

State Examination Commission – Physics Higher Level, 2010

Question 10

The history of anti-matter begins in 1928 when a young English physicist named **Paul Dirac** predicted an anti-particle for the electron.

(i) What is anti-matter?

An anti-matter particle was first discovered during the study of cosmic rays in 1932.

Name the anti-particle and give its symbol.

What happens when a particle meets its anti-particle?

(18)

(ii) What is meant by pair production?

A photon of frequency 3.6×10^{20} Hz causes pair production.

Calculate the kinetic energy of one of the particles produced, each of which has a rest mass of 9.1×10^{-31} kg.

(21)

(iii) A member of a meson family consists of two particles.

Each particle is composed of up and down quarks and their anti-particles.

Construct the possible combinations.

Deduce the charge of each combination and identify each combination.

What famous Irish writer first thought up the name 'quark'?

(17)

(speed of light = 3.0×10^8 m s⁻¹; Planck constant = 6.6×10^{-34} J s)

(i) What is anti-matter?

a form of matter (atoms and particles) in which each particle (for example an electron) has the same mass but opposite electric charge to its counterpart

An anti-matter particle was first discovered during the study of cosmic rays in 1932.

Name the anti-particle and give its symbol.

Positron e^+

What happens when a particle meets its anti-particle?

(18)

The pair annihilate each other to form pure energy

(ii) What is meant by pair production?

The opposite of pair annihilation; energy changes into a particle and its anti-particle

A photon of frequency 3.6×10^{20} Hz causes pair production.

Calculate the kinetic energy of one of the particles produced, each of which has a rest mass of 9.1×10^{-31} kg.

(21)

The photon's energy becomes the mass of each of the 2 new particles and their initial kinetic energies

$$hf = 2mc^2 + 2E_k$$
$$\Rightarrow E_k = \frac{hf - 2mc^2}{2} = \frac{6.6 \times 10^{-34} \times 3.6 \times 10^{20} - (2 \times 9.1 \times 10^{-31} (3.0 \times 10^8)^2)}{2} = 3.69 \times 10^{-14} \text{ J}$$

(iii) A member of a meson family consists of two particles. Each particle is composed of up and down quarks and their anti-particles. Construct the possible combinations. Deduce the charge of each combination and identify each combination.

$$u + \bar{u} = \frac{2}{3} + \frac{-2}{3} = 0 \quad \text{no charge ... a neutral pion } \pi^0$$

$$d + \bar{d} = \frac{-1}{3} + \frac{1}{3} = 0 \quad \text{no charge ... a neutral pion } \pi^0$$

$$u + \bar{d} = \frac{2}{3} + \frac{1}{3} = +1 \quad +1 \dots \text{ a pi - plus (positive pion) } \pi^{+1}$$

$$d + \bar{u} = \frac{-1}{3} + \frac{-2}{3} = -1 \quad -1 \dots \text{ a pi - minus (negative pion) } \pi^{-1}$$

(Note: pi-plus are written π^+ not π^{+1} . Open Office Math was a bit upset when I tried to make a superscript of just a + sign, so I had to add the 1. Ditto for π^-)

What famous Irish writer first thought up the name 'quark'?

James Joyce