G482 Electrons, Waves and Photons

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 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 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			Expected Answers	Marks	Additional Guidance
2					
	a		ρ = RA/l with terms defined	M1 A1	full word definition gains both marks **allow** *A is area* as adequate; no unit cubes
	b	**i**	**either** the cable consists of (38) strands <u>in parallel;</u> **or** the area of the cable is 38 times the area of a strand or vice versa; so the resistance of 1 strand is 38 times bigger, (i.e. 1.98 Ω km^{-1}) **or** the resistance is inversely proportional to the area	B1 B1	max 1 mark for 38 x 0.052 = 1.98 with no further explanation **allow** with **either** and **or** **allow only** with **or**
		ii	A = ρ l/R = 2.6 x 10^{-8} x 1000/2.0 = 1.3 x 10^{-5} (m^2)	C1 A1	**allow** 1 mark max. for R = 0.052 giving A = 5.0 x 10^{-4} (m^2) **give** 1 mark max. for 1.3 x 10^{-8} (m^2)
	c	**i**	P = VI = 400x 10^3 x 440 = 1.8 x 10^8 (W) or 180 M(W)	C1 A1	P = VI **not** adequate for first mark **expect** 176
		ii	2000/176 = 11.4 so 12 required	B1	**ecf(c)(i);** using 180 gives 11.1
		iii	P = I^2R = 440^2 x 0.052 = 1.0 x 10^4 W (km^{-1}) or 10 kW (km^{-1})	C1 C1 A1	**accept** power/cable = 2000/12 = 167 MW I = 167M/400k = 417 A P = 417^2 x 0.052 = 9.0(3) kW (km^{-1}) **N.B.** answer mark includes consistent unit
		iv	power lost per cable = 10 k x 100 x 12 = 12.0 MW fraction remaining = (2000 – 12)/2000 = 0.994 x 100 = 0.994 so 99.4% or power lost per strand = 10 k x100 = 1.0 MW fraction remaining = (176 – 1)/176 = 0.994 so 99.4%	C1 A1	**ecf(c)(ii)(iii)** **allow** second mark for 'correct' answer as fraction not percentage with BOD sign **allow** 1 mark max. if give correct % lost given rather than % remaining **allow** 1 mark max. for 100 x (2000 – 1)/2000 = 99.95%
			Total question 2	**14**	

Question			Expected Answers	Marks	Additional Guidance
3					
	a		resistors in series add to 20 Ω and current is 0.60 A so p.d. across XY is 0.60 x 12 (= 7.2 V)	B1 B1	**accept** potential divider stated **or** formula gives (12 /20) x 12 V (= 7.2)V
	b	**i**	the resistance <u>of the LDR</u> decreases (so total resistance in circuit decreases) and current increases	M1 A1	
		ii	resistance of <u>LDR and 12 Ω</u> (in parallel)/<u>across **XY**</u> decreases so has smaller share of supply p.d. (and p.d. across XY falls)	B1 B1	**alternative** I increases so p.d. across 8.0 Ω increases; so p.d. across **XY** falls
			Total question 3	**6**	
Question			**Expected Answers**	**Marks**	**Additional Guidance**
4					
	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 x 10^3/(23 ± 1) = 83 ± 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 <u>current</u> in the circuit (when the LED conducts) otherwise it could overheat/burn out/be damaged/AW	B1 B1	
	d		in fig 4.3 the <u>voltage</u> 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**	

Question			Expected Answers	Marks	Additional Guidance
5					
	a	**i**	λ distance between (neighbouring) identical points/points with same phase (on the wave) f number of waves passing a point /cycles/vibrations (at a point) per unit time/second v distance travelled by the wave (energy) per unit time/second	B1 B1 B1	**accept** peak/crest to peak/crest, etc. **accept** number of waves produced by the wave source per unit time/second **not** v = f λ and not 'in one second'
		ii	in 1 second f waves are produced each of one wavelength λ distance travelled by first wave in one second is f λ = v	M1 A1	**accept** time for one λ to pass is 1/f so v = λ/(1/f) =f λ **give** max 1 mark for plausible derivations purely in terms of algebra (no words)
	b	**i**	infra red is part of the e-m spectrum lower f **or** longer λ than the visible region/light **or** suitable value or range of λ	B1 B1	**accept** any single λ in range 10^{-5} m to 7.5 x 10^{-7} m or any reasonable wider range
		ii1	λ = c/f = 3.0 x 10^{8}/ 6.7 x 10^{13} 4.5 x 10^{-6} (m)	C1 A1	**accept** 4.48 x 10^{-6} or more s.f.
		2	T = 1/f = 1/6.7 x 10^{13} T = 1.5 x 10^{-14} (s)	C1 A1	**accept** 1.49 x 10^{-14}
		iii	at least one cycle of a sine or cosine curve as judged by eye amplitude 8.0 x 10^{-12} m period = 1.5 x 10^{-14} s	B1 B1 B1	**ecf (b)(ii)2**
			Total question 5	**14**	

Question			Expected Answers	Marks	Additional Guidance
6					
	a	**i**	when (two) waves meet/combine/interact/superpose, etc. (at a point) there is a change in overall intensity/displacement	M1 A1	**allow** for A1 mark: (vector) sum/resultant displacement(s)/AW
		ii	constant phase difference/relationship (between the waves)	B1	just stating same frequency **not** sufficient
	b	**i**	path difference of nλ for constructive interference producing **either** maximum amplitude/intensity **or** a maximum path difference of (2n + 1)λ/2 for destructive interference producing **either** minimum amplitude/intensity **or** a minimum	M1 A1 M1 A1	**allow** waves arrive in phase **allow** waves arrive in anti-/out of phase **max** 3 marks; max 1 mark for two correct marking points but with n omitted
		ii	x = λD/a = 0.030 x 5.0/0.20 =0.75 (m)	C1 A1	**give** 1 mark max for 0.75 mm but zero for 750 m
		iii 1	intensity increases by factor of 4 position unchanged	B1 B1	
		2	intensity unchanged distance apart of maxima is doubled	B1 B1	
		3	intensity unchanged maxima move to positions of minima (and vice versa)	B1 B1	
			Total question 6	**14**	

Question			Expected Answers	Marks	Additional Guidance
7					
	a	**i**	E = hc/λ = 6.63 x 10^{-34} x 3.0 x 10^{8}/ 6.3 x 10^{-7} = 3.16 x 10^{-19} (J)	M1 A1	mark is for correct substitution into formula min of 2 sig figs;**allow** 3.1 for h = 6.6 x 10^{-34}
		ii	1.0 x 10^{-3}/3(.2) x 10^{-19} (= 3.1 x 10^{15})	B1	**accept** 3 x 10^{15}; the mark is for the expression
		iii	energy levels explanation: electrons have discrete energies in atom/AW each photon produced by electron moving between levels photon energy equal to energy difference between levels electron loses energy/making transition in correct direction	B1 B1 B1 B1	QWC mark good diagram can score marks **allow** $E_1 - E_2$ = hf or similar
		iv	blue light has a higher frequency/shorter wavelength than red light energy per photon is higher (so fewer needed to produce one mW)	B1 B1	
	b	**i**	vertical arrow up approximately through **X**	B1	**allow** tolerance e.g. ± 10^{o}
		ii	I = 0.2 ne ; = 0.2 x 3.2 x 10^{15} x 1.6 x 10^{-19} = 1.0(24) x 10^{-4} (A) or 0.10 mA (9.6 x 10^{-5} if using 3 x 10^{15})	C2 A1	**max** 2 marks if forget 0.2 factor 0.51 mA (0.48) if forget 0.2 factor
		iii	reflection/absorption at top layer; light/some photons reach bottom layer; photons below threshold energy/photons absorbed by electrons without release; recombination of ion pairs in insulating layer; scattering of light/photons out of insulating layer	B1	**award** mark for any sensible comment; see examples given
			Total question 7	**14**	

Question			Expected Answers	Marks	Additional Guidance
8					
	a	**i**	paths spread out after passing through a gap or around an obstacle/AW	B1	
		ii	wavelength of electrons must be comparable/of the order of magnitude of the atomic spacing	M1 A1	**allow** electrons behave as waves/AW **allow** must be about 10^{-10} m
	b		λ = h/mv v = 6.6(3) x 10^{-34} / 9.1(1) x 10^{-31} x 1.2 x 10^{-10} = 6.0 or 6.1 x 10^{6} (m s^{-1})	C1 M1 A1	mark for selecting formula correct manipulation and subs. shown **give** all 3 marks for answers to 3 figs or more: i.e. 6.04, 6.06 or 6.07
	c	**i**	eV = ½mv^2 V = mv^2/2e = 9.1 x 10^{-31} x (6.0 x 10^{6})^2/2 x 1.6 x 10^{-19} = 1.0(2) x 10^{2} (V)	C1 C1 A1	mark for algebraic equation mark for correct substitution **give** 1 mark max for k.e. = 1.6(4) x 10^{-17} J using 6.1 gives 104 (V)
		ii	electrons should be repelled by cathode and/or attracted by anode **or** they will be attracted back to the cathode/slowed down if cathode positive	B1	**award** mark if answer indicates this idea
			Total question 8	**10**	