1 A treatment for brain tumours involves firing a beam of pions at the tumour. Pions exist for a very short time. During treatment many pions hit the tumour just as they decay. This causes the cells in the tumour to fragment, which kills them with no harmful effect to the surrounding tissue.
Pions belong to a group of sub-atomic particles called mesons. There are three types of pion: π^- π^+ π^0.

(a) The following table lists some quarks and their charge.

Quark	**Charge/*e***
u	+2/3
d	−1/3
s	−1/3
c	+2/3

State a possible quark combination for a π^-.

(1)

(b) Pions are produced when protons, accelerated in a cyclotron, are aimed at a target of beryllium and interact with protons in the beryllium.

Identify the type of pion produced in the following interaction.

$$p + p \rightarrow p + p + \pi$$

(1)

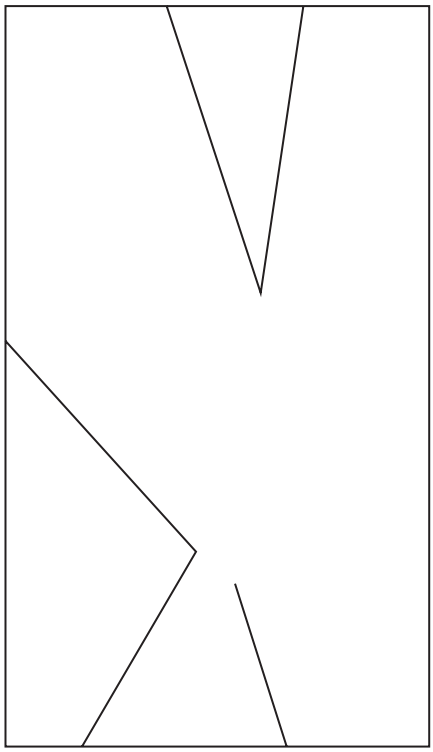
(c) The π^- mesons used for a treatment have a speed of 2.3×10^8 m s^{-1} and a range in air of 5.9 m.

Calculate the time for which these π^- mesons exist.

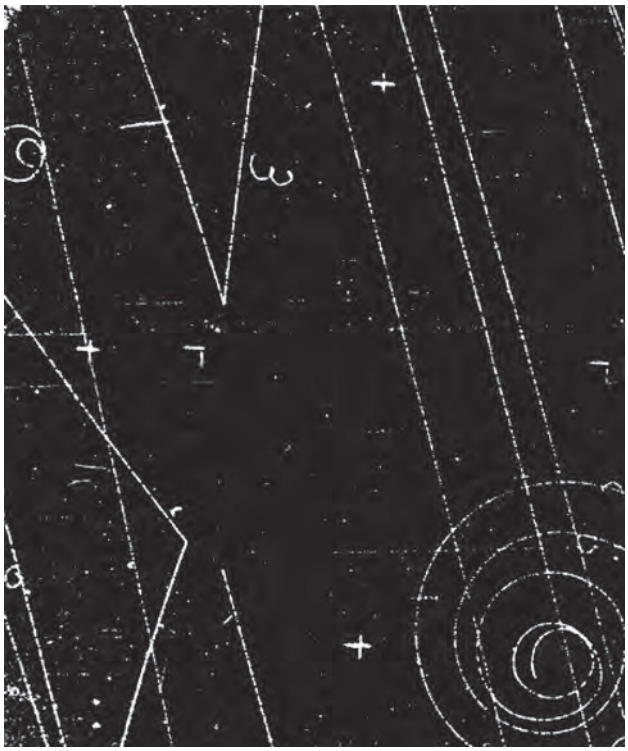
(2)

Time =

*(d) The photograph shows what happens in a Bubble Chamber when some pions enter at the bottom and travel upwards. One pion has been identified by X in the photograph and the simplified line diagram shows the visible tracks of the pion and subsequent decay products.



X



X

Explain what can be deduced about the sequence of the events shown in the line diagram.

(6)

(e) If very high speed protons are fired at beryllium, the following interaction occurs

$$p + p = p + p + p + \bar{p}$$

(i) State the name of the particle $\bar{p}$ and give its properties.

(2)

(ii) State what is likely to happen to the $\bar{p}$ particle.

(1)

(Total for Question = 13 marks)

2 Hadrons are a group of particles composed of quarks. Hadrons can be either baryons or mesons.

(a) (i) State the quark structure of a baryon.

(1)

(ii) State the quark structure of a meson.

(1)

(b) State **one** similarity and **one** difference between a particle and its antiparticle.

(2)

Similarity

Difference

(c) (i) The table gives some of the properties of up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

One or more of these quarks combine to form a K^+, a meson with a strangeness of +1.

Write down the quark combination of the K^+.

(1)

(ii) The K^+ can decay in the following way

$$K^+ \rightarrow \mu^+ + \nu_\mu$$

K^- is the antiparticle of the K^+.

Complete the equation below by changing each particle to its corresponding antiparticle in order to show an allowed decay for the K^- meson.

(2)

$$K^- \rightarrow$$

(iii) The rest mass of the K^+ is 494 MeV/c^2.

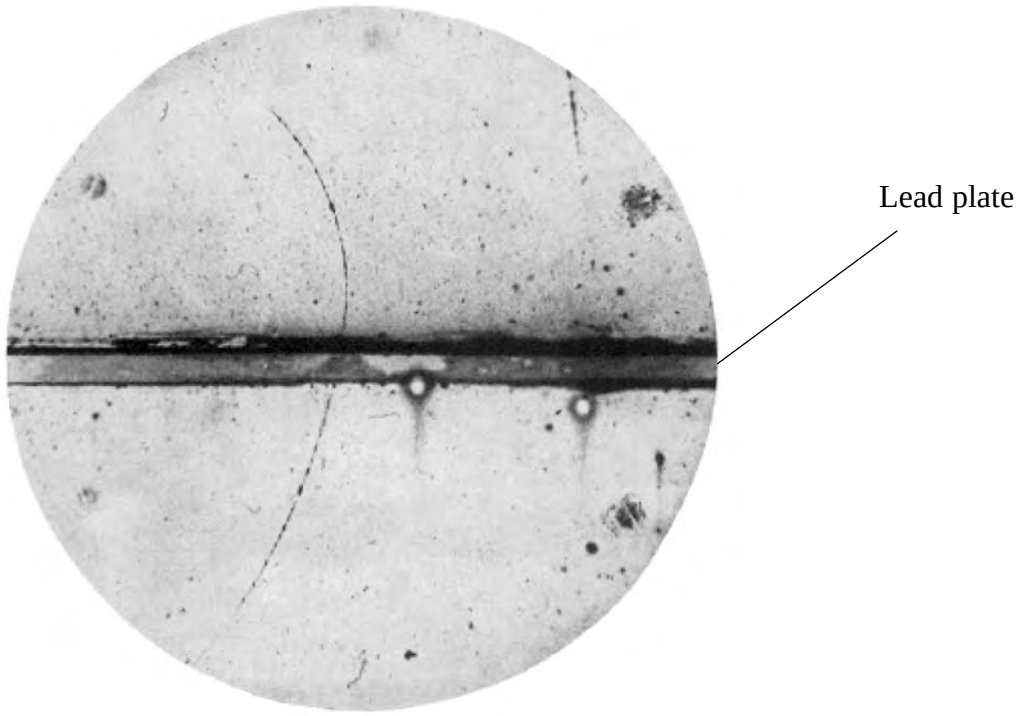
Calculate, in joules, how much energy is released if a K^+ meets and annihilates a K^-.

(3)

Energy = J

(Total for Question = 10 marks)

3 The photograph shows the track of a positively charged particle either side of a lead plate.



The particle was deflected by a magnetic field of magnetic flux density 1.5 T. The field is perpendicular to the plane of the photograph.

(a) (i) Estimate the actual radius of the track above the lead plate.

The lead plate is 6 mm thick.

(3)

Radius =

(ii) Calculate the momentum of this particle above the lead plate.
Particle charge = 1.6×10^{-19} C

(2)

Momentum =

(b) Explain whether this particle was moving up or down through the lead plate.

(3)

(c) On the list below circle the correct direction of the magnetic field.

(1)

Into the page from left to right down the page out of the page up the page

(d) This particle was identified as a positron.

(i) Calculate the speed of the positron while it is moving above the lead plate.

(2)

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Speed =

(ii) Comment on your answer.

(2)

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(Total for Question = 13 marks)