Question			Answer	M	Guidance
1					
	a		photoelectric effect	B1	
	b		**1.**Individual photons are absorbed by individual electrons (in the metal surface)/ one to one interaction/AW **2.**Only photon with energy above the work function energy will cause photoelectron emission/idea of threshold frequency **3.**Photon energy is proportional to frequency **4.**(therefore) blue photons with higher f/shorter *λ* will cause photoemission but red photons will not. **5.**hf – ϕ = KE_{max} is the equation resulting from conservation of energy **or** resulting from the meaning of each term **6.**A wave model does not explain instantaneous emission	B1 B1 B1 B1 B1	**max** 4 from 6 marking points **allow** work function (of a metal surface) is minimum energy for photoemission **allow** shorter wavelength light has higher energy (hc/ *λ)* or higher frequency higher energy (hf) **or** ….red photons with lower f/longer *λ.....* *max* must be present to score mark; equation stated in words: photon e. – w.f. = max ke of *e* to score full marks (4) the answer **must include** two terms out of *photon, work function* and *threshold frequency/wavelength* (QWC mark)
	c	**i**	work function = ϕ = hc/*λ* φ = $6.6 \times 10^{-34} \times 3.0 \times 10^{8} / 4.8 \times 10^{-7}$ = $4.1(4) \times 10^{-19}$ (J)	C1 M1 A1	allow ϕ = hf (f = 6.25×10^{14}) and f = c/*λ* must show answer initially to 2 or 3 SF; ignore any final rounding down to 1 SF
		ii	E - ϕ = ½ mv^2 $(5.2 – 4.1) \times 10^{-19} = 1.1 \times 10^{-19} = ½ mv^2$ $v = \sqrt{(2 \times 1.1 \times 10^{-19} / 9.1 \times 10^{-31})}$ $v = 4.9 \times 10^{5}$ (m s^{-1})	C1 C1 A1	can use 4.14 or 4 instead of 4.1 **allow** 5.1×10^{5} (m s^{-1}) using ϕ = 4×10^{-19} or 4.8×10^{5} (m s^{-1}) using ϕ = 4.14×10^{-19}
	d	**i**	electrons passing through a thin sheet of graphite are diffracted/produce diffraction rings on a fluorescent screen	M1 A1	any suitable/reasonably plausible situation what is observed/ interpretation
		ii	λ = h/mv $\lambda = 6.63 \times 10^{-34} / 5.0 \times 10^{5} \times 9.1 \times 10^{-31}$ $\lambda = 1.5 \times 10^{-9}$ (m)	C1 C1 A1	 1.46 to 3 SF
			Total question 6	**16**	

Question			Answer	Marks	Guidance
2	a	i	energy φ required for an electron to escape from metal surface the minimum energy.....	M1 A1	inclusion of the word minimum in the sentence scores the second mark
		ii	a photon with less than the threshold frequency f_0 cannot cause electron emission/AW so work function = h (threshold frequency)	B1 B1	**allow** $\varphi = hf_0$ when the symbols φ and f_0 have been defined somewhere in the question
		iii	$\varphi = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/550 \times 10^{-9}$ $= 3.6 \times 10^{-19}$ (J)	C1 A1	
	b	i	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ $hf = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/440 \times 10^{-9} = 4.5 \times 10^{-19}$ J $½mv^2 = 9 \times 10^{-20}$ giving $v^2 = 1.8 \times 10^{-19}/9.1 \times 10^{-31}$ $v = 4.45 \times 10^{5}$ (m s^{-1})	C1 B1 B1 A0	**ecf (a)(iii)** allow 4.5 or 4.4×10^{5}
		ii	$\lambda = h/mv = 6.63 \times 10^{-34}/9.1 \times 10^{-31} \times 4.5 \times 10^{5}$ $\lambda = 1.6 \times 10^{-9}$ (m)	C1 A1	allow 1.7×10^{-9} for $v = 4.4 \times 10^{5}$
	c	i	n = 3 to n = 2	B1	**allow** between **or** and **when** there is a downward arrow on Fig. 8.1
		ii	$E_{32} + E_{21} = E_{31}$ $hc/\lambda_{32} + hc/\lambda_{21} = hc/\lambda_{31}$ 1/590 + 1/440 = 1/252 so $\lambda_{31} = 250 \times 10^{-9}$ (m)	C1 C1 A1	**accept** equation using 1/λ **or** $1/590 + 1/440 = 1/\lambda_{31}$ **allow** 2 or 3 sf **allow** 2/3 for using 550 for 590 nm giving 244 nm
			Total	15	

Question			Answer	Marks	Guidance
3	(a)		electrons have mass, photons have zero mass electrons have charge, photons are uncharged photons travel at <u>speed of light</u>	**B1** **B1**	**max** 2 marks from 3 marking points lower speed of electrons **not** required for mark
	(b)	(i)	energy = eV = $1.6 \times 10^{-19} \times 5000 = 8.0 \times 10^{-16}$ (J)	**C1** **A1**	 **accept** 8×10^{-16} (J) (no SF error)
		(ii)	$\frac{1}{2}mv^2 = 8.0 \times 10^{-16}$ $v^2 = 1.76 \times 10^{+15}$ $v = 4.2 \times 10^{7}$ (m s^{-1})	**C1** **C1** **A1**	 evidence of calculation required
	(c)	(i)	electron wavelength depends on its speed/momentum	**B1**	**accept** de Broglie equation with labels defined
		(ii)	$\lambda = h/mv$ $\lambda = 6.63 \times 10^{-34}/(9.1 \times 10^{-31} \times 4.2 \times 10^{7})$ $= 1.7 \times 10^{-11}$ (m)	**C1** **C1** **A1**	select formula substitution; **allow** 4×10^{7} **allow** 1.8×10^{-11} (m)
	(d)		$E = hc/\lambda$ $\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/8.0 \times 10^{-16}$ $= 2.5 \times 10^{-10}$ (m)	**C1** **C1** **A1**	select equation substitute and manipulate answer 2.49×10^{-10} (m)
	(e)	(i)	photoelectric effect / emission	**B1**	
		(ii)	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ $9.0 \times 10^{-19} - 7.2 \times 10^{-19} = 1.8 \times 10^{-19}$ (J)	**C1** **A1**	can be copied from data sheet
		(iii)	Electrons in the metal have a range of energies most require more than the w.f. energy to escape from the surface/AW	**B1** **B1**	w.f. is <u>minimum</u> energy to escape from surface /AW <u>max</u> k.e. given when w.f. subtracted from photon energy **or** photon gives all of its energy to one electron
			Total	**19**	