6 (a) A beam of light is incident normally on a metal surface, as illustrated in Fig. 6.1.

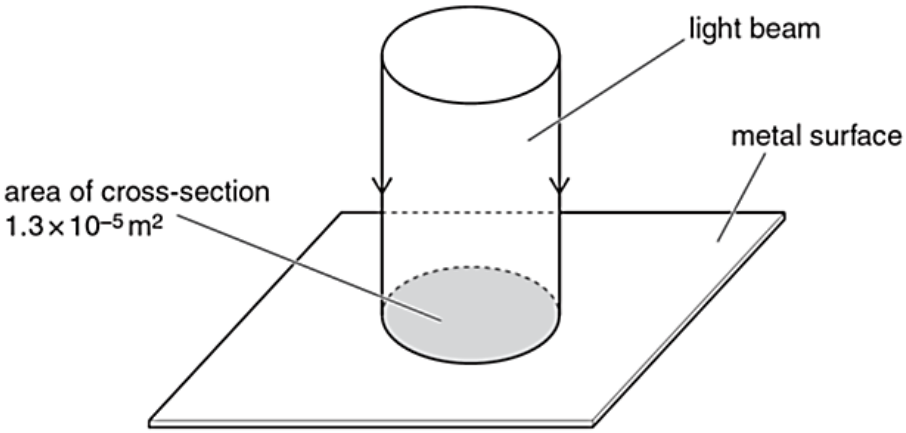

Fig. 6.1

The beam of light has cross-sectional area 1.3×10^{-5} m^2 and power 2.7×10^{-3} W.

The light has wavelength 570 nm.

The light energy is absorbed by the metal and no light is reflected.

(i) Show that a photon of this light has an energy of 3.5×10^{-19} J.

[1]

(ii) Calculate the change in momentum of the photons per unit time.

change in momentum per unit time = …… kg m s^{-2} [4]

(b) Electromagnetic radiation of frequency f is incident on a metal surface. The variation with frequency f of the maximum kinetic energy E_{MAX} of electrons emitted from the surface is shown in Fig. 6.2.

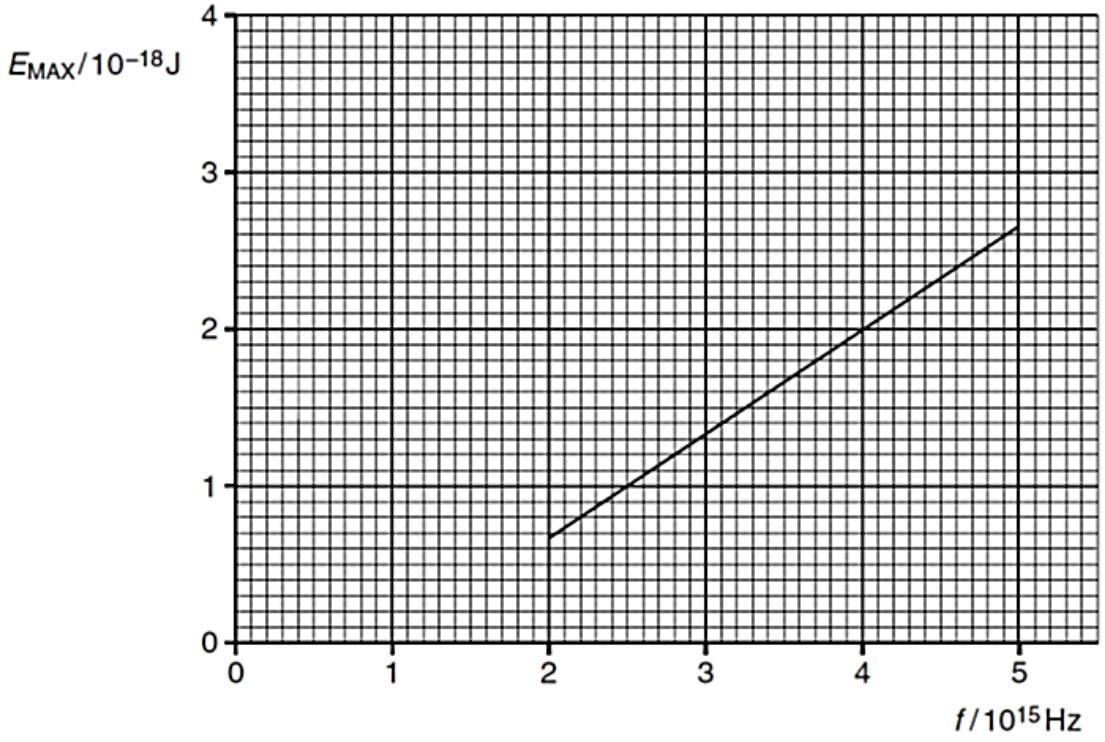

Fig. 6.2

(i) Use Fig. 6.2 to determine the work function energy in eV of the metal surface.

work function energy = …… eV [3]

(ii) A second metal has a greater work function energy than that in **(b) (i)**. On Fig. 6.2, draw a line to show the variation with f of E_{MAX} for this metal. [1]

(iii) Explain why the graphs in **(b) (i)** and **(b) (ii)** do not depend on the intensity of the incident radiation.

……...

……...

…… [2]

(c) A photon in free space has the same energy in **(a) (i)**.

The photon crosses a gold atom of diameter 2.6×10^{-10} m.

(i) Calculate the time for the photon to travel the distance of 2.6×10^{-10} m.

time = …… s [1]

(ii) Suggest, by reference to your answer in **(c) (i)**, the maximum uncertainty in the time to cross the gold atom.

…… [1]

(iii) A formula for *Heisenberg* time-energy uncertainty principle is given by $\Delta t \, \Delta E \geq h$, where Δt is the uncertainty in time detection of a photon and ΔE is the uncertainty in photon energy.

Use your answer to **(c) (ii)** and the above uncertainty principle equation to suggest why, during the time that the photon crosses the atom, its energy may not be equal to that of the photon in free space.

……...

……………………………………………………………………………………………...

…………………………………………………………………………………………… [2]

[Total: 15]