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90522

905220

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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2007

90522 Demonstrate understanding of atoms, photons and nuclei

Credits: Three
9.30 am Friday 30 November 2007

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

For all numerical answers, full working must be shown, and the answer must be rounded to the correct number of significant figures and given with an SI unit.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page(s) provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–10 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

For Assessor's use only — Achievement Criteria		
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and / or relationships.	Give explanations that show clear understanding in terms of phenomena, concepts, principles and / or relationships.
Solve straightforward problems.	Solve problems.	Solve complex problems.
Overall Level of Performance (all criteria within a column are met)		

You are advised to spend 35 minutes answering the questions in this booklet.

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You may find the following formulae useful.

$E = hf$	$hf = \phi + E_K$	$E = \Delta mc^2$	$E_n = -\frac{hcR}{n^2}$
$\frac{1}{\lambda} = R(\frac{1}{S^2} - \frac{1}{L^2})$	$E_P = qV$	$v = f\lambda$	

QUESTION ONE: STELLAR NUCLEO-SYNTHESIS

Speed of light $= 3.00 \times 10^8\ \text{m s}^{-1}$
Charge on the electron $= 1.6 \times 10^{-19}$ C
Nuclear rest masses
Neon-20 $= 33.197 \times 10^{-27}$ kg
Helium-4 $= 6.6465 \times 10^{-27}$ kg

The nuclei of many heavy elements are produced in stars in a process called stellar nucleo-synthesis. In one reaction in the carbon-fusion stage, two carbon-12 nuclei fuse to create neon. This is shown below.

$$C^{12} + C^{12} \rightarrow Ne^{20} + He^4$$

Approximately 4.78 MeV of energy is released in this reaction.

(a) Convert 4.78 MeV into joules. Show your working.

(b) (i) Show that the mass lost during this reaction has an unrounded value of 8.4978×10^{-30} kg.

(ii) Round this answer to the correct number of significant figures.

mass lost = ____________

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(c) Explain why mass is lost during this reaction.

(d) Calculate the mass of a carbon-12 nucleus.

mass =

(e) Oxygen-16 is also produced in fusion reactions. The oxygen-16 nucleus is more stable than the carbon-12 nucleus.

What is meant by nuclear stability?

QUESTION TWO: HYDROGEN SPECTRUM

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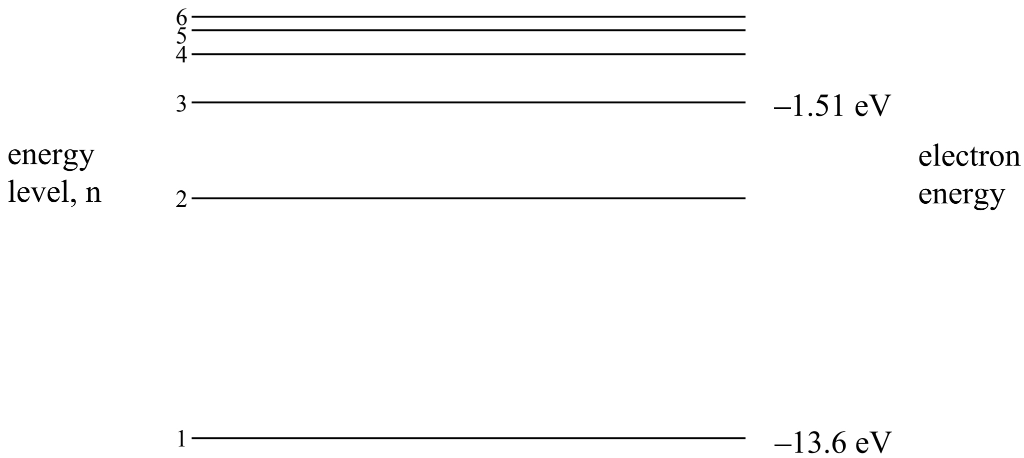
Speed of light	$= 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Charge on the electron	$= 1.6 \times 10^{-19}\ \mathrm{C}$
Planck's Constant	$= 6.63 \times 10^{-34}\ \mathrm{J\,s}$
Rydberg Constant	$= 1.097 \times 10^{7}\ \mathrm{m^{-1}}$

The electron in the hydrogen atom emits or absorbs electromagnetic radiation when it moves between different energy levels. The visible part of the spectrum emitted by hydrogen can be seen in the laboratory by applying a high voltage to a hydrogen discharge tube.

The diagram below represents some of the electron energy levels in the hydrogen atom.



(a) To which energy level does the electron drop when it emits **visible** light?

(b) The **absorption** spectrum for hydrogen gas consists of a series of dark lines within the full spectrum of colours.

Explain clearly how the dark line in the **red** part of the spectrum is produced.

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(c) Calculate the frequency of the photon produced when an electron drops from the second excited state (n = 3) to the ground state (n = 1).

frequency =

An electron in energy level 4 jumps to a higher energy level, and then drops down to the ground state, releasing a photon of frequency 3.200×10^{15} Hz.

(d) Calculate the frequency of the photon required for the first jump.

frequency =

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QUESTION THREE: PHOTOELECTRIC EFFECT

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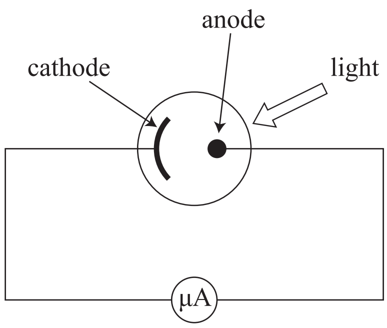
Speed of light = 3.00×10^{8} m s^{-1}
Charge on the electron = 1.6×10^{-19} C
Planck's Constant = 6.63×10^{-34} J s

Historically, photographers have used light meters containing photocells that are modelled on the photoelectric effect.

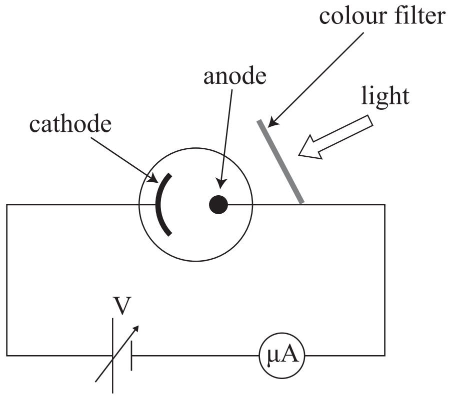
A photocell consists of a vacuum tube containing a curved sheet of zinc metal as the cathode and a metal pin as the anode, as shown in the diagram below. When light shines on the photocell, there is a current in the circuit. A very sensitive meter measures this current.



(a) Describe what causes a current in the circuit.

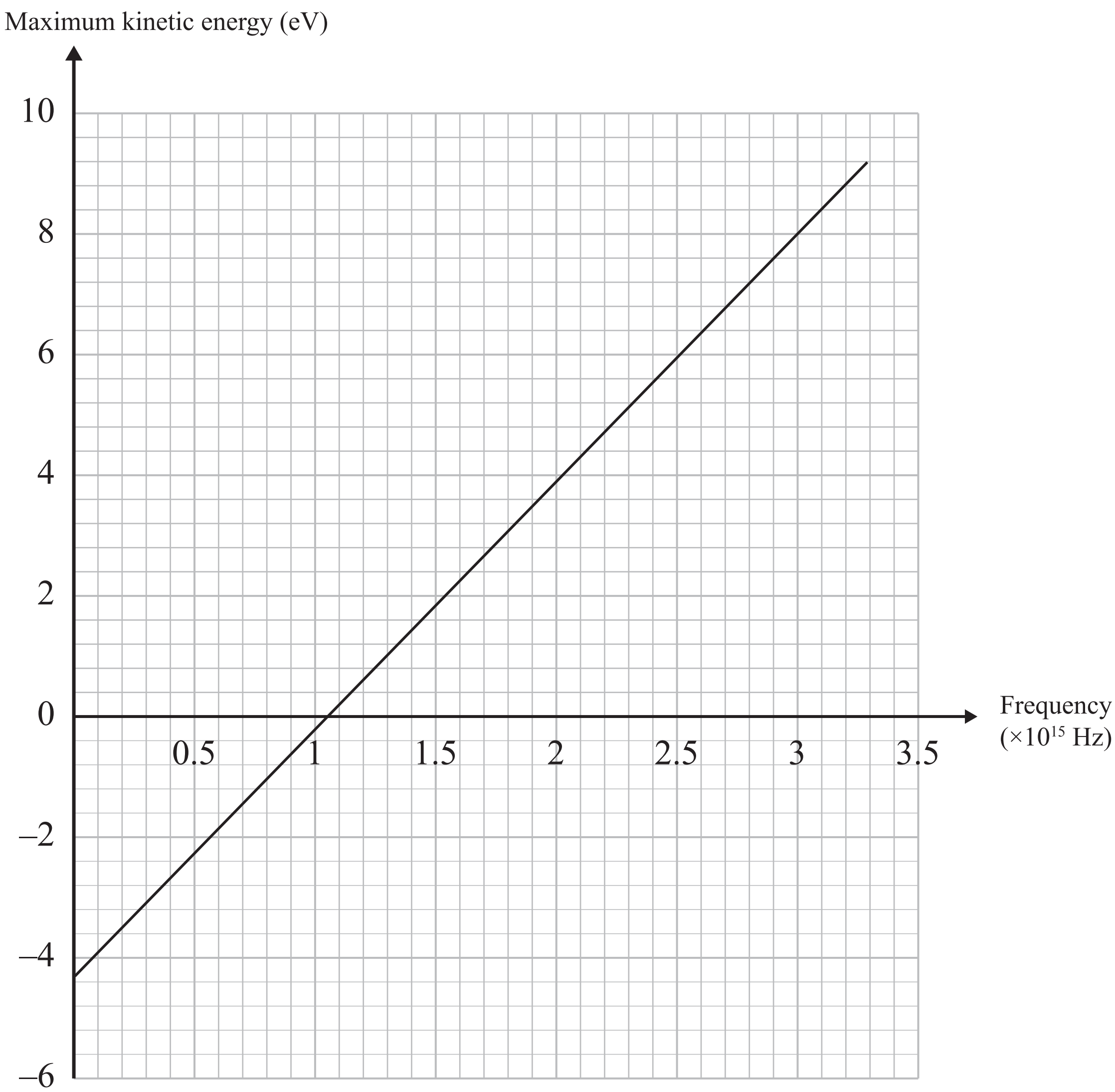
(b) Explain how changing the brightness of the light affects the size of the current in the circuit.

To investigate the properties of the photocell, a variable voltage supply is connected to the photocell, as shown in the circuit diagram. Using a colour filter makes the light hitting the zinc cathode monochromatic.



The voltage is changed until there is no current in the circuit. This voltage is a measure of the maximum kinetic energy of the released electrons, in **electron volts**.
By using different colour filters to change the frequency of the light hitting the zinc cathode, a graph of maximum electron kinetic energy, in **electron volts**, against frequency is drawn.

Maximum kinetic energy vs frequency for zinc



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(c) From the graph, determine the threshold frequency of zinc.

frequency =

(d) The equation for the maximum kinetic energy of the released electrons, in **joules**, is

$E_K = hf - \phi$.

Using information from the graph, calculate a value for Planck's Constant. Show your working.

Planck's Constant =

(e) Determine the threshold frequency for a metal that releases an electron with maximum kinetic energy of 3.94×10^{-20} J when light of wavelength 4.01×10^{-7} m shines on it.

threshold frequency =

Extra paper for continuation of answers if required.
Clearly number the question.

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Question number