Particle Physics

Q1. (a) The K^- meson has strangeness –1.

(i) State the quark composition of a meson.

.....

(1)

(ii) State the baryon number of the K^- meson.

.....

(1)

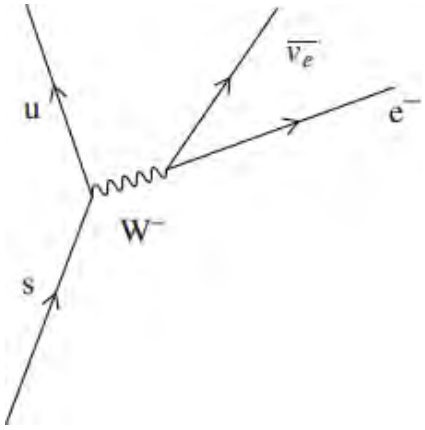
(iii) What is the quark composition of the K^- meson?

.....

.....

(1)

(b) The figure below shows a Feynman diagram for a possible decay of the strange quark.



(i) Which interaction is responsible for this decay?

.....

(1)

(ii) Energy and momentum are conserved when the W^- particle is produced. State **two** other quantities that are also conserved and **one** that is not.

conserved .....

conserved .....

not conserved .....

(3)

(iii) Complete this equation for the decay of a K^- meson.

$K^- \rightarrow$ ..... + ... + ...

(2)
(Total 9 marks)

Q2. (a) Protons can interact with electrons by gravity and by two other fundamental interactions. In the following table identify these interactions and name the exchange particle involved.

interaction	exchange particle

(2)

(b) State the quark composition of a proton.

.....

(1)

(c) A change in quark identity is involved in *electron capture*.

(i) Explain what is meant by electron capture.

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(3)

(ii) In the space below draw a Feynman diagram representing electron capture.

(3)
(Total 9 marks)

Q3. (a) (i) Give an example of an exchange particle other than a W^+ or W^- particle, and state the fundamental force involved when it is produced.

exchange particle .....

fundamental force .....

(ii) State what roles exchange particles can play in an interaction.

.....

.....

.....

(4)

(b) From the following list of particles,

p $\bar{n}$ ν_e e^+ μ^- π^0

identify **all** the examples of

(i) hadrons, ...

(ii) leptons, ….....

(iii) antiparticles, ...

(iv) charged particles. .....

(4)
(Total 8 marks)

Q4. The equation represents the collision of a neutral kaon with a proton, resulting in the production of a neutron and a positive pion.

$K^\circ + p \longrightarrow n + \pi^+$

(a) Show that this collision obeys **three** conservation laws in addition to energy and momentum.

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(3)

(b) The neutral kaon has a strangeness of +1.
Write down the quark structure of the following particles.

K° .....

π^+ .....

p .....

(4)
(Total 7 marks)

Q5. (a) The table gives information about some fundamental particles.

Complete the table by filling in the missing information.

particle	quark structure	charge	strangene	baryon number
	uud		0	
Sigma $^+$	uus	+ 1		
	$u\bar{d}$		0	0

(7)

(b) Each of the particles in the table has an antiparticle.

(i) Give **one** example of a baryon particle **and** its corresponding antiparticle.

particle .....

antiparticle .....

(1)

(ii) State the quark structure of an antibaryon.

.....

(1)

(iii) Give **one** property of an antiparticle that is the same for its corresponding particle and **one** property that is different.

Same .....

.....

Different .....

.....

(2)

(Total 11 marks)

Q6. (a) (i) Name two baryons.

.....

(2)

(ii) State the quark structure of the pion π^+.

.....

(1)

(b) (i) The K^+ kaon is a strange particle. Give **one** characteristic of a strange particle that makes it different from a particle that is not strange.

.....

.....

(1)

(ii) One of the following equations represent a possible decay of the K^+ kaon.

$$K^+ \rightarrow \pi^+ + \pi^0$$

$$K^+ \rightarrow \mu^+ + \overline{\nu_\mu}$$

State, with a reason, which one of these decays is not possible.

.....

.....

(2)

(c) Another strange particle, X, decays in the following way:

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

(i) State what interaction is involved in this decay.

.....

(1)

(ii) Show that X must be a neutral particle.

.....

.....

(1)

(iii) Deduce whether X is a meson, baryon or lepton, explaining how you arrive at your answer.

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(2)

(iv) Which particle in this interaction is the most stable?

.....

(1)

(Total 11 marks)

Q7. (a) (i) Underline the particles in the following list that may be affected by the weak interaction.

positron neutron photon neutrino positive pion

(ii) Underline the particles in the following list that may be affected by the electromagnetic force.

electron antineutrino proton neutral pion negative muon

(4)

(b) A positive muon may decay in the following way,

$$\mu^+ \Rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

(i) Exchange each particle for its corresponding antiparticle and complete the equation to show how a negative muon may decay.

$$\mu^- \Rightarrow$$

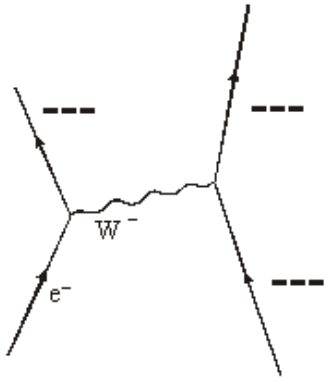
(ii) Give **one** difference and **one** similarity between a negative muon and an electron.

difference .....

similarity .....

(3)

(c) Complete the Feynman diagram, which represents electron capture, by labelling all the particles involved.



(3)
(Total 10 marks)

Q8. Sub-atomic particles can either be hadrons or leptons.

(a) (i) State **one difference** between these two groups of particles.

.....

(1)

(ii) Give an example of a non-strange hadron and an example of a lepton.

hadron .....

lepton .....

(2)

(iii) Hadrons can be further divided into two groups. Name these two groups **and** state a difference between them.

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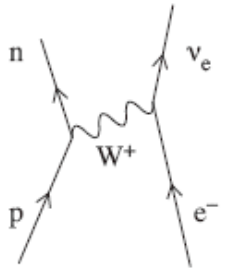
(3)

(b) The Feynman Diagram in the figure below represents an interaction known as electron capture.



State a conservation law obeyed in this interaction. Show how the property mentioned in the law is conserved.

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(2)
(Total 8 marks)

Q9. (a) *Hadrons* are a group of particles composed of quarks. Hadrons can either be baryons or mesons.

(i) What property defines a hadron?

.....

(1)

(ii) What is the quark structure of a baryon?

.....

(1)

(iii) What is the quark structure of a meson?

.....

(1)

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

similarity .....

.....

difference .....

.....

(2)

(c) Complete the table below which lists properties of the antiproton.

	charge / C	**baryon number**	**quark structure**
antiproton			

(2)

(d) The K^- is an example of a meson with strangeness –1. The K^- decays in the following way:

$K^- \rightarrow \mu^- + \overline{\nu_\mu}$

(i) State, with a reason, what interaction is responsible for this decay.

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.....

(2)

(ii) State **two** properties, other than energy and momentum, that are conserved in this decay.

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(2)
(Total 11 marks)

Q10. The quark model was developed to help understand hadrons. Quarks cannot exist separately, they form combinations.

(a) (i) List the **three** combinations that quarks can form.

....

(ii) Give the quark combination for a positive pion, π^+ and an antiproton, $\bar{p}$.

π^+ .....

$\bar{p}$ .....

(4)

(b) The event represented by, $K^- + p \rightarrow K^0 + K^+ + X$, is a strong interaction.

The K^- has strangeness –1 and the kaons K^+ and K^0 both have strangeness +1.

(i) Use the conservation laws to deduce the strangeness, charge, baryon number and lepton number of the particle represented by X.

Strangeness .....

Charge .....

Baryon number .....

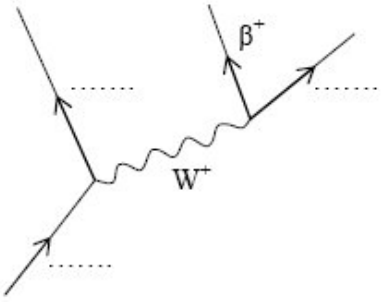
Lepton number …….....

(ii) What will particle X eventually decay into?

.....

(4)
(Total 8 marks)

Q11. (a) Complete the labelling of the Feynman diagram below representing positron emission from an individual nucleon.



(3)

(b) (i) What is the virtual exchange particle used by electromotive force?

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(ii) State **two** differences between the exchange particles used by the weak interaction and used by the electromagnetic force.

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.....

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(3)

(c) The theoretical work of Dirac suggested that for every particle there should exist a corresponding antiparticle. The first to be antiparticle to be discovered was the positron.

(i) State what is meant by an antiparticle.

.....

.....

(ii) Write down the corresponding antiparticle for each of the particles listed in the following table.

Particle	antiparticle
β^-	β^+
π^o	
K^o	
γ	

(5)
(Total 11 marks)

Q12. (a) (i) Name a force which acts between an up quark, u, and an electron. Explain, with reference to an exchange particle, how this force operates.

You may be awarded marks for the quality of written communication in your answer.

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(ii) With what particle must a proton collide to be annihilated?

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(4)

(b) A sigma plus particle, Σ^+, is a baryon.

(i) How many quarks does the Σ^+ contain?

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(ii) If one of these quarks is an s quark, by what interaction will it decay?

.....

(iii) Which baryon will the Σ^+ eventually decay into?

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(3)
(Total 7marks)