

Question	Answer	Marks
8(a)(i)	photoelectric effect	B1
8(a)(ii)	electron diffraction	B1
8(b)(i)	$\lambda = h / p$	C1
	$p = 4 \times 1.66 \times 10^{-27} \times 6.2 \times 10^7$ ( $= 4.1 \times 10^{-19} \text{ N s}$ )	C1
	$\lambda = 6.63 \times 10^{-34} / 4.1 \times 10^{-19}$ $= 1.6 \times 10^{-15} \text{ m}$	A1
8(b)(ii)	line with negative gradient throughout	B1
	curve asymptotic to both axes with non-zero $\lambda$ at $v = 6.2 \times 10^7 \text{ m s}^{-1}$	B1
8(c)	(de Broglie) wavelength negligible compared with width of doorway	B1

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9(a)(i)	<ul style="list-style-type: none"> <li>energy of photon has a corresponding frequency</li> <li>change in electron energy level emits a single photon</li> <li>photon energy = difference in energy levels</li> <li>discrete frequencies must have come from discrete energy gaps</li> <li>discrete energy changes imply discrete energy levels</li> </ul> <i>Any three points, 1 mark each</i>	B3
9(a)(ii)	transition (to $-3.400 \text{ eV}$ ) from X corresponds to 658 nm line	C1
	$E_1 - E_2 = hc / \lambda$	C1
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$ and so $E_1 = -1.51 \text{ eV}$ ( <i>full substitution and answer needed</i> )	A1
9(b)(i)	redshift	B1
9(b)(ii)	moving away (from observer)	B1
9(b)(iii)	$\Delta\lambda / \lambda = v / c$ e.g. for 658 nm line: $\Delta\lambda = 686 - 658$ $(= 28 \text{ nm})$ ( <i>other lines may be used</i> )	C1
	$28 / 658 = v / (3.00 \times 10^8)$ ( <i>other lines may be used</i> )	C1
	$v = 1.3 \times 10^7 \text{ m s}^{-1}$	A1
9(c)	$v = H_0 d$	C1
	$H_0 = (1.3 \times 10^7) / (5.7 \times 10^{24})$ $= 2.3 \times 10^{-18} \text{ s}^{-1}$	A1