**7.*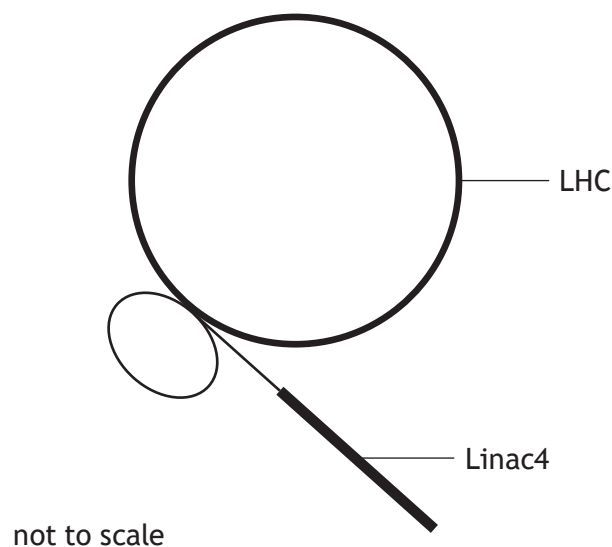* The Large Hadron Collider (LHC) at CERN has been upgraded recently. One of the upgrades is the addition of a linear particle accelerator known as Linac4.

LHC

Linac4

not to scale

Linac4 accelerates hydrogen ions before they enter the main LHC.

Linac4 consists of hollow metal tubes placed in a vacuum. The hydrogen ions are accelerated across the gaps between the tubes.

Part of Linac4 is shown below.

alternating supply voltage

hydrogen ion beam

metal tube
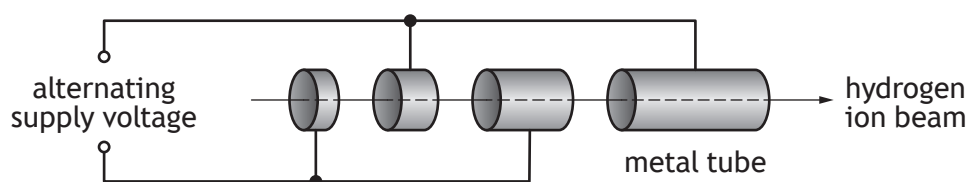
(a) (i) Explain why an alternating supply voltage is used in Linac4. **1**

(ii) Suggest one reason why the lengths of the tubes increase along Linac4. **1**

[Turn over

7. (continued)

(b) Linac4 accelerates the hydrogen ions to a speed of $0 \cdot 50c$. The hydrogen ions then travel through a connecting tube before entering the LHC.

The connecting tube has a length of 13 m in the frame of reference of a stationary observer.

Calculate the length of the connecting tube in the frame of reference of the hydrogen ions.
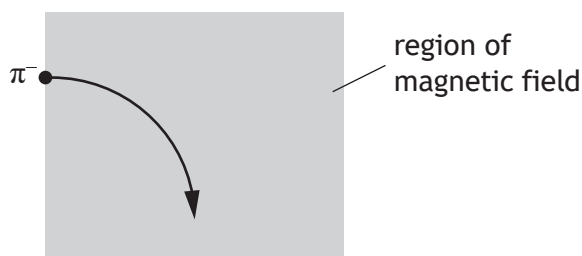
3

Space for working and answer

(c) Hydrogen ions can be collided within the LHC to produce other particles.

One of the particles produced is known as a π^- meson. The π^- meson is negatively charged.

  (i) State what is meant by the term *meson*.

1

  (ii) The π^- meson enters a region of magnetic field and follows the path shown.

π^- region of magnetic field

Determine the direction of the magnetic field acting upon the π^- meson.

1

7. (continued)

(d) In July 2018, scientists at CERN announced that the Higgs boson had been observed to decay into two bottom quarks.

(i) One of the fundamental forces involved in the decay of the Higgs boson is the weak nuclear force.

Name a force mediating particle for the weak nuclear force. **1**

(ii) A bottom quark has a mass-energy equivalence of 4·20 GeV.

$(1 \text{ eV} = 1 \cdot 60 \times 10^{-19} \text{ J})$

Determine the mass of the bottom quark. **4**

Space for working and answer