Question	Answer	Marks	Guidance
1 (a)	Axes labelled with pd / V and current / A Scale divisions of 1 or 2 V and 0.1 or 0.2 A Points plotted correctly. Line of best fit drawn to cross through as many points as possible, starting at the origin.	1 1 1 1	
1 (b)	$V = IR$ and $R = \frac{\rho L}{A}$ therefore $V = \frac{\rho L I}{A}$	1 1	
1 (c)	gradient of graph = $R = \frac{\rho L}{A}$ $= \frac{8.0\#V}{0.6\#A}$ $= 13.3\ \Omega$ Resistivity $\rho = \frac{RA}{L}$ $= 13.3 \times \pi \times \frac{(0.14 \times 10^{-3})^2}{1.60}$ $= 5.12 \times 10^{-7}\ \Omega\ m$	1 1 1 1 1 1	
2 (a)	$\Delta Q = I\,\Delta t = 40 \times 10^{-3} \times 3 \times 60$ $= 7.2$ C	1 1	Remember that current must be in A and time in s.
2 (b)	number of electrons = $\frac{7.2}{1.60 \times 10^{-19}}$ $= 4.5 \times 10^{19}$	1	From the Data Booklet, one electron has charge 1.6×10^{-19} C, so you divide the charge in C from **(i)** by this number to find the number of electrons.
2 (c)	$V = \frac{\Delta W}{\Delta Q} = \frac{8.6}{7.2}$ $= 1.2$ V	1 1	This follows from the definition of 1V as 1 J C^{-1} . Throughout this question, an earlier arithmetical error (in finding ΔQ, say) would not be further penalised: a wrong value for ΔQ could still lead to full marks here.
2 (d)	$R = \frac{V}{I} = \frac{1.2}{40 \times 10^{-3}} = 30\ \Omega$	1	A wrong value of *V* from **(c)** could still allow you to gain this mark, provided you used **your** *V* correctly in **(d)**.
3 (a)	$R = \frac{V}{I} = \frac{1.2}{1.8}$ $= 6.7\ \Omega$	2 1	Th- first mark is for choosing $R = \frac{V}{I}$, and then using it correctly. The second mark is for reading the *V* and *I* values from the top point of the graph, where the resistance is greatest. The third mark is for working out *R* correctly and showing its unit.

Question	Answer	Marks	Guidance
3 (b)	current is zero for all negative voltages for positive voltages, curve showing a steep rise in current starting at about +0.6 V (with voltage not greatly to exceed 1 V)	1 1	You have to be familiar with the shape of these characteristic curves. A diode conducts in one direction only and conducts increasingly well once the positive voltage is greater than about 0.6 V.
4 (a) (i)	readings need to be taken more quickly than could be achieved by manual timing	1	The filament heats up very quickly, so you could not possibly take readings quickly enough if you were to try to use a stop watch. Note that the advantage of the computer is that it can take frequent results over a very short time; this is nothing to do with the **accuracy** of the readings.
4 (a) (ii)	rate: more than 40 samples per second reason: the current rises very rapidly over the first 0.1 s, and you should have about 4 results on this first section	1 1	Use a ruler on the time axis to divide up and mark a scale, where only 0 and 2.0 s are marked. This should allow you to decide that initial rise takes place in about 0.1 s. A reliable graph requires several results to be taken in that time.
4 (b)	Relevant points include: • initial resistance is low so initial current is high • temperature of filament increases (or filament heats up) • resistance increases as temperature rises • increase in resistance causes current to fall • current is steady when energy supplied = energy lost from filament (or when temperature is constant) • maximum heating is produced at start when current is highest • melting of filament causes it to fail (could be mechanical failure caused by temperature rise) • when switched on energy is supplied more rapidly than it is lost so filament melts	6	This question is about the effect of temperature on the resistance of a metal wire. When it is cold the resistance is low; the resistance increases as the wire heats up. Therefore the current increases greatly at the start and then decreases as the filament temperature increases. You can observe this effect with a sensitive ammeter. The filament in lamps (such as old-fashioned domestic light bulbs) sometimes fails when they are first switched on. If, however, they are supplied through a dimmer switch that allows you to increase the current gradually, this initial failure is less likely to happen.
5 (a)	$R = \frac{\rho L}{A} = \frac{1.7 \times 10^{-8} \times 1.4}{7.8 \times 10^{-7}}$ $= 3.1 \times 10^{-2}\ \Omega$	1 1	In this example you have to start off by rearranging the resistivity equation to make R the subject.
5 (b)	since the volume is constant, $L_1 A_1 = L_2 A_2$ for the two wires $\therefore A_2 = \frac{1}{2} A_1\ (\because L_2 = 2 L_1)$ $R2 = \frac{\rho \times 2L_1}{A_1/2} = \frac{4\rho L_1}{A_1} = 4R$	1 1	If you find it difficult to do this using algebra, you could do it using numbers. L becomes 2.8 m, so A is halved to 3.9×10^{-7} m^2. Substitution of these values gives a resistance of 12.4×10^{-2} Ω, which is 4 R.

Question	Answer	Marks	Guidance
6 (a) (i)	Circuit to show: • battery, switch, wire, variable resistor and ammeter in series • voltmeter in parallel with wire	2	The variable resistor allows you to take more than one result for each length of wire, but your main need is to take results for different lengths.
6 (a) (ii)	switch on, measure *I* and *V* change length of wire measure new *I* and *V* measure length of wire each time	1 1 1 1	The question tells you that the cross-sectional area of the wire is known. Otherwise you would also have to measure the diameter of the wire.
6 (a) (iii)	for each length of wire calculate *R* using $R = \frac{V}{I}$ and plot a graph of *R* against *L* since $R = \frac{\rho L}{A}$, the graph is a straight line of gradient $\frac{\rho}{A}$ $\rho = A \times$ gradient, and *A* is known	1 1 1	In this part you must show how you would use your results for *I*, *V* and *L* in order to determine the value of *ρ*. Graphical methods are preferred because they lead to a more reliable average value.
6 (b)	$R = \frac{V}{I} = \frac{240}{2.0 \times 10^{-3}} = 1.20 \times 10^{5}\ \Omega$ $\rho = \frac{RA}{L} = \frac{120 \times 103 \times (80 \times 10^{-3})^{2}}{1.5 \times 10^{-3}}$ $= 5.1 \times 10^{5}\ \Omega\ \text{m}$	1 1 1	This part makes you think carefully about the application (it is not a wire this time). You are told that a current is passing through the plastic material. The metal films (which coat the end areas) are where the current enters and leaves the plastic, so *A* is $(80 \times 10^{-3})^{2}$.
7 (a) (i)	a component (or substance) which has no electrical resistance	1	It is far better to refer to resistance than to say it is an excellent conductor!
7 (a) (ii)	Sketch graph of *R* against *T* to show: • correct high temperature graph with abrupt discontinuous vertical line indicating that R has become zero at a certain temperature • temperature axis labelled (e.g. $T_{transition}$) at the corresponding temperature	2	At higher temperatures than $T_{transition}$ the resistance increases steadily with temperature. Below $T_{transition}$ the resistance remains zero.
7 (b)	Reason: when resistance is zero there is no energy (heat, or power) lost Applications: power cables, electromagnets, generators, motors, transformers, MRI scanners, monorail trains, particle accelerators, fusion reactors	1 any 2	This tests your knowledge of facts. A superconductor used as a power cable is only really useful if less energy is used to maintain the (generally low) transition temperature of the substance than is saved by using the superconductor.