

G482 Electrons, Waves and Photons

Question			Expected Answers	Marks	Additional Guidance
1					
	a	i	$E = (Pt) = 36 \times 3600$ $= 1.3 \times 10^5 \text{ (J)}$	C1 A1	allow $I = 3 \text{ A}$ and $E = VIt$, etc. accept 129600 (J)
		ii	$Q = E/V = 1.3 \times 10^5/12$ or $Q = It = 3 \times 3600$ $= 1.1 \times 10^4$ unit: C	C1 A1 B1	ecf (a)(i) accept 1.08×10^4 allow A s not J V^{-1}
		iii	$Q/e = 1.1 \times 10^4/1.6 \times 10^{-19}$ $= 6.9 \times 10^{22}$	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 <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 $I = nAev$ ($= 3.0 \text{ A}$) $v = 3.0/8.0 \times 10^{28} \times 1.1 \times 10^{-7} \times 1.6 \times 10^{-19}$ $= 2.1 \times 10^{-3} \text{ (m s}^{-1}\text{)}$	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	$\rho = RA/l$ with terms defined	M1 A1	full word definition gains both marks allow <i>A is area</i> 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. $1.98 \Omega \text{ km}^{-1}$) or the resistance is inversely proportional to the area	B1 B1	max 1 mark for $38 \times 0.052 = 1.98$ with no further explanation allow with either and or allow only with or
		ii $A = \rho l/R = 2.6 \times 10^{-8} \times 1000/2.0$ $= 1.3 \times 10^{-5} \text{ (m}^2\text{)}$	C1 A1	allow 1 mark max. for $R = 0.052$ giving $A = 5.0 \times 10^{-4} \text{ (m}^2\text{)}$ give 1 mark max. for $1.3 \times 10^{-8} \text{ (m}^2\text{)}$
	c	i $P = VI = 400 \times 10^3 \times 440$ $= 1.8 \times 10^8 \text{ (W)}$ 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 $P = I^2R$ $= 440^2 \times 0.052$ $= 1.0 \times 10^4 \text{ W (km}^{-1}\text{)}$ or 10 kW (km ⁻¹)	C1 C1 A1	accept power/cable = $2000/12 = 167 \text{ MW}$ $I = 167\text{M}/400\text{k} = 417 \text{ A}$ $P = 417^2 \times 0.052 = 9.0(3) \text{ kW (km}^{-1}\text{)}$ N.B. answer mark includes consistent unit
		iv power lost per cable = $10 \text{ k} \times 100 \times 12 = 12.0 \text{ MW}$ fraction remaining = $(2000 - 12)/2000 = 0.994 \times 100 = 0.994$ so 99.4% or power lost per strand = $10 \text{ k} \times 100 = 1.0 \text{ MW}$ 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 $100 \times (2000 - 1)/2000 = 99.95\%$
		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 $I = 23.0 \pm 1.0$ (mA) $R = 1.9 \times 10^3 / (23 \pm 1) = 83 \pm 4 \Omega$	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 $v = f \lambda$ 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 $f \lambda = v$	M1 A1	accept time for one λ to pass is $1/f$ so $v = \lambda/(1/f) = f \lambda$ 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 7.5×10^{-7} m or any reasonable wider range
	ii1	$\lambda = c/f = 3.0 \times 10^8 / 6.7 \times 10^{13}$ 4.5×10^{-6} (m)	C1 A1	accept 4.48×10^{-6} or more s.f.
	2	$T = 1/f = 1/6.7 \times 10^{13}$ $T = 1.5 \times 10^{-14}$ (s)	C1 A1	accept 1.49×10^{-14}
	iii	at least one cycle of a sine or cosine curve as judged by eye amplitude 8.0×10^{-12} m period = 1.5×10^{-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 $n\lambda$ for constructive interference producing either maximum amplitude/intensity or a maximum path difference of $(2n + 1)\lambda/2$ 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	$x = \lambda D/a = 0.030 \times 5.0/0.20$ $=0.75$ (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	

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Mark Scheme

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Question		Expected Answers	Marks	Additional Guidance
7				
a	i	$E = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / 6.3 \times 10^{-7}$ $= 3.16 \times 10^{-19} \text{ (J)}$	M1 A1	mark is for correct substitution into formula min of 2 sig figs; allow 3.1 for $h = 6.6 \times 10^{-34}$
	ii	$1.0 \times 10^{-3} / 3.2 \times 10^{-19} (= 3.1 \times 10^{15})$	B1	accept 3×10^{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. $\pm 10^\circ$
	ii	$I = 0.2 ne ; = 0.2 \times 3.2 \times 10^{15} \times 1.6 \times 10^{-19}$ $= 1.0(24) \times 10^{-4} \text{ (A) or } 0.10 \text{ mA } (9.6 \times 10^{-5} \text{ if using } 3 \times 10^{15})$	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		$\lambda = h/mv$ $v = 6.6(3) \times 10^{-34} / 9.1(1) \times 10^{-31} \times 1.2 \times 10^{-10}$ $= 6.0 \text{ or } 6.1 \times 10^6 \text{ (m s}^{-1}\text{)}$	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	$eV = \frac{1}{2}mv^2$ $V = mv^2/2e = 9.1 \times 10^{-31} \times (6.0 \times 10^6)^2 / 2 \times 1.6 \times 10^{-19}$ $= 1.0(2) \times 10^2 \text{ (V)}$	C1 C1 A1	mark for algebraic equation mark for correct substitution give 1 mark max for k.e. = $1.6(4) \times 10^{-17} \text{ J}$ 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	