



VCE PHYSICS UNITS 3&4 [2020]

Unit 4 AOS 2 - How are light and matter similar? - Topic exam 2

YOUR NAME: Vishnu Prasad Sivakumar

STRUCTURE OF EXAM

Section A - Short Answer

12 questions

37 marks

37 marks

WHEN YOU FINISH

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SECTION A – SHORT ANSWER

Question 1

1 mark

Imaging using optical microscopes is limited by the wavelength of visible light. If light of frequency 55×10^{12} Hz is used, estimate the size of the smallest object that could be successfully imaged by this light.

Provide calculations to justify your answer.

Question 2

1 mark

Explain how electron microscopes can produce more detailed images than optical microscopes.

Question 3

3 marks

Einstein's explanation of the photoelectric effect reopened the question about the nature of light.

Explain briefly how the results of the photoelectric effect experiment supported a competing model to the one supported by Young's experiment.

Question 4

3 marks

The photoelectric effect experiment supports the particle model of light rather than the wave model of light. The following are observed in a photoelectric effect experiment.

Observation 1: The number of emitted electrons (the photocurrent) depends on the intensity of the incident light.

Observation 2: The energy of emitted electrons depends only on the frequency of the incident light and is independent of the intensity.

Observation 3: The energy of the emitted electrons depends on the metal surface involved.

The particle model can account for all the above three observations.

The wave model can explain two of these observations but not a third.

The particle model can account for all three observations.

The wave model can explain two of these observations but not a third.

Select the observation that the wave model cannot explain.

Explain how the particle model satisfactorily explains this observation.

Question 5

2 marks

Students set up the apparatus shown in Figure 2 to study the photoelectric effect.

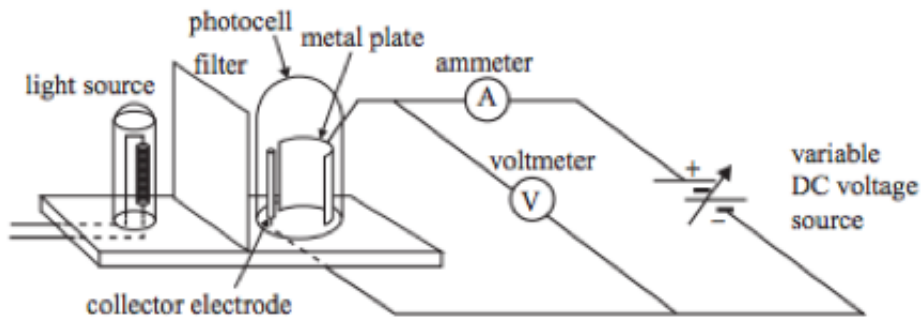


Figure 2

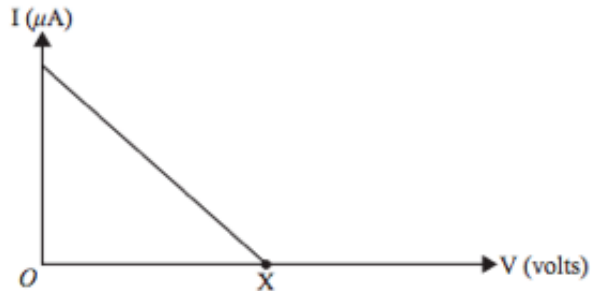


Figure 3

The apparatus consists of

- a source of white light
- a set of filters that only allow light of selected wavelengths to pass through
- a metal plate and a collector electrode enclosed in an evacuated (no air) glass case
- a voltmeter (V), ammeter (A) and variable DC voltage source in a circuit, as shown in Figure 2.

With a particular filter in place, the students gradually increase the voltage as measured by the voltmeter, V, from zero.

They plot the current measured through the ammeter, A, as a function of the voltage measured by the voltmeter, V. This is shown in Figure 3.

Explain why the current drops to zero at point X.

Question 6 (4 marks)

A photon of visible light has a wavelength of 580 nm.

Question 6.a

2 marks

Calculate the energy (in joules) of this photon.

Question 6.b

2 marks

Calculate the frequency of this photon.

Question 7 (3 marks)

Students are investigating the photoelectric effect by shining monochromatic light with a frequency of 1.00×10^{15} Hz onto a sodium plate. Their apparatus is shown in Figure 26.

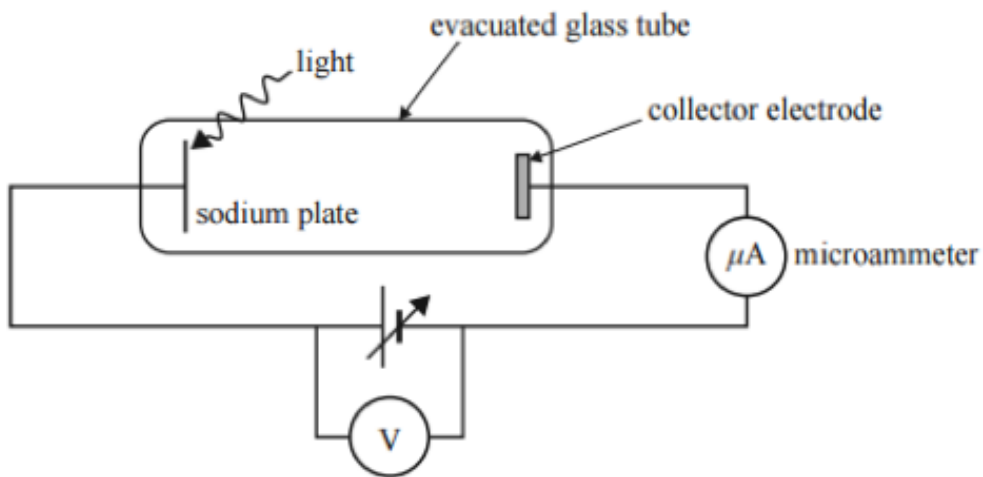


Figure 26

Figure 27 shows a graph of the relationship between the photocurrent and the reading on the voltmeter.

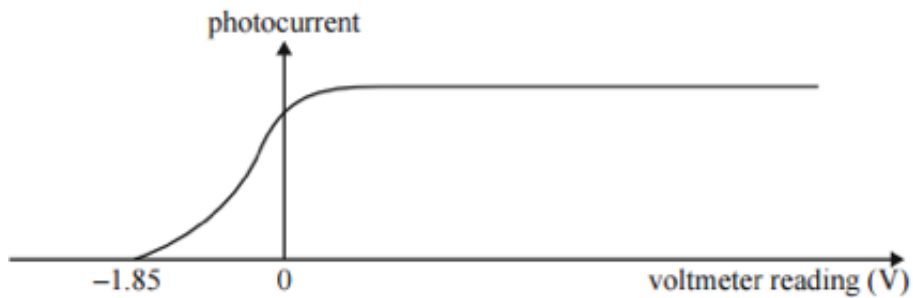


Figure 27

Question 7.a

1 mark

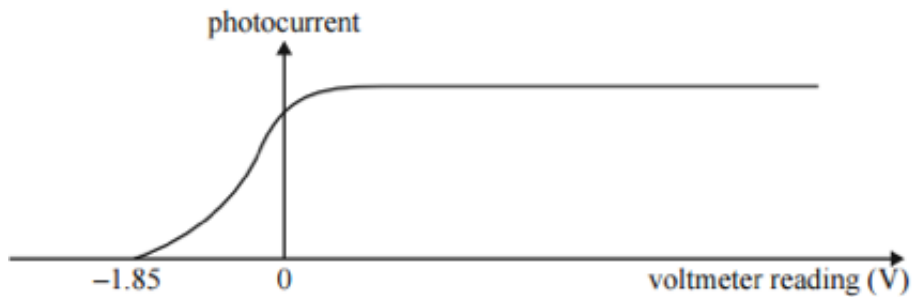
Use the information in the graph to calculate the maximum kinetic energy (in joules) of the photoelectrons.

Question 7.b

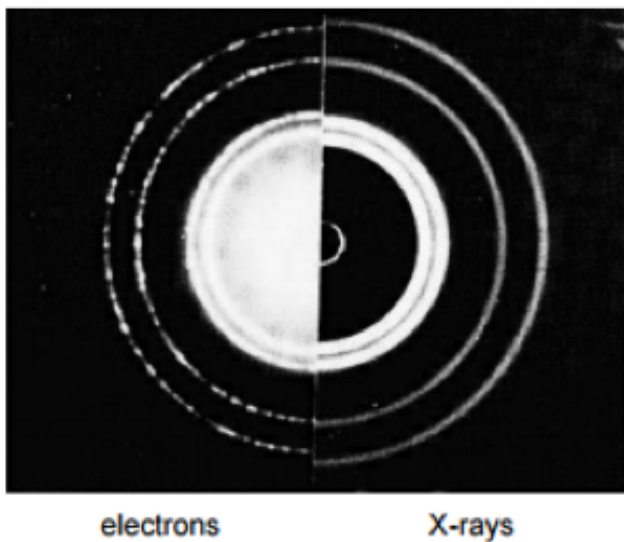
2 marks

The intensity of the light is now reduced and the experiment is repeated. The students obtain a new graph of photocurrent against voltage.

Sketch the new graph on Figure 27.

**Figure 27****Question 8 (7 marks)**

The image below shows a combination of 2 images of diffraction patterns, one for electrons and one for x-rays when directed at an aluminum foil. The pictures are produced to the same scale. The x-rays were produced with a photon energy of 55 keV.

**Question 8.a**

2 marks

Calculate the wavelength of the x-rays.

Question 8.b

4 marks

Calculate the velocity of the electrons.

Question 8.c (1 mark)

If the velocity of the electrons was reduced what would happen to the electron diffraction pattern observed?

- A** No change
- B** Pattern becomes more spread out
- C** Pattern becomes less spread out
- D** More rings would be visible

Question 9

3 marks

Figure 4 shows the energy level diagram for the hydrogen atom

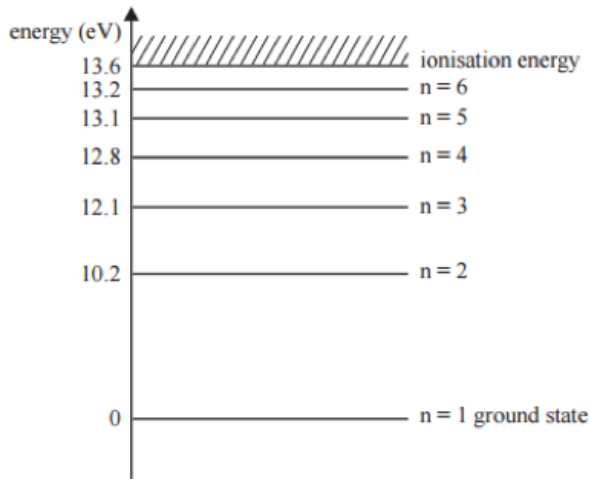


Figure 4

An atom of hydrogen is in the $n = 4$ state.

List below all the possible energies, in eV, of photons that could be emitted as this atom decays to the ground state.

Question 10 (5 marks)

According to one model of atoms, electrons in atoms move in stable circular orbits around the nucleus. In an atom modelled in this way, an electron is moving at $2.0 \times 10^6 \text{ m s}^{-1}$.

Question 10.a

2 marks

Take the mass of an electron as $9.1 \times 10^{-31} \text{ kg}$.

Calculate the de Broglie wavelength of this electron. Give your answer in nm.

Question 10.b

3 marks

Describe how the wave nature of electrons can be used to explain the quantised energy levels in atoms.

Question 11

3 marks

When electrons are fired through a single slit they produce a diffraction pattern. As the size of the slit is reduced the spread of this pattern increases.

Explain how an understanding of Heisenberg's uncertainty principle can be applied to explain this observed phenomenon.

Question 12

2 marks

An X-ray photon has a momentum of $4.6 \times 10^{-23} \text{ kg m s}^{-1}$.

Calculate the energy of this photon in keV.
