9 **(a)** Photoelectrons are emitted with insignificant time lag when electromagnetic radiation of a certain frequency is incident on a metal plate.

State and explain one other observation from the photoelectric effect that provides evidence for the particulate nature of electromagnetic radiation.

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..... [4]

(b) Two parallel zinc plates placed a distance *d* apart are used to investigate the photoelectric effect, as shown in Fig. 9.1. Zinc has a work function of 4.33 eV.

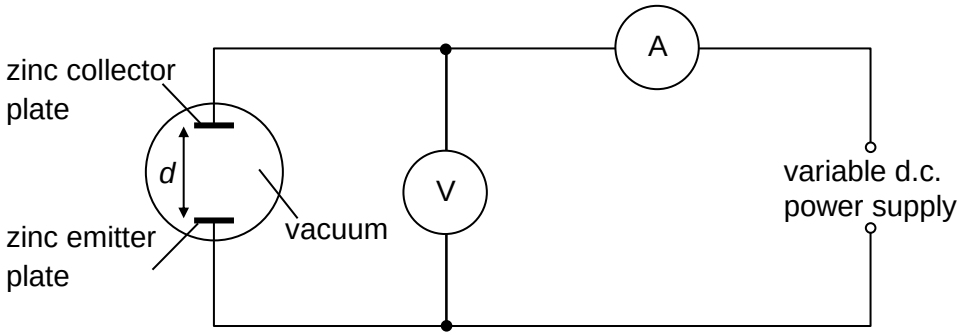

Fig. 9.1

Electromagnetic radiation of wavelength 210 nm is incident on the zinc emitter plate. The potential of the zinc collector plate is varied from −3.0 V to +3.0 V with respect to the zinc emitter plate.

The variation of the current I with the potential difference V is shown in Fig. 9.2.

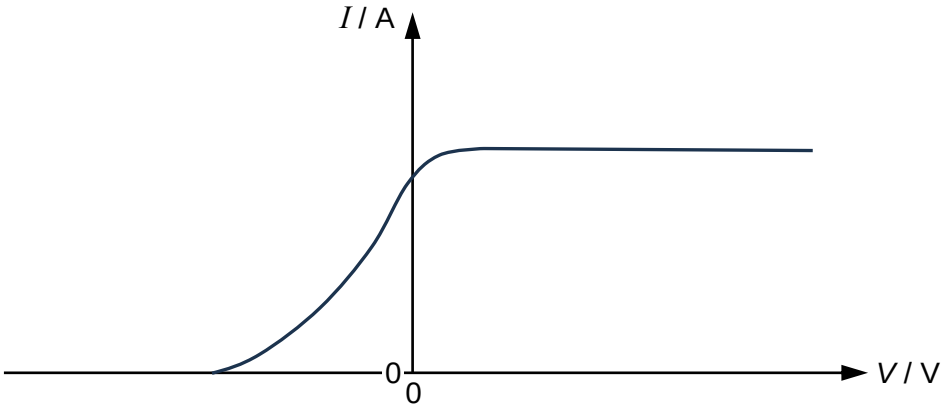

Fig. 9.2

(i) Calculate the threshold wavelength for the zinc plate.

wavelength = ... nm [2]

(ii) Calculate the maximum speed of the emitted photoelectrons.

speed = ... $m\ s^{-1}$ [2]

(iii) Photoelectrons in **(b)** are emitted perpendicularly to the zinc emitter plate.

Explain why the subsequent motion of the emitted photoelectrons is different when $V = 0$ V and $V = +3.0$ V .

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(iv) On Fig 9.2, draw the variation of I with V if the zinc emitter plate is now illuminated with radiation of a shorter wavelength but the same intensity as in **(b)**.

[2]

(c) Electrons are accelerated in a vacuum before passing through a graphite film, as shown in Fig. 9.3. The electrons are then incident on a fluorescent screen.

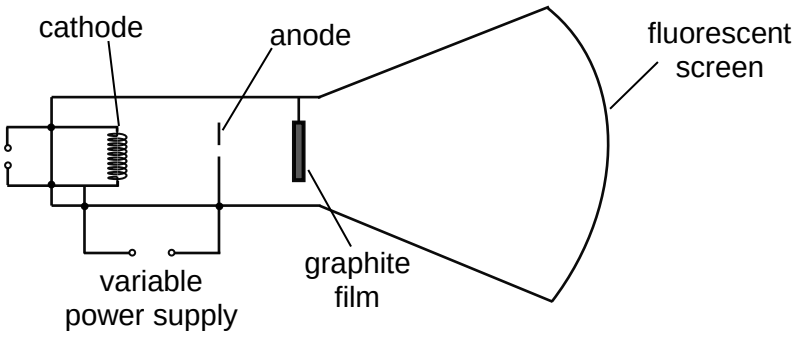

Fig 9.3

Concentric rings of light are observed on the screen.

(i) Explain how the observation of the concentric rings of light provides evidence for the wave nature of electrons.

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..... [2]

(ii) The electrons are accelerated from rest through a potential difference of 5.0 kV.

Calculate the de Broglie wavelength of the accelerated electrons.

wavelength = ... m [3]

(iii) Optical and electron microscopy techniques are widely utilised for imaging and analysing microscopic structures.

With reference to **(c)(ii)**, state and explain an advantage of an electron microscope compared to an optical microscope.

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[Total: 20]