Particle Physics

Question paper

Level	International A Level
Subject	Physics
Exam Board	Edexcel
Topic	Physics on the move
Sub Topic	Particle Physics
Booklet	Question paper

Time Allowed: **77 minutes**

Score: **/64**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 A student suggests that two colliding protons could undergo the interaction

$$p + p = p + n + \pi^+$$

Which of the following statements is true?

☒ **A** The interaction is not possible because charge is not conserved.

☒ **B** The interaction is not possible because the number of particles is not conserved.

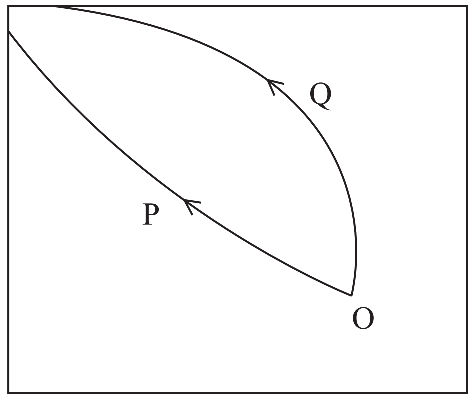
☒ **C** The colliding protons must have a very high value of kinetic energy.

☒ **D** The resulting particles must have a very high value of kinetic energy.

(Total for Question 1 = 1 mark)

Questions 2 and 3 refer to the diagram below.

The diagram shows the tracks in a particle detector. A lambda particle has decayed at O and two particles P and Q were created.



2 Which of the following is a correct statement about momentum in this decay?

- ☒ **A** The total momentum of the system is zero.
- ☒ **B** The momentum of P is equal to the momentum of Q.
- ☒ **C** The sum of the momenta of P and Q must equal zero.
- ☒ **D** The sum of the momenta of P and Q must equal that of the lambda particle.

(Total for Question 2 = 1 mark)

---

3 Which of the following must be a correct statement about energy in this decay?

- ☒ **A** total energy of P and Q < total energy of the lambda particle
- ☒ **B** total energy of P and Q = total energy of the lambda particle
- ☒ **C** total energy of P and Q > total energy of the lambda particle
- ☒ **D** total energy of P > total energy of Q

(Total for Question 3 = 1 mark)

4 The Large Hadron Collider is designed to accelerate protons to very high energies for particle physics experiments. Very high energies are required to

☒ **A** annihilate hadrons.

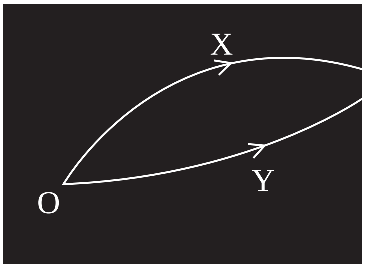
☒ **B** collide hadrons.

☒ **C** create particles with large mass.

☒ **D** produce individual quarks.

(Total for Question 4 = 1 mark)

Question 5 refer to the diagram which shows tracks from a particle detector.



Two particles X and Y were created by the decay of a lambda particle at O.

The diagram shows the tracks of particles X and Y.

5 Which of the following is a valid conclusion from the information given?

☒ **A** X is a negatively charged particle.

☒ **B** Y is a positively charged particle.

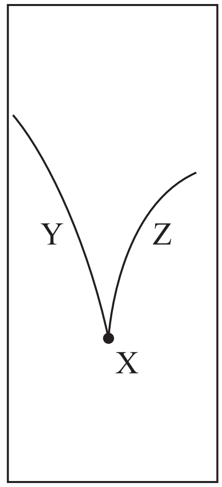
☒ **C** The lambda particle is neutral.

☒ **D** The magnetic field is acting into the paper.

(Total for Question 5 = 1 mark)

---

6 A moving pion decays into two particles Y and Z. This decay occurs at point X in a particle detector and the tracks observed are shown.



Which of the following is a valid conclusion from these tracks?

☒ **A** Momentum has not been conserved.

☒ **B** The pion is a neutral particle.

☒ **C** Y and Z have different masses.

☒ **D** Z is a negatively charged particle.

(Total for Question 6 = 1 mark)

---

7 The rest mass of a kaon is 494 MeV/c^2.
This mass in kg is

☒ **A** 3.4×10^{10}

☒ **B** 2.6×10^{-19}

☒ **C** 8.8×10^{-28}

☒ **D** 8.8×10^{-34}

(Total for Question 7 = 1 mark)

8 The equation for β^+ decay is

$$p \rightarrow n + e^+ + v_e$$

(a) Using information in the table, describe how a proton changes into a neutron.

Type of quark	**Charge / *e***
u	+2/3
d	−1/3

(2)

....

....

....

....

(b) With reference to the charges of the particles, show that this decay is possible.

(2)

....

....

....

....

(c) The kinetic energy of the positron is 1.58 MeV. It annihilates with a stationary electron and two photons of equal energy are emitted.

Calculate the wavelength of the emitted photons.

mass of stationary electron = 0.511 MeV/c^2
mass of stationary positron = 0.511 MeV/c^2

(4)

....

....

....

....

....

....

....

....

....

....

Wavelength = ...

(d) Linear accelerators (linacs) can produce electrons with energies up to 20 GeV.

(i) Calculate the de Broglie wavelength associated with 20 GeV electrons.
At these energies, the energy and momentum of a particle are connected by the relativistic equation $E = pc$.

(3)

Wavelength = ...

(ii) Experiments have been carried out where these 20 GeV electrons are aimed at a hydrogen target which consists of protons. Suggest, with reasons, what happens to the path of the electrons.

(2)

(Total for Question 8 = 13 marks)

9 The table gives the quark structure of three particles.

The up quark has a charge of +2/3e and the down quark has a charge of –1/3e.

Particle	**Quarks**
neutron n	udd
pion π^-	$d\bar{u}$
delta Δ^-	ddd

(a) Show that udd is a possible combination of quarks for the neutron.

(1)

....

....

(b) State, in terms of quark structure, why the Δ^- is classed as a baryon and the π^- a meson.

(2)

....

....

(c) Another particle in the delta family, the Δ^{++}, is also composed of up and/or down quarks. Its decay is shown by

$$\Delta^{++} \rightarrow p + \pi$$

Deduce the quark content of the Δ^{++} and the charge on the pion.

(2)

....

Quark content of Δ^{++} ....

....

Charge on pion ....

(Total for Question 9 = 5 marks)

10 (a) In 1962, the existence of a particle with strangeness −3 was predicted. Two years later it was identified in an experiment involving the interaction of a proton and a K^- meson which has a strangeness of −1. The new particle was given the name omega, Ω.

The interaction, which conserves strangeness, was

$$K^- + p = \Omega + K^+ + K^0$$

(i) Deduce with reasons the charge on the Ω and whether it is a baryon or a meson.

(2)

....

....

....

....

(ii) Using the information given in the table below deduce the quark composition of each of the particles involved.

(4)

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

....

....

....

....

....

(b) In another experiment, involving a head-on collision between two protons, the following interaction was observed.

$$p + p \rightarrow p + 7\pi^+ + 7\pi^- + K^+ + \Lambda$$

mass of p = 938 MeV/c^2

mass of π^+ and π^- = 140 MeV/c^2

mass of K^+ = 494 MeV/c^2

mass of Λ = 1115 MeV/c^2

(i) Calculate the minimum kinetic energy of each proton, in MeV, for this interaction to occur.

(3)

....

....

....

....

....

....

....

....

....

Minimum kinetic energy = ...

(ii) This interaction would **not** have taken place if one of the protons had been stationary and the other had twice the calculated value of kinetic energy.

Explain why.

(2)

....

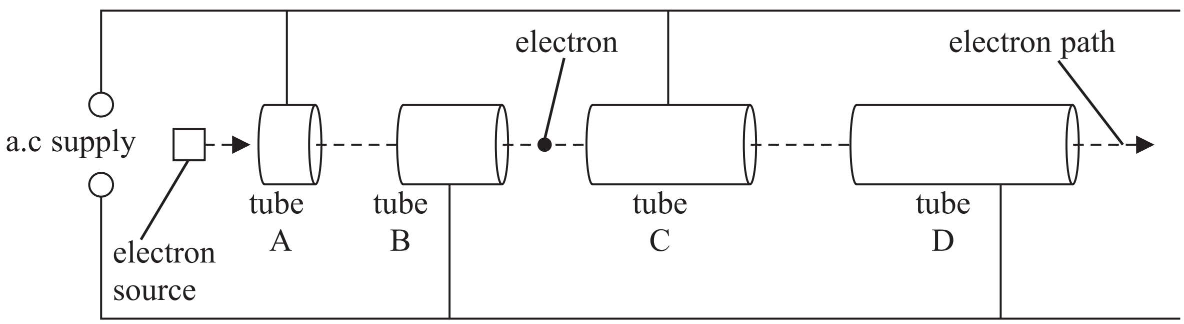
....

....

....

(Total for Question 10 = 11 marks)

11 (a) High energy particles used to investigate the structure of matter are produced in particle accelerators. The diagram shows the main features of a linear accelerator (linac).



(i) An electron is shown between tubes B and C.

The circles on the diagram indicate the terminals of the a.c. supply. Indicate on the diagram their polarity when the electron is between tubes B and C.

Explain your answer.

(2)

....

....

....

(ii) Explain why it is necessary for the tubes to increase in length along the linac.

(1)

....

....

(iii) The peak voltage of the a.c. supply is 250 kV.

Calculate the increase in electron kinetic energy, in joules, as the electron moves from tube A to tube D.

(3)

....

....

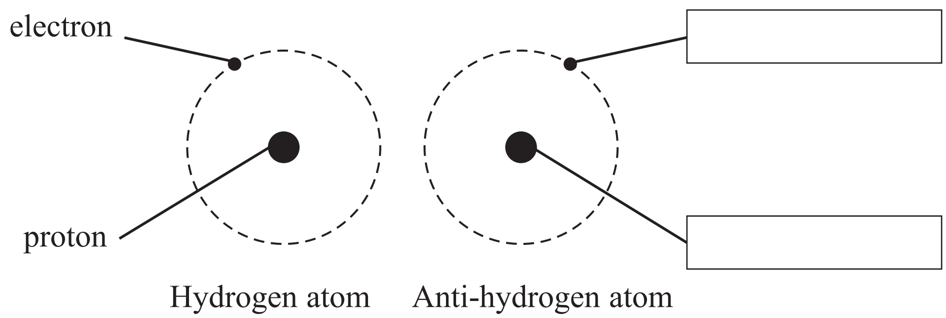
....

....

Increase in kinetic energy = ... J

(b) The Antiproton Decelerator at CERN slows down very high energy antiprotons to produce anti-atoms such as anti-hydrogen.

The diagram is a representation of a hydrogen atom and an anti-hydrogen atom.



(i) Use the boxes in the diagram to identify the particles in the anti-hydrogen atom.

(1)

(ii) State one difference and one similarity between the electron and its corresponding particle in the anti-hydrogen atom.

(2)

....

....

....

(iii) State what would happen if a hydrogen atom collided with an anti-hydrogen atom.

(1)

....

....

(c) In the early 1960s Murray Gell-Mann proposed a quark model that consisted of three quarks. The table gives some of the properties of these quarks.

Quark	Charge	Predicted mass in MeV/c^2
Up (u)	+2/3	4
Down (d)	−1/3	4
Strange (s)	−1/3	80

(i) Explain what is meant by a charge of +2/3.

(2)

....

....

....

(ii) State the predicted mass and charge of the $\bar{u}$ quark.

(2)

....

....

(iii) Calculate the mass of the $\bar{s}$ quark in kg.

(3)

....

....

....

....

Mass = ... kg

(Total for Question 11 = 17 marks)

12 The photograph shows the circular tunnel of the Large Hadron Collider (LHC), which is an underground particle accelerator. The circumference of the tunnel is 27 km.

*(a) In the LHC, a magnetic field allows charged particles to move at a constant speed in a horizontal circular path of the required radius.

By reference to the force acting on the charged particles, explain how this is achieved.

(4)

....

....

....

....

....

....

....

....

....

....

....

....

(b) In practice the LHC uses electric fields to accelerate the particles so that their momentum gradually increases.

State and explain how the magnetic field in the LHC must change as the momentum of the particles increases.

(2)

....

....

....

....

(c) (i) Collisions between particles in high-energy physics experiments often result in the production of an electron-positron pair.

Calculate the minimum energy, in joules, required to produce an electron-positron pair.

(2)

....

....

....

Minimum energy = ... J

(ii) By converting your minimum energy into MeV, give the rest mass of the electron in MeV/c^2.

(3)

....

....

....

Rest mass of electron = ... MeV/c^2

(Total for Question 12 = 11 marks)