newcollaborative Learning Trust

Opening doors to a brighter future

A-Level Physics

Summer Independent Learning

Y12 – 13

Task 1 Progression exam focus areas
Task 2 Electricity exam questions
Task 3 Thermal Physics required knowledge
Task 4 Thermal Physics exam questions

Welcome to Y13 A Level Physics, please complete the following tasks ready for your first day back at New College. You can either write on the document electronically, print the document out or write your notes and answers on paper to bring in for your first lesson in September.
Please be aware that you will have an assessment on these topics shortly after beginning your A level Physics course and the knowledge covered is essential to understanding the subsequent content.

Task 1 (approximately 2 hours)
Complete the task from the progression DIRT form.

Task 2 (approximately 2 hours)
Complete the three 30 minutes on Electricity.
Mark and improve your answers.

Task 3 (approximately 1 hour)
Answer each of the required knowledge questions from the lessons of Thermal Physics that we have done. Mark your answers and create flash cards on the content that you could not retrieve.

Task 4 (approximately 1 hour)
Answer at least 30 marks of question on Thermal Physics.
Mark and improve your answers.

Name ____

Physics Assessment	**Interim**	Number of marks:	**21**
		Number of minutes:	**30**

Electricity 1

Basics, Resistivity and Superconductivity

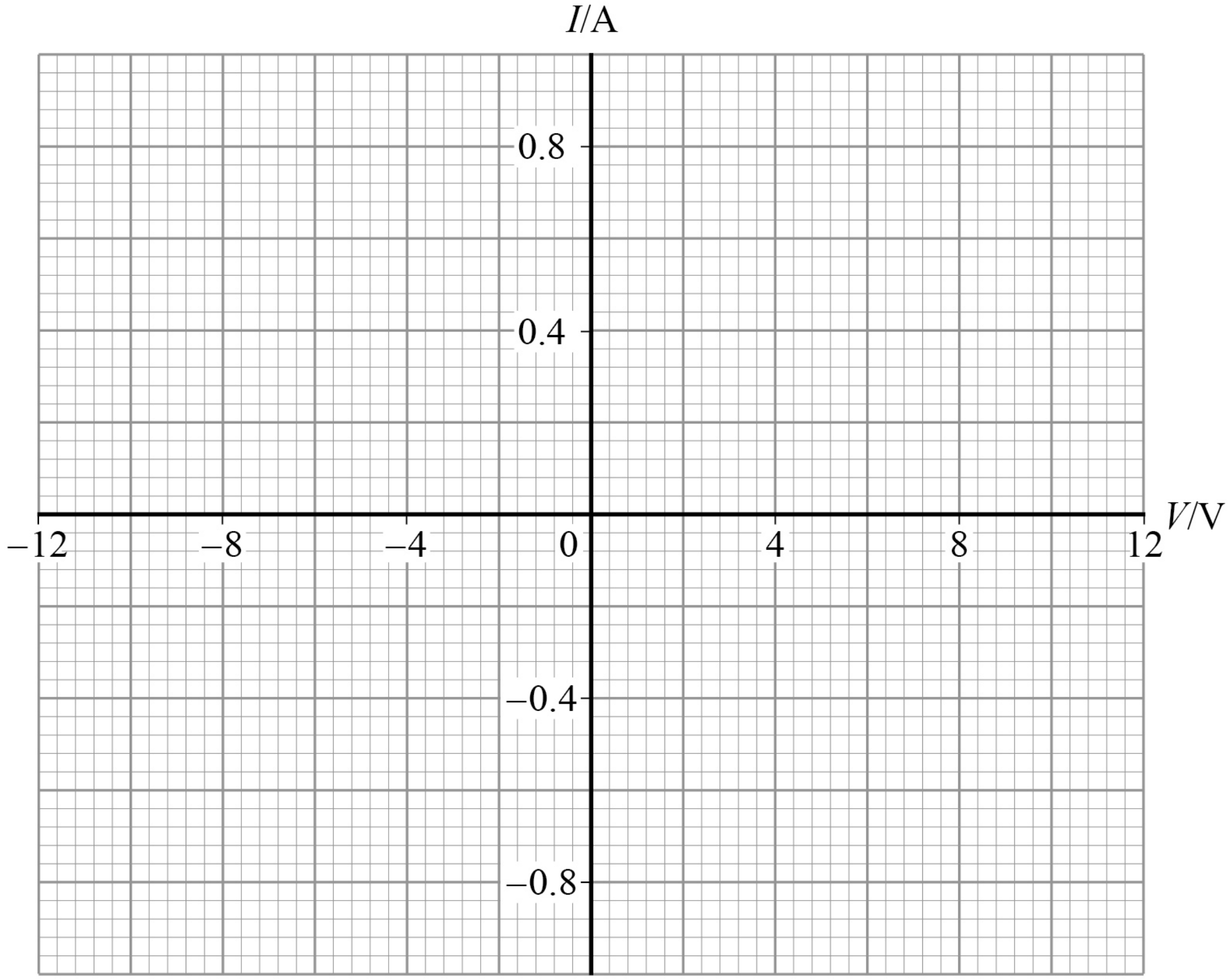
Q1.1 During a lightning strike, 9.4×10^{18} electrons move from a cloud to the ground in a time of 18 μs.

Calculate the current in the lightning strike due to the transfer of electrons.

current = ____________________ A **(2)**

Q1.2 filament lamp rated 12 V, 0.8 A has a resistance of 5.0 Ω when the current is very small.

Sketch, on the axes below, the current–voltage (I−V) characteristic for this lamp.



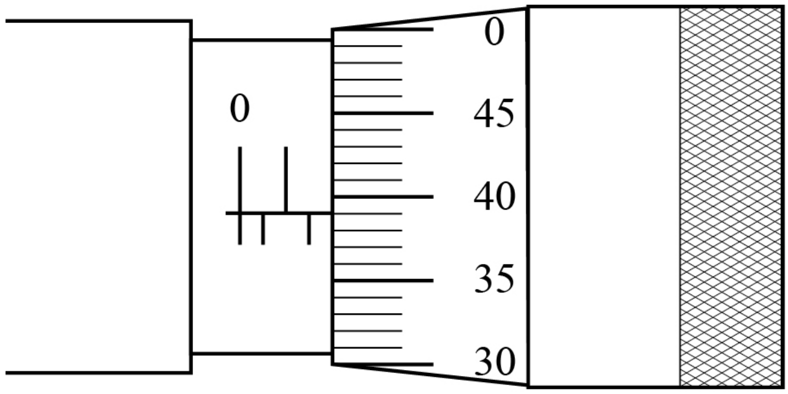
(4)

(Total 9 marks)

Q2. Light undergoes total internal reflection in an optical fibre with no cladding. A student uses a micrometer, that has no zero error, to measure the diameter of a copper wire.

Figure 1 shows the micrometer scales as the diameter is measured.

Figure 1



Q2.1 Show that the cross-sectional area of the wire is about 2.8×10^{-6} m^2

(2)

Q2.2 resistivity of copper is 1.7×10^{-8} Ω m
The wire has a length of 85 cm

Calculate the resistance of the wire.
Give your answer to an appropriate number of significant figures.

resistance = ____________________ Ω **(3)**

Q3.1 State **one** application of superconductors.

____ **(1)**

Q3.2 Explain why superconductors are necessary in the application given in **Q3.1**.

____

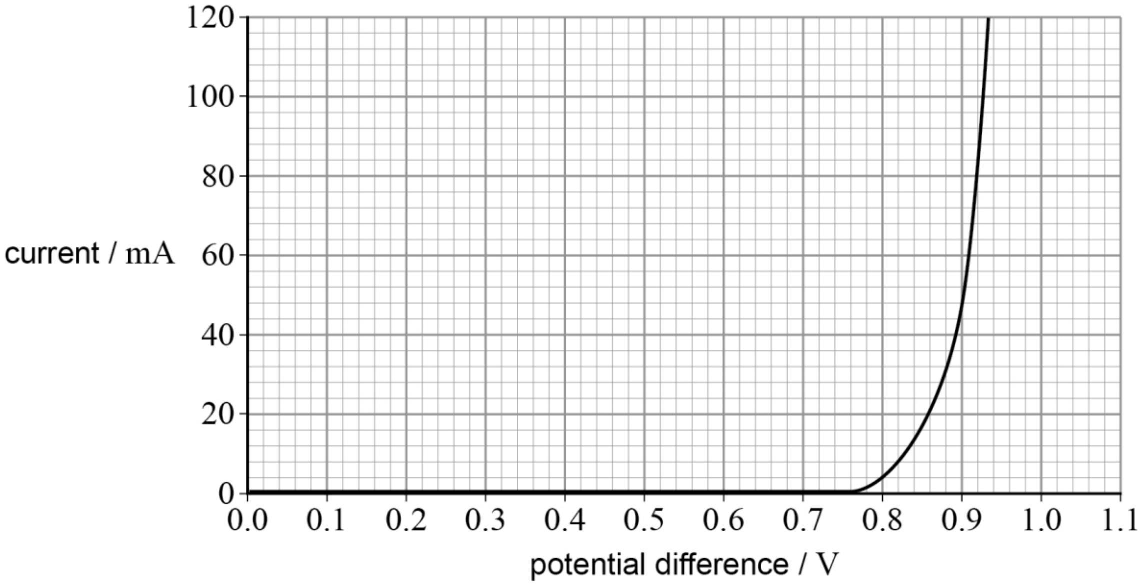
____

____

____ **(1)**

Figure 2 shows the variation of current with potential difference for an electrical component.

Figure 2



Q3.3 Identify the component.

____ **(1)**

Q3.4 Identify the component. Calculate the resistance of the component when there is a potential difference of 0.90 V across it.

resistance = ____________________ Ω **(2)**

(Total 6 marks)

Q4. A metal wire of length 1.3 m has a resistance of 0.70 Ω.
The wire has a diameter of 0.50 mm

What is the resistivity of the metal?

A 1.1×10^{-5} Ω m ⬭

B 1.1×10^{-7} Ω m ⬭

C 2.1×10^{-7} Ω m ⬭

D 4.2×10^{-7} Ω m ⬭

(Total 1 mark)

Q5. The table shows the values of V and corresponding values of I for components **A**, **B**, **C** and **D**.

	A	**B**	**C**	**D**
V / V	I / A	I / A	I / A	I / A
0	0.0	0.0	0.0	0.0
2	0.4	0.9	0.2	0.0
4	0.8	1.5	0.4	0.1
6	1.2	1.9	0.6	0.7
8	1.6	2.1	0.8	1.4
10	2.0	2.2	1.0	2.1

Which component is an ohmic conductor with the lowest resistance?

A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q6. A solid copper cylinder has a volume 1.3×10^{-4} m^3 and length 15 cm. Copper has a resistivity of 1.7×10^{-8} Ω m.

What is the resistance between the two ends of the copper cylinder?

A 2.9×10^{-6} Ω ⬭

B 2.0×10^{-5} Ω ⬭

C 2.0×10^{-3} Ω ⬭

D 2.9×10^{-2} Ω ⬭

(Total 1 mark)

Q7. What is a unit for potential difference?

A A Ω^{-1} ○

B C J^{-1} ○

C J A^{-1} s^{-1} ○

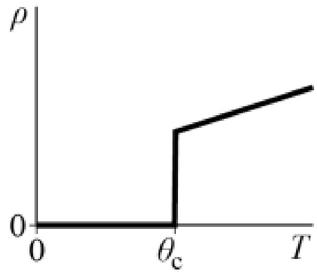
D W A ○

(Total 1 mark)

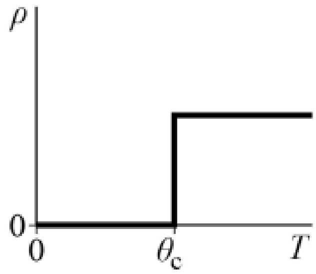
Q8. A superconductors has a critical temperature.

Which graph shows the variation of resistivity ρ with temperature T for this superconductor?

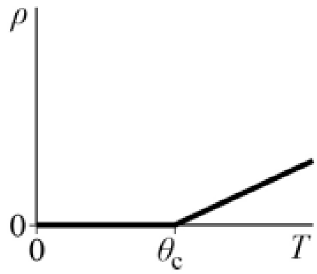
A



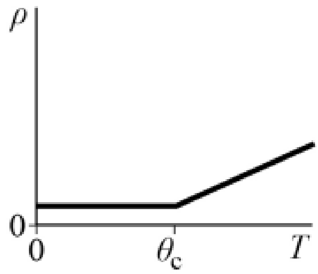
B



C



D



A ○

B ○

C ○

D ○

(Total 1 mark)

Name ____

Physics Assessment	**Interim**	Number of marks:	**21**
		Number of minutes:	**30**

Electricity 2

Series, Parallel and Potential Dividers

Q1. **Figure 1** shows the variation of resistance with temperature for a negative temperature coefficient (ntc) thermistor.

Figure 1

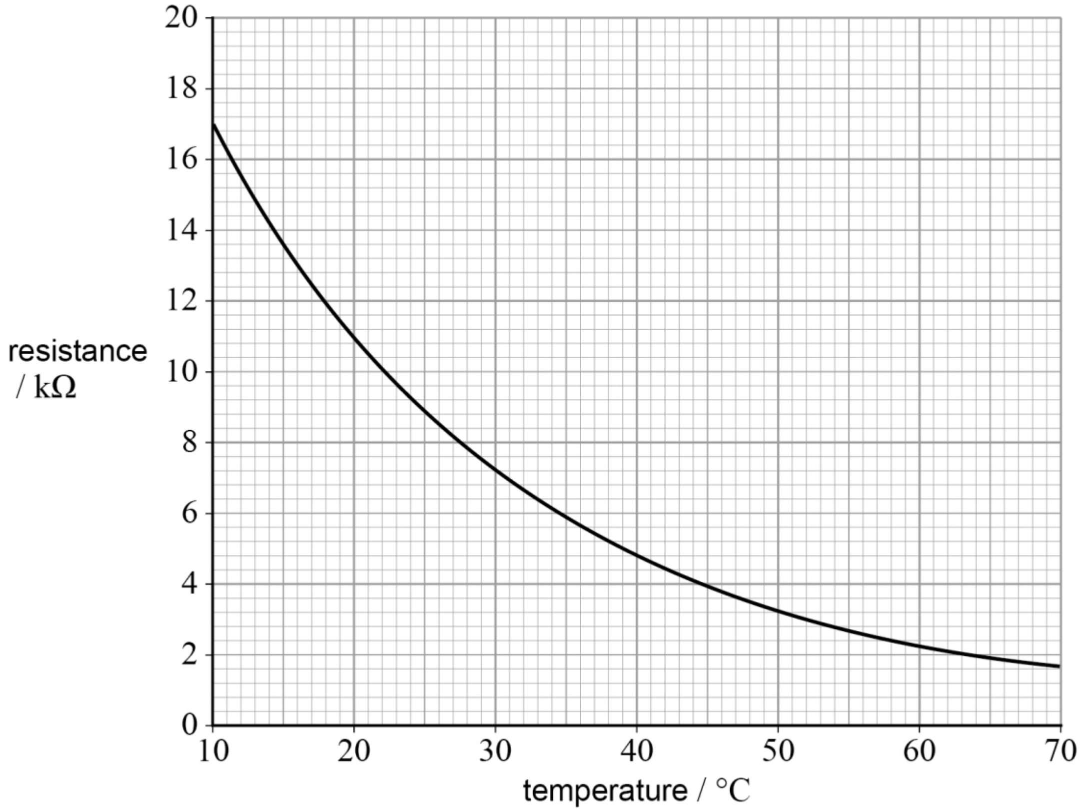
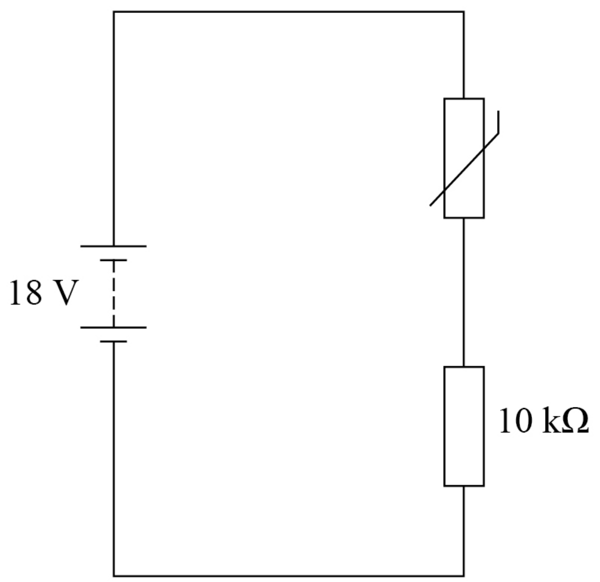


Figure 2 shows the ntc thermistor connected in series with a 10 kΩ resistor and a battery of emf 18 V. The temperature of the thermistor is 50 °C. The battery has negligible internal resistance.

Figure 2



Q1.1 Determine the current in the circuit.

State an appropriate unit for your answer.

current = ______________________

unit = ______________________ **(4)**

Q1.2 Calculate the rate of energy transfer by the 10 kΩ resistor.

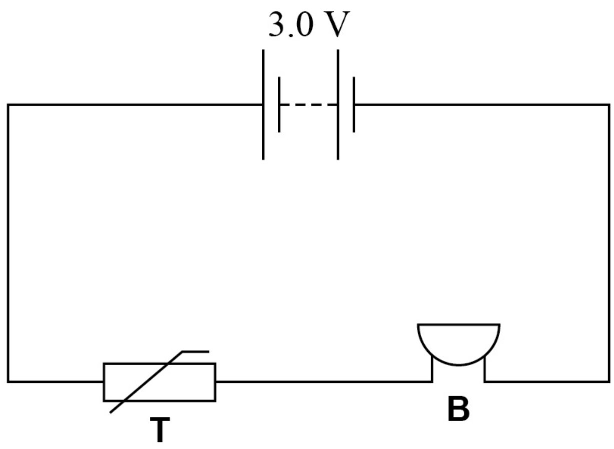
rate of energy transfer = ______________________ W **(2)**

(Total 6 marks)

Q2. **Figure 3** shows a thermistor T used in an alarm circuit for a refrigerator. The alarm is designed to sound a buzzer B when the temperature exceeds a threshold value. B has a constant resistance of 123 Ω.

The battery has a negligible internal resistance.

Figure 3



The buzzer sounds when the potential difference across it is greater than 1.8 V.

Q2.1 Explain why the potential difference across the buzzer increases when the temperature increases.

____

____

____

____

____

____

____

____ **(3)**

Q2.1 Show that, when the potential difference across the buzzer is 1.8 V, the resistance of the thermistor is about 80 Ω

(2)
(Total 5 marks)

Q3. **Figure 4** shows a simplified circuit for the main lights on a car. The battery has an emf of 12 V and no internal resistance.

Figure 4

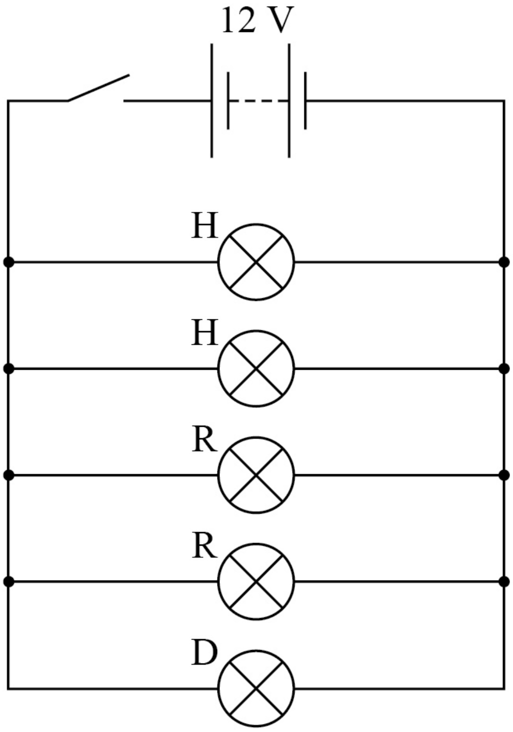


Table 1 gives data about the lamps used in the circuit. The resistance values are correct when each lamp is at its operating voltage.

Table 1

Lamp	Operating voltage / V	Resistance / Ω
H, headlight lamp	12	3.5
R, rear lamp	12	5.8
D, dashboard lamp	12	74

Q3.1 Calculate the power of a single headlight lamp when operating at 12 V

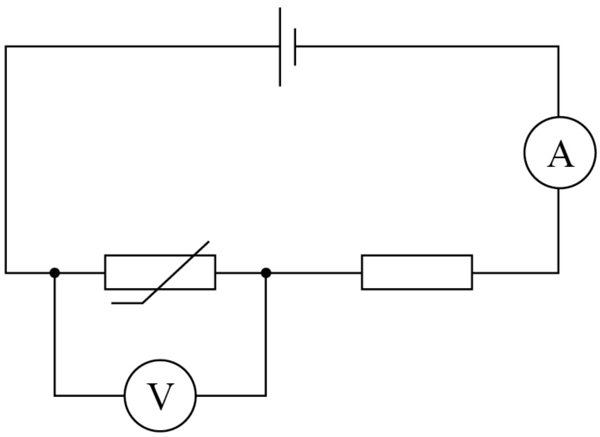
power = ____________________ W **(2)**

Q3.2 Calculate the resistance of the combination of lamps when operating at 12 V

resistance = ______________________ Ω **(3)**

(Total 5 marks)

Q4. A negative temperature coefficient thermistor is connected to a resistor and a cell as shown.



The temperature of the thermistor increases.

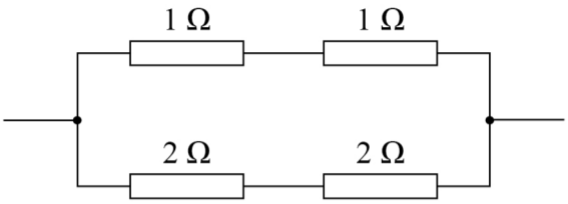
What are the changes in the ammeter reading and the voltmeter reading?

	Ammeter reading	Voltmeter reading	
A	Increases	Increases	⬭
B	Increases	Decreases	⬭
C	Decreases	Increases	⬭
D	Decreases	Decreases	⬭

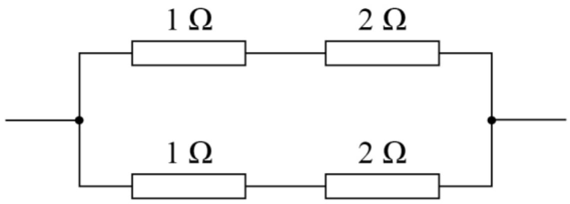
(Total 1 mark)

Q5. Which network of resistors has the largest total resistance?

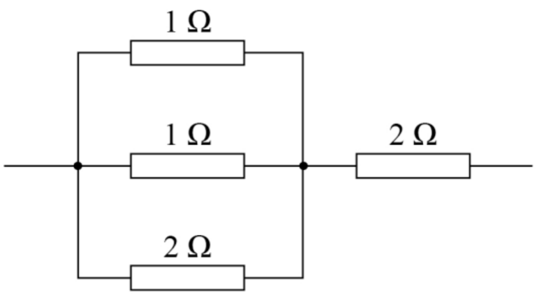
A



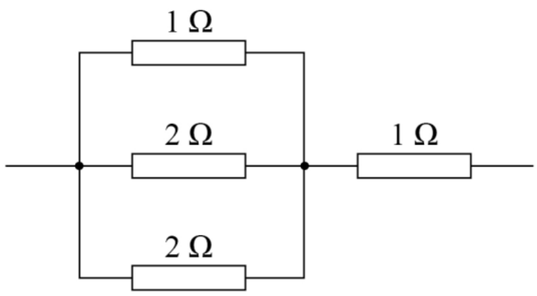
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q6. A metal wire has resistance R. The wire is cut in half and the two cut pieces are joined in parallel to form one component

What is the resistance of the component?

A $4R$ ⬭

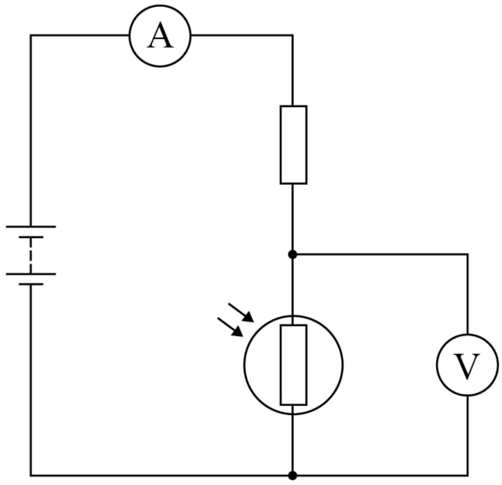
B $2R$ ⬭

C $\frac{R}{2}$ ⬭

D $\frac{R}{4}$ ⬭

(Total 1 mark)

Q7. The diagram shows a potential-divider circuit

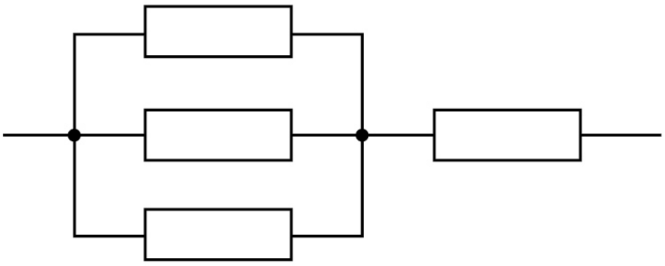


Which row shows the changes in the ammeter and voltmeter readings when the intensity of the light incident on the LDR increases?

	Ammeter reading	**Voltmeter reading**	
A	Increases	Increases	⬭
B	Increases	Decreases	⬭
C	Decreases	Increases	⬭
D	Decreases	Decreases	⬭

(Total 1 mark)

Q8. Four resistors each of resistance X are connected in a network as shown.



What is the total resistance of the network?

A $\frac{X}{4}$ ⬭

B $\frac{X^2 + 3}{X}$ ⬭

C $4X$ ⬭

D $\frac{4X}{3}$ ⬭

(Total 1 mark)

Name ____

Physics Assessment	**Interim**	Number of marks:	**21**
		Number of minutes:	**30**

Electricity 3

EMF, Internal Resistance and Power

Q1.1 Define the electromotive force (emf) of a battery.

____

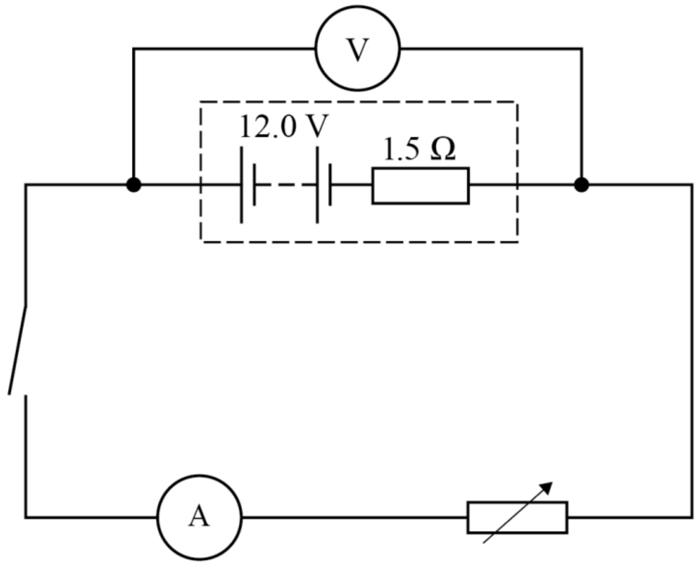
____

____

____ **(2)**

Q1.2 A battery with an emf of 12.0 V and an internal resistance of 1.5 Ω is connected in the circuit shown in **Figure 1.**

Figure 1



The voltmeter reading is 9.0 V when the current in the circuit is 2.0 A

Calculate the resistance of the variable resistor when the voltmeter reads 9.0 V

resistance = ______________________ Ω **(2)**

Q1.3 Determine the maximum current that can be provided by the battery.

maximum current = ______________________ A **(2)**

Q1.4 With the switch closed the variable resistor is adjusted to obtain a range of ammeter and voltmeter readings. Finally the switch is opened and a final ammeter and voltmeter reading are obtained.

Sketch on **Figure 2** a graph to show the variation of voltmeter reading V with current I.

Label your axes with suitable numerical values

Figure 2

(2)

Q1.5 The battery, when fully charged, can deliver a total charge of 1.15×10^4 C

For a particular application, the fully-charged battery is required to supply a constant current to an external circuit of resistance 0.1 Ω for 30 minutes.

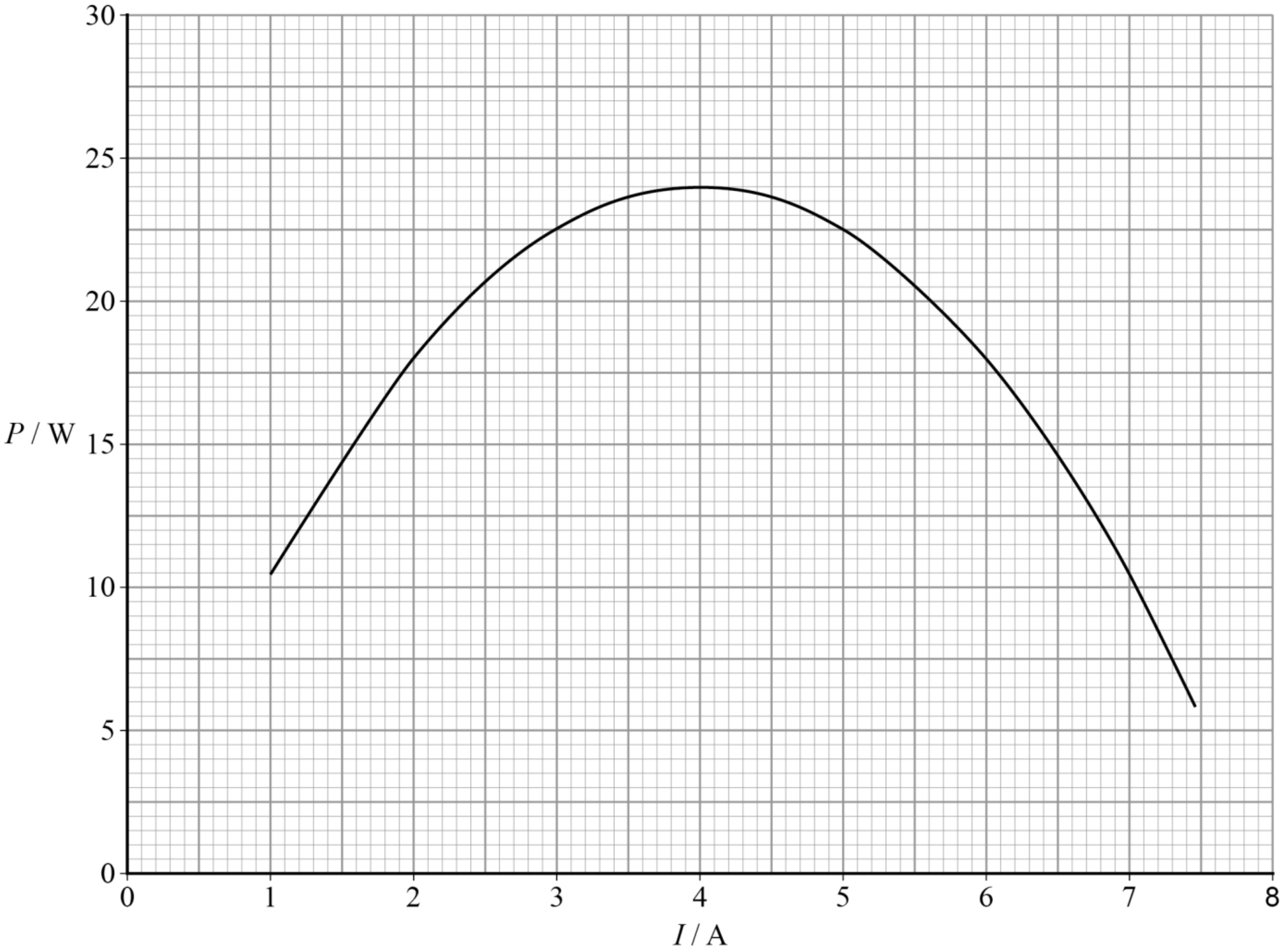
Discuss the suitability of the battery for this application.

You should use calculations to support your answer.

(3)

Q1.6 **Figure 10** shows the variation with current of the power dissipated in the variable resistor.

Figure 3



Calculate using data from **Figure 3** the value of the variable resistance when P is a maximum.

variable resistance = ______________________ Ω **(3)**

Q1.7 **Figure 3** suggests that as the current increases past 7.5 A, the power dissipated in the variable resistor eventually reaches zero.

Explain why the circuit behaves in this way.

___

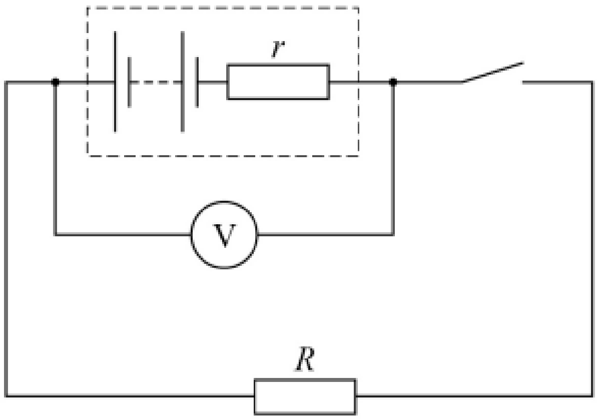
___

___

___ **(2)**

(Total 16 marks)

Q2. The diagram shows a 12 V battery connected to a resistor of resistance R. The voltmeter reads 10 V when the switch is closed.



What is the internal resistance r of the battery?

A $\frac{R}{6}$ ○

B $\frac{R}{5}$ ○

C $5R$ ○

D $6R$ ○

(Total 1 mark)

Q3. A lamp with a power rating of 24 W and a resistance of 12 O is operated for 2 minutes.

What charge flows through the lamp in this time?

A 15 C ○

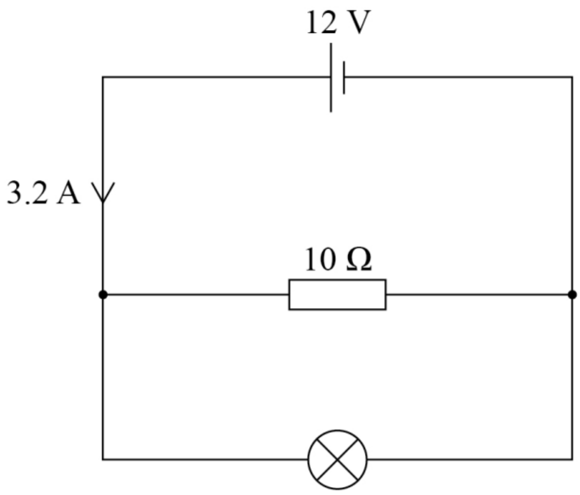
B 89 C ○

C 170 C ○

D 240 C ○

(Total 1 mark)

Q4. A cell of negligible internal resistance is connected to a resistor and a lamp in parallel as shown.



What is the power dissipated by the lamp?

A	14 W	⬭
B	16 W	⬭
C	24 W	⬭
D	38 W	⬭

(Total 1 mark)

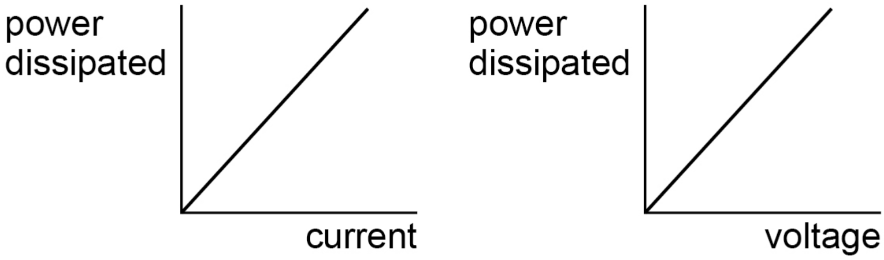
Q5. Which is a unit of power?

A	$C^2\ \Omega\ s^{-1}$	⬭
B	$J\ C^{-1}\ s^{-1}$	⬭
C	$V\ C\ s^{-1}$	⬭
D	$V^2\ \Omega$	⬭

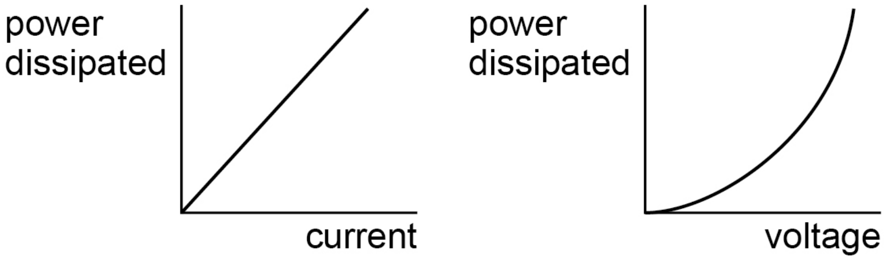
(Total 1 mark)

Q6. Which pair of graphs shows the variation of power dissipated with current, and the variation of power dissipated with voltage, for a resistor of constant resistance?

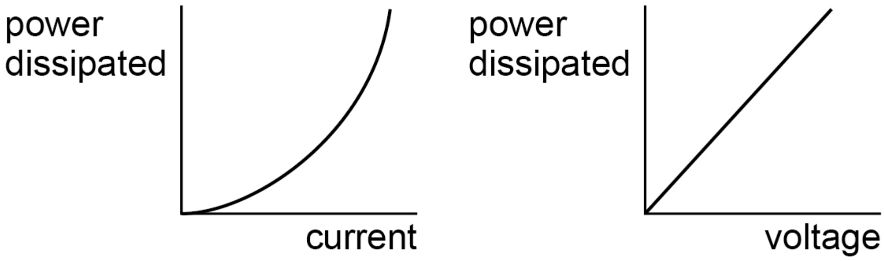
A



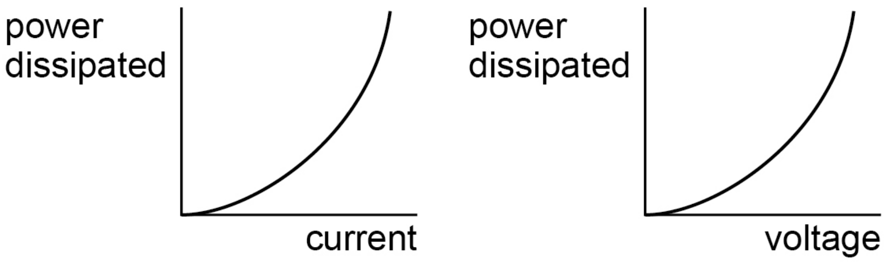
B



C



D



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

Thermal Physics Lesson 1: Heat, Temperature and Internal Energy

1. Describe the structure of a solid.
2. Describe the structure of a liquid.
3. Describe the motion of a gas.
4. Describe how the motion of gas molecules changes as they are heated.
5. What is meant by Brownian motion?
6. How is Brownian motion observed?
7. What did Brownian motion prove?
8. Where does heat flow?
9. What is meant by being in thermal equilibrium?
10. What is the internal energy of a substance?
11. How is the internal energy of a material increased?
12. Which types of energy change when a material changes temperature?
13. Which types of energy change when a material changes state?
14. Sketch a graph of temperature against time for a material that is being heated.

Thermal Physics Lesson 2: The Specifics

15. What is meant by the term specific heat capacity?
16. What is meant by the specific latent heat of fusion?
17. What is meant by the specific latent heat of vaporisation?
18. Why is the specific latent heat of vaporisation a much bigger value than the specific latent heat of fusion for the same material?
19. How is power connected to energy? Define all terms in the equation and state the units used.
20. What is the equation used for calculating the energy required to change temperature? Define all terms in the equation and state the units used.
21. What is the equation used for calculating the energy required to change state? Define all terms in the equation and state the units used.
22. How is temperature rise calculated from power and flow rate?
23. What would happen if a material was replaced with one of different specific heat capacity?

Q1. Molten lead at its melting temperature of 327°C is poured into an iron mould where it solidifies. The temperature of the iron mould rises from 27°C to 84°C, at which the mould is in thermal equilibrium with the now solid lead.

mass of lead = 1.20 kg
specific latent heat of fusion of lead = 2.5×10^4 J kg^{-1}
mass of iron mould = 3.00 kg
specific heat capacity of iron = 440 J kg^{-1} K^{-1}

Q1.1 Calculate the heat energy absorbed by the iron mould.

energy = ________________ J **(2)**

Q1.2 Calculate the heat energy given out by the lead while it is changing state.

energy = ________________ J **(1)**

Q1.3 Calculate the specific heat capacity of lead.

answer = ________________ J kg^{-1} K^{-1} **(3)**

Q1.4 State **one** reason why the answer to **1.3** is only an approximation.

____

____

____ **(1)**

(Total 7 marks)

Q2. An electrical heater is placed in an insulated container holding 100 g of ice at a temperature of –14 °C. The heater supplies energy at a rate of 98 joules per second.

Q2.1 After an interval of 30 s, all the ice has reached a temperature of 0 °C. Calculate the specific heat capacity of ice.

answer = ________________ $J\ kg^{-1}\ K^{-1}$ **(2)**

Q2.2 Show that the final temperature of the water formed when the heater is left on for a further 500 s is about 40 °C.

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

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

(3)

Q2.3 The whole procedure is repeated in an uninsulated container in a room at a temperature of 25 °C.

State and explain whether the final temperature of the water formed would be higher or lower than that calculated in **2.2**.

____

____

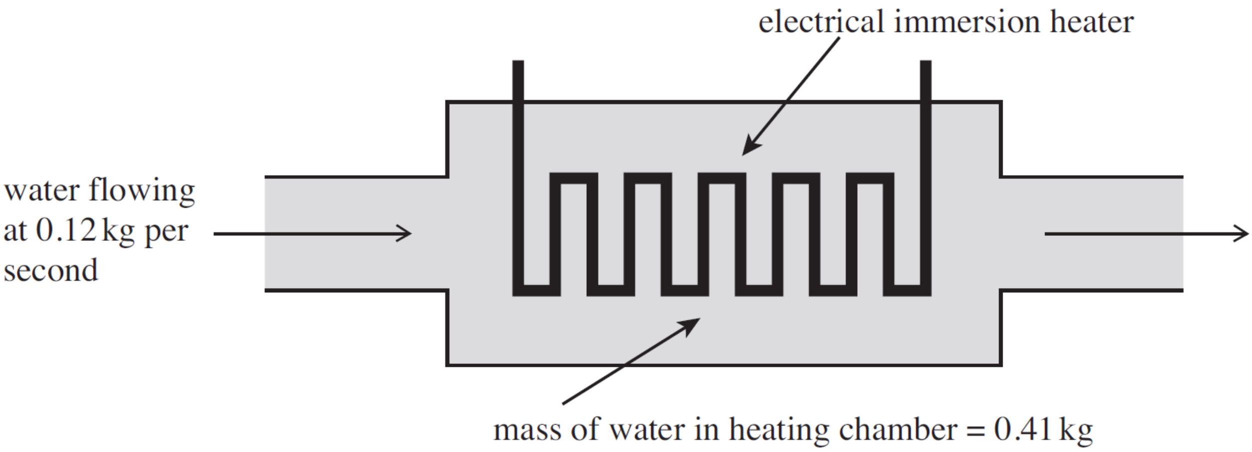
____

____ **(2)**

(Total 7 marks)

Q3. 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.



Q3.1 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)**

Q3.2 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)

Q4. A cola drink of mass 0.200 kg at a temperature of 3.0 °C is poured into a glass beaker. The beaker has a mass of 0.250 kg and is initially at a temperature of 30.0 °C.

specific heat capacity of glass = 840 J kg^{-1} K^{-1}

specific heat capacity of cola = 4190 J kg^{-1} K^{-1}

Q4.1 Show that the final temperature, T_f, of the cola drink is about 8 °C when it reaches thermal equilibrium with the beaker.

Assume no heat is gained from or lost to the surroundings.

(2)

Q4.2 The cola drink and beaker are cooled from T_f to a temperature of 3.0 °C by adding ice at a temperature of 0 °C.
Calculate the mass of ice added.
Assume no heat is gained from or lost to the surroundings.

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

specific latent heat of fusion of ice = 3.34×10^5 J kg^{-1}

mass = ____________________ kg **(3)**

(Total 5 marks)

Q5.1 Define the specific latent heat of vaporisation of water.

____

____

____

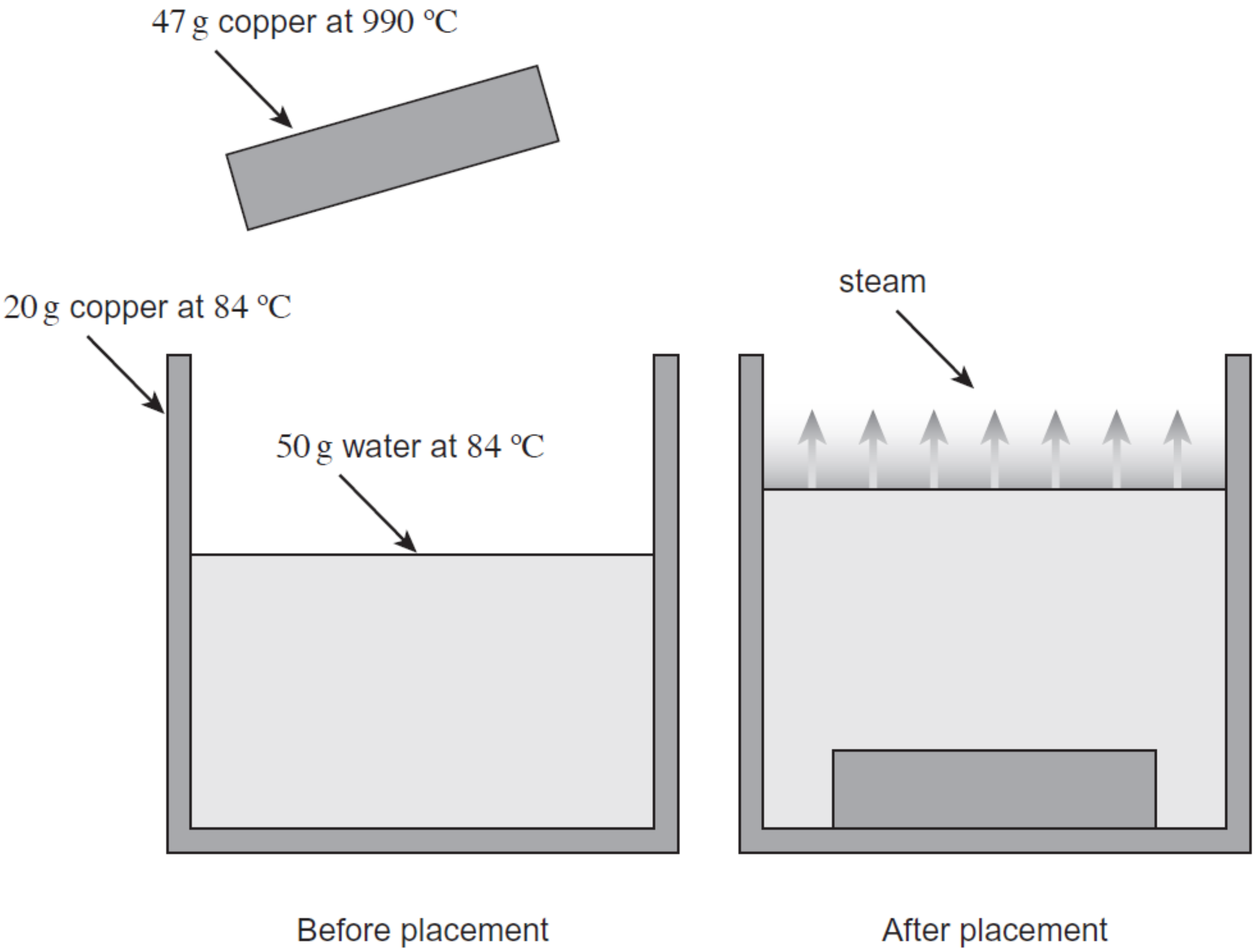
____ **(2)**

An insulated copper can of mass 20 g contains 50 g of water both at a temperature of 84 °C. A block of copper of mass 47 g at a temperature of 990 °C is lowered into the water as shown in the figure below. As a result, the temperature of the can and its contents reaches 100 °C and some of the water turns to steam.

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

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

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



Q5.2 Calculate how much thermal energy is transferred from the copper block as it cools to 100 °C.

Give your answer to an appropriate number of significant figures.

thermal energy transferred = ____________________ J **(2)**

Q5.3 Calculate how much of this thermal energy is available to make steam.

Assume no heat is lost to the surroundings.

available thermal energy = ____________________ J **(2)**

Q5.4 Calculate the maximum mass of steam that may be produced.

mass = ____________________ kg **(1)**

(Total 7 marks)

Q6.1 Lead has a specific heat capacity of 130 J kg^{-1} K^{-1}.

Explain what is meant by this statement.

____

____

____

____ **(1)**

Q6.2 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)

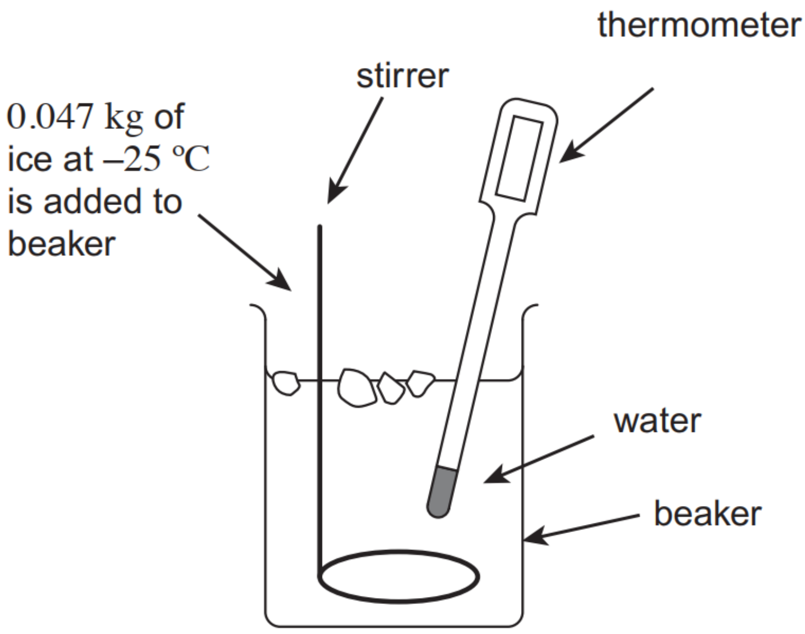
Q7.1 Which statement explains why energy is needed to melt ice at 0°C to water at 0°C?

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)

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.

Q7.2 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)**

Q7.2 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)**

Q7.3 Calculate the specific heat capacity of the ice.
State an appropriate unit for your answer.

specific heat capacity = ________________ unit = ___________ **(2)**

(Total 5 marks)

Q8.1 Explain what is meant by specific latent heat of fusion.

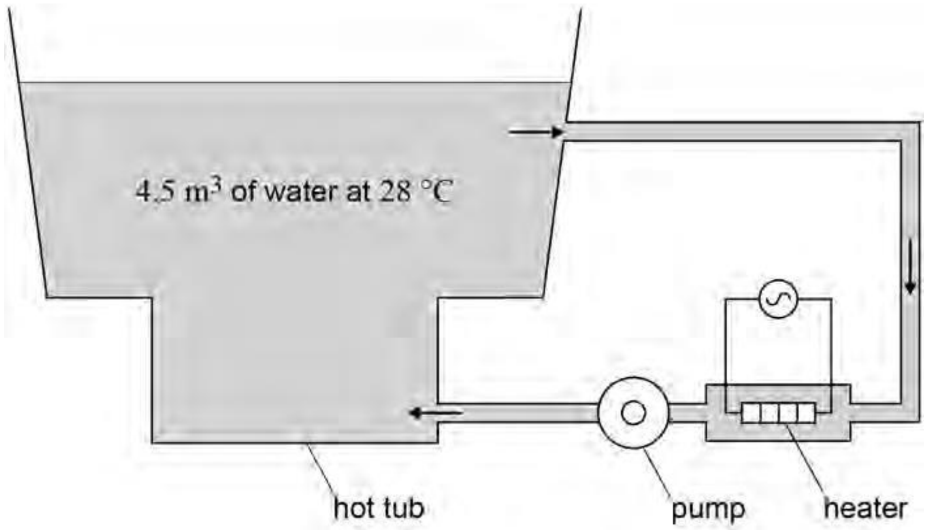
____

____

____

____ **(2)**

Q8.2 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)**

Q8.3 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.

___

___

___

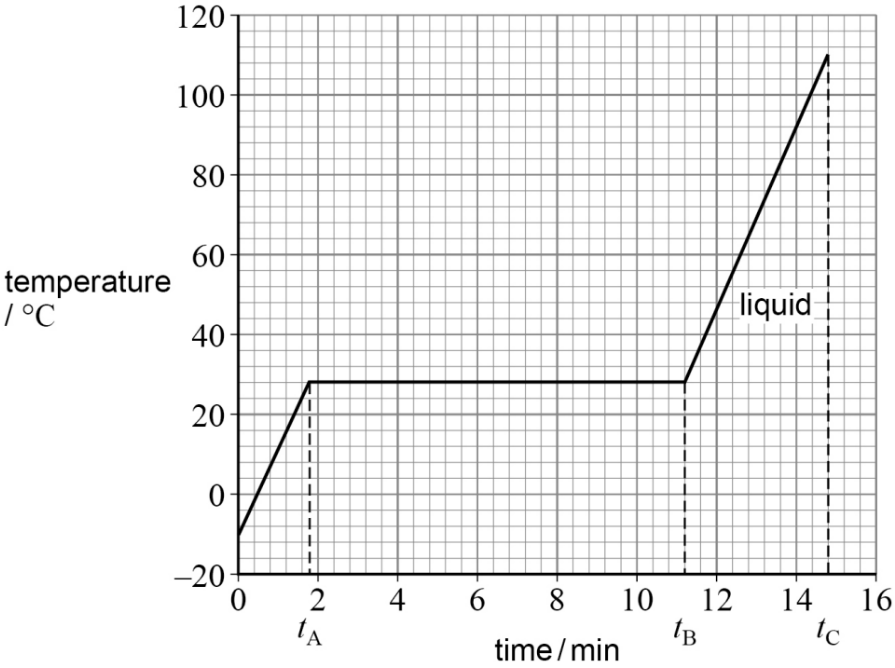
___

___ **(2)**

(Total 7 marks)

Q9. 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.



Q9.1 State the melting temperature of **M**.

temperature = ________________ °C **(1)**

Q9.2 Explain how the energy transferred to the sample changes the arrangement of the atoms during the time interval t_A to t_B.

___

___

___

___ **(1)**

Q9.3 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.

___

___

___

___

___

___ **(2)**

Q9.4 Describe how the motion of the atoms changes during the time interval t_B to t_C.

____

____

____ **(1)**

Q9.5 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)**

Q9.6 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)

Mark Schemes

30 minutes on 15: Electricity 1 – Basics, Resistivity and Superconductivity
Mark Scheme

Question	Marking guidance	Mark	Comments
1.1	$I = Q/t = 9.4 \times 10^{18} \times 1.6 \times 10^{-19} / 18 \times 10^{-6}$ ✓ = 84 000 A (83 556 A) ✓	2	
1.2	Correct general shape in 1st quadrant ✓ Symmetry in 1st and 3rd quadrant ✓ Goes through (12, 0.8) ± 1mm but doesn't get to 0.8A before 10V✓ gradient at (0, 0) should be 0.2 (can check with, for example, (1,0.2) or (2, 0.4)) ✓	4	Must not be linear beyond V = ± 2V
2.1	States diameter = 1.89 (mm) or radius = 0.945 (mm) Area = $\pi \times (0.945 \times 10^{-3})^2 = 2.81 \times 10^{-6}$ m^2 (must see at least 3 sig. fig.)	1 1	Convincing treatment of powers of 10 necessary for 2nd mark
2.2	$R = \frac{1.7 \times 10^{-8} \times 0.85}{2.81 \times 10^{-6}}$ $= 5.1 - 5.2 \times 10^{-3}\Omega$ 2 sig. fig.	1 1 1	1st mark is for a correct substitution or rearrangement Correct answer gets first 2 marks 3rd mark is stand alone
3.1	MRI scanners / particle accelerators / MAGLEV trains / SQUIDs / electrical power transmission ✓	1	Allow other examples not listed here Not electromagnet or power magnet
3.2	high magnetic fields / low or no heating effect / increased efficiency for power transmission ✓	1	Reason must match application given in 03.1
3.3	(semi-conductor) diode ✓	1	Allow LED Allow phonetic spellings
3.4	Correct reading of current (48 ± 4 mA) from graph ✓ 18.0 or 18.8 or 19.6 (Ω) ✓	2	Condone power of ten error for current for 1st mark only Answers must be from 48 ± 2 mA. May be given as 2 sf.

Q4 B

Q5 A

Q6 A

Q7 C

Q8 A

30 minutes on 16: Electricity 2 – Series, Parallel and Potential Dividers
Mark Scheme

Question	Marking guidance	Mark	Comments
1.1	Three from: ✓ ✓ ✓ reading from graph: 3.2 ± 0.2 (kΩ) their R_T + 10 × 10^3 (Ω) use of I = 18/R Unit consistent with power of 10 used for R 1.34 to 1.38 × 10^{-3} (A) or 1.34 to 1.38 (mA) ✓	4	Full marks for correct answer. Allow alternative method using pot divider equation. Condone power of ten omission for 1st MP Allow C s^{-1} and V Ω^{-1} Accept answers rounded to 2sf from correct graph reading
1.2	use of P = I^2R eg (their 06.1)^2 × 10 × 10^3 ✓ 0.018 or 0.019 or 0.020 (W) ✓	2	Condone power of ten error for current and/or resistance for 1st MP only. Allow 1st MP for calculation of power of circuit: P = 18^2/total R or P = 18 × their 0.61), or use of V=IR Allow ecf from 06.1
2.1	As temperature increases, the resistance of the thermistor decreases ✓ As more charge carriers become available for conduction/ are raised to the conduction band ✓ A larger share/proportion of the battery pd across the buzzer (or reference to a potential divider) ✓	3	
2.2	Use of $\frac{1.2}{1.8} = \frac{R}{123}$ or $I = \frac{1.8}{123}$ or $I = 0.0146\ (A)$✓ R = 82 (Ω) ✓	2	Must see 82 not just 80. Answers based on checking can only score both marks if unrounded values are seen.
3.1	Use of P=V^2/R with substitution 144/any value of R ✓ R = 41.1 (W) ✓	2	
3.2	Use of 1/R formula with substitution of some data even if not all 5 resistors 1/R = 0.93 R = awrt 1.1 (Ω)	3	

Q4 B

Q5 C

Q6 D

Q7 B

Q8 D

30 minutes on 17: Electricity 3 –EMF, Internal Resistance and Power Mark Scheme

Question	Marking guidance	Mark	Comments
1.1	The work done OR energy transferred per unit charge to the entire circuit including the internal resistance	1 1	Note the following is worth 1 mark: The p.d. across the battery terminals when there is no current through it OR on open circuit
1.2	Use of V=IR (with V = 9 or 3) R = 4.5 Ω	1 1	
1.3	$\epsilon = I(R + r)$ $12 = I\,(0 + 1.5)$ Maximum current = 8.0 A cao	 1 1	
1.4	Straight line with negative gradient Passing through any two correct data points	1 1	 Look for (0,12), (8,0) OR (2,9)
1.5	Current is 7.5 A (which is less than the maximum possible current) Attempt at calculating lifetime $t = \frac{1.15\times10^4}{7.5}$ OR attempts to calculate charge delivered in 30 minutes Q = $7.5 \times 30 \times 60$ Correct calculation leading to 25.6 min or 1536 s OR 1.35×10^4 C PLUS a statement that the battery is unsuitable	1 1 1	
1.6	Identifies P = 24 W when I = 4.0 A Use of P = I^2 R R = 1.5 Ω OR I = 4.0 A $R_{tot} = \frac{V}{I} = \frac{12}{4.0} = 3.0\ \Omega$ $R_{variable} = 3.0 - 1.5 = 1.5\ \Omega$	1 1 1 1 1 1	
1.7	(To obtain maximum current) the variable resistor has zero resistance hence all power is dissipated in the internal resistance of the battery OR R = 0 so P= I^2R = 0	1 1	

Q2 B

Q3 C

Q4 C

Q5 C

Q6 D

1. Describe the structure of a solid.

Molecules are closely packed together in a regular, repeating arrangement.

There are strong bonds between all neighbouring molecules. The molecules vibrate in their fixed positions.

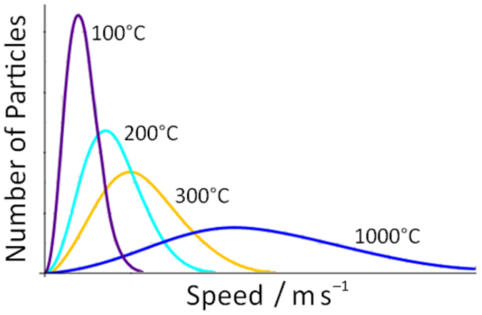
2. Describe the structure of a liquid.

Molecules are closely packed together in a random arrangement.

There are bonds between most neighbouring molecules. The molecules vibrate and can slide past each other.

3. Describe the motion of a gas.

Gas molecules move freely with random motion, in every direction at a range of speeds.



4. Describe how the motion of gas molecules changes as they are heated.

The mean speed of the molecules increases.

Motion continues to be random.

5. What is meant by Brownian motion?

Random motion; unpredictable, changing direction and speed and without pattern.

6. How is Brownian motion observed?

A transparent illuminated box contains small smoke particles and air. The smoke particles are observed to move randomly when viewed through a microscope.

7. What did Brownian motion prove?

Brownian motion provides evidence of atoms.

The motion of the smoke particles is caused by collisions between air molecules (and smoke particles).

Air particles are much smaller than the smoke particles and moving much faster.

8. Where does heat flow?

From an area of high temperature to an area of lower temperature.

9. What is meant by being in thermal equilibrium?

When two objects are in thermal equilibrium there is no net flow of heat between them; they are at the same temperature.

If two systems, A and B, are in thermal equilibrium with each another, and B is in thermal equilibrium with a third system, C, then A is also in thermal equilibrium with C.

10. What is the internal energy of a substance?

The sum of the (random distributions of) kinetic and potential energies of the particles / atoms / molecules in the substance.

11. How is the internal energy of a material increased?

Internal energy is given by: $\Delta U = \Delta Q + \Delta W$

1. By heating the material (transferring thermal energy, ΔQ).
2. By doing work on the material (ΔW).

12. Which types of energy change when a material changes temperature?

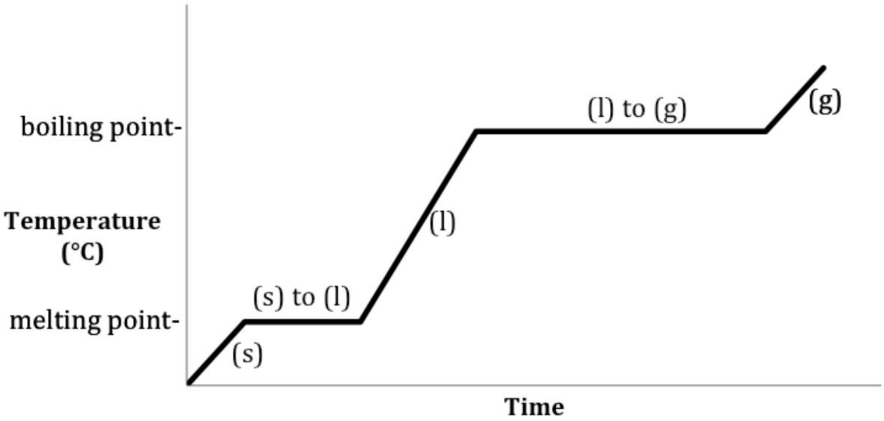
The mean kinetic energy changes but the potential energy remains constant.

Increasing the temperature increases the mean kinetic energy and decreasing the temperature decreases the mean kinetic energy.

13. Which types of energy change when a material changes state?

The potential energy changes but the mean kinetic energy remains constant.

14. Sketch a graph of temperature against time for a material that is being heated.



15. What is meant by the term specific heat capacity?

The energy required to raise the temperature of 1 kg of a substance by 1 K (or by 1 °C).

The energy released when the temperature of 1 kg of a substance falls by 1 K (or by 1 °C).

16. What is meant by the specific latent heat of fusion?

The energy required to change 1 kg of a solid to a liquid without a change in temperature.

The energy released when 1 kg of a liquid changes to a solid without a change in temperature.

17. What is meant by the specific latent heat of vaporisation?

The energy required to change 1 kg of a liquid to a gas without a change in temperature.

The energy released when 1 kg of a gas changes to a liquid without a change in temperature.

18. Why is the specific latent heat of vaporisation a much bigger value than the specific latent heat of fusion for the same material?

To change from a solid to a liquid requires some bonds to be broken but to change from a liquid to a gas requires all bonds to be broken. Energy is required to break bonds so more energy is needed to change each kilogram of liquid to gas than to change a solid to a liquid; there is a bigger change of potential energy.

19. How is power connected to energy? Define all terms in the equation and state the units used.

Power is the energy transferred per unit time (per second) or the rate of doing work.

1 W is equal to 1 J every second.

$$P = \frac{\Delta W}{\Delta t}$$

P is the power, measured in watts, W.

ΔW is the energy transferred or work done, measured in joules, J.

Δt is the time taken (for the energy to be transferred), measured in second, s.

20. What is the equation used for calculating the energy required to change temperature? Define all terms in the equation and state the units used.

$$Q = mc\Delta T$$

Q is the energy required, measured in joules, J.

m is the mass (that is changing temperature), measured in kilograms, kg.

c is the specific heat capacity, measured in joules per kilogram per kelvin, J kg^{-1} K^{-1} (or J kg^{-1} $°C^{-1}$).

ΔT is the change in temperature, measured in kelvin or degrees Celsius, K or °C.

21. What is the equation used for calculating the energy required to change state? Define all terms in the equation and state the units used.

$$Q = ml$$

Q is the energy required, measured in joules, J.

m is the mass, measured in kilograms, kg.

l is the specific latent heat, measured in joules per kilogram, J kg^{-1}.

22. How is temperature rise calculated from power and flow rate?

Combining the power and specific heat equations gives:

$$Pt = mc\Delta T \quad \rightarrow \quad P = \frac{m}{t}c\Delta T \quad \rightarrow \quad \Delta T = \frac{P}{\frac{m}{t}c}$$

23. What would happen if a material was replaced with one of different specific heat capacity?

If a material was used with a lower specific heat capacity (but the same power or energy) it would result in a larger temperature rise per kilogram.

If the specific heat capacity was larger the temperature rise would be smaller.

Thermal Physics Mark Schemes

M1. (1) using $Q = mc\Delta\theta$ = 3.00 × 440 × (84 – 27) ✓

7.5 × 10^4 (J) ✓

(2) using $Q = ml$ = 1.20 × 2.5 × 10^4

= 3.0 × 10^4 (J) ✓

(3) (heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron)

3.0 × 10^4 + heat supplied by cooling lead = 7.5 × 10^4 ✓

heat supplied by cooling lead = 4.5 × 10^4 = $mc\Delta\theta$

c = 4.5 × 10^4 / (1.2 × (327 – 84)) ✓

c = 154 (J kg^{-1} K^{-1}) ✓

(4) any **one** idea ✓

no allowance has been made for heat loss to the surroundings

the specific heats may not be a constant over the range of temperatures calculated

[7]

M2. (1) (use of $\Delta Q = m\ c\ \Delta T$)   30 × 98 = 0.100 × c × 14 ✓

c = 2100 (J kg^{-1} K^{-1}) ✓

(2) (use of $P\ t = m\ l + m\ c\ \Delta T$)   500 × 98 = (0.100 × 3.3 × 10^5) ✓ + (0.100 × 4200 × ΔT) ✓

(ΔT = 38 °C) T = 38°C ✓

(3) the temperature would be higher ✓

any **one** from the following ✓

as the ice/water spends more time below 25°C

heat travels in the direction from hot to cold

ice/water first gains heat then loses heat

[7]

M3. (1) $\Delta T = \left(\frac{\Delta Q}{mc} =\right)\frac{8.5\times10^3}{4200\times0.12}$ ✓

17 K ✓

(2) $\left(\frac{\Delta T}{\Delta t} = \frac{\frac{\Delta Q}{\Delta t}}{mc}\right) = \frac{100-26}{\Delta t}\,\frac{8.5\times10^3}{0.41\times4200}$ ✓

t = 15 s ✓

[4]

M4. (1) (heat supplied by glass = heat gained by cola so $m_g c_g \Delta T_g = m_c c_c \Delta T_c$)

0.250 × 840 × (30.0 – T_{final}) = 0.200 × 4190 × (T_{final} – 3.0) ✓

1st mark for RHS or LHS of substituted equation

(210 × 30) – (210 T_{final}) = (838 T_{final}) – (838 × 3)

T_{final} = 8.4(1) (°C) ✓

2nd mark for 8.4 °C

Alternatives:

8 °C is substituted into equation (on either side shown will get mark) ✓

resulting in 4620 J ~ 4190 J ✓

OR 8 °C substituted into LHS ✓ (produces ΔT = 5.5 °C and hence)

= 8.5 °C ~ 8 °C ✓

OR 8 °C substituted into RHS ✓ (produces ΔT = 20 °C and hence)

= 10 °C ~ 8 °C ✓

(2) (heat gained by ice = heat lost by glass + heat lost by cola)

NB correct answer does not necessarily get full marks

(heat gained by ice = $mc\Delta T + ml$)

heat gained by ice = (m × 4190 × 3.0) + (m × 3.34 × 10^5) ✓

(heat gained by ice = m × 346600)

heat lost by glass + heat lost by cola

= [0.250 × 840 × (8.41 – 3.0)] + [0.200 × 4190 × (8.41 – 3.0)] ✓ (= 5670 J)

m (= 5670 / 346600) = 0.016 (kg) ✓

the first two marks are given for the formation of the substituted equation not the calculated values

3rd mark is only given if the previous 2 marks are awarded

if 8 °C is used the final answer is 0.015 kg

Alternative

(using cola returning to its original temperature)

(heat supplied by glass = heat gained by ice)

(heat gained by glass = 0.250 × 840 × (30.0 – 3.0))

heat gained by glass = 5670 (J) ✓

(heat used by ice = $mc\Delta T + ml$)

heat used by ice = m (4190 × 3.0 + 3.34 × 10^5) ✓ (= m (346600))

m (= 5670 / 346600) = 0.016 (kg) ✓

[5]

M5. (1) the energy required to change the state of a unit mass of water to steam / gas ✓

when at its boiling point temperature / 100°C / without a change in temperature) ✓

allow 1 kg in place of unit

allow liquid to vapour / gas without reference to water

don't allow 'evaporation' in first mark

(2) thermal energy given by copper block = $mc\Delta T$ = 0.047 × 390 × (990 – 100)

= 1.6 × 10^4 (J) ✓

2 sig figs ✓

can gain full marks without showing working

a negative answer is not given credit

sig fig mark stands alone

(3) thermal energy gained by water and copper container = $mc\Delta T_{water} + mc\Delta T_{copper}$

= (0.050 × 4200 × (100 – 84)) + (0.020 × 390 × (100 – 84)) ✓

or = 3500 (J) (3485 J)

available heat energy (= $1.6 \times 10^4 - 3500$) = 1.3×10^4 (J) ✓

allow both 12000 J and 13000 J

*allow ecf from (**Q5.2**) but working must be shown for a ecf*

take care in awarding full marks for the final answer – missing out the copper container may result in the correct answer but not be worth any marks because of a physics error

ignore sign of final answer in ecf (many ecf's should result in a negative answer)

(4) (using Q = *ml*)

($m = 1.3 \times 10^4 / 2.3 \times 10^6$) = 0.0057 (kg) ✓

allow 0.006 but not 0.0060 (kg)

*allow ecf from (**Q5.3**)*

answers between 0.0052 → 0.0057 kg resulting from use of 12000 and 13000 J

[7]

M6. (1) (it takes) 130 J / this energy to raise (the temperature of) a mass of 1 kg (of lead) by 1 K / 1 °C (without changing its state) ✓

1 kg can be replaced with unit mass.

Marks for 130 J or energy.

1 kg or unit mass.

1 K or 1 °C.

Condone the use of 1 °K

(2) (using $Q = mc\Delta T + ml$) = (0.75 × 130 × (327.5 – 21)) + (0.75 × 23000) ✓

(= 29884 + 17250)

= 47134 ✓

= 4.7×10^4 (J) ✓

For the first mark the two terms may appear separately i.e. they do not have to be added.

Marks for substitution + answer + 2 sig figs (that can stand alone).

[4]

M7. (1) Tick in 4th box ✓

(2) (using heat energy = *ml*) = $0.047 \times 3.3 \times 10^5 = 1.6 \times 10^4$ (J) ✓ (1.55×10^4 J)

answer alone gains mark

(3) (heat in from water = heat supplied to melt and raise ice temperature)

$1.8 \times 10^4 = 1.6 \times 10^4$ + (energy to raise temp of ice)

energy to raise temp of ice = 2×10^3 (J) ✓

answer alone gains mark allow 2, 2.5 or 3 × 10^3 J

allow ecf if substitution is shown

*1.8×10^4 – (**Q7.2**)*

(4) (using heat energy = $mc\Delta T$)

c = $2 \times 10^3 / 0.047 \times 25 = 2 \times 10^3$ ✓ (1.7×10^3)

(note there is a large range of correct answers)

J kg^{-1} K^{-1} or J kg^{-1} $^oC^{-1}$ ✓

only allow ecf if substitutions are seen

*c = (**Q7.2**) / 0.047 × 25*

*c = (**Q7.2**) × 0.851*

allow 1 sig fig.

common answers:

for 2.5 × 10^3 J gives 2.1 × 10^3 or 2 × 10^3

for 3 × 10^3 J gives 2.6 × 10^3 or 3 × 10^3

[5]

M8. (1) Specific latent heat of fusion is the <u>energy</u> (required) to change 1 kg / unit mass of material from the solid state to the liquid state or melt/fuse ✓

Without a change of temperature or at the freezing/melting temperature/point ✓

The direction of energy transfer must be consistent with the direction of the change of state (If energy to change… is given then required or needed is implied)

2nd mark stands alone.

(2) (Dividing both sides of the equation $\Delta Q = m\,c\,\Delta\theta$ by Δt gives $\Delta Q / \Delta t = m\,c\,\Delta\theta / \Delta t$

or $\Delta\theta = (\Delta Q / \Delta t) \times \Delta t / m\,c$ where $m = \rho V$

$\Delta\theta = 2700 \times (60 \times 60) / (4.5 \times 1000 \times 4200)$ ✓

Full substitution correct ✓

Temperature rise = $\Delta\theta$ = 0.51 (K) ✓ (= 0.514 K)

Working <u>must be seen</u> as there is a self-cancelling error with two 1000 factors.

So answer alone gains the 3rd mark only.

First mark can be gained if (60 × 60) is absent even if not re-arranged.

The change of temperature may be written as a difference between 28 °C and an unknown temperature (allow in kelvin written either way round ie with incorrect sign)

*1 sig fig is **not** acceptable.*

Max 2 if: Omits (60 × 60) giving 1.43 × 10^{-4} K

Omits 60 giving 8.57 × 10^{-3}

(3) (When the pump is working at speed) the pump is <u>doing work</u> (on the water) ✓

Work (and heat both) can raise the temperature of a body (as stated in the 1st Law of thermodynamics) (this may be expressed as work is converted to thermal energy) ✓ owtte

OR The pump increases the randomness / turbulence of the water/molecules

OR The <u>mean</u> square speed/*mean* kinetic energy is proportional to the (absolute) temperature (this may be given in the form on an equation) OWTTE

(Lenient mark – a reference to random motion or more collisions may gain this mark but a simple increase in kinetic energy is not enough).

Do not penalise answers that go nowhere unless they directly contradict a marked answer.

[7]

M9. (1) 28 (°C) ✓

(2) The energy transferred reduces the number of nearest atomic neighbours ✓

OR allows atoms to move their centre of vibration

First alternative must not imply total loss of intermolecular forces or neighbours.

Ignore any references to changes in separation.

OR breaks some of the (atomic) bonds

A reference to 'breaking <u>the</u> bonds' implies all the bonds and does not gain the mark.

No mark for saying bonds weaken.

However these errors in discussing the bonds does not prevent a mark coming from another point

OR crystalline to amorphous (owtte)

Last alternative might be expressed as 'atoms change from fixed positions to them being able to slide around each other'.

An explanation that involves increasing the kinetic energy will lose the mark.

So will any description that implies it becomes a gas.

(3) The (total or mean) kinetic energy remains constant. ✓

The (total or mean) potential energy increases. ✓

(4) The <u>mean</u> speed/<u>mean</u> kinetic energy increases ✓

Ignore references to larger separation (because it's not always true): collisions (as it is not a gas) or measures of randomness (which are usually too vague).

Condone use of average for mean.

Don't allow velocity instead of speed.

During this time interval the atoms are all in the liquid form so no credit for references that indicate a change of state.

(5) Using both $\Delta Q = mc\Delta\theta$ **and** $\Delta Q = P\Delta t$ ✓

$$\left(c = \frac{P\Delta t}{m\Delta\theta} = \frac{35 \times (14.8 - 11.2) \times 60}{0.25 \times (110 - 28)} = 369\right)$$

c = 370 ✓ (allow 365–375)

J kg^{-1} K^{-1} ✓ (or J kg^{-1} C^{-1})

First mark can be given by seeing the substitution which may have some errors for example not using exactly 28. These will be penalised in the second mark.

Correct answer gains first two marks NB 400 J kg^{-1} K^{-1} shows candidate has wrongly made calculations for the solid. No mark for the unit if a solidus is used because of the uncertainty of whether the K is on the top or bottom line. (which is correct J / kg / K or J / kg K ?)
However allow a prefix if kilojoules are used for example.

(6) (Using both $\Delta Q = ml$ and $\Delta Q = P\Delta t$)

$$l\left(= \frac{P\Delta t}{m}\right) = \frac{35\times((11.2-1.8)\times 60)}{0.25} = 79 \text{ kJ kg}^{-1}$$ ✓

hence M = gallium ✓

(condone an ecf consistent with the calculation provided a comment is made if the value falls outside the range of the table)

The calculation yields1.3 kJ kg^{-1} if the 60 seconds is omitted.

Interim stage heat supplied = 19.7 kJ

A valid calculation must be shown to gain this second mark.

[10]