Question			Expected Answers	Marks	Additional Guidance
1					
	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			Answer	Marks	Guidance
2 A A A	(a)	(i)	(atom releases energy when) electron moves from <u>high to low level</u> energy released is in form of a <u>photon</u> possible transitions are between n = 3 and n = 1, n = 3 and n = 2, n = 2 and n= 1	**B1** **B1** **B1**	can be illustrated on diagram by downward arrow connecting levels can be illustrated on diagram
	(a)	(ii)1	$\varepsilon = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 6.56 \times 10^{-7}$ $= 3.0(3) \times 10^{-19}$ (J)	 **C1** **A1**	choosing formula and substitution answer accept 3×10^{-19} (J) (no SF error)
	(a)	(ii)2	from n = 3 to n = 2	**B1**	**allow** between n = 3 and n = 2 **allow** n = 2 to n = 3 or between n = 2 and n = 3 **if** there is no contradiction with answer given in 7ai
	(b)	(i)	$d \sin\theta = \lambda$ $d \sin 11.4^{o} = 6.56 \times 10^{-7}$ $d = 6.56 \times 10^{-7}/0.198$ $d = 3.3 \times 10^{-6}$ (m)	**C1** **C1** **A1**	choosing formula and substitution manipulation and $\sin 11.4^{o} = 0.198$
	(b)	(i)2	$1/d = 3 \times 10^{5}$ m^{-1} = 300 mm^{-1}	**A1**	**ecf b(i)1**; allow 301 or 302 as data given to 3 sig figs
	(b)	(ii)	**2** rays, one either side of normal to grating at about 8^{o}, say	**B1**	**accept** any sensible angle
			Total	**11**	

Question			Expected Answers	M	Additional Guidance
3					
	a	**i**	vertical arrow upwards from ground state to zero level or above	B1	
		ii	21.8×10^{-19} (J)	B1	**no ecf** from (i); ignore sign
	b	**i**	$E = hc/\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/4.9 \times 10^{-7}$ $= 4.06 \times 10^{-19}$ (J) **or** 4.1×10^{-19} (J)	M1 A1	**accept** use of 6.6 instead of 6.63 which can round down answer to 4.0(4)
		ii	vertical arrow downwards between n = 4 to n = 2 levels	B1	
	c		some photons will be <u>absorbed</u> hydrogen atoms become excited (excited) hydrogen atoms re-emit photons the photon energy is equal to the transition <u>n = 1 to n = 3</u>	B1 B1 B1 B2	**not** hits **allow** electron moves up energy levels **NB** full marks = lines 1 + 4 or 1 + 2 + 3
			Total question 8	**8**	

Question			Expected Answers	Marks	Additional Guidance
4					
	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**	