7.3 The Structure of Matter

Question Paper

Course	DP IB Physics
Section	7. Atomic, Nuclear & Particle Physics
Topic	7.3 The Structure of Matter
Difficulty	Hard

Time allowed: 70

Score: /51

Percentage: /100

Question 1a

Particle X has a strangeness of −1 and decays to produce a proton and a pion.

$$X \rightarrow p + \pi^{-}$$

(a)
Deduce the quark structure of particle X.

[3]

[3 marks]

Question 1b

A strange quark decays in the following way

$$s \rightarrow u + Y + d$$

(b)
Deduce particle Y.

[3]

[3 marks]

Question 1c

(c)
Hence, draw a Feynman diagram at the quark level for the decay of particle X.

[3]

[3 marks]

Question 2a

a)
Explain why the discovery of the Higgs Boson was of crucial significance.

[3]

[3 marks]

Question 2b

(b)
Draw a Feynman diagram for the interaction

$$e^- + e^+ \rightarrow d + \bar{d}$$

Assume that the time axis is from left to right.

[3]

[3 marks]

Question 2c

(c)
Explain why multiple hadrons have been produced in this reaction.

[3]

[3 marks]

Question 3a

A young student of physics reads up about particles and anti-particles.

In their physics lesson, they excitedly tell their teacher how they learned that a proton has an anti-particle called an anti-proton, and the neutron has an anti-particle called an anti-neutron.

They go on to say that, since the neutron is neutrally charged, it is its own anti-particle.

(a)
Identify the student's misconception and explain why they are incorrect.

[3]

[3 marks]

Question 3b

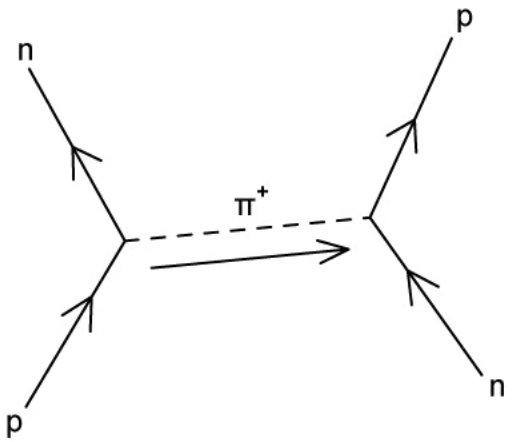
(b)
Suggest another particle which is an example of being its own anti-particle and explain your reasoning.

[2]

[2 marks]

Question 3c

Interactions between protons and neutrons can temporarily violate conservation laws.



One such interaction is shown.

(c)

(i)

Identify the type of interaction shown.

[1]

(ii)

By referencing the properties of the exchange particle, explain how it temporarily violates conservation laws.

[2]

[3 marks]

Question 4a

The baryon decuplet is a vision tool used by particle physicists to classify groups of particles called baryons.

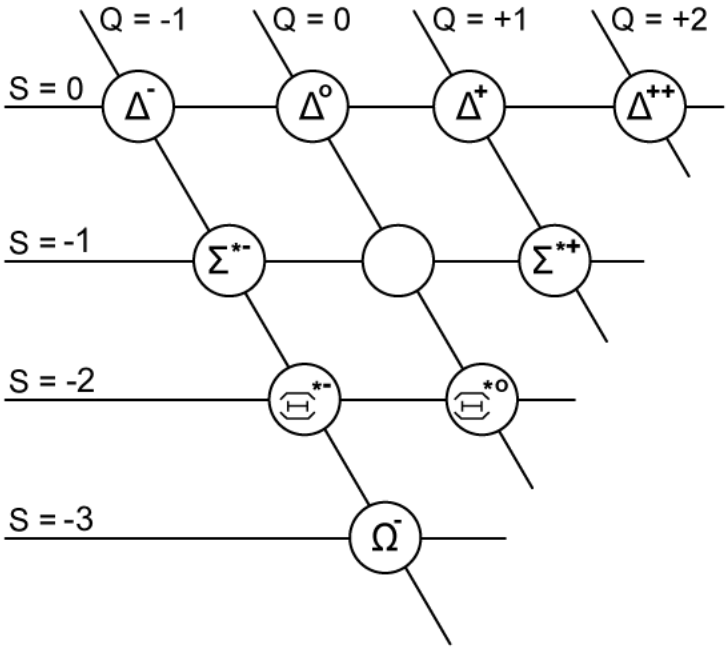
(a)
Discuss the properties of baryons.

[4]

[4 marks]

Question 4b

In the baryon decuplet, strangeness S is plotted on the horizontal axes and charge Q is plotted on the diagonal axe. Some information is missing.



(b)

Deduce the quark composition of the Ω^- baryon, using each axis to justify your answer.

[3]

[3 marks]

Question 4c

(c)

Deduce the quark composition and an appropriate symbol for the missing baryon.

[4]

[4 marks]

Question 5a

(a)

(i) State two particles that are their own antiparticle.

[2]

(ii) Explain why K^0 is not its own antiparticle.

[1]

[3 marks]

Question 5b

(b)

The K^0 meson decays into two pions and has a strangeness of 1. State the decay equation at the quark level for the K^0 meson.

[3]

[3 marks]

Question 5c

Heavier quarks can decay into lighter quarks by exchanging a virtual particle that meditates the type of interaction. This particle can then decay into a quark and its equivalent anti-quark.

(c)
Draw a Feynman diagram for the decay of the K^0 meson at the quark level. Clearly label the K^0 meson and the two pions.

[4]

[4 marks]

Question 5d

Muons decay via the same interaction as the K^0 meson into leptons. One such decay is

$$\mu^- \rightarrow e^- + \overline{\nu}_e + \_\_\_\_$$

(d)
(i)
Complete the missing particle in the decay.

[1]

(ii)
Draw the Feynman diagram for the decay of a negative muon, (μ^-). Clearly label the time axis.

[3]

[4 marks]