Name of the Student:_____
Max. Marks : 25 Marks **Time : 25 Minutes**

Q1.

Cosmic rays mostly consist of high-energy protons. These protons can collide with atomic nuclei in the Earth's upper atmosphere producing pions (π^-). Pions are unstable and decay into high-energy muons (μ^-).

(a) (i) Which of the following is the particle group for pions (π^-)?

Tick (✔) the correct answer.

Baryons ☐

Leptons ☐

Mesons ☐

Photons ☐

(1)

(ii) Complete the equation for the decay of a pion (π^-).

$$\pi^- \longrightarrow \mu^- + \_\_\_\_\_$$

(1)

(b) 2.5×10^8 muons are created simultaneously above the EarthÙs surface.
These muons are unstable and have a half-life of 2.2 μs. They are created at a height of 10.7 km and travel towards the Earth's surface with a constant vertical velocity of 2.85×10^8 m s^{-1}.

(i) Show that, for the reference frame of an observer on Earth, the time taken for the muons to reach the Earth's surface is approximately 17 muon half-lives.

(2)

(ii) Estimate the number of these muons that an observer on Earth would expect to remain after 17 half-lives.

number _____

(2)

(iii) The number of muons that reach the Earth's surface is considerably different from the estimated number in part **(b)(ii)**.

Identify the theory that explains the difference between the estimated and observed number of muons.

_____

(1)

(iv) Outline why the number of muons that actually reach the Earth's surface is different from the estimated number in part **(b)(ii)**.

_____

_____

_____

(1)

(v) Calculate, for the reference frame of a muon, the time taken for the muons to travel this distance.

time _____ s

(3)

(vi) Calculate the number of muons that remain at the end of the time interval calculated in part **(b)(v)**.

number _____

(3)

(Total 14 marks)

Q2.

(a) (i) Describe how Newton used the corpuscular theory to explain the refraction of light as it passes from one substance into a substance of higher optical density.

_____

(3)

(ii) Huygens used a wave theory to explain refraction.

Explain why the corpuscular theory was rejected in favour of a wave theory to explain refraction.

(2)

(iii) Describe and explain the difference in the appearance of the fringes in Young's double-slit experiment that are predicted by the corpuscular theory and by the wave theory for light.

(2)

(b) Electromagnetic waves and matter are now known to exhibit both particle and wave behaviour. The photons for a particular X-ray wavelength have energy 5.0 keV.

Calculate the potential difference through which an electron has to be accelerated so that its de Broglie wavelength is the same as that of this X-ray.

(4)
(Total 11 marks)