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90522

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Level 3 Physics, 2005

90522 Demonstrate understanding of atoms, photons and nuclei

Credits: Three
9.30 am Tuesday 29 November 2005

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

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.

Formulae and information 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 2–8 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.

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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 concise 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 ☐		

You may find the following formulae and information useful.

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

Charge on an electron $= 1.60 \times 10^{-19}$ C
Speed of light $= 3.00 \times 10^{8}$ m s^{-1}
Planck's constant $= 6.63 \times 10^{-34}$ J s
Rydberg's constant $= 1.10 \times 10^{7}$ m^{-1}

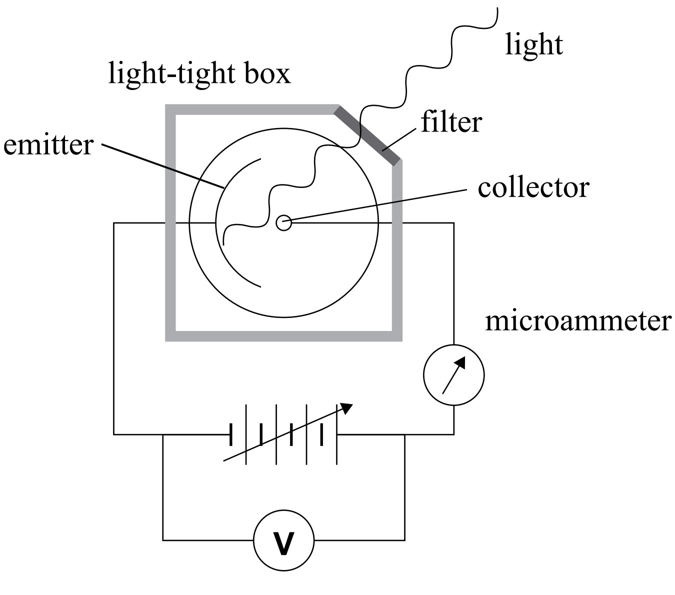
You are advised to spend 30 minutes answering the questions in this booklet.

QUESTION ONE: LIGHT ENERGY CHANGED TO ELECTRICAL ENERGY

Year 13 photography students were taking photographs of Prince William on his recent visit to New Zealand. The camera they were using had a light meter that measured the brightness of the light. One of the students mentioned that the light meter was developed from the photoelectric cell.

light meter

In a photoelectric cell, electrons are released to generate a current when light is incident on the metal surface of the cell. The circuit diagram of a cell is shown below.



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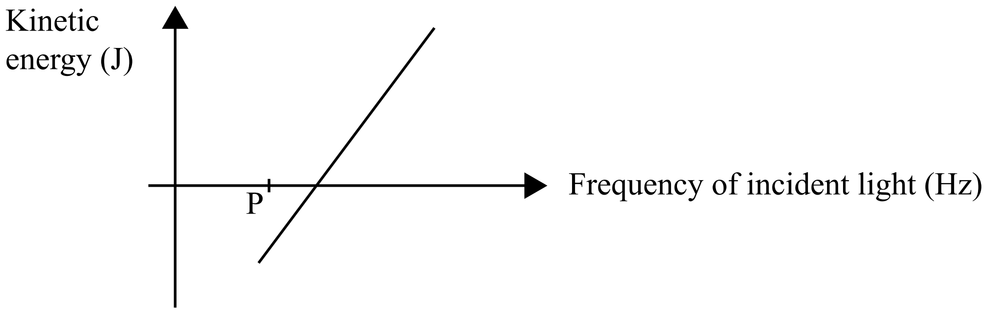
(a) Light of frequency 6.16×10^{14} Hz is incident on the photoelectric cell. Calculate the energy of the light photons.

energy = ______________________

Each photon will release an electron. The graph below shows the relationship between the kinetic energy of the released electrons and the frequency of light incident on the cell.



(b) Describe what would happen if light of frequency P were incident on the photoelectric cell.

(c) Each photon of frequency 6.16×10^{14} Hz will release an electron with a maximum kinetic energy of 0.35 eV. Calculate the threshold frequency of the metal surface of the cell.

threshold frequency = ______________________

(d) If the metal of the photoelectric cell is now changed to one with a **greater** work function, draw a line on the graph above to represent how its kinetic energy would depend on the frequency of the incident light.

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(e) Explain what effect the brightness of the light will have on the current generated in the photoelectric cell.

If the battery is reversed, its voltage can be adjusted until the current stops.

(f) Explain how this cut-off (stopping) voltage, when the light is brighter, compares with the cut-off voltage when the light is less bright.

(g) State TWO different ways in which the wave model of light fails to explain the photoelectric effect. Explain ONE of the statements you make.

QUESTION TWO: LIGHT EMITTED FROM A STAR

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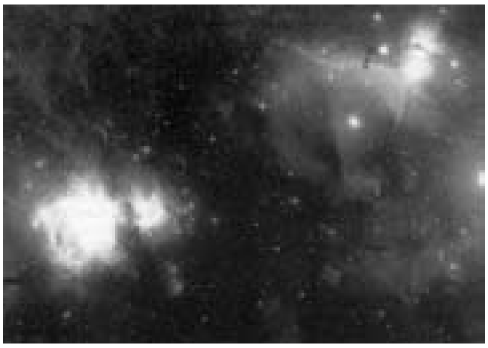
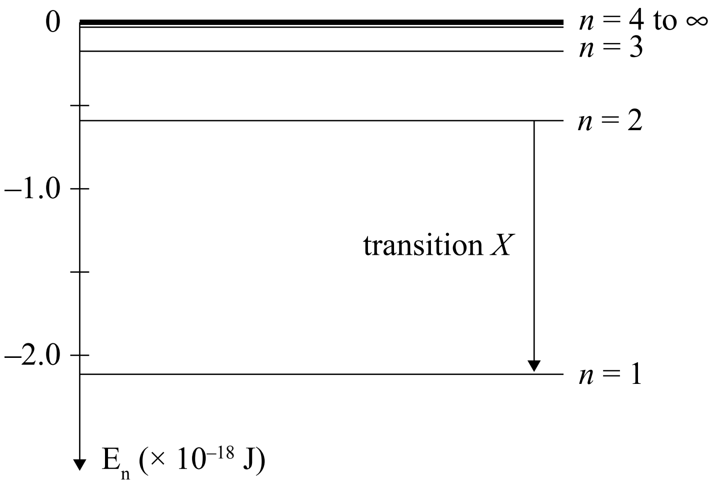
Light from stars is photons of electromagnetic radiation created by electron transitions between energy states. These photons produce spectra that identify the atoms that are producing the light. A common element that produces light from a star is hydrogen.



The Horsehead Nebula has a pink glow that comes from ionised hydrogen gas.

The possible energy states (levels) of the hydrogen atom electron are shown in the diagram below.



(a) In which part of the electromagnetic spectrum is the radiation emitted by transition *X*?

____

(b) Calculate the wavelength of the photons emitted by transition *X*.

____

____

____

wavelength = ______________________

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(c) Explain which transition produces the **red** line in the **visible** part of the hydrogen atom emission spectrum.

(d) Calculate the value of the ground state energy of the hydrogen electron. Give your answer to the correct number of significant figures.

ground state energy = ______

(e) In order for an electron in a hydrogen atom to move from the third energy level to the fifth energy level, a photon of electromagnetic radiation must be absorbed. Calculate the energy of this photon.

energy = ______

QUESTION THREE: ENERGY FROM A NUCLEAR REACTOR

Plutonium (Pu) is used as a fuel in a nuclear reactor to generate large amounts of energy. The following equation shows a fission reaction of plutonium that releases energy.

$$^{239}_{94}\text{Pu} + ^{1}_{0}\text{n} \rightarrow ^{142}_{56}\text{Ba} + ^{93}_{38}\text{Sr} + 5\,^{1}_{0}\text{n}$$

The rest masses of the particles involved are:

239 plutonium:	$396.92935 \times 10^{-27}$ kg
142 barium:	$235.64216 \times 10^{-27}$ kg
93 strontium:	$154.27837 \times 10^{-27}$ kg
neutron:	1.67493×10^{-27} kg

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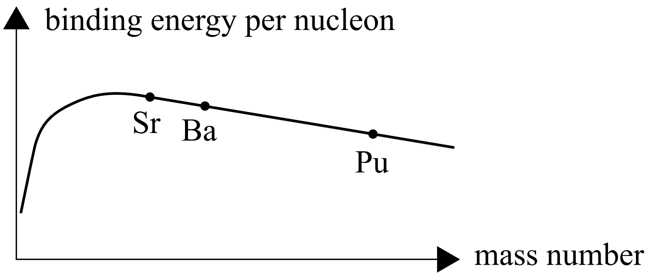
(a) Calculate the amount of energy, in electron volts (eV), generated in this reaction.

energy =

(b) If the binding energy per nucleon of the barium isotope $^{142}_{56}Ba$ is 1.4567×10^{-29} J, calculate the total binding energy of this nucleus.

binding energy =

The diagram below shows a sketch graph of average binding energy per nucleon against mass number for the elements in the nuclear reaction given on page 6.



(c) Using the graph, explain why energy is **generated** in this nuclear reaction.

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

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Question number