Question			Expected Answers	M	Additional Guidance
1					
	a		an eV is the <u>energy</u> acquired by an electron accelerated/moves through a p.d. of 1 V 1 eV = 1.6×10^{-19} J	B1 B1	
	b	**i**	300 (eV) 4.8×10^{-17} (J)	B1 B1	1 mark if write correct answers on wrong lines **ecf** for (first answer) x 1.6×10^{-19} e.g. 7.68×10^{-36} using 4.8×10^{-17}
		ii	$\frac{1}{2}mv^2 = 4.8 \times 10^{-17} \Rightarrow v^2 = 9.6 \times 10^{-17} / 9.1 \times 10^{-31}$ $(= 1.06 \times 10^{14})$ $v = 1.03 \times 10^{7}$ (m s^{-1})	M1 A1	**allow** 1 mark only for $v^2 = 2 \times$ **b(i)**/ 9.1×10^{-31} if **b(i)** incorrect **allow** 1.0×10^{7}, 1×10^{7} is not acceptable
	c	**i**	Electrons are observed to behave as waves/show wavelike properties where the electron wavelength depends on its speed/momentum	B1 B1	**accept** by being diffracted (by a crystal lattice)/AW **accept** de Broglie eqn with m,v or p defined
		ii	$\lambda = h/mv = 6.63 \times 10^{-34} / (9.1 \times 10^{-31} \times 1.03 \times 10^{7})$ $= 7.1 \times 10^{-11}$ (m)	C1 A1	**allow** 1 mark for 3.9 or 4.0×10^{-14} (m) caused by subs m_p for m **allow** 7.3×10^{-11} (m)
			Total question 6	**10**	

Question			Expected Answers	M	Additional Guidance
2					
	a	**i**	a quantum/lump/unit/packet/particle of (e-m) energy/light	B1	
		ii	<u>all</u> wavelengths/frequencies are present (in the radiation)/AW	B1	**accept** colours
	b	**i**	**1** infra red **2** the bulb of the lamp is **hot**	B1 B1	
		ii	5/100 x 24 = 1.2 W n = 1.2/4 x 10^{-19} = 3.0 x 10^{18}	C1 C1 A1	**allow** 2 marks if forgotten 5% and obtain 6 x 10^{19} allow 3 x 10^{18} – no SF as estimate
	c	**i**	7^{o} violet/blue 12^{o} red	B1 B1	**not** purple
		ii	d = 1/3 x 10^{5} = 3.3 x 10^{-6} m sin θ = λ/d = 5.4 x 10^{-7}/3.3 x 10^{-6} (= 0.162) θ = 9.3^{o} or 9.4^{o} do not accept 9^{o}	B1 M1 A1	with d = 3 x 10^{-6} m θ = 10.4^{o} give 2 out of 3 **ecf** incorrect value of d substituted correctly, scores 1 out of 3
			Total question 7	**12**	

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		$\lambda = h/mv$ $v = 6.6(3) \times 10^{-34} / 9.1(1) \times 10^{-31} \times 1.2 \times 10^{-10}$ $= 6.0$ or 6.1×10^{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**	$eV = \frac{1}{2}mv^2$ $V = mv^2/2e = 9.1 \times 10^{-31} \times (6.0 \times 10^{6})^2/2 \times 1.6 \times 10^{-19}$ $= 1.0(2) \times 10^{2}$ (V)	C1 C1 A1	mark for algebraic equation mark for correct substitution **give** 1 mark max for k.e. = $1.6(4) \times 10^{-17}$ 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**	

Question			Answer	Marks	Guidance
5	(a)		$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.1\times10^{-6}}$ $E = 1.8\times10^{-19}$ (J)	M1 A0	Values must be substituted Answer to 3sf is 1.81 x 10^{-19} (J)
	(b)		$m = \rho V = 8.1\times10^{-12}\times4.5\times10^{3} = \left(3.645\times10^{-8}\right)$ Thermal energy gained $= \left(mc\,\Delta\theta\right) = 3.645\times10^{-8}\times520\times\left[1700-20\right]$ $\left(=0.0318\right)$ $1.81\times10^{-19}\times6.3\times10^{19}\times t = 0.0318$ $t = 2.8\times10^{-3}$ (s)	C1 C1 A1	**Allow**: ecf from (a) and mass of titanium
	(c)		Thermal energy is conducted / transferred to the rest of <u>titanium/metal</u> Photons are reflected / scattered from / not absorbed the titanium surface	B1 B1	**Not:** heat lost to surroundings
	(d)		(Photon) energy is converted into potential energy (rather than kinetic energy) OR Energy is used to change solid to liquid / phase (rather than increase kinetic energy) OR Energy provides (specific) latent heat of fusion (rather than increase kinetic energy)	B1	**Allow:** energy is used to overcome the forces between atoms / breakdown the crystal structure of titanium (rather than increase kinetic energy)
			Total	**7**	