17 Experiments with muons are taking place at Fermilab in the USA to improve our understanding of the standard model.

(a) The muon belongs to the same family of particles as the electron.

State how the muon is classified in the standard model.

(2)

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(b) A muon (μ) can be produced by the decay shown in this nuclear equation.

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

State the names of the two other particles involved.

(2)

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(c) A website states: "The rest mass of a muon is $106\,\text{MeV}/c^2$, which is a little over 200 times that of an electron."

Deduce whether this statement is correct.

(3)

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(d) Muons are stored in a 'storage ring' at Fermilab. The website describes the ring as having a circumference of 44.7 m and using a magnetic field of flux density 1.45 T.

The website claims that this enables the storage ring to confine muons with a momentum of 3.10 GeV/c.

(i) Explain why the unit GeV/c is a valid unit for momentum.

(2)

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(ii) Deduce whether the website's claim is correct.

muon charge $= -1.6 \times 10^{-19}$ C
3.10 GeV/c $= 1.65 \times 10^{-18}$ N s

(3)

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(iii) Stationary muons are unstable and have a mean lifetime of a few microseconds.

Explain why muons in the ring are observed to have a much greater mean lifetime.

(2)

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(Total for Question 17 = 14 marks)