WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 3

PHYSICS



EXAM QUESTION PACK

3.4 PHOTONS

SCORE	PERCENTAGE
/142	%

STEMUP

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#1

(a) Calculate the de Broglie wavelength of an electron accelerated by a pd of 2200 V. [3]

(b) Explain how electrons can be used in a laboratory to produce a diffraction pattern and the effect of increasing the pd on the diffraction pattern. [3]

Question taken from Eduqas examination paper 842103, November 2020

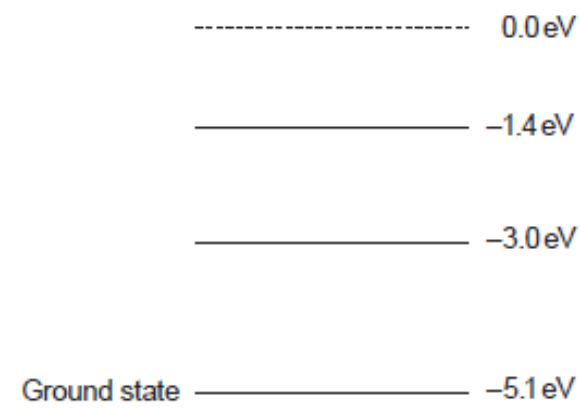
#2

(a) A sphere made of caesium is placed in space and illuminated by ultraviolet radiation of photon energy 10.3 eV. The work function of caesium is 2.1 eV. Explain in clear steps, using Einstein's photoelectric equation (and other physics), why the maximum potential attainable by the caesium sphere is +8.2 V. [5]

(b) Hence, calculate the maximum electric field strength around the caesium sphere given that its radius is 6.5 cm. [3]

Question taken from Eduqas examination paper 842103, November 2020

6. The diagram shows three energy levels of a sodium atom.



(a) State the ionisation energy of a sodium atom. [1]

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(b) White light passes through a cloud of sodium atoms. The light which emerges is found to have the continuous spectrum of white light but with dark lines crossing the spectrum. State briefly how the dark lines are caused and what happens to the atoms in the process. [3]

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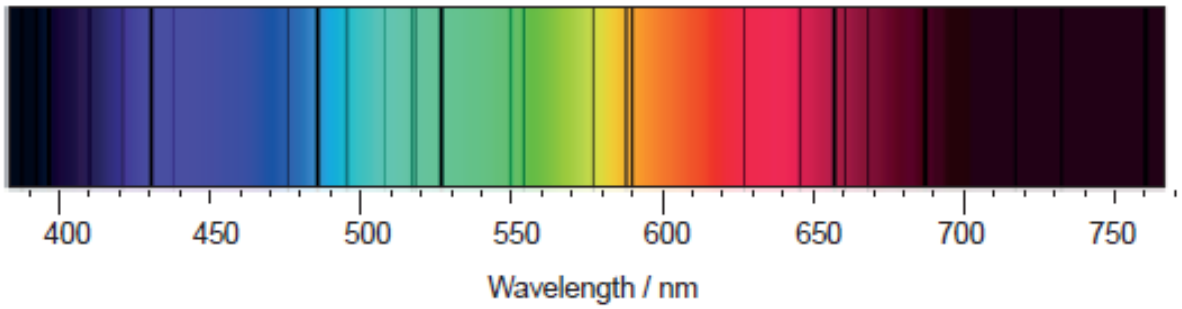
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(c) (i) The spectrum of a star is shown below. The wavelength of one of the dark lines is 590 nm. Evaluate whether this is evidence for the presence of sodium in the star. [3]



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(ii) The wavelength of peak emission of the star is 100 nm. Determine its surface temperature. [3]

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Question taken from Eduqas examination paper 842002, June 2019

#4

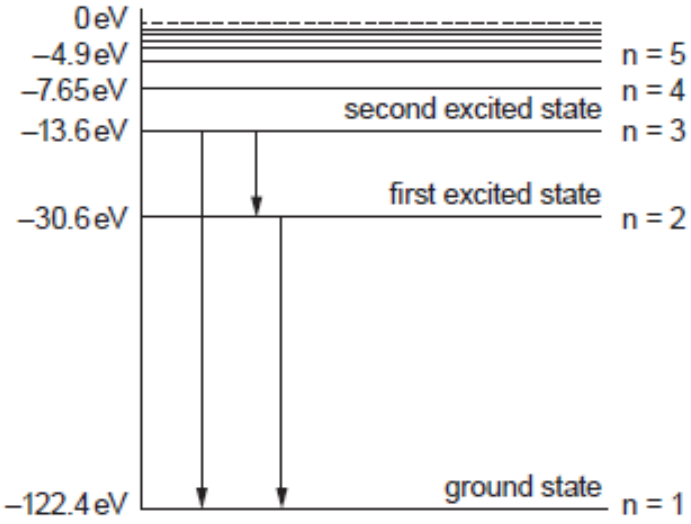
(a) Describe an experiment using a range of LEDs to determine the Planck constant. [6 QER]

(b) A university research group uses a new experimental method to determine a value for the Planck constant that is higher than the accepted value of 6.63×10^{-34} Js. Explain how other scientists would attempt to confirm this result. [2]

Question taken from Eduqas examination paper 842002, June 2017

#5

8. The energy levels of a lithium ion are shown.



(a) Calculate the ionisation energy of the lithium ion in joules. [2]

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(b) Calculate the wavelength of the electromagnetic radiation emitted when an electron drops from the second excited state (n = 3) to the first excited state (n = 2) and state the region of the electromagnetic spectrum to which it belongs. [3]

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(c) The emission and absorption spectra of another element are shown below.



Emission spectrum



Absorption spectrum

Explain briefly the processes that give rise to these spectra and why the lines appear at the same wavelengths in the two spectra. [3]

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Question taken from Eduqas examination paper 842103, June 2019

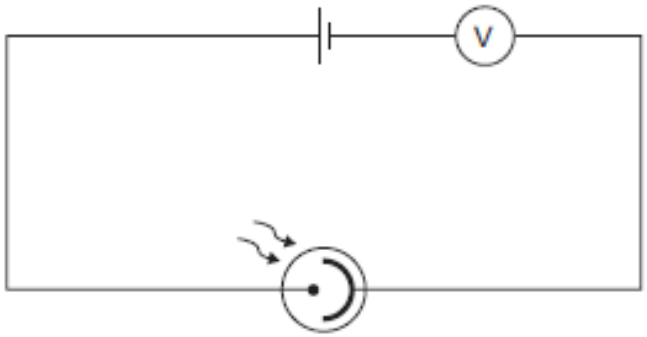
3. *(a)* (i) State what is meant by the photoelectric effect. [1]

(ii) Einstein's photoelectric equation may be written as:

$$E_{k\max} = hf - \phi$$

Explain this equation in terms of energy. [3]

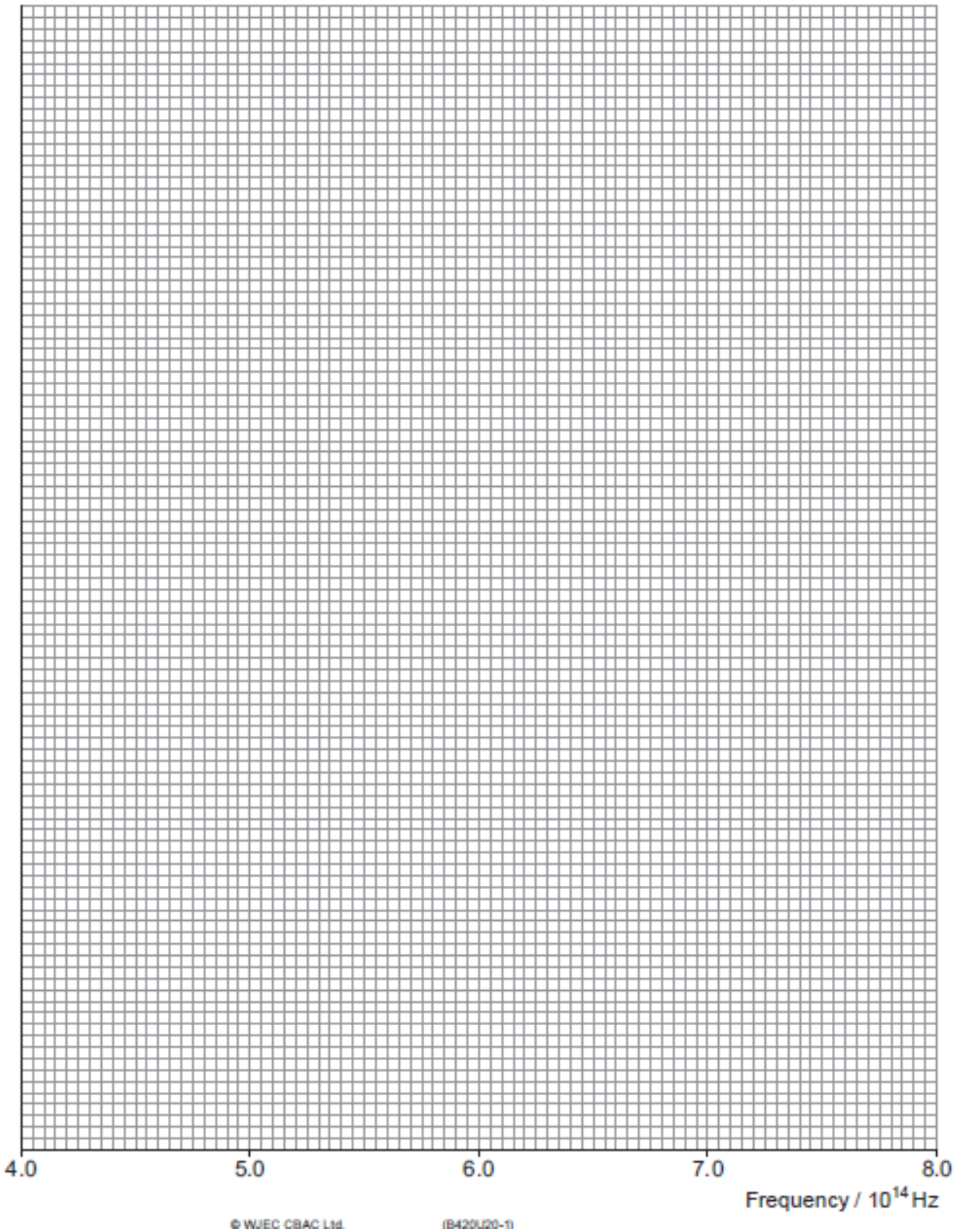
(b) Evaluate why the following circuit is incorrect and cannot be used to measure the maximum kinetic energy of the emitted electrons. [4]



(c) Different frequencies of light are used with a correct circuit and the following results are obtained.

Frequency / 10^{14} Hz	5.1	6.0	6.9	7.5
$E_{k\max}$ / 10^{-19} J	0.36	0.93	1.50	1.95

(i) Plot $E_{k\max}$ (y-axis) against frequency (x-axis) on the grid below and draw a line of best fit through your data. [3]



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(ii) Explain whether or not your graph is in agreement with Einstein's photoelectric equation. [3]

(iii) Calculate a value for the Planck constant using the gradient of your graph. [3]

(iv) An answer can be considered to be accurate if it is within 5% of the accepted value for the Planck constant. Evaluate whether your answer for the Planck constant can be considered to be accurate. [2]

Question taken from Eduqas examination paper 842002, June 2018

#7

7. Einstein's photoelectric equation can be written as

$$E_{k\,max} = hf - \phi$$

(a) Explain what is meant by the term work function, ϕ. [2]

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(b) (i) Light of frequency 7.3×10^{14} Hz is incident on a sodium surface at a rate of 2.5×10^{-10} Js^{-1}. Determine the number of photons per second incident on the sodium surface. [2]

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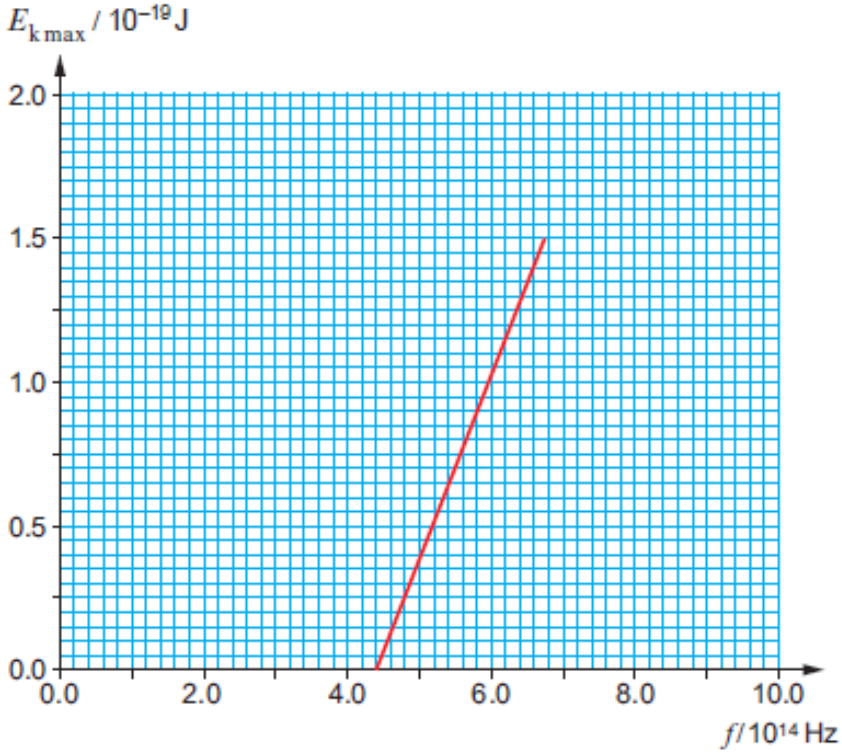
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(ii) A graph of $E_{k\,max}$ against f for the sodium surface is given below.



I. Calculate the work function of sodium. [2]

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II. Draw a line on the graph to show how $E_{k\,max}$ varies with f for a metal which has a greater work function than sodium. [2]

III. The rate at which light falls on to the sodium surface is increased from $2.5 \times 10^{-10}\,J\,s^{-1}$ to $3.0 \times 10^{-10}\,J\,s^{-1}$. Explain clearly why the graph would not change. [2]

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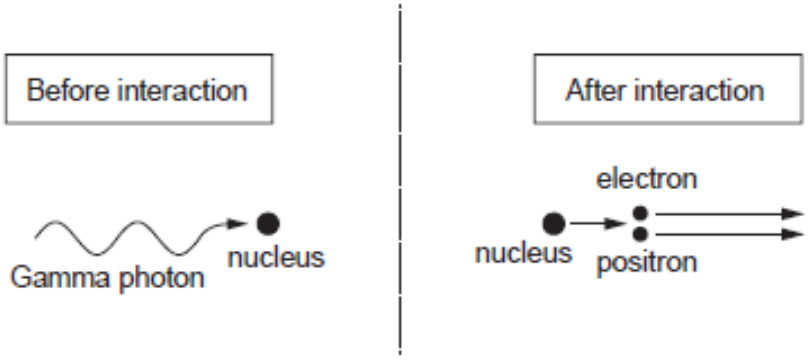
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Question taken from Eduqas examination paper 842002, June 2019

#8

5. The following interaction can take place when a gamma photon encounters a stationary nucleus.



The energy of the gamma photon "creates" a positron-electron pair and the nucleus gains some momentum in the direction of the original gamma photon.

(a) Show that this interaction can only take place if the energy of the gamma photon is greater than 1.02 MeV. [3]

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(b) The actual energy of the incident gamma photon is 1.03 MeV. **Assuming that the kinetic energy of the nucleus after the interaction is negligible**, explain briefly why the kinetic energies of the positron and electron are approximately 0.005 MeV **each**. [2]

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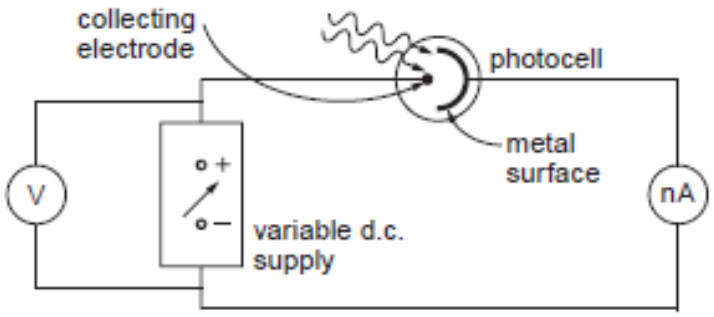
(c) Use the kinetic energies of 0.005 MeV and conservation of momentum to show that the speeds of the positron and electron are $4.2 \times 10^{7}\,\text{m s}^{-1}$ and that the momentum of the nucleus after the collision is $4.7 \times 10^{-22}\,\text{kg m s}^{-1}$. [4]

(d) The momentum of the nucleus ($4.7 \times 10^{-22}\,\text{kg m s}^{-1}$) is essential otherwise conservation of momentum would be impossible. Deduce whether or not the assumption in part *(b)* is valid (the mass of the nucleus is $3.3 \times 10^{-25}\,\text{kg}$). [2]

Question taken from Eduqas examination paper 842103, June 2019

#9

3. Light is incident on a photoelectric cell as shown.



(a) Explain why a current is detected by the ammeter. [3]

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(b) The work function of the metal surface is 2.7 eV and electrons are emitted with a maximum kinetic energy of 1.2 eV.

Calculate the frequency of the incident photons. [3]

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(c) (i) Explain how you would modify and use the circuit opposite to measure the stopping potential. [3]

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(ii) The metal surface of the photocell is radioactive and emits alpha particles some of which arrive at the collecting electrode. Explain briefly what effect this would have on measuring the stopping potential and what could be done to reduce this effect. [3]

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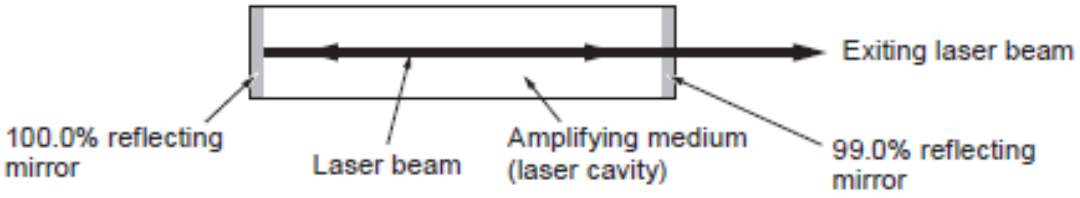
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Question taken from Eduqas examination paper 842103, June 2018

#10

4. A laser has two mirrors either side of the amplifying medium as shown.



(a) Explain the purpose of the 99.0% reflecting mirror and the 100.0% reflecting mirror. [2]

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(b) Explain the purpose of a population inversion in the laser cavity. [3]

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(c) (i) The light intensity inside a powerful laser is 2.0×10^{15} W and its wavelength is 1.05 μm. Show that this corresponds to approximately 1×10^{34} photons per second. [2]

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(ii) Show that the momentum of a 1.05 μm photon is approximately 6×10^{-28} kg m s^{-1}. [1]

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(iii) Show that the force exerted on a 100.0% reflecting mirror by a beam of power 2.0×10^{15} W is approximately 1×10^{7} N. [2]

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(iv) Calculate the strain produced in a laser structure if the power of the beam between the mirrors is 2.0×10^{15} W. You may assume that the structure of the laser cavity has a cross-sectional area of 43 cm^2 and is made of a material with Young modulus 2.8×10^{11} Pa. [3]

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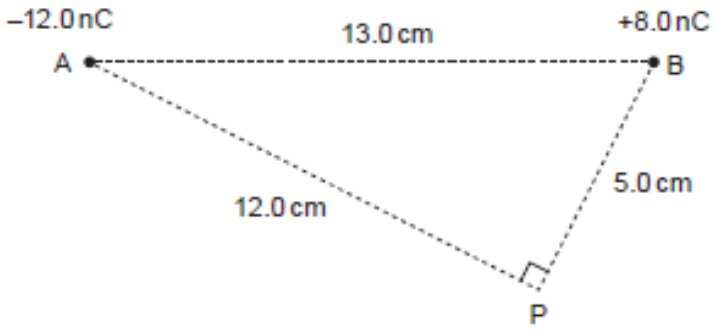
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Question taken from Eduqas examination paper 842103, June 2018

7. *(a)* Complete the following table: [3]

Quantity	Definition	Vector or Scalar
Electric field strength, E	.....	.....
Electric potential, V	.....	.....

(b) Point charges of –12.0 nC and +8.0 nC are placed at A and B, 13.0 cm apart as shown. P is a point in space which is 12.0 cm from A and 5.0 cm from B.



(i) Draw on the diagram **two** arrows to show the directions of the field strength at P due to each charge. [1]

(ii) Hence draw on the diagram **one** arrow to represent the direction of the resultant field strength at P. **Label this arrow R.** [1]

(iii) Calculate the **magnitude and direction** of the electric field strength at P. [4]

(c) (i) Show that the potential at P is + 540 V. [2]

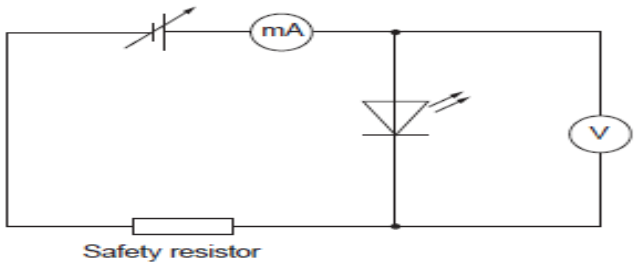
(ii) Calculate the gain in kinetic energy in joules of an electron as it moves from infinity to P. [2]

(d) Without calculation, explain how the de Broglie wavelength of the electron changes as it moves towards P. [3]

Question taken from Eduqas examination paper 842102, June 2018

#12

7. *(a)* The following circuit is used to find the pd across an LED when it is switched on.



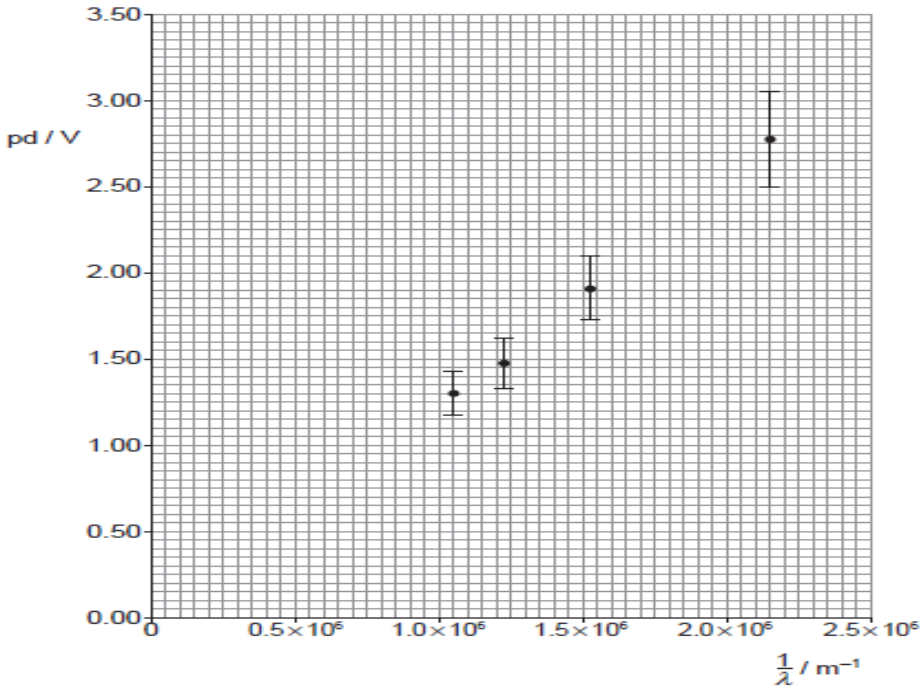
Aled decides that the LED is switched on when a current of 10.0 mA passes through it. He adjusts the variable power supply and records the switching-on pd. He repeats this procedure for different LEDs which emit light of different wavelengths. His results are tabulated below.

(i) **Complete** the table. [2]

Wavelength λ of LED / nm	$\frac{1}{\lambda}$ / m^{-1}	Switching-on pd / V (± 10%)
465	2.15×10^6	2.78 ± 0.28
569	..... $\times 10^6$	2.26 ± .....
660	1.52×10^6	1.91 ± 0.19
820	1.22×10^6	1.47 ± 0.15
890	..... $\times 10^6$	1.44 ± .....
950	1.05×10^6	1.29 ± 0.13

(ii) **Complete** the graph by plotting the two missing points whose values you have calculated together with their error bars. [2]

(iii) **Draw** the line of maximum gradient and the line of minimum gradient through the error bars. [2]



(b) Conservation of energy applied to an electron and photon involved in the light emitting process of the LED gives:

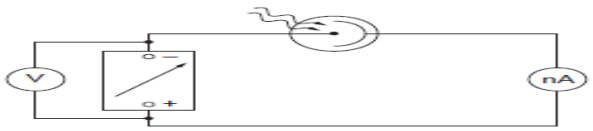
$$eV = \frac{hc}{\lambda}$$

(i) Use your two lines from *(a)*(iii) to obtain a value for the Planck constant along with its absolute uncertainty to an appropriate number of significant figures. [5]

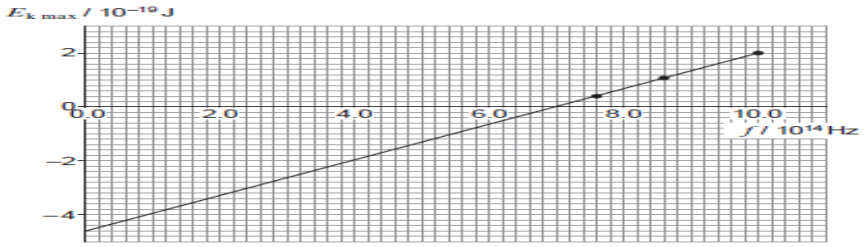
(ii) Explain to what extent Aled's data displayed in the graph confirm the relationship.
$eV = \frac{hc}{\lambda}$ [4]

(c) Suggest **one** reason why choosing a constant current of 10.0 mA is better than using your eye to detect the emitted radiation for these LEDs. [1]

(d) The Planck constant can also be determined using the photoelectric effect. Light of various frequencies is incident on a calcium photoelectric cell as shown and the maximum kinetic energy, $E_{k\,max}$, of the emitted electrons is determined for each frequency, f.



The following graph is obtained.



(i) Determine a value for the Planck constant. [2]

(ii) Determine a value of the work function of calcium and explain why no data points are possible below a frequency of 6.9×10^{14} Hz. [3]

Question taken from Eduqas examination paper 842103, June 2019

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**

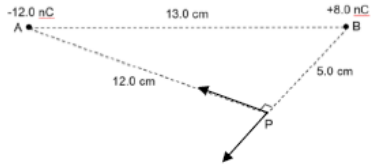
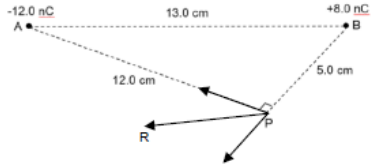
#9

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. $\times 1.6 \times 10^{-19}$ (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**

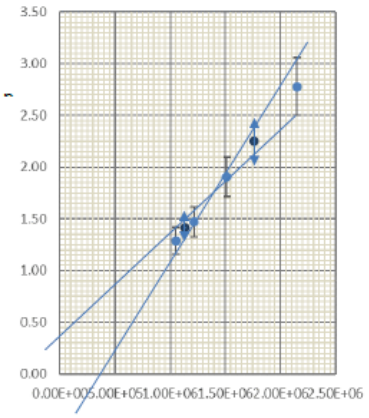
#10

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**