Question 19 **(21 marks)**

The Big European Bubble Chamber (BEBC)

Figure 1: The BEBC

Fundamental particles are extremely small and usually fast moving. This makes them hard to detect. If they are passed through a medium which records the path of their movement, new particles can be identified by their behaviour. The products of collisions between known particles can also be observed.

One such medium is superheated hydrogen. A superheated liquid is one which is held just above its natural boiling point. These liquids are unstable and 'boil' when the slightest disturbance is experienced. Charged particles moving at high speeds will cause the formation of tiny bubbles in the hydrogen and therefore leave a trace of the particles' trajectory. An example of this is shown in Figure 2 on page 31.

Figure 2: The collision of a gamma ray and a hydrogen atom's electron in a bubble chamber

A gamma ray enters from the left and collides with the electron of a hydrogen atom. It is neutral so there is no trace. Its path is shown as a dotted line. The gamma ray loses some energy which creates an electron and its antiparticle, a positron. The electron from the hydrogen atom recoils to the bottom right. Because the chamber is in a strong magnetic field, the charged particles spiral in different directions and with different momenta.

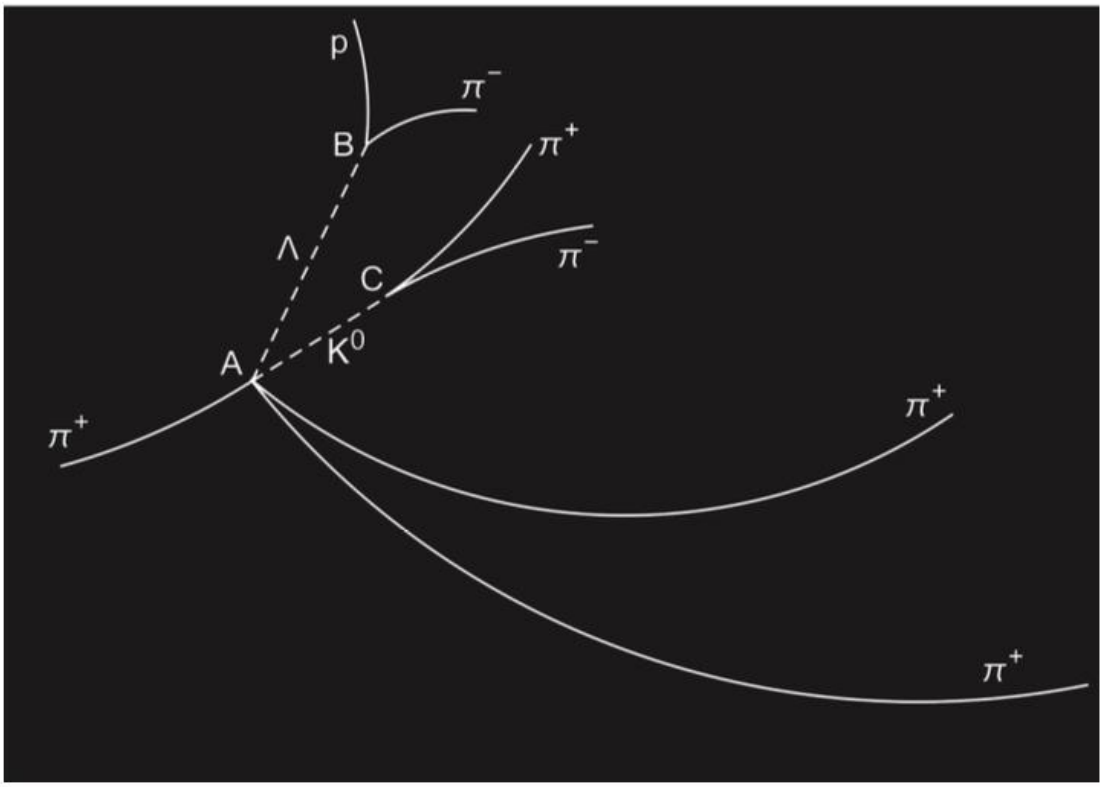

Figure 3: The collision between a positive pion and a proton in a bubble chamber

In Figure 3, a positive meson called a pion (π^+) enters from the left and strikes a proton at A. The pion and the proton become two new pions, a kaon (K^0) and a lambda particle (Λ). Both the kaon and lambda particles are neutral so they travel in straight lines and do not leave a trail. The lambda particle decays into a proton and a negative pion at B. The kaon decays into a positive and a negative pion at C.

Question 19 (continued)

In summary, a proton and one pion have been converted into a proton and five pions. There are three varieties of pion: +, –, and 0. The antiparticle of the positive pion is the negative pion and the π^0 is its own antiparticle.

(a) Discuss how the diagram in Figure 2 on page 31, shows that the two charged particles produced in the collision have different momenta. (4 marks)

(b) Explain how one proton and one pion can be converted into one proton and five pions. (3 marks)

(c) Why do the lambda and kaon particles leave no tracks in the bubble chamber? (2 marks)

(d) Is charge conserved in the overall reaction? Justify your answer with a calculation of the total charge before and after the collision. (4 marks)

(e) List a possible quark composition of the π^+ and π^- particles. (3 marks)

Particle	Quark composition
π^+	
π^-	

(f) The approximate mass of the incoming π^+ is 2.48×10^{-28} kg. If the radius of the circular path the pion is taking is 2.30 mm and it has a forward velocity of 3.70×10^5 m s^{-1}, estimate the strength of the magnetic field in the bubble chamber. (5 marks)

Answer: _____ T