22. Quantum Physics

22.3 Wave-particle duality

Paper 4

Marking Scheme

Q1.

(a)	diffraction is characteristic of wave behaviour so shows that electrons can behave like waves	**B1**
(b)	$qV = \frac{1}{2}mv^2$	**C1**
	$p = mv$	**C1**
	$p = m \times \sqrt{(2qV / m)}$ $= \sqrt{(2qVm)}$	**A1**
(c)	(electrons have) greater momentum so smaller (de Broglie) wavelength	**B1**
	fringes become closer together	**B1**
(d)(i)	straight line with positive gradient	**B1**
	line with positive gradient passing through the origin	**B1**
(d)(ii)	Planck constant	**B1**

Q2.

(a)	wavelength associated with a moving particle	**B1**
(b)(i)	(electron) diffraction	**B1**
(b)(ii)	beam spreads out indicating diffraction **or** light and dark regions indicate an interference pattern	**B1**
	electron beam is behaving as a wave	**B1**
(c)(i)	central blob and concentric rings	**B1**
	rings closer together (than previously)	**B1**
(c)(ii)	(greater p.d. so) electrons to have greater momentum	**B1**
	greater momentum so decrease in (de Broglie) wavelength	**B1**
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle **or** smaller angle of intensity maxima (for each order) **or** decrease in fringe spacing in diffraction pattern	**B1**

Q3.

(a)(i)	photoelectric effect	**B1**
(a)(ii)	electron diffraction	**B1**
(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**
(b)(ii)	line with negative gradient throughout	**B1**
	curve asymptotic to both axes with non-zero λ at $v = 6.2 \times 10^{7}\ \text{m s}^{-1}$	**B1**
(c)	(de Broglie) wavelength negligible compared with width of doorway	**B1**

Q4.

(b)	from $p = p_0 / 2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	**B1**
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	**B1**

Q5.

(a)(i)	photoelectric effect	**B1**
(a)(ii)	electron diffraction	**B1**
(b)(i)	$\lambda = h / p$	**M1**
	h is the Planck constant	**A1**
(b)(ii)	de Broglie (wavelength)	**B1**
(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^{7})$	**C1**
	$= 1.8 \times 10^{-11}$ m	**A1**

Q6.

(b)	$mv = h / \lambda$	**C1**
	$v = (6.63 \times 10^{-34}) / [(2.6 \times 10^{-11}) \times (9.11 \times 10^{-31})]$ $(= 2.80 \times 10^{7}$ m s$^{-1})$	**C1**
	$qV = ½mv^2$	**C1**
	$V = [9.11 \times 10^{-31} \times (2.80 \times 10^{7})^2] / [2 \times 1.60 \times 10^{-19}]$ $= 2.2 \times 10^{3}$ V	**A1**