Name: ____________________ /50

Yr 12 ATAR Physics EMR Test 2019

Instructions

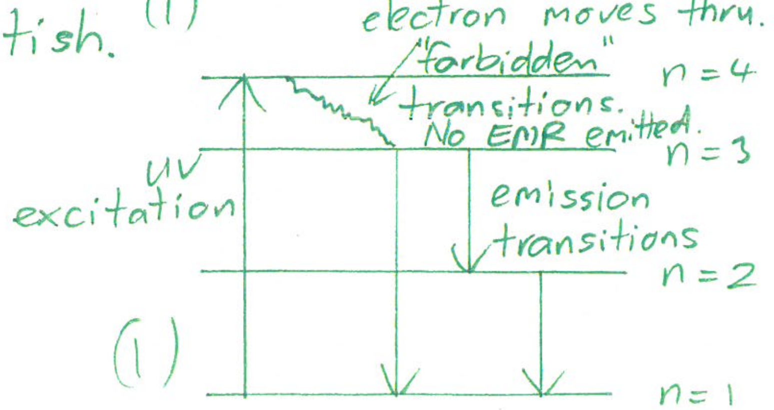
1. Answer all questions in the spaces provided. If you need extra space there is a blank page at the back of the booklet – ensure you clearly indicate if you use this.
2. Give all numerical answers to three significant figures, except where you are required to estimate values where two significant figures will be appropriate.
3. Show all working – marks may be awarded for logical working even when an incorrect final answer is arrived at.
4. Up to four marks may be deducted for incorrect significant figures and / or units.

Time Limit – 50 minutes

QUESTION ONE **(4 marks)**

Todd gets a new watch for his birthday. He wears it throughout a sunny day, before carefully placing it next to his bed before he goes to sleep. Waking unexpectedly in the middle of the night Todd sees the hands and numbers on his glowing and he can clearly read the time as being 3.30am. With the aid of simple diagrams explain how and why this glowing can occur.

- This is an example of phosphorescence. (1)
- The coating on the hands/numbers absorbs blue/UV light from the sun, causing electrons to be-come excited and to move to higher energy levels. (1)
- The electrons then return to the ground state, after a time delay, in one or more transitions, emitting a mixture of photons whose colours combine to appear whitish. (1)



QUESTION TWO **(13 marks)**

The table below contains photoelectric properties collected experimentally for a range of metals.

Element	Symbol	Work Function (eV)
Potassium	K	2.29
Calcium	Ca	2.87
Scandium	Sc	3.50
Titanium	Ti	4.33
Chromium	Cr	4.50
Cobalt	Co	5.00

a) Explain what is meant by the term work function as it relates to the photoelectric effect. (2 marks)

- The work function relates to the lowest energy photon that will cause the photoelectric effect to occur for a given metal.
- The work function is the product of Planck's constant and the threshold frequency.

b) Calculate the maximum kinetic energy (in eV) of an ejected photoelectron when light of wavelength 338nm is shone on a piece of scandium. (4 marks)

$$KE_{MAX} = E_{photon} - W$$

$$= h \times f \left(\text{ie } \frac{hc}{\lambda}\right) - W$$

$$= \frac{(6.63 \times 10^{-34}) \times (3.0 \times 10^{8})}{(3.38 \times 10^{-7})} - (3.5 \times 1.6 \times 10^{-19})$$

$$= (5.8846... \times 10^{-19}) - (5.60 \times 10^{-19})$$

$$= 2.85 \times 10^{-20}\ J \quad (= 0.178\ eV)$$

c) When violet light of wavelength 386nm is shone on one of the metals, the stopping potential is increased until it reaches 0.350V where the photocurrent reduces to zero. Determine the work function of this metal, and then use the table to identify the most likely metal. (4 marks)

$KE_{electron} = qV_{STOPPING} = E_{photon} - W$ (1)

$\therefore W = E_{photon} - qV_{STOPPING}$

$= \frac{hc}{\lambda} - (1.6 \times 10^{-19} \times 0.35)$ (1)

$= \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{(3.86 \times 10^{-7})} - (0.56 \times 10^{-19})$ (1)

$= (5.1528\ldots \times 10^{-19}) - (0.56 \times 10^{-19})$

$= 4.592\ldots \times 10^{-19} J$ (1)

$=$ ~~2.52eV~~ (Ca?) 2.87eV

d) Explain how the photoelectric effect supports the idea that light has a particle nature. (3 marks)

- Light less than the threshold freq., no matter how intense, will never cause the PE effect.
- More intense light (of freq. $> f_0$) results in more photo-electrons, not more energetic photo-electrons.
- There is no time delay between arrival of light and the ejection of electrons.

QUESTION THREE **(8 marks)**

During a science activity at school, the teacher uses a green laser to highlight certain key points. Grace, sitting in the front row, notices that the laser is rated at 5.00mW and emits a wavelength of 532nm.

a) Determine how many photons per second are emitted by the laser. (4 marks)

• Total energy (per sec) = 0.005 J.

• $E_{photon} = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})\times(3.0\times10^{8})}{(5.32\times10^{-7})}$

$= 3.738... \times 10^{-19}$ J

No. photons/sec $= \frac{E_{TOTAL}}{E_{photon}} = \frac{5.0\times10^{-3}}{3.738..\times10^{-19}}$

$= 1.34\times10^{16}$ photons sec^{-1}

b) Briefly explain how the laser operates to produce a monochromatic, coherent beam of light. (4 marks)

• A power source energies the laser producing material (gain medium) exciting electrons around a majority of atoms (pop. inv.)

• The excited electrons spontaneously transition back to lower levels, emitting photons.

• These photon emissions can stimulate the emission of another photon if they encounter ~~ad~~ an atom in an excited state.

• These stimulated photons are all identical, having the same wavelength (ie monochromatic), direction of travel and are in phase (ie coherent). If they exit the 98% reflective mirror they produce a beam

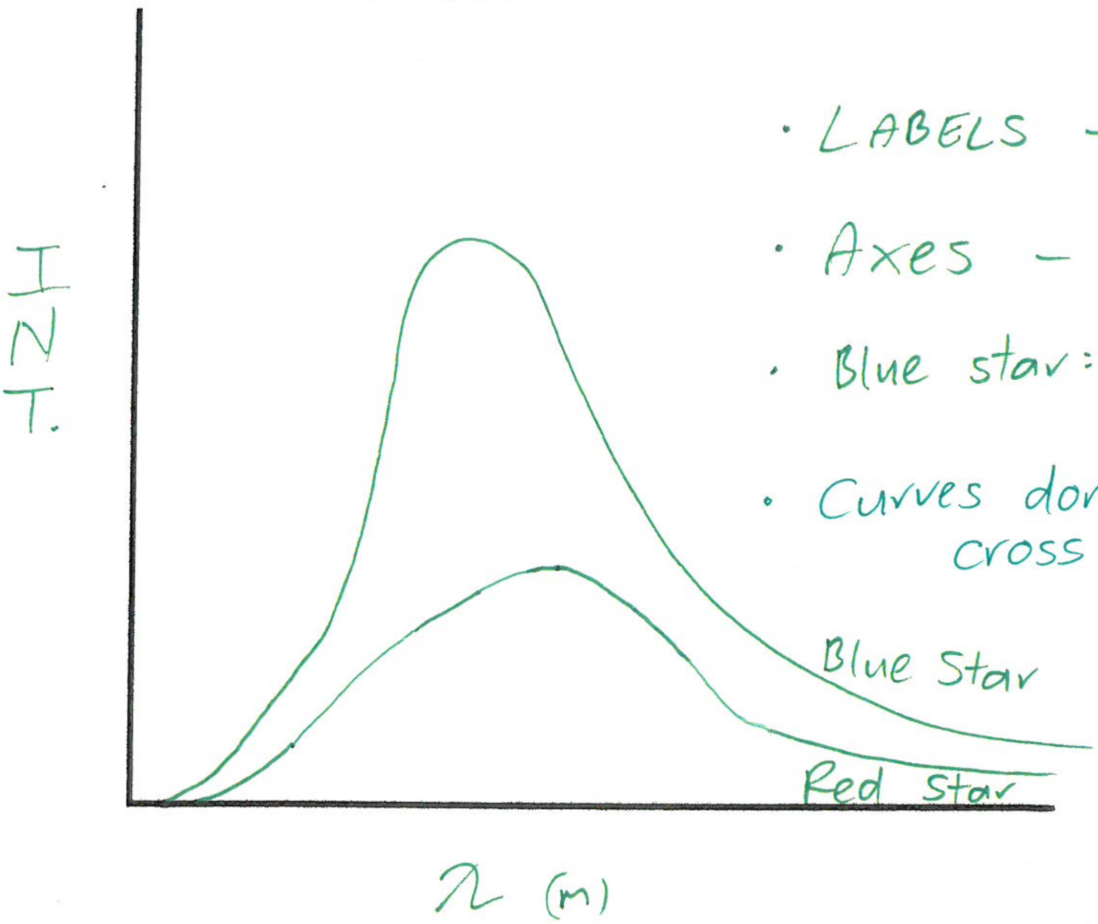
QUESTION FOUR **(17 marks)**

Murray has just started taking an interest in the night sky and has noticed that the stars are not all the same colour. Some appear red, others yellow and some white and even blue.

a) On the axes below sketch labelled graphs showing how the blackbody spectrum of a red star compares to a blue star (4 marks)

- 1 for

- Blue peak : higher (1)
  to the left (1)
- LABELS – Red / Blue (1)
- Axes – int / λ
- Blue star : > area under graph.
- Curves don't cross



b) Use the curves you have sketched to explain why the concept of light quanta was necessary. (3 marks)

Classical theory predicted large amounts of intensity in the UV (short wavelength) parts of the spectrum, but this wasn't observed.
Quantum theory suggested that higher freqs (ie shorter λ) were associated with more energy and came from molecules in the blackbody vibrating faster.
The spectra always tail off abruptly in the UV as the modes of vibration require too much energy.

c) A tungsten bar heated to 700⁰C glows red. If it is heated to 2700⁰C it will glow white. Describe the appearance of the spectra (through a spectroscope) produced by tungsten at these two temperatures. (3 marks)

- Both are continuous spectra (1)
- The 700°C spectra will have a very ~~large~~ intense section in the red range and only small int. in the other colours. (1)
- The 2700°C spectra will be brighter overall, and ~~have~~ appear more intense across all colours. (1)

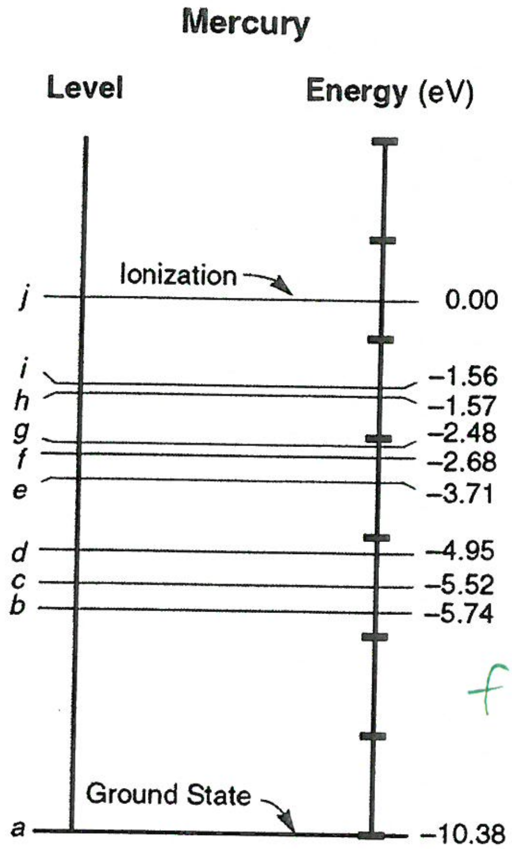
d) Explain how these spectra are produced. (3 marks)

- Blackbodies are dense bodies whose electron shells overlap neighbouring atoms. to a large extent. (1)
- Heating excites electrons and they move away from the nucleus. (1)
- As they return towards the nucleus, the overlappin of shells means that every possible λ is ~~possible~~ emitted

e) When viewed from the earth the Sun's spectrum looks significantly different from a piece of metal heated and glowing the same colour. Describe the difference and explain why the difference occurs. (4 marks)

- HOT METAL – Continuous spectrum. (1)
- The SUN – Continuous spectrum with lots of black lines. (1)
- They are essentially both blackbodies, but the sun's light travels through a heliospher of gases. (1)
- The electron's around the nuclei of these gases absorb photons of light, deleting them from the spectra observed. (1)

QUESTION FIVE **(8 marks)**



A Few Energy Levels for the Mercury Atom

a) Indicate which one of the following transitions is the most energetic by circling it. (1 mark)

i) e to b — 2.03.

ii) g to d — 2.47

iii) i to e — 2.15

b) Determine the frequency and wavelength of the photon that would result from your answer to (a) (3 marks)

$2.47 eV = 3.952 \times 10^{-19} J$

$f = \frac{E}{h} = \frac{(3.952 \times 10^{-19})}{6.63 \times 10^{-34}}$ (1)

$= 5.96 \times 10^{14} Hz$ (1)

$\lambda = \frac{c}{f} = \frac{(3.0 \times 10^{8})}{(5.96 \times 10^{14})} = 503 nm$ (1)

c) An electron with KE 4.70eV strikes a mercury atom and transfers some energy to an electron causing it to transition from the Ground State to the b level in a mercury atom. It then leaves the mercury atom with the remaining kinetic energy. Determine the De Broglie wavelength of the electron as it leaves the mercury atom. (4 marks)

a − b requires $(10.38 - 5.74) = 4.64 eV$

There electron leaves with : $(4.7 - 4.64) = 0.06 eV$ (1)

$\lambda_{De Broglie} = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31}) \times (1.45 \times 10^{5})}$

$= 5.01 \times 10^{-9} m$ (1)

to determine v :

$\frac{1}{2}mv^2 = (0.06 \times 1.6 \times 10^{-19})$ (1)

$v = \sqrt{\frac{2 \times 0.06 \times 1.6 \times 10^{-19}}{(9.11 \times 10^{-31})}}$

$= 1.451... \times 10^{5} ms^{-1}$

1.45175×10^{5} (1)

END OF TEST