

State Examination Commission – Physics Higher Level, 2006

Question 12

The first Nobel Prize in Physics was awarded in 1901 for the discovery of X-rays.

What are X-rays? Who discovered them? (9)

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)

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)

(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)

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 rays of high frequency (energy) discovered by Wilhelm Roentgen

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;

By thermionic emission caused by heating the cathode electrically

(ii) accelerated? (6)

By applying a large p.d. (typically 50 kV) across the x-ray tube

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

$$\begin{aligned} E_k \text{ gained by electron} &= \text{work done, } W, \text{ by electric field on electron} &= QV \\ E_k &= eV \\ &= 1.6 \times 10^{-19} \times 5 \times 10^4 \\ &= 8 \times 10^{-15} \text{ J} \end{aligned}$$

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

$$\begin{aligned} E &= hf \\ &= hc/\lambda \\ \Rightarrow \lambda &= hc/E \\ &= (6.6 \times 10^{-34} \times 3 \times 10^8) / 8 \times 10^{-15} \\ &= 2.5 \times 10^{-11} \text{ m} \end{aligned}$$