

- 21 Pions are created in the upper atmosphere when high-energy cosmic rays interact with nuclei. Pions are mesons and they quickly decay to muons. Muons are leptons with a mass of $106 \text{ MeV}/c^2$.

(a) Give a possible quark structure of a pion.

(1)

(b) The equation shows a pion decaying into a muon and an antineutrino.

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

Energy and momentum must be conserved in this decay.

Explain two other conservation laws that apply to this decay.

(4)

(c) Calculate the mass, in kg, of a muon.

(3)

Mass of muon = kg



- (d) When at rest, pions have an average lifetime of 26 ns. When produced in the upper atmosphere, high-energy pions have a speed of up to $0.99c$.

Explain how the average lifetime of these high-energy pions compares with the lifetime of pions at rest.

You do not need to carry out any calculations.

(2)

(Total for Question 21 = 10 marks)