A-Level Physics

The Discovery of Photoelectricity

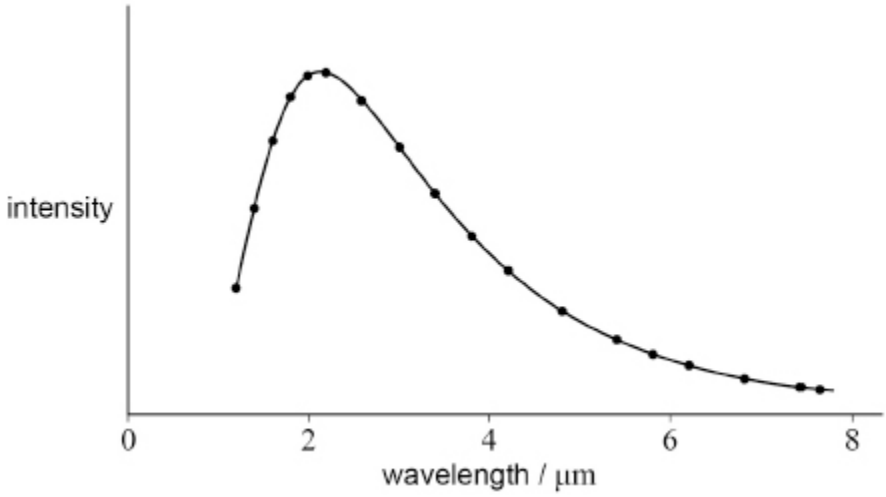
Question Paper

Time available: 62 minutes
Marks available: 52 marks

1. At the end of the 19th century new information was obtained about black-body radiation and the photoelectric effect. This information challenged classical physics theories.

In 1895, Wien and Lummer carried out experiments to measure black-body radiation accurately.

The figure shows a typical black-body radiation curve of the type obtained by Wien and Lummer.



(a) State what is meant by black-body radiation.

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(2)

(b) Describe how the predictions of classical theory compare with Wien and Lummer's experimental results.

Annotate the figure above as part of your answer.

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(2)

(c) In 1900 Max Planck suggested a solution to the problems of the classical theory.

Outline the main aspects of his suggestion.

(2)

(d) Planck's suggestion was developed by Albert Einstein to explain the results of photoelectric effect experiments.

Discuss Einstein's explanation of photoelectricity and its significance in terms of the nature of electromagnetic radiation.

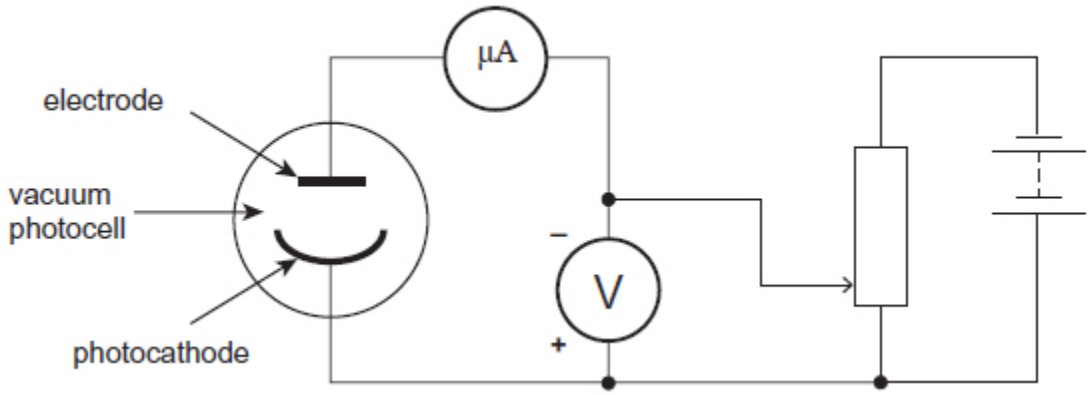
In your answer you should

- describe **two** relevant observations made in photoelectric experiments
- explain the failure of classical physics to account for these observations
- include the main aspects of Einstein's theory and how he explained the observations.

(6)

(Total 12 marks)

2. (a) The arrangement shown in the diagram is used by a student in a photoelectric effect experiment.



Monochromatic light falls on the photocathode. A current is recorded when the potential difference (pd) between the photocathode and the electrode is zero.
The student gradually increases the magnitude of the pd between the photocathode and electrode and makes observations of the effect this has on the current.

Describe and explain the observations that you would expect the student to make. In your answer you should refer to:

- the stopping potential
- the kinetic energy of the photoelectrons
- how Einstein's photoelectric equation applies to this experiment.

The quality of your written communication will be assessed in your answer.

(6)

(b) Using the circuit in the diagram, the stopping potential recorded is 0.24 V when light of wavelength 490 nm is incident on the surface of the photocathode.

(i) Calculate the work function of the surface material.

work function = _____ J

(3)

(ii) The polarity of the battery in the diagram is now reversed and light of 490 nm is incident on the photocathode. The energy of the light falling on the surface of the photocathode each second is 6.1 μJ.

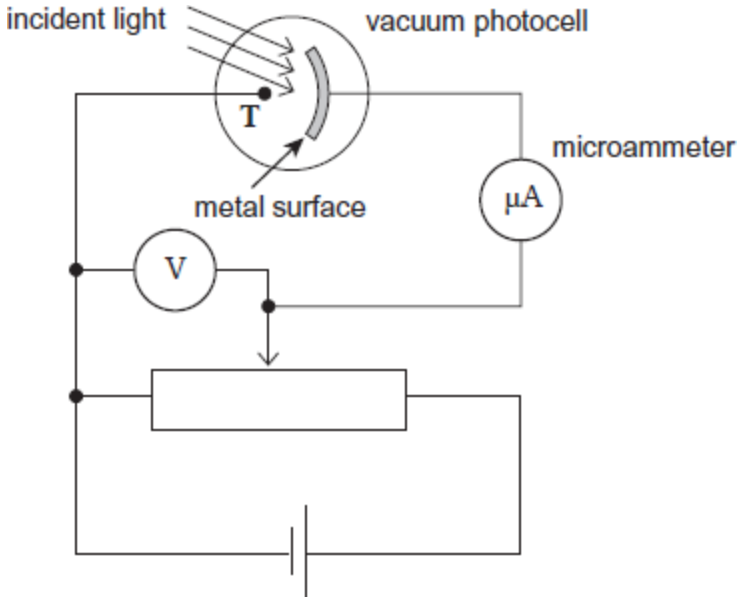
Calculate the maximum current that the microammeter could record.

maximum current = _____ μA

(2)

(Total 11 marks)

3. The figure below shows a metal surface in a vacuum photocell illuminated by light of a certain frequency. Electrons emitted from the metal surface are collected by terminal **T** in the photocell.

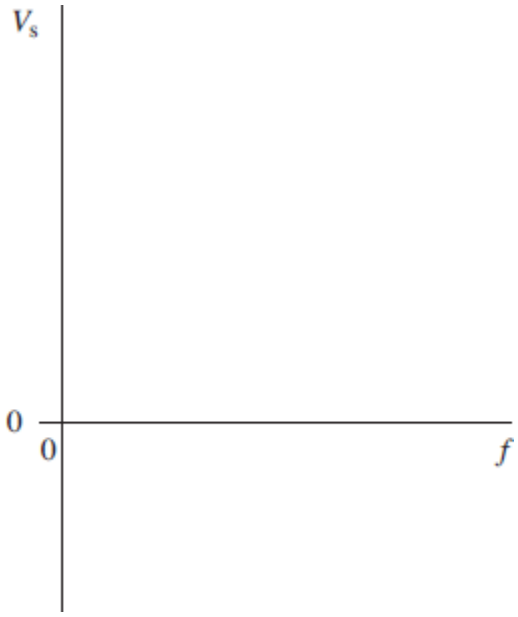


(a) The potential of the metal surface may be changed by adjusting the potential divider. Explain why the microammeter reading decreases when the metal surface is made more positive relative to **T**.

(3)

(b) The stopping potential V_s is the minimum potential that is applied to the metal surface to reduce the photoelectric current to zero when monochromatic light is incident on the surface. The circuit is used with light of different frequencies to measure the stopping potential V_s when the surface is illuminated at each frequency.

(i) Draw a graph on the axes below to show how V_s varies with the frequency f of the incident light.



(2)

(ii) Use the photoelectric equation $hf = \phi + E_k$ to explain your graph.

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(3)

(c) Using the circuit in the diagram above, the stopping potential was 1.92 V for light of wavelength 418 nm.

Use this information to calculate the work function of the metal surface.
Give an appropriate unit in your answer.

work function _____ unit _____

(4)

(Total 12 marks)

4. When light of wavelength 590 nm is directed at an uncharged surface of a certain metal X, electrons are emitted from the metal surface causing a photoelectric current.

(a) When the metal surface is charged positively, the photoelectric current decreases and becomes zero when the potential of the surface is +0.35 V.

(i) Calculate the maximum kinetic energy of a photoelectron emitted from the surface when the metal surface is uncharged.

answer = _____ J

(2)

(ii) Calculate the work function of the metal surface, in J.

answer = _____ J

(3)

(b) When the experiment was repeated using a different metal, Y, illuminated by light of the same wavelength, there was no photoelectric emission when the metal surface was uncharged.

(i) Explain this observation.

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(2)

(ii) How did this observation contribute to the failure of the wave theory of light?

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(2)

(Total 9 marks)

5. (a) A certain metal has a work function of 1.2 eV.

(i) Explain what is meant by this statement.

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(ii) Calculate the threshold wavelength of light for this metal surface.

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(3)

(b) When blue light is incident on a certain metal surface, electrons are emitted from the surface. No electrons are emitted when red light, instead of blue light, is incident on the same surface at the same potential.

(i) Use Einstein's theory of light to explain these observations.

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(ii) Outline the significance of Einstein's explanation.

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(5)

(Total 8 marks)