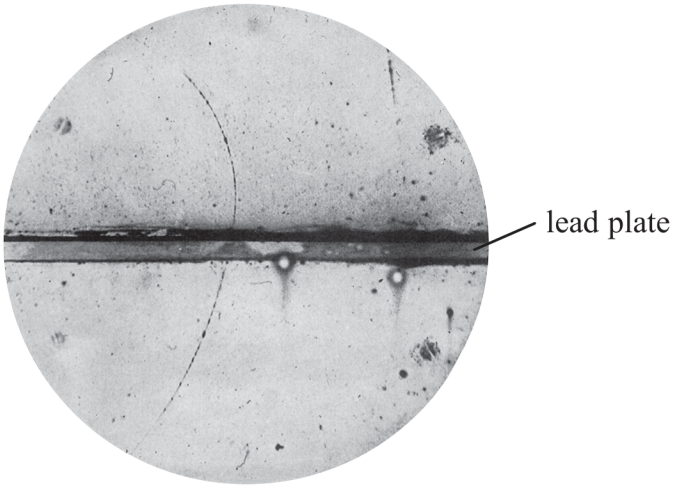
18 In 1932, Carl Anderson published this photograph of a track in a cloud chamber. The cloud chamber contained a lead plate. There was a magnetic field perpendicular to the plane of the track.



(Source: Anderson, Carl D. (1933). "The Positive Electron". Physical Review 43 (6): 491–494. DOI:10.1103/PhysRev.43.491.)

The photograph shows the track of a positron from cosmic rays and is the first photographic record of the existence of an antiparticle.

(a) State the properties of a positron that show it is the antiparticle to the electron.

(3)

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(b) Deduce the direction of the magnetic field.

(3)

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Direction of magnetic field = ...

(c) In the upper part of the photograph the positron had an energy of 23 MeV.

(i) Show that the positron must have been travelling at a relativistic speed. Assume that all of its energy is kinetic energy.

(3)

(ii) For relativistic particles such as this positron, momentum obeys the relationship

$$E = pc$$

where E = particle energy, p = particle momentum and c = speed of light.

Determine the magnetic flux density of the magnetic field.

radius of curvature of path = 3.7 cm

(3)

Magnetic flux density = ...

(d) A positron travelling at a non-relativistic speed of $1.5 \times 10^7 \, m \, s^{-1}$ collides with an electron travelling at the same speed in the opposite direction. This collision results in the production of gamma radiation.

Calculate the frequency of the gamma radiation produced.

(4)

Frequency = ...

(Total for Question 18 = 16 marks)