Question 1

(i) electrons and holes; (ii) electrons **(2 × 2; 3)**

Question 2

Energy of incident photon = Work function + KE of electron **(4)**

1.35 (eV) / 2.16 × 10^{-19} (J) **(3)**

Question 3

***(i)* How are X-rays produced?**

accelerated / fast moving electrons	4
strike a (heavy) metal (target) / anode	3

Question 8

What is a photon?

packet/bundle/quantum 3
of (light) energy/electromagnetic radiation 3

6

An investigation was carried out to establish the relationship between the current flowing in a photocell and the frequency of the light incident on it. The graph illustrates the relationship.

Draw a labelled diagram of the structure of a photocell.

(wire) anode / electrode 3
(cylindrical) cathode / electrode 3
vacuum 3
(glass) casing 3

(–1 for each missing label)

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Using the graph, calculate the work function of the metal.

$\phi = h f_0$ // $\phi = (6.6\times10^{-34})(5.2\times10^{14})$ 3

$\phi = 3.432\times10^{-19}$ J **(–1 for omission of or incorrect unit)** 3

What is the maximum speed of an emitted electron when light of wavelength 550 nm is incident on the photocell?

any correct format of formula, e.g. $hf = \phi + \frac{1}{2}mv^2$ // $\frac{hc}{\lambda} = W + E_k$, *etc* 3

(1 mark per correct component)

correct substitution // $\frac{(6.6\times10^{-34})(3\times10^{8})}{550\times10^{-9}} = (3.432\times10^{-19}) + \frac{1}{2}(9.1\times10^{-31})v^2$ 3

(1 mark per correct component substitution)

$v = 1.922\times10^{5}\ \mathrm{m\,s^{-1}}$ **(–1 for omission of or incorrect unit)** 3

Explain why a current does not flow in the photocell when the frequency of the light is less than 5.2×10^{14} Hz.

frequency less than 3
threshold frequency 3

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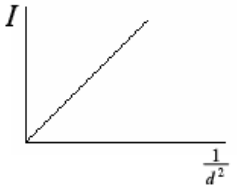
The relationship between the current flowing in a photocell and the intensity of the light incident on the photocell was then investigated. Readings were taken and a graph was drawn to show the relationship.

Draw a sketch of the graph obtained. How was the intensity of the light varied?



(or intensity)

labelled axes 3
correct shape 3
vary distance from light source to photocell 5

What conclusion about the nature of light can be drawn from these investigations?

light is made up of photons / bundles of energy
// light has a corpuscular nature // light has not got a wave nature 6

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Question 5

(*h*) Give two ways of deflecting a beam of electrons.

(by means of) an electric field and a magnetic field (any order) 4+3

Question 6

(*f*) What is the force exerted on an electron when it is in an electric field of strength 5 N C^{-1}?

$F = E\,q$ 4

$F = 5(1.6 \times 10^{-19})$ // $F = 8.0 \times 10^{-19}$ N (no penalty for units) 3

Question 7

(i) **How are electrons accelerated in a cathode ray tube?**

(by a large) p.d /voltage / H.T / E.H.T./ electric field 7

Question 8

(d) **The first Nobel Prize in Physics was awarded in 1901 for the discovery of X-rays. What are X-rays? Who discovered them? (9)**

electromagnetic radiation 3

of short wavelength / high frequency 3

Rontgen 3

In an X-ray tube electrons are emitted from a metal cathode and accelerated across the tube to hit a metal anode. How are the electrons

(i) emitted from the cathode;

(ii) accelerated? (6)

by thermionic emission / by heating the cathode 3

by the (E.) H.T / high voltage (between the anode and cathode) 3

Calculate the kinetic energy gained by an electron when it is accelerated through a potential difference of 50 kV in an X-ray tube.

Calculate the minimum wavelength of an X-ray emitted from the anode. (13)

$E_k\ (= W) = q\ V$ 3

$= (1.6 \times 10^{-19})(50 \times 10^{3})$ / 8.0×10^{-15} J 3

(-1 for omission of or incorrect units)

$E = h\,c/\lambda$ 3

$\lambda = [6.6 \times 10^{-34} \times 3.0 \times 10^{8}]/(8.0 \times 10^{-15})$ 2

$\lambda = 2.475 \times 10^{-11}$ m ($\approx 2.5 \times 10^{-11}$ m $\Longrightarrow$ 0.025 nm) 2

(-1 for omission of or incorrect units)

(Planck constant = 6.6×10^{-34} J s; speed of light = 3.0×10^{8} m s^{-1};
charge on electron = 1.6×10^{-19} C)

Question 9

(i) How are electrons produced in an X-ray tube? (7)

at the (heated) cathode / filament 4

thermionic emission occurs 3

Question 12 (d)

One hundred years ago, Albert Einstein explained the photoelectric effect.

What is the photoelectric effect? (6)

emission of electrons from the surface of a metal 3

when light of suitable frequency / energy shines on it 3

Write down an expression for Einstein's photoelectric law. (9)

$hf = \phi + \frac{1}{2}mv^2$ (each incorrect item … -3) 3×3

Summarise Einstein's explanation of the photoelectric effect. (9)

photons (of light) / quanta / packets (or bundles) of energy 3

all of energy from one photon is given to one electron 3

energy must be greater than work function of metal for P.E.E. to occur / for electron to escape 3

Give one application of the photoelectric effect. (4)

sound track in film, photography, counters, photocell, burglar alarm, automatic doors, etc. 4