

Name: \_\_\_\_\_

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## Yr 12 Physics Light Duality Test 2016

### Instructions

1. Answer all questions in the spaces provided.
2. Give all numerical answers to three significant figures, except where you are required to estimate values where two significant figures will be appropriate.
3. Show all working – marks may be awarded for logical working even when an incorrect final answer is arrived at.
4. If you require extra working space, write “PTO” on the bottom of the page and continue working on the back of the page.

48 marks for answering the questions, 2 marks for units and significant figures

### Question 1

(4 marks)

Louis de Broglie thought that if a wave could behave like a particle, then perhaps a particle could behave like wave. He proposed that the wavelength of a material particle was related to its linear momentum  $p = mv$ .

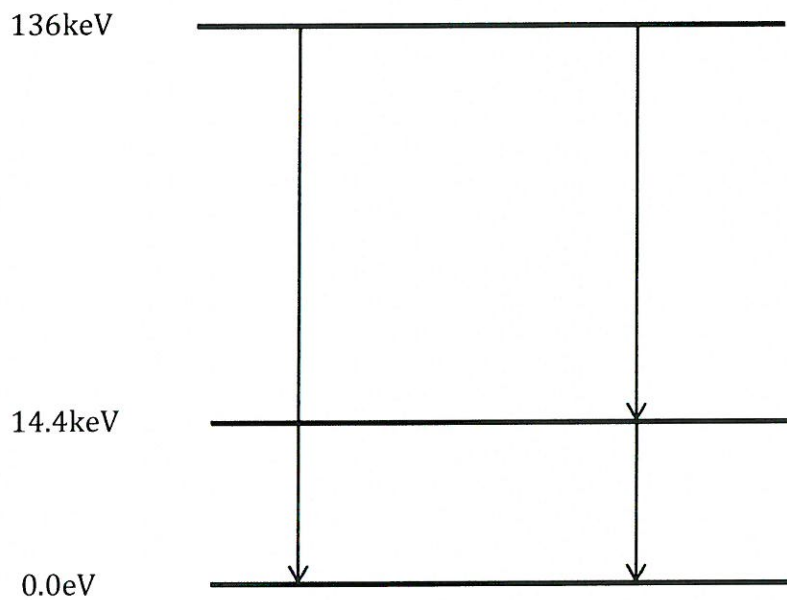
Compare, through calculations, the de Broglie wavelengths for a 5.0kg ball travelling at  $14\text{m s}^{-1}$  to that of an electron travelling at  $5.9 \times 10^6\text{m s}^{-1}$ .

From these results, determine which of these particles has a wavelength in the X-ray region of the electromagnetic spectrum.

**Question 2****(4 marks)**

When a radioactive isotope undergoes gamma decay, a nucleus in an excited state decays to a lower energy state of the same isotope by the emission of a photon. This decay is similar to the emission of light when an electron in an atom moves from a higher energy level to a lower level. The isotope Fe-57 can decay to the ground state in the two ways shown on the energy level diagram below.

Calculate the wavelength and frequency of the photon emitted in the transition from the level with energy of 136 keV to the level with energy of 14.4 keV.

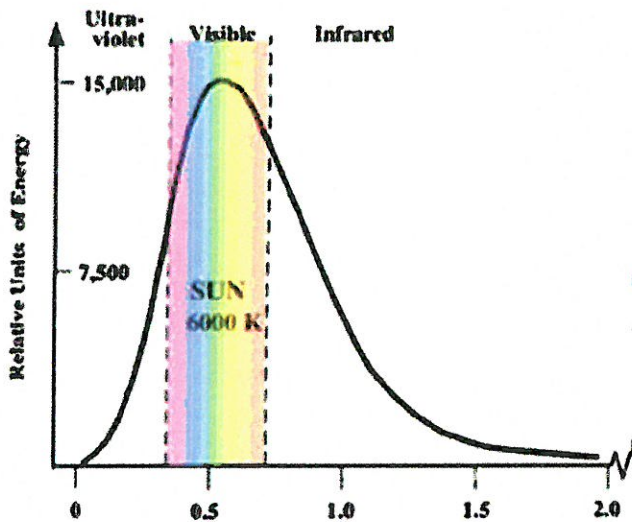


### Question 3

(4 MARKS)

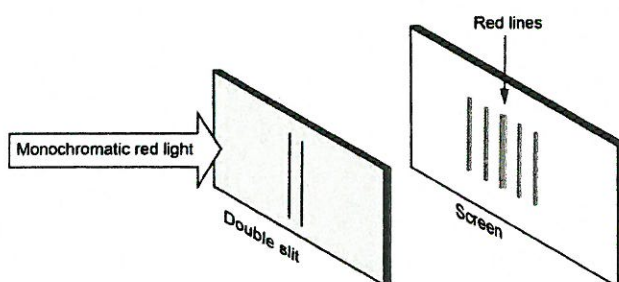
The diagram below shows the spectrum of the (blackbody) EMR emitted by the sun.

- One the diagram, sketch and label the general curve for
- a cooler, red star (2 marks)
  - a warmer, blue star (2 marks)



### Question 4

(3 marks)



The pattern observed when monochromatic light passes through a piece of cardboard with twin slits close together is often considered evidence for the wave theory of light. A diagram of an experimental set up is shown to the left.

Explain how the pattern of red lines is formed on the screen and why this is considered to be evidence for the wave theory of light.

# QUESTION 5

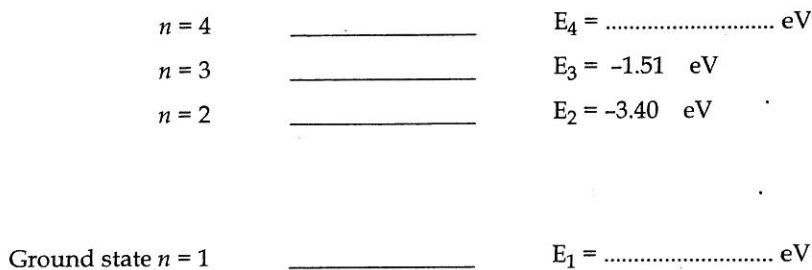
(13 MARKS)

A hydrogen atom, in an excited energy level, undergoes relaxation by emitting a photon. The energy values are given by  $E_n = -\frac{13.6}{n^2}$  eV. The initial state of the electron is in energy level  $n = 4$  and the final state after relaxation is ground state ( $n = 1$ ).

- (a) Does the average radius of the electron orbital remain the same, increase or decrease in value during this transition? Circle the correct answer. [1]

remains the same                      increases                      decreases

- (b) Use the formula  $E_n = -\frac{13.6}{n^2}$  eV to complete the energy level diagram below. The diagram is **not** drawn to scale. [2]



- (c) On the diagram above, draw in all the possible transitions when an electron undergoes relaxation from  $n = 4$  to the ground state. [3]

- (d) (i) Calculate the wavelength of the photon emitted from the  $E_3$  to  $E_2$  transition. Show **all** workings. [4]

- (ii) The transitions of  $E_4$  to  $E_2$  and  $E_3$  to  $E_2$  produce red and green photons. Explain which transition produces which colour. [3]

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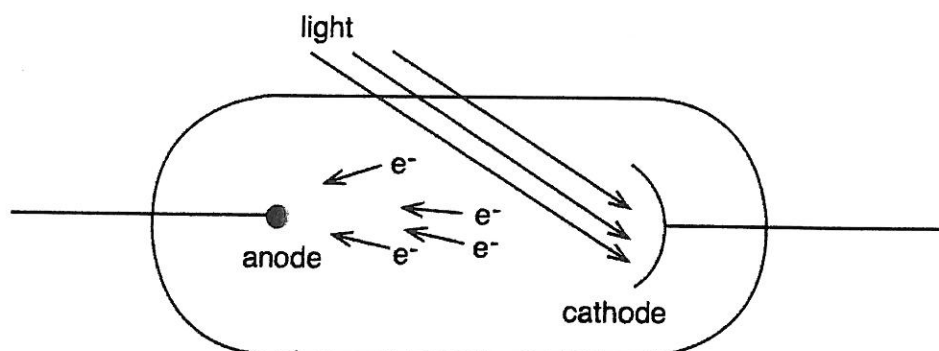
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Question 7

(14 marks)

A group of students set up a photocell to investigate the photoelectric effect and determine a value for Planck's constant.



The photocell works when incident light falls on a metal cathode and causes electrons to be ejected with a certain kinetic energy from the metal. These electrons then move across the cell to the anode. The kinetic energy of an ejected electron is equal to the energy of the incident light minus the work function  $W$  (the energy required to remove the electron from the metal).

$$E_k = hf - W$$

To determine the kinetic energy of the electrons, a reverse voltage is applied to the anode and cathode so that it will just completely stop the electrons from reaching the anode. This is called the 'stopping voltage'. At this point, the work done by the electric field must equal the kinetic energy of the ejected electrons:

$$E_k = q_e V$$

The students then shone incident light that had passed through a filter of known wavelength onto a photocell. The photocell was connected to a circuit that allowed the students to adjust the stopping voltage so that zero current flowed through the tube.

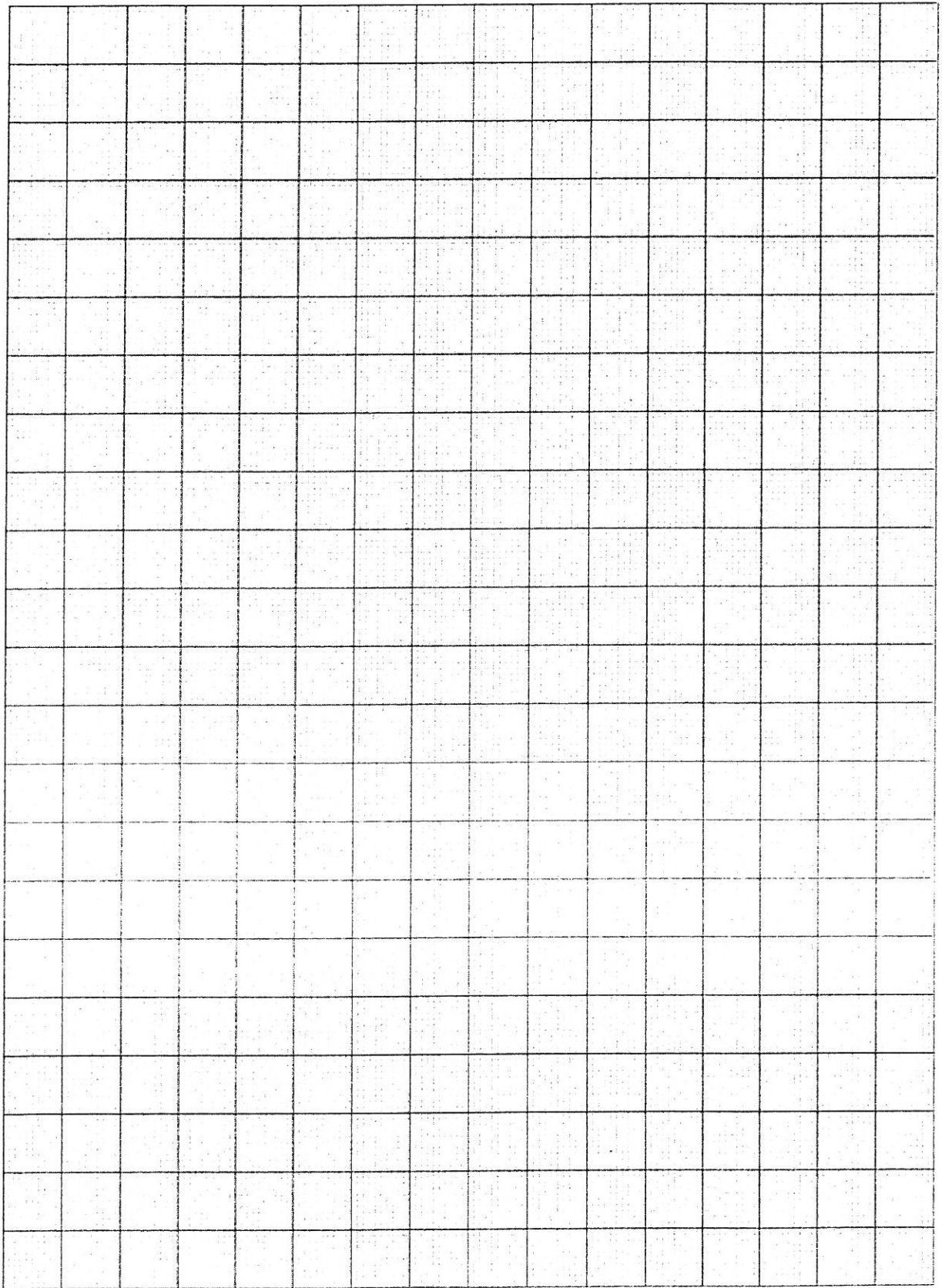
The students combined several relationships to produce the following equation:

$$q_e V = \frac{hc}{\lambda} - W$$

The data was recorded and processed in the table below.

Filter colour	Wavelength (nm)	$\frac{1}{\lambda}$ ( $\text{m}^{-1}$ )	Stopping voltage (V)
Blue	426	$2.35 \times 10^6$	1.12
Green	464	$2.16 \times 10^6$	0.88
Yellow	493	$2.03 \times 10^6$	0.72
Orange	534	$1.87 \times 10^6$	0.57
Red	589	$1.70 \times 10^6$	0.33

- (a) Plot stopping voltage on the  $y$ -axis against  $\frac{1}{\lambda}$  on the grid below. Draw the  $x$ -axis in the middle of the grid, and extend the  $y$ -axis to  $\pm 2$  volts. (3 marks)



- (b) Given the aim of the experiment, explain why the students graphed  $\frac{1}{\lambda}$ . (1 mark)

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- (c) Determine the gradient of the line of best fit and give its units. (3 marks)

- (d) Use the gradient from part (c) to determine the experimental value in J s for Planck's constant. (2 marks)

- (e) Use the graph to determine the work function, and give its units. (3 marks)

- (f) Explain what information the intercept with the x-axis provides and how this supports Einstein's theory that light is made up of photons. (2 marks)

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