Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Substitution into $p = \frac{h}{\lambda}$ (1) Use of KE = 2 200 e (1) Answer = 2.62×10^{-11} [m] (1)	1	 1 1		 3	 3	
	(b)		Incident on thin crystal/graphite accept reflected off crystal (1) Pattern/concentric rings viewed on screen (1) Pattern closer due to smaller wavelength (1)	1 1	 1		 3		 3
			Question total	**3**	**3**	**0**	**6**	**3**	**3**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		2.1 eV required to free electron **OR** subbing into Einstein's (1) Remainder (8.2 eV) can become KE (1) 8.2 V corresponds to 8.2 eV (for electrons) (1) +ve will stop electrons from escaping (or attractive force) (1) Hence, +8.2 V is just enough to stop any electrons escaping (or any greater and the electrons can't escape etc.) (1)	1 1	 1 1 1		 5 		
	(b)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ quoted **OR** used **OR** implied (1) Hence, $E = \frac{V}{r}$ **OR** Q obtained using V equation (59.3 pC) (1) Answer = 126 [V m^{-1}] **OR** 1.26 if [V cm^{-1}] (1)	1	 1 1		 3	 2	
			Question total	**3**	**5**	**0**	**8**	**2**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		5.1 [eV]	1			1		
	(b)		Particular wavelengths of the light are absorbed (1) Atoms or electrons are raised to higher energy levels (1) Light re-radiated in all directions (1)	3			3		
	(c)	(i)	Energy ($= \frac{hc}{\lambda}$) = 3.4×10^{-19} [J] (1) Conversion to eV = 2.1 [eV] (1) Correct conclusion with justification – does correspond to energy difference in levels (1)			3	3	2	
		(ii)	Wien's Law $\lambda_{max} = \frac{W}{T}$ (1) $T = \frac{2.9 \times 10^{-3}}{\lambda_{max}}$ (1) Temperature = 29 000 [K] (1)	1	 1 1		 3	 3	
			Question 6 total	**5**	**2**	**3**	**10**	**5**	**0**

#4

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		**Diagram and Method** Attempt at circuit diagram or explained in words Correct circuit diagram drawn Vary wavelength/frequency with different LEDs Vary pd until LED light is on or significant current on Measure pd when light just turns on Repeat readings **Results** Equation $V = \frac{hc}{e\lambda}$ *or* $\frac{hf}{e}$ included Mean V determined Plot graph of V against $\frac{1}{\lambda}$ or f or suitable alternative Determine gradient h can be determined as gradient = $\frac{hc}{\lambda}$ or $\frac{h}{e}$ **5-6 marks** Comprehensive description of the method including correct circuit diagram provided along with comprehensive description of how to analyse results. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Either comprehensive description of the method including circuit diagram provided or comprehensive description of how to analyse results provided or reasonable attempt at both areas. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Either an attempt at a description of the method / circuit diagram provided or an attempt how to analyse results. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*	6			6		6
	(b)		Repeat same experiment (1) Obtain similar results **or** enables comparison (1)			2	2		
			Question total	**6**	**0**	**2**	**8**	**0**	**6**

#5

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
8	(a)		122.4 eV obtained [1] $\times 1.6 \times 10^{-19} = 1.96 \times 10^{-17}$ [J] [1]		2		2	1	
	(b)		30.6 – 13.6 seen or implied [1] λ = 73 n[m] or equivalent [1] UV [1]		3		3	1	
	(c)		Energy levels in atoms/for electrons [1] Drops give emission **and** up gives absorption [1] Linking the same energy [transitions] to the same wavelengths [1]		3		3		
			Question 8 total	**0**	**8**	**0**	**8**	**2**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)	The emission of electrons from a surface due to light or em rad^{n}	1			1		
		(ii)	Energy of light is in the form of photons/packets of energy = hf (1) The work function ϕ is needed for the electron to escape (1) $E_{k\,max}$ is the energy remaining for the electron (1)	3			3		
	(b)		Polarity is incorrect/All the electrons will reach collecting electrode (1) No ammeter in circuit (1) Voltmeter not connected correctly (1) No variable supply (1)			4	4		4
	(c)	(i)	Axis labelled correctly with units and suitable scale so that data points occupy half of the axis (1) All points plotted correctly to within ±½ small square division (1) Good line of fit consistent with data (1)		3		3	3	3
		(ii)	Straight line graph of positive gradient (1) Passes close to all data points (1) Cannot determine if passes through origin (allow ecf) does not pass through origin/clear negative y intercept (must be consistent with graph)' (1)			3	3	1	3
		(iii)	Planck constant = gradient (implied) (1) Large triangle used [or 2 equivalent suitable points clearly indicated on the graph] and correct values for gradient calculation (1) Gradient calculated correctly and Planck constant = 6.6 (± 0.2) × 10^{-34} (J s) (1)		3		3	2	2
		(iv)	5% of Planck constant (6.63 × 10^{-34} J s) determined (± 0.33 × 10^{-34}) (1) Valid conclusion e.g. value obtained is within 5% (1)		1	1	2		
			Question 3 total	**4**	**7**	**8**	**19**	**7**	**14**

#7

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	(a)			energy needed (1) ….. …. to remove an electron from a surface(1)	2			2		
	(b)	(i)		Energy of one photon = 4.8 × 10^{-19} [J] (1) Number of photons = 5.2 ×10^{8} (1)		2		2	2	
		(ii)	I	Threshold frequency = 4.4 × 10^{14} [Hz] (1) Work function = hf_0 = 2.9 × 10^{-19} [J] (1)		2		2	2	
			II	Line drawn with intercept greater than 4.4 × 10^{14} Hz (1) Line has same gradient (1)		2		2	1	
			III	Photon energy would stay the same (1) Same surface or work function would stay the same (1)		2		2		
				Question 7 total	**2**	**8**	**0**	**10**	**5**	**0**

#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)		E = [2×] $9.11 \times 10^{-31} \times c^2$ or $m = \frac{9.11 \times 10^{-31}}{1.66 \times 10^{-27}}$ [= 0.000549 u] [1] Conversion to eV i.e. dividing by 1.6×10^{-19} or ×931 [1] 1.025 MeV seen or $2 \times 9.11 \times 10^{-31} \times \frac{(3 \times 10^8)^2}{1.6 \times 10^{-19}}$ or $2 \times 0.000549 \times 931$ [1]		3		3	3	
	(b)		Excess energy or 0.01 MeV [1] Equal amounts shared by electrons & positron due to equal (light) masses [1]		2		2		
	(c)		$0.5 \times 9.11 \times 10^{-31} \times v^2 = 0.005 \times 10^6 \times 1.6 \times 10^{-19}$ seen or equivalent: $(0.5 \times 9.11 \times 10^{-31} \times (4.2 \times 10^7)^2$ giving 0.005 MeV or 4.19×10^7 seen [1] Momentum of gamma ray [= $\frac{E}{c}$] = 5.49×10^{-22} [N s] [1] Momentum of electron or positron = $9.11 \times 10^{-31} \times 4.2 \times 10^7$ = 3.8×10^{-23} or 7.6×10^{-23} [1] $5.49 \times 10^{-22} - 2 \times 4.2 \times 10^7 \times 9.11 \times 10^{-31}$ seen [1]		4		4	3	
	(d)		KE calculated (3.35×10^{-19} J or 2.1 eV) [1] Correct conclusion – negligible [1] **No ecf**			2	2	1	
			Question 5 total	**0**	**9**	**2**	**11**	**7**	**0**

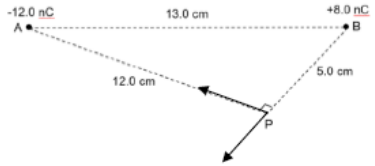
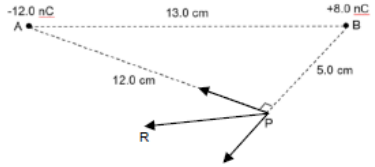
#9

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)		Photons have enough energy [or frequency or hf high enough] (1) to emit / release electrons (from metal surface) (1) These arrive at the anode / [collecting] (& give current) (1)	1 1	1		3		3
	(b)		Applying Einstein's equation i.e. 2.7 + 1.2 (= 3.9 eV) (1) Converting to J i.e. × 1.6×10^{-19} (1) Answer = 9.4×10^{14} Hz (1) N.B. 5.9×10^{33} Hz → 1 mark only	1	1 1		3	2	
	(c)	(i)	Reverse polarity of supply [or equivalent, e.g. make collecting electrode negative / reversing the photocell] (1) [Increase pd] until current is [just] zero (1) Record the pd (from voltmeter) [or this is the stopping potential] (1)		3		3		3
		(ii)	(Alpha particles +ve so) opposite current (1) Current zero at smaller pd (1) More accurate if light intensity large (accept any insightful comment e.g. obtain activity and compensate / measure the dark current) [Accept - wait for activity to decrease] (1)			3	3		3
			Question 3 total	**3**	**6**	**3**	**12**	**2**	**9**

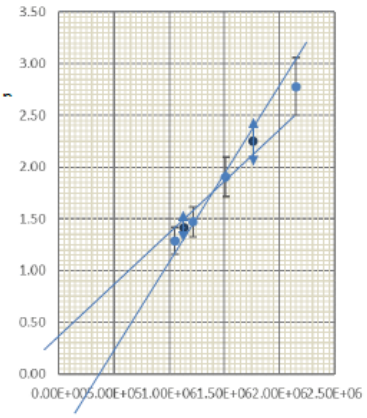
#10

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)		{Multiple passes of beam / reflection / keeps most of the light} for more amplification / stimulated emission or increased collimation (1) Some light (1%) transmitted by 99% mirror (1)	2			2		
	(b)		Increase of stimulated emission (1) Compared with absorption (1) [Exponential] increase in intensity or amplification or more power] (1) NB Stimulated emission > absorption → 2 marks	3			3		
	(c)	(i)	Energy of photon = 1.89×10^{-19} [J] seen or implied (1) $\frac{2 \times 10^{15}}{1.89 \times 10^{-19}}$ seen or implied (1.056×10^{34}) (1) [no e.c.f.]		2		2	2	
		(ii)	$p = \frac{6.63 \times 10^{-34}}{1.05 \times 10^{-6}}$ [kg m s^{-1}] seen or implied [= 6.314×10^{-28} N s]		1		1	1	
		(iii)	$1.06 \times 10^{34} \times 6.31 \times 10^{-28}$ [N] seen or implied (1) 2 × due to reflection stated (1) [→1.33×10^{7} N] [Using the 'show that' figures → 1.2×10^{7} N]		2		2	1	
		(iv)	$E = \frac{\text{stress}}{\text{strain}}$ used (1) [or by implication] $\text{Stress} = \frac{F}{A}$ used (1) [or by implication] Answer = 0.0083 or 0.011 (or 0.0105) seen (depends on (iii) but check) (1) [0.83% ✓]	1 1	1		3	3	
			Question 4 total	**7**	**6**	**0**	**13**	**7**	**0**

#11

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Electric field strength, E, is the force per unit charge [on a small positive test charge placed at the point]. (1) Electric potential, V, [at a point] is the work done per unit charge [in bringing the charge] from infinity [to that point]. (1) E- vector **and** V- scalar (both needed) (1)	3			3		
	(b)	(i)	 Both arrows seen. Ignore length of arrows. [Must be along dotted lines]	1			1		
		(ii)	 R correctly drawn and labelled [ecf]. Ignore length of arrow.		1		1		
		(iii)	E at P due to A (–12.0 nC) = 7 500 N C^{-1} (1) E at P due to B (+8.0 nC) = 28 800 N C^{-1} (1) (Deduct 1 mark for powers of 10 error) Resultant field strength at P = $(7\,500^2 + 28\,800^2)^{1/2}$ = 29 760 N C^{-1} (1) (**ecf** on both values of E) [or using horizontal and vertical components] Correct trigonometric relationship applied e.g. between R and A: $\theta = \cos^{-1}\left(\frac{7500}{29760}\right)$ = 75.4° (or 14.6° between R and B) [accept 2 sf and different ways of expressing directions] (1)		4		4	4	
	(c)	(i)	V_P due to A (–12.0 nC) =[–] 900 V V_P due to B (+ 8.0 nC) = [+] 1 440 V **Both potentials regardless of signs** (1) Correct sign convention [and addition clearly shown] (= + 540 V) (1) **Alternative** $\therefore V_P = \frac{1}{4\pi\varepsilon}\left\{\frac{-12\times10^{-9}}{12\times10^{-2}} + \frac{8\times10^{-9}}{5\times10^{-2}}\right\}$ values(1) and signs (1)		2		2	2	
		(ii)	Correct substitution into $W = q\Delta V$ i.e -1.6 × 10^{-19} (+540 – 0) (1) **Or** W = - 8.64 × 10^{-17} J seen (accept 540 eV converted into J) Hence gain in E_k = (+) 8.64 × 10^{-17} J (1) (+) can be awarded by implication	1	1		2	1	
	(d)		de Broglie $\lambda = \frac{h}{p}$ (1) Electron accelerates (or velocity or E_k increases) towards point P, **so** momentum increases (need to explain why momentum increases here) (1) So λ decreases (1) Ecf from (c) on marks 2 and 3: If $\Delta E_k < 0$ then opposite answer required.	1	1 1		3		
			Question 7 total	**6**	**10**	**0**	**16**	**7**	**0**

#12

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)	(i)	1.76 and 1.12 [1] 0.23 and 0.14 [1]			2	2	2	2
		(ii)	 Both points correct ± ½ small square division [1] Both error bars correct [1]		2		2	2	2
		(iii)	Line of maximum gradient correct [1] Line of minimum gradient correct [1] Allow ecf on plots and error bars for 1 mark only if imperfect		2		2		2
	(b)	(i)	Correct gradients (expect 1.73×10^{-6}, 0.98×10^{-6} but allow ecf on lines, just check for consistency) [2] Correct value of h obtained expect 7.2×10^{-34} [J s] (regardless of method, allow ecf but check consistent with lines) [1] Correct % uncertainty (expect around 27%) or $2\times$ correct values of h obtained e.g. 9.1 and 5.3 [1] (just check that these are consistent with the drawn lines) Final expression consistent with sig figs only 1 or 2 sig figs for uncertainty (allow ecf) e.g. $(7.2\pm1.9)\times10^{-34}$ [J s], $(7.2\pm1.8)\times10^{-34}$ [J s], $(7.2\pm2.0)\times10^{-34}$ [J s], $(7\pm2)\times10^{-34}$ [J s] [1]			5	5	4	5
		(ii)	**Any 4 × (1) from:** • Straight line ✓ • Through all error bars ✓ • Straddles origin / best fit line goes through origin ✓ • Value of h consistent (with data booklet) / gradient = $\frac{hc}{e}$ accept h is slightly large ✓ • Large uncertainty or scatter in data ✓			4	4	4	4
	(c)		Eye sensitivity changes with wavelength or long/some wavelengths invisible Don't accept reference to human error			1	1		
	(d)	(i)	Method correct (obtaining gradient or substituting values) e.g. $\frac{6.6\times10^{-19}}{10\times10^{14}}$ or $h\times10\times10^{14}=4.6\times10^{-19}+2\times10^{-19}$ [1] $h=6.6\times10^{-34}$ [J s] or other consistent value [1]		2		2	2	2
		(ii)	$h\times6.9\times10^{14}=4.57\times10^{-19}$ J OR y-intercept $=4.6\times10^{-19}$ J [1] Photon energy is too low [1] to release electrons [1]	1 1	1		3	1	3
			Question 7 total	**2**	**7**	**12**	**21**	**15**	**21**