1)

i	(sum of/total) current into a junction equals the (sum of/total) current out conservation of charge	B1 B1	total vector sum of currents is zero
ii	(sum of) e.m.f.s = (sum /total of) p.d.s/sum of voltages in/around a (closed) loop (in a circuit) energy is conserved	B1 B1	

2)

a		current moves from + to – (of battery in circuit) **and** electrons move from – to +	B1	
b		$C\,s^{-1}$ $V\,\Omega^{-1}$	B1 B1	2 correct 2 marks; 1 correct 1 mark, withhold a mark for each additional answer given
c	i	statement of Kirchhoff's first law or conservation of charge	B1	**accept** wires are in series or current is the same (at every point) in a series circuit/AW **not** current in = current out

3)

a	i	E = (Pt =) 36 x 3600 = 1.3×10^5 (J)	C1 A1	**allow** I = 3 A and E = VIt, etc. **accept** 129600 (J)
	ii	Q = E/V = $1.3 \times 10^5/12$ **or** Q =It =3 x 3600 = 1.1×10^4 unit: C	C1 A1 B1	**ecf (a)(i)** **accept** 1.08×10^4 **allow** A s **not** $J\,V^{-1}$
	iii	Q/e = $1.1 \times 10^4/1.6 \times 10^{-19}$ = 6.9×10^{22}	C1 A1	**ecf (a)(ii)** **accept** 6.75 or 6.8×10^{22} using 10800
b	i	the average displacement/distance travelled of the electrons along the wire per second; (over time/on average) they move slowly in one direction through the metal/Cu lattice (when there is a p.d. across the wire); (because) they collide constantly/in a short distance with the lattice/AW	 B1 B1 B1	no mark for quoting formula **allow** in one second **max 2 marks** from 3 marking points
	ii	select I = nAev (= 3.0 A) v = $3.0/8.0 \times 10^{28} \times 1.1 \times 10^{-7} \times 1.6 \times 10^{-19}$ = 2.1×10^{-3} ($m\,s^{-1}$)	C1 C1 A1	1 mark for correct formula 1 mark for correct substitutions into formula 1 mark for correct answer to 2 or more SF
		Total question 1	**12**	

4)

(a)		V is not proportional to I the characteristic/line is a curve/not a straight line	B1 B1	**accept** statement of Ohm's law for 1 mark **not** resistance is not constant/AW
(b)	(i)	variable power supply **or** fixed supply + potential divider ammeter in series with and voltmeter in parallel with lamp	B1 B1	value of power supply **not** required **accept** cross or Ω in circle for lamp symbol **penalise** each extra component connected (up to two)
	(ii)	vary p.d. (across lamp)/current (in circuit) by changing voltage supply/moving contact on the potential divider take/record set of values of V and I	B1 B1 B1	 **accept** increase voltage in steps of 1 V/AW **accept as ecf** changing variable resistor in series in circuit QWC mark
(c)		From Fig. 1.1 lamp I_L = 0.25 A for R I_R = 6/20 = 0.30 A so I_P = 0.55 (A)	C1 C1 A1	1 mark for each current; 1 mark for $I_R + I_L$ **or** R_L = 6/0.25 = 24 Ω; Rs in // gives R_{tot} = 10.9; so I_P = 6.0/10.9 = 0.55 A
(d)	(i)	straight line through origin and 300,6	B1	
	(ii)	appreciation that p.d.s across both components add to 6 V attempt to find where current is the same in both components I_S = 0.16 to 0.17 (A) **or** $165 \pm 5 \times 10^{-3}$ A **or** 165 ± 5 mA	B1 B1 B1	**accept** answers in terms of lines drawn on fig.1.1 **or** description of using ruler horizontally on graph and adding squares across graph,etc. **ecf (d)(i)**
		Total	**14**	

5)

(a)		resistance = p.d./current	B1	**accept** voltage instead of p.d.; ratio of voltage to current; voltage per (unit) current **not** R = V/I or p.d. = current x resistance or p.d. per amp or answer in units or voltage over current
(b)	(i)	6 V	B1	
	(ii)	R = V/I = 6/0.25 = 24 (Ω)	C1 A1	**ecf (b)(i)** 240 V gives 960 Ω **award** 0.024 Ω 1 mark only (POT error)
(c)	(i)	6 V supply with potential divider 'input' across it and lamp across p.d. 'output' ammeter in series with lamp voltmeter across lamp	B1 B1 B1	**accept** 0 – 6 V variable supply with lamp across it **not** variable R in series with supply circuit with no battery present can only score voltmeter mark
	(ii)	non-zero intercept line indicating increasing value of R with current	B1 B1	curve must reach y-axis **accept** straight line or upward curve
	(iii)	resistivity/resistance of filament wire increases with temperature the temperature of the lamp increases with current/voltage increase more frequent electron-ion/atom collisions/AW increased ion vibrations	B1 B1	**accept** any two of the four statements **accept** AW, e.g the lamp heats up because of the current
(d)	(i)	lamps do not light	B1	**ignore** reasons unless too contrary
		remaining lamps are lit with qualification	B1	qualification could be more dimly or sensible explanation
	(ii)	using resistors in parallel formula to obtain a value of R per unit R per unit = 19.4 Ω or R total = 774 Ω I = 6/19.4 or 240/774 = 0.31 A	C1 C1 A1	eg takes R of bulb = 10 Ω giving R per unit = 9.1 Ω gains first mark only **ecf (b)(i)(ii)** **accept** R of resistors = 4000 Ω; current in chain = 0.06 A; total current = 0.06 + 0.25 = 0.31 A 0.3 A is SF error so gains 2 marks only apply **SF error only once** in paper
		Total question 1	**16**	

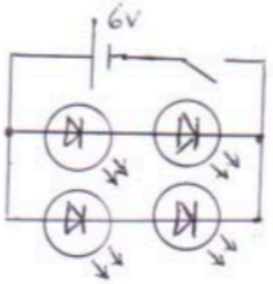
6)

Question			Expected Answers	Marks	Additional Guidance
	a	i	no current/no light/does not conduct until V is greater than 1.5 V brightness/intensity of LED increases with current/voltage above 1.5 V above 1.8 V current rises almost linearly with increase in p.d./AW the LED does not obey Ohm's law as I is not proportional to V/AW below 1.5 V, LED acts as an infinite R/ very high R/acts as open switch above 1.5 V, LED resistance decreases (with increasing current/voltage)	B1 B1 B1 M1 A1 B1 B1	**allow** 1.4 to 1.6 V (QWC mark) (alternative QWC mark) **max 5 marks** which must include at least one of the first 2 marking points
		ii 1 2	infinite resistance I = 23.0 ± 1.0 (mA) R = $1.9 \times 10^3/(23 \pm 1) = 83 \pm 4$ Ω	B1 C1 A1	 **apply** POT error for 0.083 Ω
	b		LED symbol with correct orientation resistor (need not be labelled) and ammeter in series with it voltmeter in parallel across LED only	B1 B1 B1	diode symbol + circle + at least one arrow pointing away
	c		the resistor limits the current in the circuit (when the LED conducts) otherwise it could overheat/burn out/be damaged/AW	B1 B1	
	d		in fig 4.3 the voltage range is from zero to maximum possible in fig. 4.2 the resistance variation is small/AW (so) in fig. 4.2 voltage variation across LED is small	B1 B1 B1	**allow** 6.0 V **accept** the LED is part of a potential divider **accept** only at the top end of the range/AW
			Total question 4	**16**	

7)

a	**i**	When <u>connected/using</u>/AW to the <u>230 V</u> supply the <u>power/energy per second</u> from supply/output/dissipated/AW is <u>25 W</u>	B1 B1	**accept** when working normally/AW **not** 230 V (going) through/into lamp/AW **accept** transferred from electrical (into other) form(s) is 25 W
	ii	$25 = 230^2/R$ R = 2100 Ω **or** 2.1 kΩ	C1 A1	**accept** I = 25/230 = 0.11 A R = 230/0.11 = 2100 Ω (2116 Ω)
	iii	Using the equation in the form P = VI, for larger P need larger I so 60 W	M1 A1	accept $P = V^2/R$, for larger P need smaller R so larger I; do **not** allow any argument using 880 Ω unless this value is calculated here
	iv1	1/R = 1/2100 + 1/880 R = 620 Ω	C1 A1	substitution into formula for Rs in parallel **ecf (a)(ii)**
	iv2	I = 230/620 I = 0.37 (A)	C1 A1	**ecf (a)(iv)1** using 1/R gives 143 kA accept total P = 85 W so I = 85/230 ;= 0.37 (A)
b		the resistivity/resistance (of a metal) increases with temperature **or** R is greater when hot(ter) at 6V/low I little heating effect **or** at 230 V/high I large heating effect	B1 A1	**ora** less when colder **QWC mark**: explanation linked to observations
c	**i**	(a unit of) <u>energy</u> equal to 3.6 MJ **or** 1 kW for 1 h/AW	B1	**eg** 1000 W for 3600 s or similar
	ii	0.06 x 8 = 0.48 (kWh) or 60 x 8 = 480 (Wh) 0.48 x 21 = 10(.1) p	C1 A1	no marks for using s instead of h POT error e.g. 100 or 10000 p
		Total question 2	**15**	

8)

a	**i**	read off value of current (at V = 6.0 V) calculate R using V/I	B1 B1	any reference to using gradient scores 0/2 **accept** I = 0.25 (A) or 250 (mA) **accept** R = 24 Ω
	ii	V is not proportional to I	B1	**accept** not a straight line; R is not constant
b	**i** **ii** **iii**	Q = It = 0.25 x 1 = 0.25 C E = VIt or QV = 6 x 0.25 = 1.5 J E = VIt = 1.5 x 4 x 60 x 60 $= 2.16 \times 10^4$ J	B1 B1 C1 A1	 **ecf(b)(i)** **ecf b(ii)** **accept** 2.2×10^4 J; **allow** 360 J for 1 mark only
c	**i** **ii** **iii**	energy transfer per unit charge from electrical to other forms 30 mA Use of P = VI suitable method (may be expressed purely in numerical form) = 0.36 W	B1 B1 A1 M1 A1 A0	**or** energy transfer/charge; work done /charge **or** across LED 3 x 0.030 = 0.090 W per LED so 0.090 x 4 **or** 30 mA in two branches at 6 V **or** total current is 60 mA from 6 V battery
	iv		B1 B1 B1	symbol for LED correct orientation of LED correct circuit
d		draws a lower current/ light lasts longer (before battery discharged/)AW **or** LEDs more efficient (at converting electrical energy into light) **or** if one LED fails there are still two lit **or** more robust/longer working life	B1	 **allow** lower power consumption/AW
		Total question 1	**16**	

9)

(a)	(i)1	infinity	**B1**	accept symbol
(a)	(i)2	R = 1.8/10 x 10^{-3} R =180 Ω	**C1** **A1**	0.18 Ω scores 1 mark
(a)	(ii)	resistance decreases because I increases more than V therefore since R = V/I value decreases/AW	**B1** **B1** **B1**	**accept** calculation at second value, e.g. at 2.0 R = 53 Ω, with comparison **OR** at two other values **QWC mark** for second marking point
(b)		correct symbol and direction for LED R in series with LED across XY ammeter in series voltmeter in parallel with LED only	**B1** **B1** **B1** **B1**	circle not essential, internal line optional no variable resistor
(c)		torch; car brake/rear light/ traffic light, etc. torch: draws a lower current / light lasts longer before battery discharged/AW **or** LEDs (much) more efficient (at converting electrical energy into light)/AW **or** if one LED fails remainder still lit/AW	**M1** **A1**	suitable example **accept** any **one** sensible statement, include longer life, more durable contradictory statements score zero
		Total	**12**	

10)

i	V is not proportional to I	**B1**	**accept** not a straight line; R is not constant
ii	R (approximately) constant up to V = 0.5 V and I = 50 mA so R = 0.5/0.05 = 10 (Ω)	**B1** **B1**	**allow** graph is (almost) linear/straight (to V = 0.5 V) or constant gradient **allow** any correct calculation, e.g. 0.2/0.02
iii	the resistivity/resistance of the (metal) filament increases with temperature the larger the current in the filament the hotter it becomes/AW	**B1** **B1**	larger current heats filament so resistance increases **or** electron-ion collisions increase/AW; **allow** atom for ion

11)

a	**i**	ammeter in series voltmeter in parallel with LED	**B1**	both correct to score 1 mark
	ii	(at 20 mA) V_{led} = 4.0 V V_R = 0.020 x 100 = 2.0 V so p.d. = 6.0 V	**B1** **C1** **A1**	**allow** R_{led} = (4.0/ 0.02) = 200 Ω p.d. = 0.020 (200 + 100) **allow** answer to 1 SF
b	**i**	energy in eV = 4.1 x 10^{-19}/1.6 x 10^{-19} = 2.6 (eV)	**B1**	**expect** 2.56 eV
	ii	LED strikes at 2.6 V/ only conducts above 2.6 V an electron must pass through a p.d. of 2.6 V to lose energy as a photon of blue light/AW.	**M1** **A1**	
c	**i**	n = I/e = 0.02/1.6 x 10^{-19} = 1.3 x 10^{17}	**C1** **A1**	**expect** 1.25 x 10^{17}
	ii	energy/s = 1.25 x 10^{17} x 4.1 x 10^{-19} or 2.6 V x 0.020 A = 0.051 to 0.053 (J s^{-1})	**C1** **A1**	**ecf (c)(i); NOT** 4.0 x 0.020 answer is 0.053 using 1.3 x 10^{17}
	iii	efficiency = 0.052/(4.0 x 20 x 10^{-3}) = 0.64	**C1** **A1**	**ecf (c)(ii)** **accept** $V_{strike}/V_{operate}$ = 2.6/4.0 or any other correct (P or W out)/ (P or W in) calculation **accept** 64 %
d		shape similar to the curve drawn leaving x-axis at close to 2.0 V and passing through (3.4, 20)	**B1** **B1**	Within half a square
		Total	**15**	

d		total current in circuit = 2600/230 = 11.3 A so 13 A fuse required	M1 A1	**accept** I = 2500/230 = 10.9 A
e	**i**	(a unit of) energy equal to 3.6 MJ **or** 1 kW for 1 h/AW	B1	**e.g.** 1000 W for 3600 s or similar; **NOT** 1 kW **per** hour
	ii	1.6 x 4 x 18 115 (p)	C1 A1	**allow** 1 mark for 108 p; i.e. using 1.5 x 4 x 18 **or** 1 mark for 79 p; i.e. using 1.1 x 4 x 18 **NOT** 72 p
		Total question 1	**18**	

12)

a	**i**	straight line through origin passing through (2, 30)	B1 B1	**allow** 2.0 ± 0.05, i.e. half a square
	ii	V is proportional to I for the resistor R but the LED the characteristic/line is a curve/not a straight line	B1 B1	**accept** statement of Ohm's law **allow** V α I **NOT** gradient changes **nor** gradient not constant
b	**i**	From Fig. 2.1, V across R at 30 mA = 2.0 V **or** 0.03 x 67 = 2.0 V V across LED = 5.0 – 2.0 = 3.0 V I in LED at 3.0 V is 30 mA	 B1 B1 B1	**allow** 1 SF answers in **b(i)** and **(ii)** at 30 mA R of LED = 100 Ω total R = 167 Ω I in LED = 5.0/167 = 30 mA **or** in reverse
	ii 1	0.030 (C)	A1	**allow** 30 mC or 3.0 x 10^{-2} C
	ii 2	QV or VI = 3.0 x 0.03 **or** $I^2R = 0.03^2$ x 100 energy = 0.090 (J)	C1 A1	**possible ecf from (ii)1** **allow** 90 mJ or 9.0 x 10^{-2} J **allow** 1 mark for 0.15 (J), i.e. taking V = 5 V
	ii 3	$P = I^2R = 0.03^2$ x 67 = 0.060 (J)	C1 A1	**possible ecf from b(i) for R value** **allow** P = VI = 2.0 x 0.03 = 0.060 J **or** $P = V^2/R = 2.0^2/67$ = 0.0597 J
	iii	current required is 0.63 A so nearest larger value is best 1.0 A	M1 A1	
c		suitable example, e.g. torch bulb, traffic light, car rear lamp,etc. (replaced by cluster of LEDs) advantage, e.g. draws a lower current/ more efficient (at converting electrical energy into light)/if one LED fails others are still lit/greater lifetime/more robust	 B1 B1	**accept** TV screens etc. **allow** size e.g. back lighting in mobile **NOT** cost
		Total question 2	**16**	