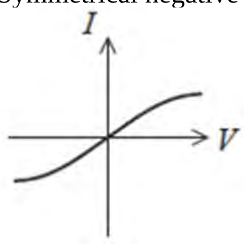
Question Number	Answer	Mark
1	Use of resistors in parallel formula **(1)** Use of resistors in series formula **(1)** R = 68 Ω **(1)** <u>Example of calculation</u> (1/22 Ω) + (1/620 Ω) = 0.0471 Ω^{-1} Resistance for parallel section = 21.2 Ω 47 Ω + 21.2 Ω = 68.2 Ω	**3**
	Total for question	**3**

Question Number	Answer	Mark
2(a)	Correct curve in + + section (accept *V* – *I* or *I* – *V* graph but axes must be labelled) **(1)** Symmetrical negative curve (accept if ++ curve incorrect) **(1)** 	**2**
2(b)	Drift velocity (of electrons) increases (as current increases) **Or** electrons gain (kinetic) energy (as current increases) **Or** rate of flow of electrons/charge increases (as current increases) **(1)** More (frequent) collisions of electrons with lattice ions **(1)** lattice ion vibrations increased **Or** (More) energy dissipated as heat in lattice **Or (**More) energy transferred when electrons collide with lattice ions **(1)** (accept charge carriers for electrons and atoms/ions/particles for lattice ions.)	**3**
	Total for question	**5**

<table>
<tr><th></th><th>Answer</th><th>Mark</th></tr>
<tr><td>3(a)</td><td>

Switch combination	Total resistance of circuit	
A open. B closed.	*R*	
A open. B open.	2*R*	**(1)**
A closed. B closed.	*R*/2 or 0.5 R	**(1)**
A closed. B open.	2*R*/3 or 0.7 R	**(1)**

Answers must be in simplest form, e.g. not *R* + *R*</td><td>3</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>3(b)</td><td>Reference to $P = V^2/R$ OR $P= VI$ and $V=IR$
(Accept energy equations.) (1)
(most power/energy) from the switch combination with the lowest resistance (1)

[Ignore the table when awarding these method marks.]</td><td>2</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>3 (c)</td><td>(Internal resistance will) reduce current Or reduce V Or increase total R Or cause lost volts Or energy transferred to internal resistance (1)

less energy/power output (in all combinations) (1)</td><td>2</td></tr>
<tr><td></td><td>Total for question</td><td>7</td></tr>
</table>

Question Number	Answer	Mark
4(a)(i)	Resistance at 20 ^{o}C = 1250 - 1300 (Ω)	**(1)**
4(a)(ii)	Converts kΩ → Ω [look for 1000 (Ω)] Use of potential divider formula **OR** use of 2300 (Ω) to find current Reading on voltmeter = 2.6 – 2.7 V (ecf value from (a)(i)) <u>Example of calculation</u> V = (1000 Ω ÷ 2300 Ω) × 6 V V = 2.6 V	**(1)** **(1)** **(1)**
4(b)	(decreasing temp causes) resistance of <u>thermistor</u> to increase Voltmeter reading decreases Candidates who think resistance will decrease leading to voltmeter increase can get 2nd mark.	**(1)** **(1)**
	Total for question	**6**

Question Number	Answer	Mark
5(a)	<u>Effect of stretching wire</u>	
	Refers to $R = \rho l/A$	**1**
	Increasing length leads to increase in resistance	**1**
	Decreasing area leads to increase in resistance [must relate thinner to area]	**1**
	[last two points may be combined to give single statement, can score both marks]	
(b)	<u>Resistance calculation</u>	
	Use of $R = \rho l/A$	**1**
	× 8	**1**
	R = 0.22 (Ω)	**1**
	[Omitting x8 gives R = 0.028 Ω scores 1]	
	Example of answer	
	$R = (9.9 \times 10^{-8}\ \Omega\ \text{m}) \times (8 \times 0.025\ \text{m}) \div 0.9 \times 10^{-7}\ \text{m}^2$	
	R = 0.22 Ω	
(c)	<u>Relationship and increase in R</u>	
(i)	Attempts to substitute for $A = V/l$ in $R = \rho l/A$	**1**
	$R = \rho l^2/V$	**1**
(ii)	Any attempt to relate original resistance of gauge to 2.5^2 (possibly × 8, cm or m)	**1**
	Relates this to resistance associated with increase in length	**1**
	Change in resistance = 1.76×10^{-3} Ω	**1**
	OR	
	Uses $V=lA$ to find new area	**1**
	Uses this A with new length to find new R	**1**
	Change in resistance = 1.76×10^{-3} Ω	**1**
	[if candidate assumes A constant and finds new R and ΔR = 0.001 Ω, score 1 mark]	
	Example of answer	

	New $R = (\frac{2.51^2}{2.5^2} \times 0.22) - 0.22$ $\Delta R = 1.76 \times 10^{-3}\ \Omega$	
(d)	<u>Zigzag pattern</u> Each section of wire increases in length/gives a longer total length/long wire in small space Small change in length of gauge leads to larger change in resistance	**1** **1**
	Total for question	**13**

Question Number	Answer	Mark
6(a)	Resistance of parallel combination much less than resistance of V_1 **(1)** (Therefore) voltage of parallel combination is much less than voltage of V_1 **(1)** **Or** Identifies current (nearly) zero (because of resistance of V_1 very large) **(1)** (So) p.d. across 10 Ω is zero by $V = IR$ **(1)** (Credit for each marking point may be obtained by completing a calculation.)	**2**
6(b)	Identifies resistance of parallel combination is 5 MΩ **(1)** Use of resistors in parallel formula **(1)** R = 10 MΩ **(1)**	**3**
	Total for question	**5**

Question Number	Answer		Mark
7(a)	(Ω =) V A^{-1} **OR** (Ω =) V/A **OR** $R = V / I$ [**OR** volt in alternative equivalent units divided by ampere in alternative equivalent units, as long as Ω isn't part of it] [Units and quantities must not be mixed.]	**(1)**	
7(b)(i)	Use of $R = V / I$ with values feasibly from the graph R = 6.8 Ω to 8.0 Ω (marks not awarded if using a gradient)	**(1)** **(1)**	**2**
7(b)(ii)	resistance of metal remains constant resistance of thermistor decreases (as p.d. increases)	**(1)** **(1)**	**2**
7(b)(iii)	(Increasing) current leads to temperature increase / leads to thermistor 'heating up' More conduction electrons / more electrons released / more free electrons / more charge carriers / charge carrier density increased / n increases	**(1)** **(1)**	**2**
	Total for question		**7**

Question Number	Answer	Mark
8(a)	Use of $P = V^2/R$ **OR** $P = IV$ and $V = IR$ (1) $R = 48.4\ \Omega$ (accept 48 Ω or 50 Ω) (1) <u>Example of calculation</u> $R = V^2/P$ $R = 220 \times 220 / 1000$ $R = 48.4\ \Omega$	**2**
8(b)	Use of $E = Pt$ OR $E=VIt$ OR $E = V^2t/R$ with 3 or 3 × 60 as the time (1) E = 180 000 J (1) (ecf values of R and/or I from (a)) (3000 J scores 1 mark)	**2**
8(c)(i)	Attempts to calculate power (1) Power = 250 W (1) Time to boil 12 mins/ 720 s (1) **OR** Calculates new current 2.27 A (1) Use of Energy=VIt with their current (1) Time = 12 mins /720 s (because of rounding, accept 700s -740 s if method correct) (1) **OR** $P \alpha V^2 \alpha$ ¼ (1) $t \alpha 1/P \alpha 4$ (1) time 12 mins (1) (for any method, an answer of 6 mins scores 1 mark)	**3**
8(c)(ii)	Use of equation ,$V = IR$ or $P = V^2/R$ or $P = VI$ leading to increased current or power. (1) Cause damage/fuse to melt/ circuit breaker to trip /element to burn out/wire to melt (1) Do not credit ‘short circuit’ and ‘explosions’ Do not give 2nd mark if reference to overheating or fuses is related to resistance increasing	**2**
	Total for question	**9**

Question Number	Answer	Mark
9(a)	Use of resistors in parallel formula $R = 9.1\ \Omega$ **Example of answer** $1/R = 1/10 + 1/100$ $1/R = 11/100$ $R = 9.1\ \Omega$	**1** **1**
(b)	Voltmeter is connected in parallel (stated or implied) OR voltmeter draws little/no current Resistors in parallel formula with either R_V or large value used $1/R_V$ is <u>very</u> small/negligible OR calculated value of 9.1 Ω with comment	**1** **1** **1**
	Total for question	**5**