Name: _____

Quantum Physics

Mark Scheme

Date:

Time:

Total marks available:

Total marks achieved: _____

Mark Scheme

Q1.

Question Number	Answer	Mark
	D	1

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
	B	1

Q4.

Question Number	Answer	Mark
	A	1

Q5.

Question Number	Answer	Mark
	B ground state to level 2	1
	Incorrect Answers: A – incorrect change in energy C – incorrect change in energy and direction D – incorrect direction	

Q6.

Question Number	Answer	Mark
	B	1

Q7.

Question Number	Answer	Mark
	B	1

Q8.

Question Number	Answer	Mark
	C	1

Q9.

Question Number	Answer	Mark
	C	1

Q10.

Question Number	Answer	Mark
	A	1

Q11.

Question Number	Answer	Mark
	C	1

Q12.

Question Number	Answer	Mark
	B	1

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	• Wave model (1) **Any two** • (Demonstration) provided experimental evidence (in support of wave model) (1) • (Demonstration) supported previous evidence (1) • (This demonstration was) reproducible **Or** (This demonstration) could be repeated by others (1)		3

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• The deflection/fields experiments indicate that electrons have a mass (and a charge) **Or** the deflection/fields experiments indicate that electrons have particle behaviour. (1) • The diffraction experiments indicate that electrons must have a wave nature (1) • Idea that a model of electron behaviour must include wave-particle duality (1)	In MP1 allow a description of deflection e.g. electrons are deflected by (electric and magnetic) fields indicating that they have a mass (and charge)	3

Q15.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Use of $p = mv$ using mass of electron • Use of $\lambda = \frac{h}{p}$ • $\lambda = 3.3 \times 10^{-11}$ m	(1) (1) (1)	Example of Calculation $\lambda = \frac{6.63 \times 10^{-34}\ \text{J s}}{9.11 \times 10^{-31}\text{kg} \times 2.2 \times 10^{7}\ \text{m s}^{-1}}$ $\lambda = 3.3 \times 10^{-11}$ m	3

Q16.

Question Number	Answer		Mark
(a)	The wavelength (associated) with a particle/electron with a given momentum **Or** $\lambda = h/p$ all terms defined	(1) (1) (1) (1)	2
(b)(i)	Use of $E_k = eV$ Use of $E_k = p^2/2m$ **Or** use of $E_k = mv^2/2$ **and** $p = mv$ Momentum = 1.21×10^{-23} kg m s^{-1} Example of calculation $E_k = 1.6 \times 10^{-19}$ C $\times$ 500 V $p^2 = 2\,m\,E_k = 2 \times 9.11 \times 10^{-31}$ kg $\times$ $(1.6 \times 10^{-19} \times 500)$ J $p = 1.21 \times 10^{-23}$ kg m s^{-1}	(1) (1) (1)	3
(b)(ii)	Use of $\lambda = h/p$ $\lambda = 5.49 \times 10^{-11}$ m (ecf value of p from (i)) (show that value gives 6.63×10^{-11} m) Example of calculation $p = 6.63 \times 10^{-34}$ J s / 1.21×10^{-23} kg m s^{-1} $\lambda = 5.49 \times 10^{-11}$ m	(1) (1)	2
	Total for question		7

Q17.

Question Number	Answer		Mark
(a) (i)	Use of $\lambda = h/p$ and $p = mv$ **Or** $v = h/m\lambda$ Use of $m = 9.11 \times 10^{-31}$ kg $v = 7.28 \times 10^{6}$ m s^{-1} Example of calculation $\lambda = h/mv$ $v = 6.63 \times 10^{-34}$ J s /(9.11×10^{-31} kg $\times$ 1.0×10^{-10} m) $v = 7.28 \times 10^{6}$ m s^{-1}	**(1)** **(1)** **(1)**	**3**
(a) (ii)	Use of $E_k = ½ mv^2$ **Or** $E_k = p^2/2m$ **Or** see $E_k = 2.41 \times 10^{-17}$ J Divided by 1.60×10^{-19} $E_k = 151$ eV (accept values in range 150 – 152 eV) (ecf value of v from (a)) Example of calculation $E_k = ½ (9.11 \times 10^{-31}$ kg$)(7.28 \times 10^{6}$ m s$^{-1})^2$ / (1.60×10^{-19} J eV^{-1}) $E_k = 151$ eV	**(1)** **(1)** **(1)**	**3**
(b)	The wavelength is similar in size to the nucleus The wavelength /nucleus is (much) smaller / 10^{-15}m / 10^{-14} m (if value is not given, 'wavelength is small' or 'wavelength is very small' is not sufficient)	**(1)** **(1)**	**2**

Q18.

Question Number	Answer		Mark
(a)	Photon – quantum/packet of something relevant e.g. light, radiation, any other named e-m radiation, energy	(1)	
	(quantum/packet) of <u>electromagnetic</u> energy/radiation/waves (dependent mark)	(1)	2
(b)	Use of $(20.66 - 18.70) \times 1.6 \times 10^{-19}$	(1)	
	Use of $E = hf$ (with energy in eV or J)	(1)	
	$f = 4.7 \times 10^{14}$ Hz	(1)	3
	<u>Example of calculation</u> $f = (20.66 - 18.70) \times 1.6 \times 10^{-19} \ / \ 6.63 \times 10^{-34}$ $f = 4.73 \times 10^{14}$ Hz		
(c)	From kinetic energy of atoms	(1)	1
(d)	Diffraction	(1)	
	Light spreads (sideways) as it passes through the slit	(1)	
	Narrower slit causes more diffraction/spreading **Or** diffraction increasing as gap width gets closer to wavelength	(1)	3
	Total for question		9

Q19.

Question Number	Answer		Mark
(a)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Electrons/atoms move to higher energy levels / get excited They then move to lower energy levels (accept ground state) The energy from the move is given out in the form of a <u>photon</u> The energy levels are discrete **Or** only certain energy levels are possible The energy of the photon must be equal to the difference in energy levels **Or** $hf = E_2 - E_1$ There are only a limited number of energy differences and only a corresponding number of frequencies (looking for differences /changes **not** levels) (The marks above may be obtained from a suitably labelled diagram – but the order of excitation and de-excitation cannot be assumed for two marks just from the presence of both)	(1) (1) (1) (1) (1) (1)	6
(b)	Doppler (accept blue shift) The wavelength of the radiation is decreased / frequencies increases Star moving towards Earth or vice versa	(1) (1) (1)	3
(c)	Light behaves as both particle and wave **Or** wave-particle duality	(1)	1
	Total for question		10

Q20.

Question Number	Answer		Mark
(a)	photon absorbed by electron electron moves to higher energy level **Or** electron excited where photon energy = difference in energy levels only certain changes/differences possible between discrete energy levels	(1) (1) (1) (1) (1)	5
(b)(i)	Use of $E = hf$ Use of conversion factor to eV Energy of photon = 1.91 (eV) Identify levels 3.41 (eV) and 1.51 (eV) **Or** levels 1 and 2 <u>Example of calculation</u> $E = 6.63 \times 10^{-34}$ J s $\times$ 4.6×10^{14} Hz ($= 3.05 \times 10^{-19}$ J) $E = 6.63 \times 10^{-34}$ J s $\times$ 4.6×10^{14} Hz $\div$ 1.6×10^{-19} J s = 1.91 eV = 3.41 eV − 1.51 eV (1.90 eV) as the closest match	(1) (1) (1) (1)	4
(b)(ii)	Just-free electrons have zero energy state **Or** energy value of level $n = \infty$ is 0 (Bound) electrons need to gain energy to attain this state **Or** electrons need to gain energy to move to a higher level (Accept Because they must gain energy to move up for second mark) (accept answers in terms of ionisation energy)	(1) (1)	2
(c)	Look for corresponding pattern of lines / frequency spacings at different place in spectrum **Or** reference to known normal positions moving away increases observed wavelength / decreases frequency (or the case for moving towards) so if shifted to red end then moving away (or blue = towards) **Or** the greater the velocity the greater the change in frequency	(1) (1) (1)	3
	Total for question		**14**