Quantum Physics – 2021 A2

1. Nov/2021/Paper_41/No.10

(a) State an experimental phenomenon that provides evidence for:

(i) the particulate nature of electromagnetic radiation

.... [1]

(ii) the wave nature of matter.

.... [1]

(b) A particle of matter moves with momentum *p*.

(i) State the equation that gives the effective wavelength λ of the particle. State the name of any other symbols used.

[2]

(ii) State the name given to the wavelength of the moving particle.

.... [1]

(c) Electrons are accelerated from rest through a potential difference (p.d.) of 4.8 kV.

(i) Show that the final speed of the electrons is $4.1 \times 10^7\,\text{m s}^{-1}$.

[2]

(ii) Calculate the effective wavelength of a beam of electrons moving at the speed in **(c)(i)**.

wavelength = ... m [2]

[Total: 9]

2. Nov/2021/Paper_42/No.9

(a) State what is meant by:

(i) the *photoelectric effect*

....

....

.... [2]

(ii) *work function energy*.

....

.... [1]

(b) A polished calcium plate in a vacuum is investigated by illuminating the surface with light.

It is found that no photoelectric current is produced when the frequency of the light is less than 6.93×10^{14} Hz.

(i) State the name of the frequency below which no photoelectric current is produced.

.... [1]

(ii) Explain how the photon model of electromagnetic radiation accounts for this phenomenon.

....

....

....

.... [3]

(iii) Calculate the work function energy, in eV, of calcium.

work function energy = ... eV [2]

[Total: 9]

3. June/2021/Paper_41/No.12

(a) Electromagnetic radiation of a single constant frequency is incident on a metal surface. This causes an electron to be emitted.

Explain why the maximum kinetic energy of the electron is independent of the intensity of the incident radiation.

....

....

....

....

.... [3]

(b) Ultraviolet radiation of wavelength 250 nm is incident on the surface of a sheet of zinc. The maximum kinetic energy of the emitted electrons is 1.4 eV.

Determine, in eV:

(i) the energy of a photon of the ultraviolet radiation

energy = ... eV [3]

(ii) the work function energy of the surface of the zinc.

energy = ... eV [2]

[Total: 8]

4. June/2021/Paper_42/No.12

(a) State what is meant by a *photon*.

....

....

.... [2]

(b) A stationary nucleus of samarium-157 ($^{157}_{62}Sm$) emits a gamma-ray (γ-ray) photon of energy 0.57 MeV.

Determine, for one γ-ray photon:

(i) its wavelength

wavelength = ... m [2]

(ii) its momentum.

momentum = ... N s [2]

(c) (i) Using your answer to **(b)(ii)**, determine the speed of the samarium-157 nucleus after emission of the photon.

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

(ii) By reference to your answer in **(c)(i)**, explain quantitatively why the speed of the samarium-157 nucleus may be assumed to be negligible compared with the speed of the photon.

....

.... [1]

[Total: 9]

5. March/2021/Paper_42/No.11

(a) Electrons are accelerated through a potential difference of 15 kV. The electrons collide with a metal target and a spectrum of X-rays is produced.

(i) Explain why a continuous spectrum of energies of X-ray photons is produced.

....

....

....

....

.... [3]

(ii) Calculate the wavelength of the highest energy X-ray photon produced.

wavelength = ... m [3]

(b) A beam of X-rays has an initial intensity I_0. The beam is directed into some body tissue. After passing through a thickness x of tissue the intensity is I. The graph in Fig. 11.1 shows the variation with x of ln (I/I_0).

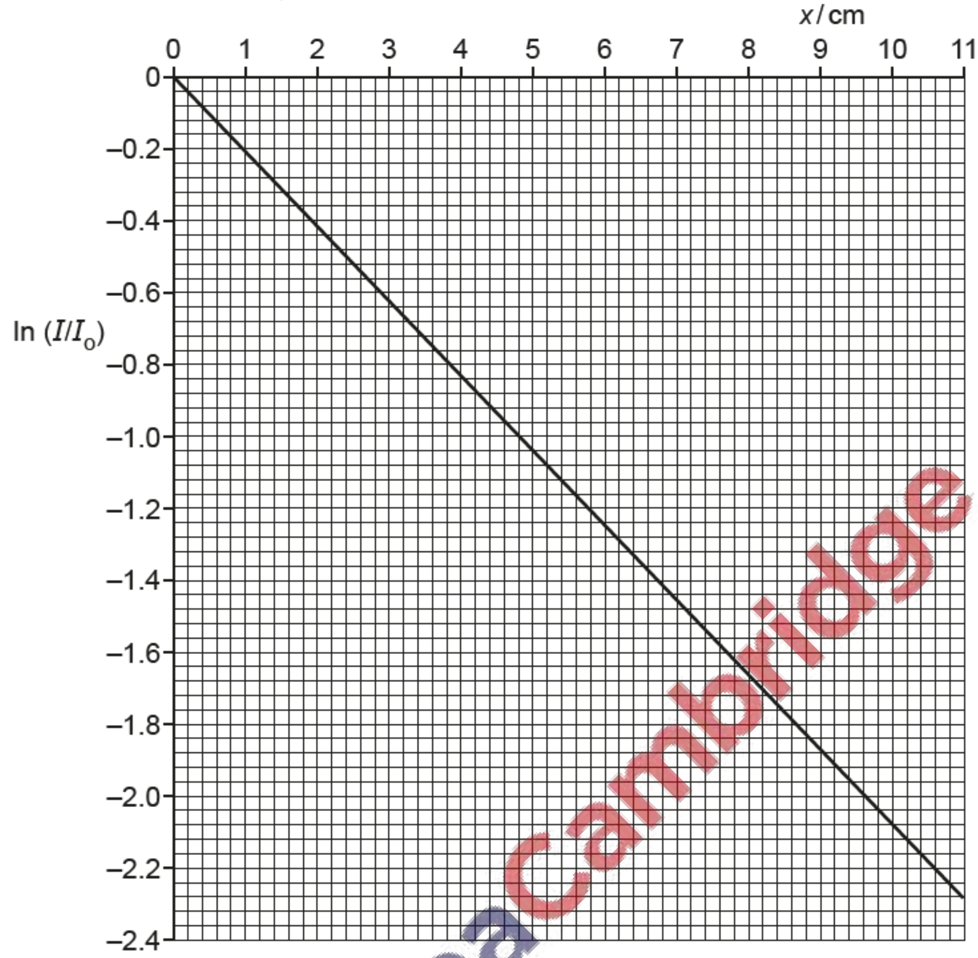

Fig. 11.1

(i) Determine the linear attenuation (absorption) coefficient μ for this beam of X-rays in the tissue.

μ = ... cm^{-1} [2]

(ii) Determine the thickness of tissue that the X-ray beam must pass through so that the intensity of the beam is reduced to 5.0% of its initial value.

thickness = ... cm [2]

[Total: 10]