Question			Expected Answers	Marks	Additional Guidance
1					
	a	**i**	E = (Pt =) 36 x 3600 = 1.3 x 10^5 (J)	C1 A1	**allow** I = 3 A and E = VIt, etc. **accept** 129600 (J)
		ii	Q = E/V = 1.3 x 10^5/12 **or** Q =It =3 x 3600 = 1.1 x 10^4 unit: C	C1 A1 B1	**ecf (a)(i)** **accept** 1.08 x 10^4 **allow** A s **not** J V^{-1}
		iii	Q/e = 1.1 x 10^4/1.6 x 10^{-19} = 6.9 x 10^{22}	C1 A1	**ecf (a)(ii)** **accept** 6.75 or 6.8 x 10^{22} using 10800
	b	**i**	the average displacement/distance travelled of the electrons <u>along the wire</u> 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 x 10^{28} x 1.1 x 10^{-7} x 1.6 x 10^{-19} = 2.1 x 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**	

Question			Answer	M	Guidance
2					
	a	**i**	Q = It= 0.45 x 4.67 x 60 x 60 = 7600 C or As	C1 A1 B1	**accept** 7560 or 7570
		ii 1,2	**1** positive; **2** clockwise energy must be transferred to the cell **or** current in opposite direction transfers energy from the cell to the circuit/AW	M1 A1	positive plus correct direction of arrow for first mark; do not penalise if arrow not labelled I. **allow** (conventional) current is from positive to negative ; **or** electron flow from – to + [but current must be clockwise in **1**]
		3	V_{XY} = 1.5 + 0.45 x 0.90 V_{XY} = 1.9 (V)	C1 A1	**accept** 1.905 or 1.91
		4	P = VI = 0.45 x 1.5 P = 0.675 (J s^{-1})	C1 A1	**allow** QV/t with **ecf a(i)** if necessary (11340/16800) **allow** 0.7 as final line if 0.675 appears above
	b		**1.**cell across variable resistor R ammeter in series and voltmeter in parallel across R or cell **2.**Take (set of) readings of V and I for different positions/values of the variable resistor **3.**plot a graph of V against I **4.**(find) y-intercept = E **5.**(find) the gradient of the V against I graph which equals the internal resistance in magnitude **or 4 or 5** take one pair of values of V,I and substitute into equation E = V + Ir to find r or E	B1 B1 B1 B1 B1	QWC last marking point needed for full marks **allow** use (digital) voltmeter across <u>unloaded</u> cell to find E; add R and find one value of V and I; then use equation to find r (points 2 to 5) **ignore** sign of gradient in determining r **allow** for no graph plot, using 2 pairs of values of V and I substituted into equation allows r and E to be found.(points 2 to 5)
	c	**i**	4 x 1.5 V cells gives 6.0 V with r of 3.6 Ω so current is 6.0/(3.6 + 18) = 0.28 A requires (2 W/6 V =) 0.33 A to light normally or power delivered = (0.28^2 x 18 or 5.0 x 0.28)= 1.4 W **alt**: use 0.33 A & 6 V to show need emf of 7.2 V (1.8 V per cell)	B1 B1 B1	**allow** AW such as: 6 V but total R now 21.6 Ω; 6 V across 21.6 Ω gives 5 V across 18 Ω; requires 6 V to light normally **allow** P = 1.(6)7 W for 2 marks; only give the third mark if P labelled as power delivered by cell
		ii	1.5 n = 0.33 (18 + 0.9 n) **or** 1.5n = 6 + 0.3n so 3.6 n = 18 **or** 1.2n = 6 giving n = 5	M1 A1	**alt:** lamp needs V = 6V and I = 0.33 A terminal p.d per cell is 1.5 = V + 0.9 x 0.33 giving V = 1.2 V so n = 6/1.2 = 5 **allow** trial and error method but working must be shown to score any marks
			Total question 3	**19**	

Question			Expected Answers	M	Additional Guidance
3					
	a	**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	
	b		a photon is absorbed by an electron (in a metal surface); causing electron to be emitted (from surface). Energy is conserved (in the interaction).	B1 B1 B1	**not** hits QWC mark
			Only photons with energy/frequency above the work function energy/threshold frequency will cause emission Reference to Einstein's photoelectric energy equation (energy of photon) = (work function of metal) + (maximum possible kinetic energy of emitted electron) work function energy is the minimum energy to release an electron from the surface Number of electrons emitted also depends on light intensity Emission is instantaneous	B1 B2 B1 B1 B1	3 marks from 6 marking points in symbols only scores 1 mark out of 2, i.e. selects from formula sheet
			Total question 5	**10**	

Question			Answer	Marks	Guidance
4	**(a)**	**(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 **allow** 'point in a circuit' for 'junction'
		(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	**allow** 'in a (closed) circuit' in place of 'loop'
	(b)	**(**	current in 750 Ω = 0.020 A	A1	**allow** 20 mA **or** 0.02 A
		(ii)	V across 750 Ω = 0.02 x 750 = 15 V	A1	**ecf b(i)**
		(iii)	R_1 = (45 – 15)/0.03 = 1000 Ω R_2 = 15/0.01 = 1500 Ω	A1 A1	**ecf b(ii)**
	(c)	**(**	correct symbol connected in circuit	B1	2 arrows pointing towards the resistor at about 45^0 with or without a circle; arrows outside circle if drawn
A **A** **A**		**(ii)**	total R falls so I in circuit/in R_1 increases so V across R_1 increases and V across 750 Ω falls	B1 M1 A1	**accept** sum of R's in parallel falls R_1 is fixed so V across R_1 increases so V across R's in parallel falls (so V across 750 Ω falls) **or** correct potential divider argument
		(iii)	in series with LDR / in parallel with LDR ammeter (A) / voltmeter (V) 50 mA / 20 V	M1 A1 B1	**allow** voltmeter in parallel with R_1 (30 – 50 V) **allow** multimeter connected as A (series) or V (parallel) and a correct unit for range given **allow** 20 to 100 mA; or 15 to 50 V
			Total	**15**	