A Level OCR Physics

Chapter 14 Quantum physics

Q	Answers	Extra information	Mark	AO	Spec reference
1(a)	An electron moves from level C to level B when the atom absorbs a photon When an electron moves from level B to level C a photon is emitted The energy/frequency of the photon is the same in each case. (0.92×10^{-19} J)		1 1 1	2	4.5.1
(b)	$E = (-8.86 - (-7.94))\times10^{-19}$ J $= 9.2 \times 10^{-20}$ J $E = \frac{hc}{\lambda},\ \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{9.2 \times 10^{-20}}$ $= 2.16\times10^{-6}$ m / 2.2×10^{-6} m	Correct equation to work out energy Substitution Answer	1 1 1	2	4.5.1
(c)	1 eV = 1.6×10^{-19} J Energy of photon = $1.8 \times 1.6\times10^{-19}$ J $= 2.89\times10^{-19}$ J $\Delta E = (-8.86\times10^{-19}\text{ J} - E) = 2.89\times10^{-19}$ J $E = -5.97\times10^{-19}$ J	Energy of photon Substitution Correct value of energy Negative value	1 1 1 1	3	4.5.1
(d)	$\lambda = \frac{hc}{E} = \frac{6.63 \times10^{-34} \times 3 \times 10^{8}}{2.89 \times 10^{-19}}$ $= 6.87\times10^{-7}$ m/687 nm No, this is in the visible region of the electromagnetic spectrum / red light	Substitution Answer Conclusion	1 1 1	3	4.5.1
2(a)	hf = energy of photon with frequency f ϕ = work function = energy required to remove an electron from the surface of a metal KE = energy of ejected electron when photon has an energy greater than the work function		1 1 1	1	4.5.2
(b)	Work function = $4.26 \times 1.6\times10^{-19}$ J = 6.82×10^{-19} J	Energy in joules Substitution	1 1	2	4.5.2

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	$E = hf$, $f = E/h = \frac{6.82 \times 10^{-19}}{6.63 \times 10^{-34}} = 1.02 \times 10^{15}$ Hz.				
(c)	Difference in energy = $hf - \phi = 4.26 \times 1.6 \times 10^{15} \times 6.63 \times 10^{-34} - 6.82 \times 10^{-19}$ $= 2.1 \times 10^{-18}$ J $= \frac{1}{2} mv^2$ $v = \sqrt{\frac{2 \times 2.1 \times 10^{-19}}{9.11 \times 10^{-31}}}$ $= 2.1(5) \times 10^{6}$ m s^{-1}	Energy Substitution Answer	1 1 1	2	4.5.2
(d)	$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2.15 \times 10^{6}}$ $= 3.38 \times 10^{-10}$ m	Substitution ECF Answer	1 1	2	4.5.3
(e)	Yes, the wavelength is the same as the order of magnitude as the spacing of atoms.		1	3	4.5.3
3(a)	The frequency or frequencies of the light emitted is too low The photons hitting the metal interact with surface electrons but do not have enough energy to enable the electrons to escape/the energy of each photon is less than the work function of the metal.		1 1	1	4.5.2
(b)	$E = hf = \frac{hc}{\lambda} = f\theta + \text{KE}$ Assuming electrons are emitted with zero kinetic energy then $\phi = \frac{hc}{\lambda}$	Assumption Substitution Answer	1 1 1	2	4.5.2

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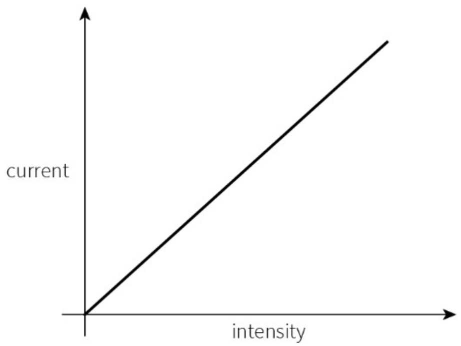
	$= \dfrac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{100 \times 10^{-9}} = 1.99 \times 10^{-18}$ J				
(c)	Some electrons are emitted with kinetic energy, so the figure calculated in **2(b)** is bigger than the actual value of the work function. 4 eV = $4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ J < 1.99×10^{-18} J	Statement e.c.f. Use of numbers	1 1	2	4.5.2
(d)	$E = hf = \dfrac{hc}{\lambda} = \phi + \text{KE}$ $\text{KE} = \dfrac{hc}{\lambda} - \phi = 1.99 \times 10^{-18} - 6.4 \times 10^{-19}\text{ J} = 1.35 \times 10^{-18}\text{ J}$ $v = \sqrt{\dfrac{2E}{m}} = \sqrt{\dfrac{2 \times 1.35 \times 10^{-18}}{9.11 \times 10^{-31}}}$ $= 1.7 \times 10^{6}\text{ m s}^{-1}$	Calculation of energy Substitution Answer	1 1 1	2	4.5.2
4(a)		Positive relationship (straight or curved) Correctly labelled axes	1 1	3	4.5.2
(b)	Yes, more intense radiation transfers more energy per second, releasing more electrons per second, producing more current.		1	3	4.5.2

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(c)	The power supply can be turned around So that the potential can be applied so as to stop the electrons = stopping potential		1 1	2	4.5.2
(d)	$eV_{stopping} = ½ mv^2 = hf - \phi$ $\phi = hf - eV_{stopping}$ $= (6.63×10^{-34} × 6.00×10^{14}) – (1.60×10^{-19} × 0.5)$ $= 3.97×10^{-19} – 0.8×10^{-19}$ $= 3.17×10^{-19}$ J	Use of equation Substitution of one pair of numbers Answer	1 1 1	2	4.5.2
(e)	It would not be affected The potential indicates the energy of the electrons released, which depends on the frequency and not the intensity/the intensity affects the number of electrons emitted at a particular frequency.		1 1	3	4.5.2
5(a)	**Level 3 (5–6 marks)** Clear explanation of method with description of circuit and components used and clear analysis *The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear.* **Level 2 (3–4 marks)** Some explanation of method and either some components or some analysis explained. *The student presents relevant information and in a way which assists the communication of meaning. SP&G are sufficiently accurate not to obscure meaning.* **Level 1 (1–2 marks)** Limited explanation and description or limited analysis. *The student presents some relevant information in a simple form. SP&G allow meaning to be derived although errors are sometimes obstructive.* 0 marks No response or no response worthy of credit.	**Indicative scientific points may include:** Method: • Connect a LED to a variable power supply. Use a protective resistor. Connect a voltmeter across the LED, not the resistor. Observe the LED by looking down a tube. Increase the p.d. across the LED until it just glows Record the reading on the voltmeter. Repeat 3 times and take an average. Repeat with different coloured LED Analysis: • Record the wavelength using the manufacturer's	Max 6	1	4.5.1

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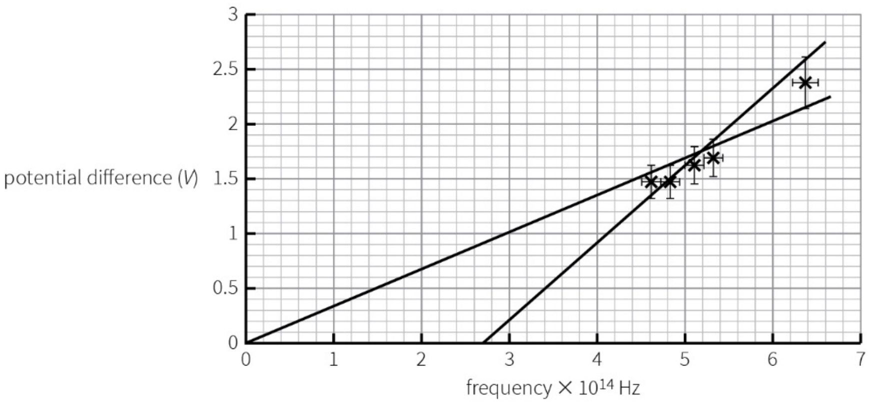
		specification. Calculate the frequency for each colour using $f = v/\lambda$			
(b)	 Maximum gradient = $(2.5 – 0)/(6.3×10^{14} – 2.7×10^{14}) = 6.9×10^{–15}$ V s Minimum gradient = $(2.0 – 0)/(5.9×10^{14} – 0) = 3.4×10^{–15}$ V s	Lines of max and min gradient Two gradients calculated	2 1	3	4.5.1
(c)	When the LED just lights $eV = hf$ A graph of V vs f has a gradient of h/e h = gradient × e = $6.9×10^{-15}$ V s × $1.6×10^{-19}$ = $1.1×10^{-33}$ J s h = gradient × e = $3.4×10^{-15}$ V s × $1.6×10^{-19}$ = $5.4×10^{-34}$ J s Planck's constant = $(1.1×10^{-33} + 5.4×10^{-34})/2 = 8.2×10^{-34}$ J s Value = $8.2 \pm 2.8×10^{-34}$ J s	Correct equations Value of gradient Two values of h	1 1 1 1	2	4.5.1
(d)	It is very difficult to judge when the LED has just lit/ the eye is limited as an instrument to see when the LED just lights up		1	2	4.5.1
6(a)	$eV = ½ mv^2$ $mv = \sqrt{2meV}$	Equating energy to find mv	1 1	2	4.5.3

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	$\lambda = \frac{h}{mv}$ $= \frac{h}{\sqrt{2meV}}$ $= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 3000}}$ $= 2.24\times10^{-11}$ m	Expression for λ, explicit or implied Answer	1		
(b)	Assuming the diffraction obeys the equation for diffraction: Or assume that for appreciable diffraction the size of the grating spacing/aperture Grating spacing for electrons is approximately 10^{-10} m. $n\lambda = d \sin\theta$ If the angles are the same, assuming n = 1 $\left(\frac{\lambda}{d}\right)_{\text{visible}} = \left(\frac{\lambda}{d}\right)_{\text{electrons}}$ $d_{\text{visible}} = \lambda_{\text{visible}}\left(\frac{d}{\lambda}\right)_{\text{electrons}}$ $= 540\times10^{-9} \times10^{-10}/2.24\times10^{-11}$ $= 2.4\times10^{-6}$ m	Clear assumption Grating spacing for electrons Relationship between wavelength and spacing Answer	1 1 1 1	3	4.4.3
(c)	The wavelength is larger so the angle at which maxima are observed will be larger, so the pattern will spread out		1 1	3	4.4.3
(d)	The wavelength of the electrons is inversely proportional to the potential difference used to accelerate the electrons To increase the wavelength for the electrons the potential difference will need to be reduced		1 1	3	4.4.3

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(e)	$R = R_0A^{1/3}$ $A = \left(\frac{R}{R_0}\right)^3$ $= \left(\frac{6.6 \times 10^{-15}}{1.1 \times 10^{-15}}\right)^3$ $= 216$	 Substitution Answer	1 1 1	2	6.4.1
7(a)	Number of protons = 88 Number of neutrons = 138		1	2	6.4.1
(b)	${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$	Symbol for alpha A and Z for Rn	1 1	2	6.4.3
(c)	$E = hf = \frac{hc}{\lambda} = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{532 \times 10^{-9}} = 3.74 \times 10^{-19}$ J $= \frac{3.74 \times 10^{-19}\text{ J}}{1.6 \times 10^{-19}\text{ J}} = 2.34$ eV		1 1	2	4.5.1
(d)	Suggested mechanism e.g. The alpha particle collides with an atom in the paint. An electron is excited to a higher energy level, and emits a photon when it returns to its ground state.	Collision producing excitation Emission of photon	1 1	3	4.5.1
8(a)	The largest energy gap gives the highest frequency photon, which would be the smallest wavelength K_{beta}	Reasoning Answer	1 1	3	4.5.1

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(b)	Bones contain elements that have energy levels with differences that correspond to the energy of X-ray photons		1	3	4.5.1
(c)	Power = $V \times I$ $= 52\times10^{3} \times 41\times10^{-3}$ $= 2132$ W ≈ 2100 W	 Substitution Answer	 1 1	2	4.2.5
(d)	Energy required = mL $= 15\times10^{-3} \times 247\times10^{3}$ J $= 3.71\times10^{3}$ J Power = energy/time, time = energy/power = 3.71×10^{3} J/2100 W = 1.7(4) seconds	 Energy Substitution Answer	 1 1 1	3	3.3.3
(e)	The specific heat capacity of water is bigger/2.5 times bigger, so that it will require more energy to raise the temperature by 1 K / lower increase in temperaeture for the same amount of energy Less water needs to flow per second to cool the anode		1 1	3	5.1.3