Year 12 Physics TEST # 4 – Waves and Quantum Theory 2022

NAME: SOLUTIONS

Total Marks: 35 *Time Allowed: 45 minutes*

(Formula sheet and scientific calculator permitted)

Question 1 **(5 marks)**

(a) An electron in an atom of fluorescent coral releases green light of wavelength 552 nm when it returns to ground state. Calculate the energy difference in eV involved in this transition. [4]

$$f = \frac{c}{\lambda}$$

$$= \frac{3 \times 10^{8}}{552 \times 10^{-9}}$$

$$\approx 5.43 \times 10^{14} \text{ Hz}$$

$$\therefore E = hf$$

$$= 6.63 \times 10^{-34} \times 5.43 \times 10^{14}$$

$$\approx 3.60 \times 10^{-19} \text{ J}$$

$$= \frac{3.60 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\approx \underline{2.25 \text{ eV}}$$

4

(b) Briefly explain how phosphorescence is different from fluorescence. [1]

With phosphorescence, there is a delay between the excitement of the electron and the release of a photon as the electron returns to ground state.

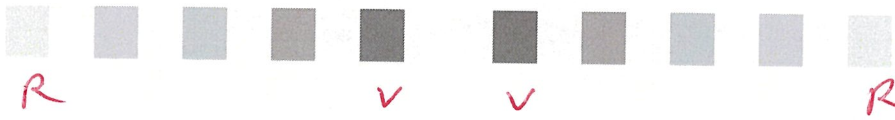
1

[The electron first moves to a metastable state where it remains for some time.]

5

Question 2 **(4 marks)**

The diagram below shows two first-order spectra on a screen, which have been produced by passing white light through a single slit.



(a) Place the letters R (red) and V (violet) on each spectrum to indicate the orientation of the spectra. [2]

2

(b) Does the above phenomenon support the wave or particle model of light? Why? [2]

Wave model: The spectra are caused by diffraction, which is a wave property.

2

Question 3 **(4 marks)**

Explain how studying the light from a distant star enables physicists to determine the star's chemical composition.

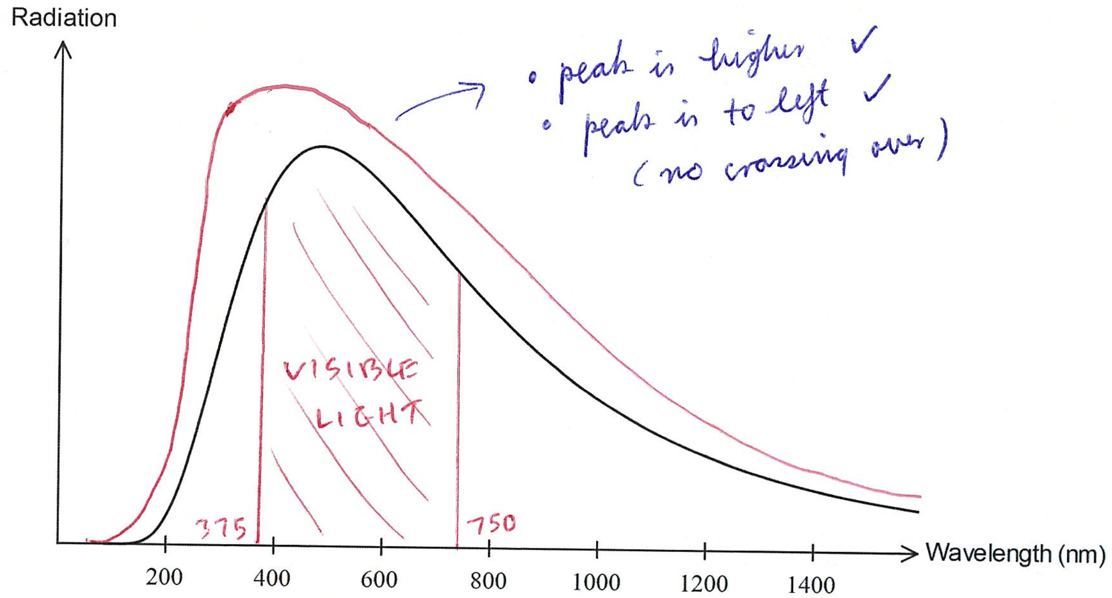
- The light is emitted from various atoms, each of which produces a characteristic spectrum
- This is because the emitted frequencies correspond to specific energy levels in the atoms, which are different for each element
- as a result of collisions, excited electrons rise to a higher energy level, then give off the corresponding frequency of light when they drop back to their normal level
- Hence scientists can determine the element responsible by comparing the spectrum to those seen on Earth.

4

8

Question 4 **(6 marks)**

The following graph represents the black body radiation for an object at 4500 K.



Visible light has a frequency range of approximately 4×10^{14} Hz to 8×10^{14} Hz.

(a) Mark a band on the graph above showing the visible light emitted by an object at 4500 K. [2]

4×10^{14} Hz $\rightarrow$ $\lambda = \dfrac{3 \times 10^8}{4 \times 10^{14}} = 7.5 \times 10^{-7}$ m $= 750$ nm ✓

8×10^{14} Hz $\rightarrow$ $\lambda = \dfrac{3 \times 10^8}{8 \times 10^{14}} = 3.75 \times 10^{-7}$ m $= 375$ nm ✓

2

(b) Add a curve to the diagram above showing the black body radiation for an object at 5000 K. [2]

2

(c) For which part of the graph, very low wavelengths or very high wavelengths, does the graph above support both particle and wave natures for light? Why? [2]

Very high. ✓

At this range, the wave-model graph approx. coincides with the graph above. ✓

2

6

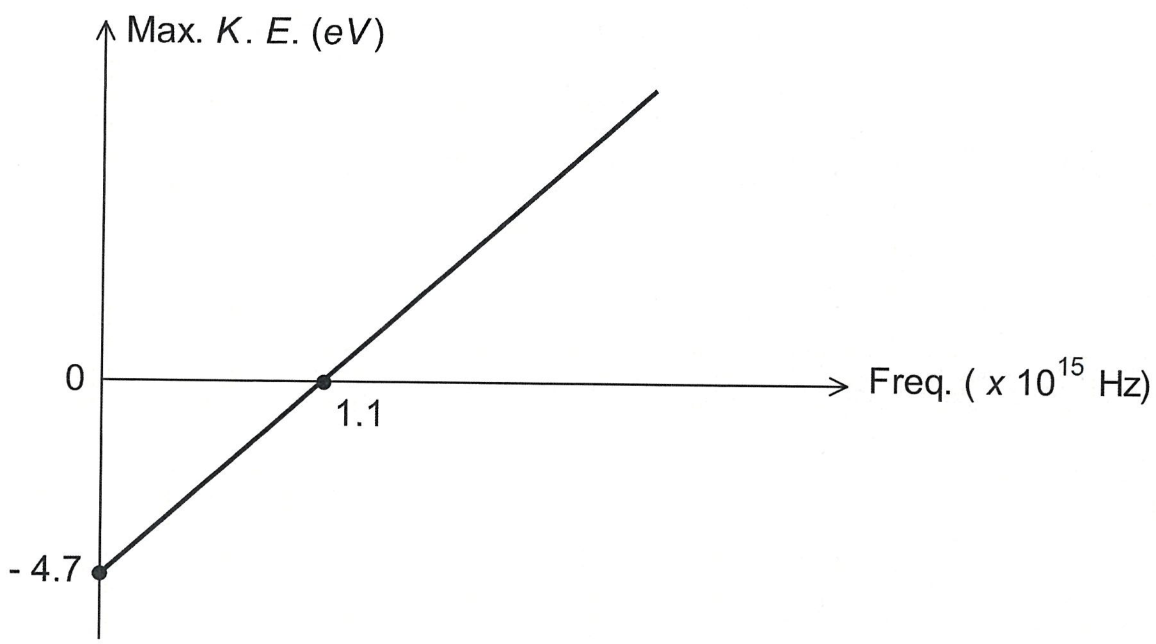
Question 5 **(6 marks)**

(a) State and explain one observation that can be made in a photoelectric effect experiment that demonstrates that light is quantized. [2]

(e.g.) There is no photoelectric effect unless the frequency of the incoming light exceeds a certain threshold ✓, indicating that the light energy comes in packets ($E = hf$) and sufficient energy (work function) is needed to release each electron from its atom. ✓

2

(b) Students recorded the results of a photoelectric effect experiment that used a copper plate. They produced the following line of best fit for their data:



2

(i) Use the graph to find the threshold frequency for copper (to 2 significant figures). [1]

1.1×10^{15} Hz ✓ 1

(ii) Use the graph to find the work function (in eV) for copper (to 2 significant figures). [1]

4.7 eV ✓ 1

(iii) Hence estimate the value of Planck's constant. [2]

$W = hf_0$

$4.7 \times 1.6 \times 10^{-19} = h \times 1.1 \times 10^{15}$ ✓

$\therefore h \approx \underline{6.8 \times 10^{-34}}$ Js ✓

2

4

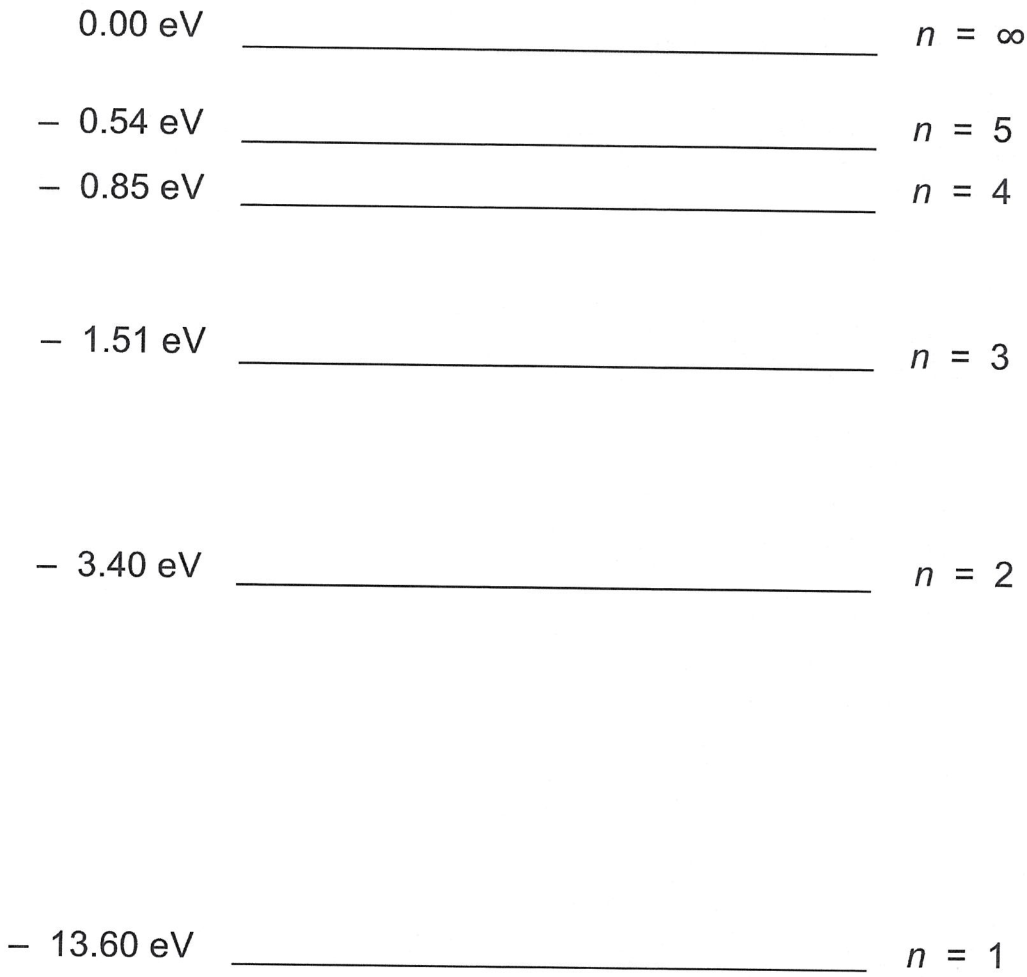
Question 6 **(10 marks)**

Electrons are accelerated from rest by a voltage of 10.5 V.

(a) What is the energy of each electron in eV? [1]

10·5 eV ✓ 1

(b) Use the hydrogen energy level diagram below to determine the frequency of light emitted from ground state hydrogen atoms after they are bombarded by the accelerated electrons. [4]



$-3.40 - (-13.60) = 10.2\text{ eV}$ ✓ 4

$\therefore$ Only level 2 possible.

$E = 10.2\text{ eV} = 10.2 \times 1.6 \times 10^{-19}\text{ J}$ ✓

$\therefore f = \frac{E}{h} = \frac{10.2 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$ ✓

$\approx \underline{2.46 \times 10^{15}\text{ Hz}}$ ✓

5

(c) Find the de Broglie wavelength of the accelerated electrons. [5]

$E = 10.5 \times 1.6 \times 10^{-19}$ J

$\frac{1}{2}mv^2 = 1.68 \times 10^{-18}$ ✓

$v^2 = \frac{1.68 \times 10^{-18}}{0.5 \times 9.11 \times 10^{-31}}$ ✓

$\therefore v \approx 1.92 \times 10^{6}$ ms^{-2} ✓

$\therefore p = mv$

$= 9.11 \times 10^{-31} \times 1.92 \times 10^{6}$

$\approx 1.75 \times 10^{-24}$ $kg\ ms^{-1}$ ✓

$\therefore \lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{1.75 \times 10^{-24}}$

$\approx \underline{3.79 \times 10^{-10}\ m}$ ✓

5

- End of Questions -

5