Question Number	Answer	Mark
1(a)	Use of $Q = It$ or $\Delta Q = I\Delta t$ with any relevant time (1) $t = 5 \times 3600$ (1) divide Q by 1.6×10^{-19} (1) number of electrons = 4×10^{23} (1) <u>Example of calculation</u> Number of electrons = It/e Number of electrons = $3.5\ A \times 5 \times 3600\ s / 1.6 \times 10^{-19}\ C$ Number of electrons = 3.9×10^{23}	**4**
1(b)	Use of $E=hf$ (ignore powers of 10 errors in f) (1) (gives $E = 3.6 \times 10^{-19}$ J) Divides 10 by their value of energy (1) Number of photons = 3×10^{19} (1) (likely to see 2.7 or 2.8 depending on use of calculator: both correct) <u>Example of calculation</u> Energy of 1 photon = 6.63×10^{-34} Js $\times$ 5.5×10^{14} Hz = 3.6×10^{-19} J Number of photons = $10\ W / 3.6 \times 10^{-19}$ J Number of photons = 2.8×10^{19}	**3**
	Total for question	**7**

Question Number	Answer	Mark
2(a)(i)	(The) photoelectric (effect) (1)	**1**
2(a)(ii)	3×10^{8} (ms^{-1}) **OR** speed of light **OR** speed of electromagnetic radiation (1)	**1**
2(a)(iii)	(Work function) is the (minimum) amount of energy that a surface electron needs to break free/be released (1) (There must be some reference to surface. Do not credit electrons plural or 'electron and photon')	**1**
2(b)(i)	Attempt to subtract energy values (1) Multiply by 1.6×10^{-19} (1) 1.8×10^{-19} (J) (1) (Alternative method :multiplying by e first and then subtracting Will see 8.64×10^{-19} and 6.88×10^{-19}) <u>Example of calculation</u> Energy = (5.4 eV – 4.3 eV) $\times 1.6 \times 10^{-19}$ Energy = 1.8×10^{-19} J	**3**
2(b)(ii)	Use of KE = ½ m v^2 using their energy value and $m_e = 9.11 \times 10^{-31}$ kg (1) Max speed = 6.2×10^{5} m s^{-1} or correct value using their energy (1) (allowing a full e.c.f even if speed > speed of light) <u>Example of calculation</u> 1.8×10^{-19} J = ½ (9.11×10^{-31} kg $\times v^2$) $v = \sqrt{}$ ($2 \times 1.8 \times 10^{-19}$ J / 9.11×10^{-31} kg $v = 6.2 \times 10^{5}$ m s^{-1}	**2**
2(c)	No change (1)	**1**
	Total for question	**9**

Question Number	Answer	Mark
3	**QOWC** **Work must be clear and organised in a logical sequence** **Particle theory** Reference to $E=hf$ or quanta of energy /packets of energy/photons (1) Increased f means more energy of photon (1) Release of electron requires minimum energy /work function (1) One photon releases one electron (1) Greater energy of photon means greater KE of electrons (1) More intense light means more photons, therefore more electrons (1) **Wave theory** Wave energy depends on intensity (1) More intense light should give greater K.E of electrons (1) Energy is spread over the whole wave (1) If exposed for long enough photons eventually released, doesn't happen. (1) **Max 4 for particles and max 2 for waves.**	**6**
	Total for question	**6**

Question Number	Answer	Mark
4(a)	Energy of the photon is less than the work function (of lithium) **OR** frequency of photons is below the threshold frequency (of lithium) (1) Work function is the minimum energy for electrons to be released **OR** No electrons are emitted **OR** no (electron) emission occurs (1) 'There is not enough energy for (electron) emission to occur' scores 1/2	**2**
(b)	Energy 1.8 eV current 0 (1) Energy 3.8 eV current 2.0×10^{-11} (1)	**2**
(c)(i)	Use of 1.6×10^{-19} (1) Energy = 3.7×10^{-19} J (1)	**2**
(c)(ii)	Use of $hf = \varphi + ½ mv^2_{max}$ (1) ecf (c)(i) KE = 4.4×10^{-18} J (1) Use of KE = ½ mv^2 (1) Speed = 3.1×10^6 m s^{-1} (1) **Example of calculation** KE = 4.8×10^{-18} J - 3.68×10^{-19} J = 4.4×10^{-18} J $v^2 = 2 \times 4.4 \times 10^{-18}$ J ÷ 9.11×10^{-31} kg v = 3.1×10^6 m s^{-1}	**4**
	Total for question	**10**

Question Number	Answer		Mark
5	electron emitted by absorption of light/UV/photon	**(1)**	
	one photon absorbed by one electron	**(1)**	
	if frequency above threshold frequency then electron emitted **Or** if photon energy above work function energy then electron emitted	**(1)**	
	Use of $hf = \varphi$ (using work function to find corresponding frequency or wavelength) **Or** Use photon energy = hf (using any identified frequency or wavelength of visible light or UV to find corresponding photon energy)	**(1)**	
	Threshold frequency = 1.0×10^{15} Hz **Or** wavelength = 2.9×10^{-7} m **Or** Photon energy for light = a value between 2.9×10^{-19} J and 5.1×10^{-19} J **Or** photon energy for UV = a value between 5.1×10^{-19} J and 1.99×10^{-17} J	**(1)**	
	State visible light frequency too low / wavelength too long **Or** compare photon energy to work function	**(1)**	**6**
	Example of calculation $f = 6.88 \times 10^{-19}$ J $\div$ 6.33×10^{-34} J s $= 1.0 \times 10^{15}$ Hz		
	Total for question		**6**

Question Number	Answer		Mark
6(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**
6(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 Example of calculation $E = 6.63 \times 10^{-34}$ J s $\times$ 4.6×10^{14} Hz (= 3.05×10^{-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**
6(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**
6(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**