1. Nov/2020/Paper_41/No.11

A photon of wavelength 540 nm collides with an isolated stationary electron, as illustrated in Fig. 11.1.

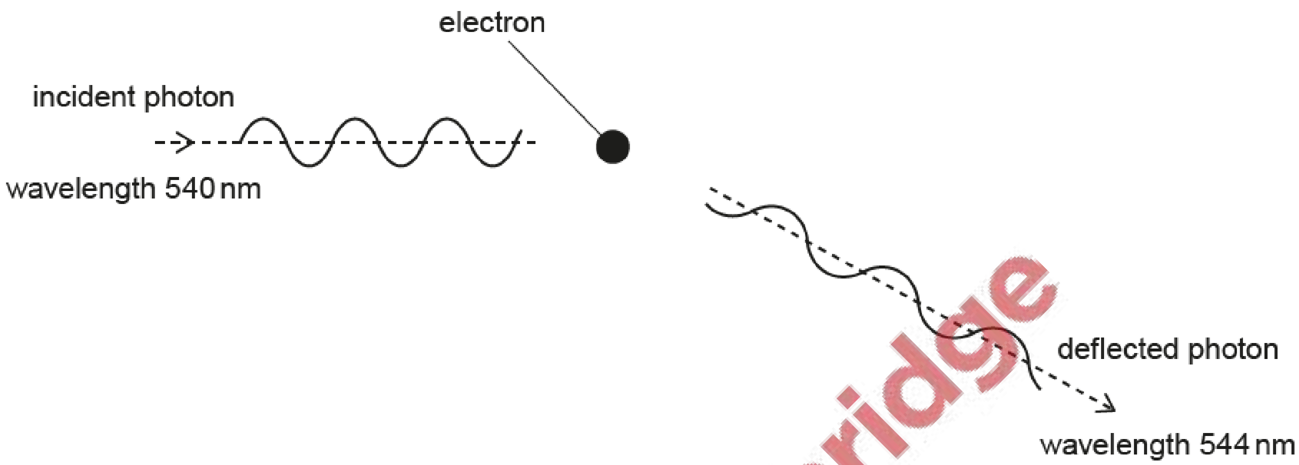

Fig. 11.1

The photon is deflected elastically by the electron.
The wavelength of the deflected photon is 544 nm.

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

....

....

.... [2]

(ii) On Fig. 11.1, draw an arrow to indicate the approximate direction of motion of the deflected electron. [1]

(b) Calculate:

(i) the momentum of the deflected photon

momentum = ... N s [2]

(ii) the energy transferred to the deflected electron.

energy = ... J [2]

(c) Another photon of wavelength 540 nm collides with an isolated stationary electron.

Explain why it is not possible for the deflected photon to have a wavelength less than 540 nm.

....

....

.... [2]

[Total: 9]

2. Nov/2020/Paper_42/No.11

(a) Electromagnetic radiation is incident on a metal surface.

It is observed that there is a minimum frequency of electromagnetic radiation below which emission of electrons does not occur.

This observation provides evidence for a particulate nature of electromagnetic radiation.

State **two** other observations associated with photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1. ....

....

2. ....

.... [2]

(b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 11.1.

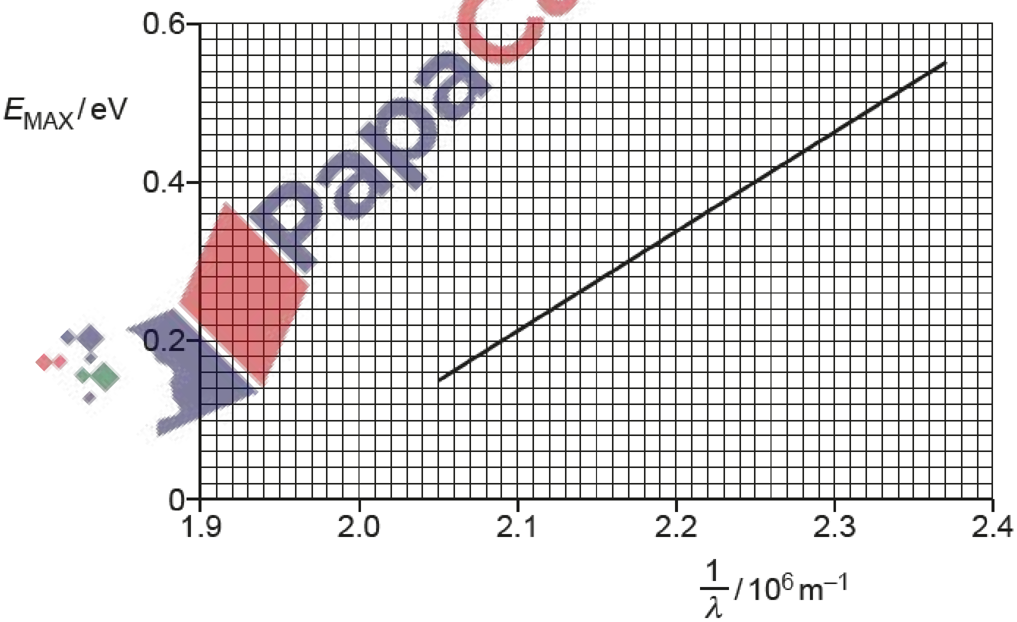

Fig. 11.1

(i) Use Fig. 11.1 to determine the threshold frequency f_0.

f_0 = ... Hz [2]

(ii) Use the gradient of the line on Fig. 11.1 to determine a value for the Planck constant h. Explain your working.

h = ... J s [4]

(c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in **(b)**.

On Fig. 11.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX}. [2]

[Total: 10]

3. June/2020/Paper_41/No.10

(a) White light passes through a cloud of cool low-pressure gas, as illustrated in Fig. 10.1.

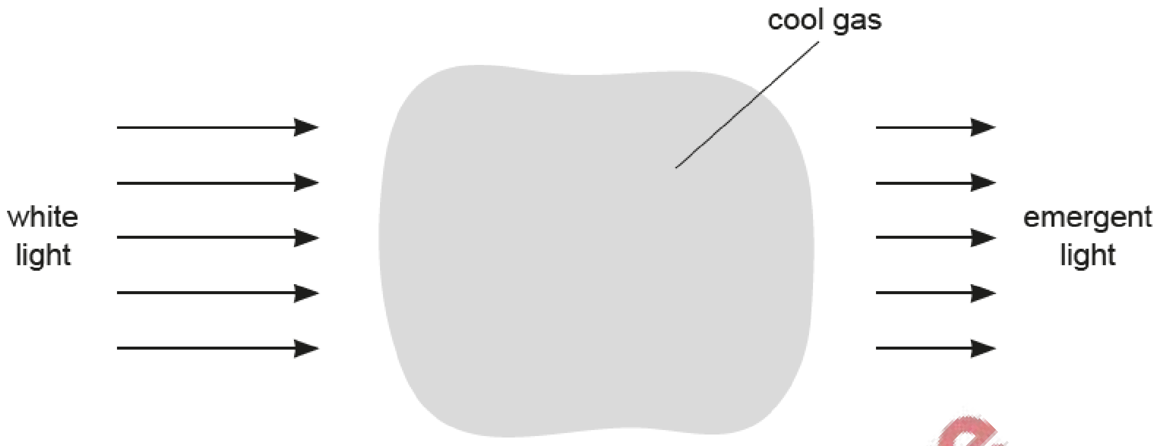

Fig. 10.1

For light that has passed through the gas, its continuous spectrum is seen to contain a number of darker lines.

Use the concept of discrete electron energy levels to explain the existence of these darker lines.

....

....

....

....

....

.... [4]

(b) The uppermost electron energy bands in a solid are illustrated in Fig. 10.2.

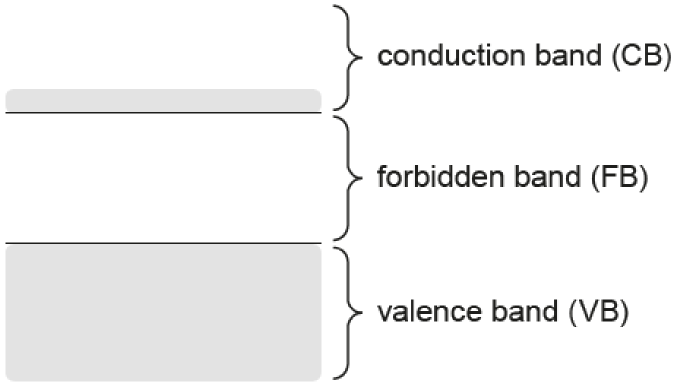

Fig. 10.2

Use band theory to explain the dependence on light intensity of the resistance of a light-dependent resistor (LDR).

....

....

....

....

....

....

.... [5]

[Total: 9]

4. June/2020/Paper_41/No.11

An electron, at rest, has mass m_e and charge $-q$.

A positron is a particle that, at rest, has mass m_e and charge $+q$.

A positron interacts with an electron. The electron and the positron may be considered to be at rest.
The outcome of this interaction is that the electron and the positron become two gamma-ray (γ-ray) photons, each having the same energy.

(a) Calculate, for one of the γ-ray photons:

(i) the photon energy, in J

energy = ... J [2]

(ii) its momentum.

momentum = ... N s [2]

(b) State and explain the direction, relative to each other, in which the γ-ray photons are emitted.

....

....

....

.... [2]

[Total: 6]

5. June/2020/Paper_42/No.11

(a) The uppermost energy bands in a solid are known as the valence band (VB), the forbidden band (FB) and the conduction band (CB).

A copper wire is at room temperature.

Use band theory to explain why the resistance of the copper wire increases as its temperature increases.

....

....

....

....

....

....

.... [4]

(b) The structure of a copper crystal is to be examined using electron diffraction.

Electrons, having been accelerated from rest through a potential difference V, are incident on the crystal.

The de Broglie wavelength λ of the electrons is 2.6×10^{-11} m.

Calculate the accelerating potential difference V.

V = ... V [4]

[Total: 8]

6. March/2020/Paper_42/No.10

(a) By reference to the photoelectric effect, explain what is meant by *work function energy*.

....

....

.... [2]

(b) In an experiment, electromagnetic radiation of frequency *f* is incident on a metal surface.

The results in Fig. 10.1 show the variation with frequency *f* of the maximum kinetic energy E_{MAX} of electrons emitted from the surface.

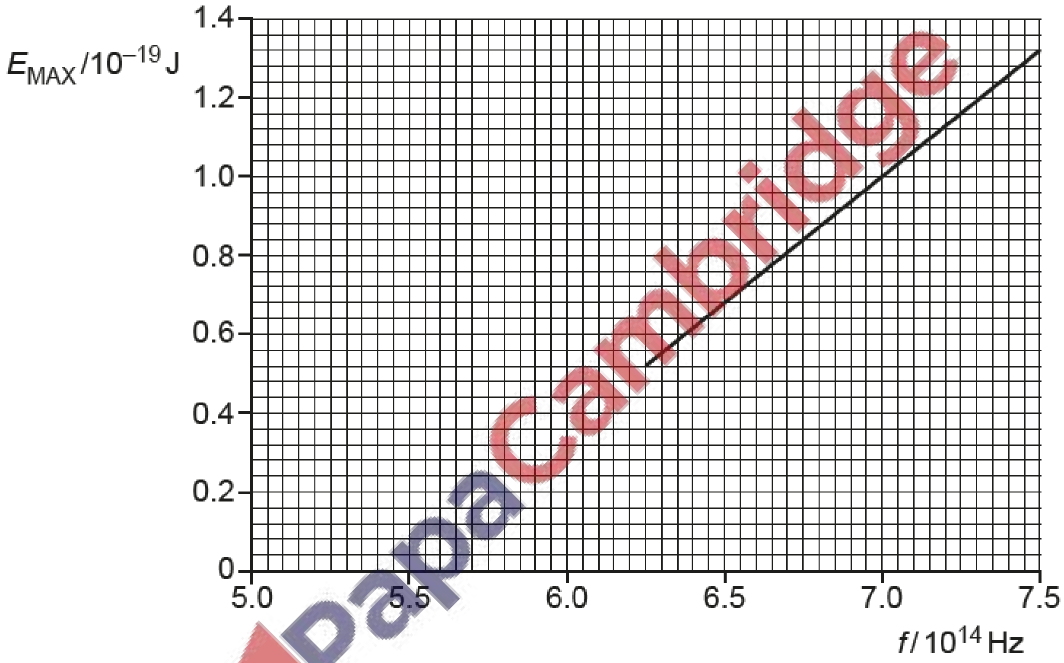

Fig. 10.1

(i) Determine the work function energy in J of the metal used in the experiment.

work function energy = ... J [2]

(ii) The work function energy in eV for some metals is given in Table 10.1.

Table 10.1

metal	work function / eV
tungsten	4.49
magnesium	3.68
potassium	2.26

Determine the metal used in the experiment. Show your working.

....

.... [1]

(c) The intensity of the electromagnetic radiation for one particular frequency in **(b)** is increased.

State and explain the change, if any, in:

(i) the maximum kinetic energy of the emitted electrons

....

.... [1]

(ii) the rate of emission of photoelectrons.

....

.... [1]

[Total: 7]