the energy is transferred to the water, calculate the rise in temperature of the water as it flows through the heater.

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

answer = ____________________ K

(2)

(b) The water suddenly stops flowing at the instant when its average temperature is 26 °C. The mass of water trapped in the heater is 0.41 kg.
Calculate the time taken for the water to reach 100 °C if the immersion heater continues supplying energy at the same rate.

answer = ____________________ s

(2)

(Total 4 marks)

7. In a geothermal power station, water is pumped through pipes into an underground region of hot rocks. The thermal energy of the rocks heats the water and turns it to steam at high pressure. The steam then drives a turbine at the surface to produce electricity.

(a) Water at 21°C is pumped into the hot rocks and steam at 100°C is produced at a rate of 190 kg s^{-1}.

(i) Show that the energy per second transferred from the hot rocks to the power station in this process is at least 500 MW.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific latent heat of steam = 2.3×10^6 J kg^{-1}

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(ii) The hot rocks are estimated to have a volume of 4.0×10^6 m^3. Estimate the fall of temperature of these rocks in one day if thermal energy is removed from them at the rate calculated in part (i) without any thermal energy gain from deeper underground.

specific heat capacity of the rocks = 850 J kg^{-1} K^{-1}
density of the rocks = 3200 kg m^{-3}

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(7)

(b) Geothermal energy originates as energy released in the radioactive decay of the uranium isotope $^{238}_{92}U$ deep inside the Earth. Each nucleus that decays releases 4.2 MeV. Calculate the mass of $^{238}_{92}U$ that would release energy at a rate of 500 MW.

half-life of $^{238}_{92}U$ = 4.5×10^9 years

molar mass of $^{238}_{92}U$ = $0.238 \text{ kg mol}^{-1}$

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(5)

(Total 12 marks)