



A-Level Physics

Photoelectric Effect

Question Paper

Time available: 63 minutes

Marks available: 49 marks

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1.

An isolated metal plate is given a negative charge. Electromagnetic radiation is incident on the plate. The plate loses its charge due to the photoelectric effect.

- (a) Discuss how the rate of loss of charge from the plate depends on the frequency and intensity of the incident radiation.

In your answer you should explain why:

- the plate loses its charge
- the photoelectric effect occurs only for frequencies greater than a particular value
- the rate of loss of charge increases with intensity for radiation above that particular value of frequency.

(6)

- (b) Charged particles are emitted from the metal plate with a maximum kinetic energy of 1.1 eV when radiation of frequency 1.2×10^{15} Hz is incident on the plate.

Calculate, in eV, the work function of the metal.

work function = _____ eV

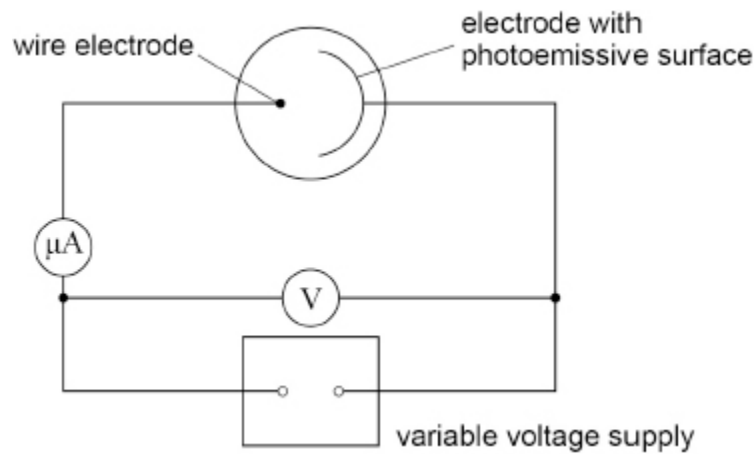
(3)

(Total 9 marks)

2.

Figure 1 shows an arrangement used to investigate the photoelectric effect.

Figure 1



A current is measured on the microammeter only when electromagnetic radiation with a frequency greater than a certain value is incident on the photoemissive surface.

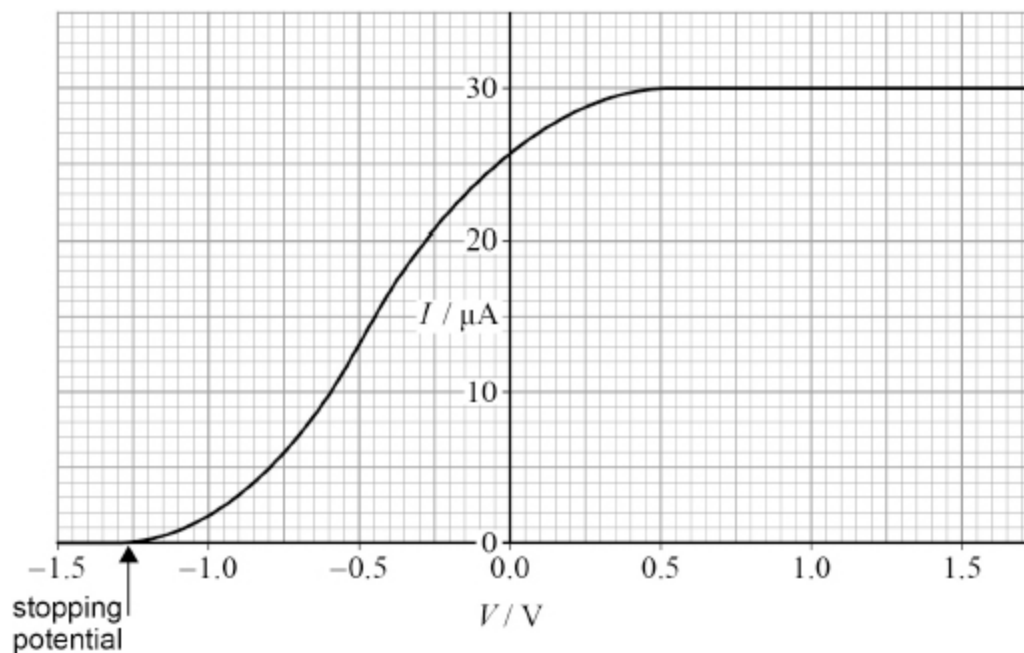
- (a) Explain why the frequency of the electromagnetic radiation must be greater than a certain value.

(2)

The apparatus in **Figure 1** is used with a monochromatic light source of constant intensity. Measurements are made to investigate how the current I in the microammeter varies with positive and negative values of the potential difference V of the variable voltage supply.

The **Figure 2** shows how the results of the investigation can be used to find the stopping potential.

Figure 2



- (b) Determine the number of photoelectrons per second leaving the photoemissive surface when the current is a maximum.

number of photoelectrons per second = _____

(2)

- (c) Explain why I reaches a constant value for positive values of V .

(2)

- (d) Explain why I decreases as the value of V becomes more negative.

(3)

- (e) The investigation is repeated with a different photoemissive surface that has a smaller value of the work function. The source of electromagnetic radiation is unchanged.

Discuss the effect that this change in surface has on the value of the stopping potential.

(3)

(Total 12 marks)

3.

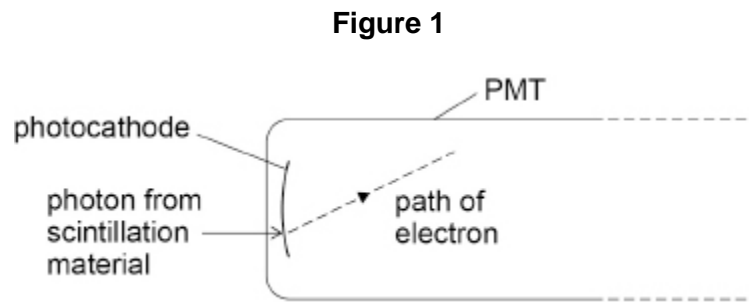
Scintillation counters are used to detect beta particles. A scintillation counter consists of a scintillation material and a photomultiplier tube (PMT).

- (a) Beta particles collide with atoms in the scintillation material, which emits photons of light as a result.

Explain how photons are produced by collisions between beta particles and atoms.

(2)

- (b) A photon of light from the scintillation material enters the PMT, as shown in **Figure 1**. The front of the PMT contains a thin photocathode. The photon strikes the photocathode to release an electron.



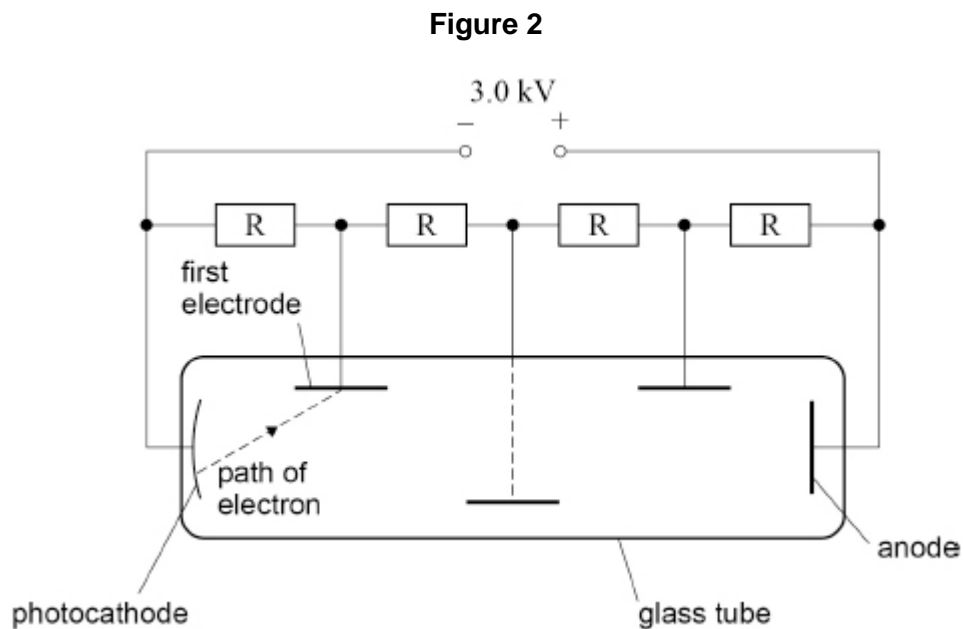
The longest wavelength of light that releases an electron from this photocathode is 630 nm.

Calculate the minimum photon energy required to remove an electron from the photocathode.

minimum photon energy = _____ J

(2)

- (c) The PMT consists of an evacuated glass tube containing the photocathode, an anode and three metal electrodes, as shown in **Figure 2**.



The electrodes, anode and photocathode are connected to a potential divider consisting of four identical resistors R . The emf of the electrical supply is 3.0 kV.

The potential difference between the photocathode and the first electrode accelerates the electron along the path shown in **Figure 2**.

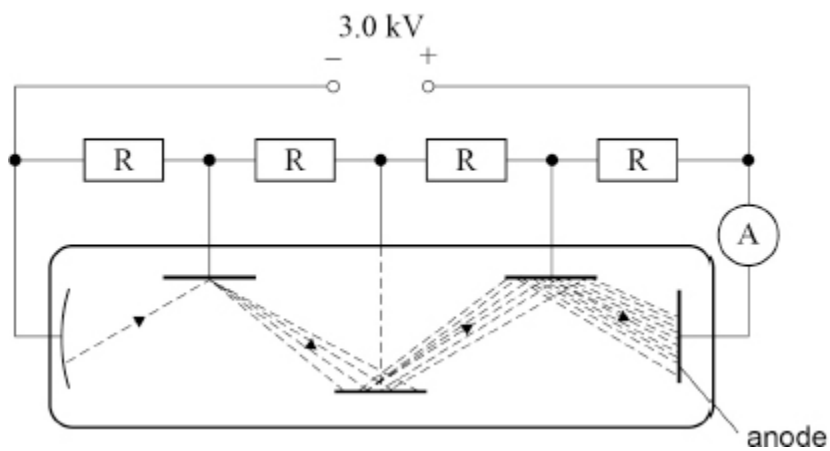
Calculate, in J, the maximum kinetic energy transferred to the electron when it accelerates from the photocathode to the first electrode.

maximum kinetic energy = _____ J

(2)

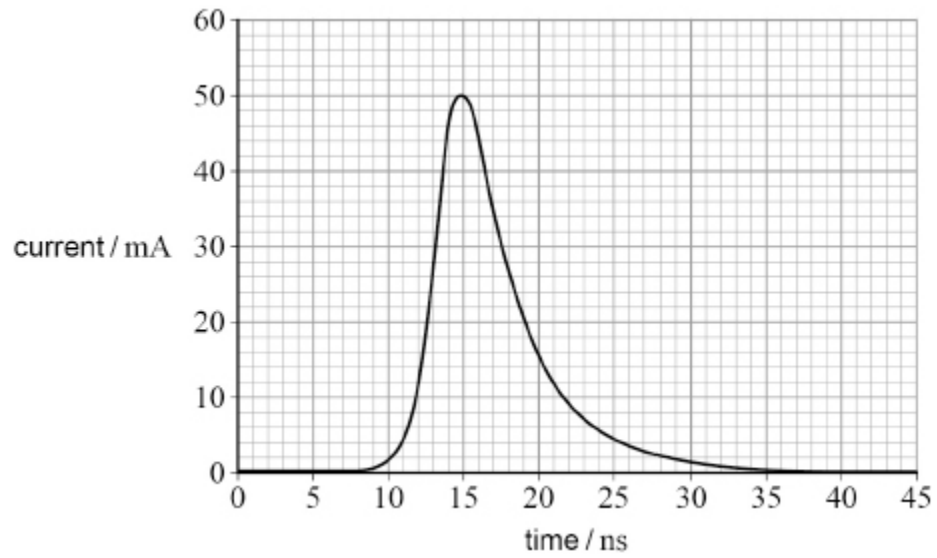
- (d) The electron hits the first electrode and causes the release of several electrons. **Figure 3** shows how a series of accelerations and collisions produces a large number of electrons. These electrons hit the anode and produce a pulse of current in an ammeter.

Figure 3



The **Figure 4** shows the variation of current in the ammeter with time due to this pulse.

Figure 4



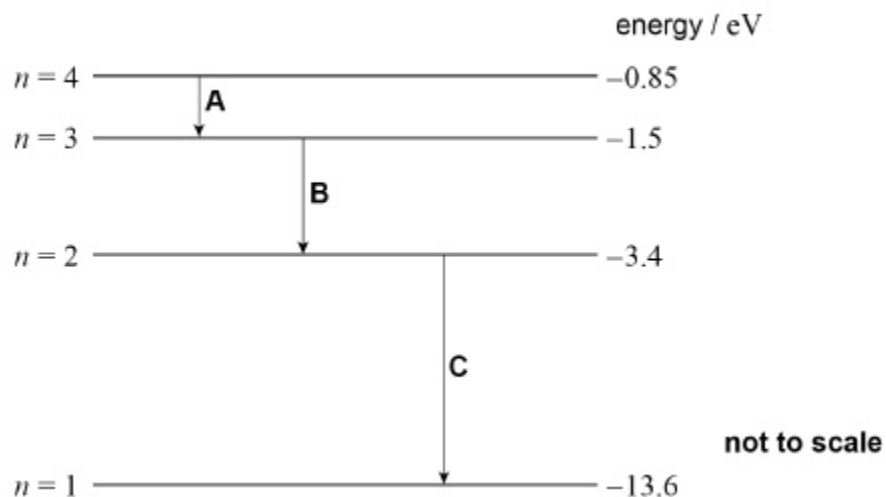
Determine the number of electrons that flow through the ammeter.

number of electrons = _____

(4)

(Total 10 marks)

4. The diagram shows some of the energy levels for a hydrogen atom.



An excited hydrogen atom can emit photons of certain discrete frequencies. Three possible transitions are shown in the diagram.

- (a) The transitions shown in the diagram result in photons being emitted in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.

To which region of the spectrum do the emitted photons belong?

Tick (✓) the correct box for each transition, **A**, **B** and **C**.

Transition	Ultraviolet	Visible	Infrared
A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
C	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(1)

- (b) Two ways to excite a hydrogen atom are by collision with a free electron or by the absorption of a photon.

Explain why, for a particular transition, the photon must have an exact amount of energy whereas the free electron only needs a minimum amount of kinetic energy.

(3)

- (c) The surface of a sample of caesium is exposed to photons emitted in each of the three transitions shown in the diagram.

The threshold frequency of caesium is 5.1×10^{14} Hz

Determine whether any of these transitions would produce photons that would cause electrons to be emitted from the surface of caesium.

(3)

- (d) Photons each with energy 12.1 eV are incident on the surface of the caesium sample.
Calculate the maximum speed of electrons emitted from the caesium.

maximum speed = _____ m s⁻¹

(3)

(Total 10 marks)

5.

- (a) Describe what occurs in the photoelectric effect.

(2)

(b) Violet light of wavelength 380 nm is incident on a potassium surface.

Deduce whether light of this wavelength can cause the photoelectric effect when incident on the potassium surface.

work function of potassium = 2.3 eV

(4)

(c) The photoelectric effect provides evidence for light possessing particle properties.

State and explain **one** piece of evidence that suggests that light also possesses wave properties.

(2)

(Total 8 marks)