Neap:

PHYSICS VCE UNITS 3&4
DIAGNOSTIC TOPIC TESTS 2017

TEST 9: HOW ARE LIGHT AND MATTER SIMILAR? (I)

SUGGESTED SOLUTIONS AND MARKING SCHEME

Question 1 (3 marks)

The wavelengths of visible light are greater than the de Broglie wavelengths of electrons. 1 mark

Thus the $\frac{\text{wavelength}}{\text{distance}}$ ratio (where distance = the length of features on the radiolarian) is much less than 0.1 for electrons than it is for visible light given the blurring in image A and the sharpness in image B. 1 mark

Thus any bright, dark bands that would be produced for election irradiation of the radiolarian are not visible, resulting in a sharper image than for irradiation of the radiolarian by visible light. 1 mark

That is, diffraction effects are not visible when electron irradiation is undertaken.

Question 2 (17 marks)

a. The minimum amount of energy is the work function.

$W = hf_c$

$= 6.63 \times 10^{-34} \times 4.4 \times 10^{+14}$ 1 mark

$= 2.9 \times 10^{-19}$ J 1 mark

OR

$W = |y\text{-intercept}|$

$= 1.8 \times 1.6 \times 10^{-19}$ 1 mark

$= 2.9 \times 10^{-19}$ J 1 mark

b. $E_{\text{Kmax}} = qVs = hf - W$

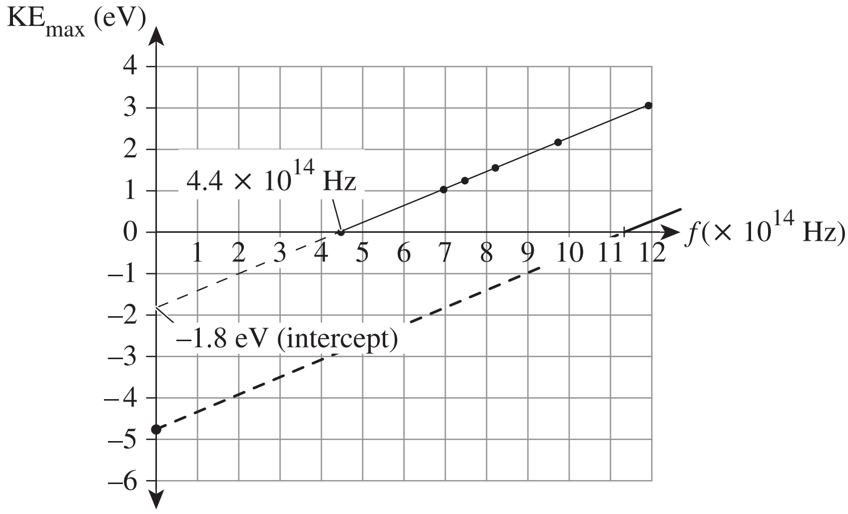
$\therefore hf = qVs + W$

$= 1.0 + 1.8$ 1 mark

$= 2.8$ eV 1 mark

*Note: Consequential on answer to **Question 6a.***

c.



The graph must be solid in the positive energy range and dotted or not drawn in the negative energy range. 1 mark

y-intercept = –4.7 1 mark

$$x\text{-intercept} = \frac{4.7}{4.14 \times 10^{-15}}$$

$$= 1.13 \times 10^{15} \text{ Hz}$$

$$= 11.3 \times 10^{14} \text{ Hz}$$ 1 mark

Note: 1 mark can also be awarded for the same gradient.

d. Since 2×10^{14} < (the critical frequency) 4.4×10^{14}, 1 mark
a photon of light does not have enough energy, if it were to be absorbed by an electron, to overcome the work function (minimum energy needed). 1 mark

Thus no electrons are emitted. 1 mark

e. In the particle model, the number of photons per second is represented by the light intensity.

Increasing the light intensity provides more photons for absorption (one per electron). 1 mark

Hence the photocurrent (number of electrons emitted per second) increases proportionately. 1 mark

Since the light frequency does not change, each photon still has the same energy and so electrons will be emitted with the same kinetic energy, requiring the same stopping voltage, as shown on the graph as the horizontal axis intercept. 1 mark

f. The wave model predicts that light of all colours should stimulate electrons to be emitted 1 mark
and that the energy of the electrons is independent of the colour. 1 mark

The energy of the emitted electrons depends on the frequency of light used, evident from the unique stopping voltage for each colour of light. 1 mark

Colours whose frequency are not great enough (red in this case) will not stimulate electron emission. 1 mark

Question 3 (7 marks)

a. $E_K = qV$

$= 1.6 \times 10^{-19} \times 1000$

$= 1.6 \times 10^{-16}$ J — 1 mark

$= \frac{1.6 \times 10^{-16}}{1.6 \times 10^{-16}}$

$= 1.0$ eV — 1 mark

b. $\frac{p^2}{2m} = E_K$

$p = \sqrt{2mE_K}$

$p = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-16}}$ — 1 mark

$= \sqrt{2.92 \times 10^{-46}}$ — 1 mark

$= 1.7 \times 10^{-23}$ Ns — 1 mark

Note: Consequential on answer to ***Question 7a.***

c. $\lambda = \frac{h}{p}$

$= \frac{6.63 \times 10^{-34}}{1.7 \times 10^{-23}}$ — 1 mark

$= 3.88 \times 10^{-11}$ m — 1 mark

Note: Consequential on answer to ***Question 7b.***

Question 4 (7 marks)

a. $\lambda = \frac{h}{\sqrt{2mqV}}$ since $p = \sqrt{2mqV}$ — 1 mark

$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 30}}$ — 1 mark

$= 2.24 \times 10^{-10}$ m — 1 mark

b. Since the ratio $\frac{\text{de Broglie wavelength}}{\text{gap width}} = \frac{2.24 \times 10^{-10}}{0.135 \times 10^{-9}}$

$= 1.66$ — 2 marks

1 mark for gap width in m.
1 mark for correct answer.

the ratio is greater than 1, indicating that the electron will diffract through the spacing. — 1 mark

Thus the electron will behave as a wave. — 1 mark

Question 5 (6 marks)

a. $p = \frac{h}{\lambda}$

$= \frac{6.63 \times 10^{-34}}{600 \times 10^{-9}}$ 1 mark

$= 1.11 \times 10^{-27}$ Ns 1 mark

b. Since the electron and the photon have the same equation for momentum based on wavelength. 1 mark

Thus $p = 1.11 \times 10^{-27}$ Ns**.** 1 mark

Note: Consequential on answer to ***Question 5a.***

c. $E_{\text{photon}} = h \times f$

$= \frac{h \times c}{\lambda}$

$= p \times c$

$= 3.0 \times 10^{-27} \times 3 \times 10^{8}$

$= 9.0 \times 10^{-19}$ J 1 mark

$= \frac{9.0 \times 10^{-19}}{1.6 \times 10^{-19}}$ eV

$= 5.6$ eV 1 mark

Question 6 (5 marks)

a. The electrons have wave-like properties. 1 mark
This is evident from the bright and dark bands present which can only be explained by interference of electrons. 1 mark

b. Given the identical positions of bright and dark bands, 1 mark
the wavelength of the X-rays and the de Broglie wavelength of the electrons are the same. 1 mark
Since momentum = $\frac{h}{\text{wavelength}}$, then the X-ray photons have the same momentum as the electrons. 1 mark