Q1.(a) Complete the following equation for beta minus (β^-) decay of strontium-90 ($^{90}_{38}Sr$) into an isotope of yttrium (Y).

$$^{90}_{38}Sr \longrightarrow \ ^{\cdots\cdots}_{\cdots\cdots}Y + \ ^{\cdots\cdots}_{\cdots\cdots}\beta^- + \ ^{0}_{0}\cdots\cdots$$

(3)

(b) During β^- decay of a nucleus both the nucleon composition and the quark composition change.
State the change in quark composition.

.....

(1)

(c) A positive kaon consists of an up quark and an antistrange quark $(u\,\bar{s})$. This kaon decays by strong and weak interactions into three pions. Two of the pions have quark compositions of $(u\,\bar{d})$. The third pion has a different quark composition.

(i) Name the unique family of particles to which the kaon and pions belong.

.....

(1)

(ii) Tick the box corresponding to the charge of the third pion.

positive ☐ negative ☐ neutral ☐

(1)

(iii) Positive kaons have unusually long lifetimes.
Give a reason why you would expect this to be the case.

.....

.....

(1)

(iv) Name the exchange particles which are involved in the strong and weak interactions of the kaon.

strong interaction .....

weak interaction .....

(1)
(Total 8 marks)

Q2. Which of the following is **not** true?

A Each meson consists of a single quark and a single antiquark. ⬭

B Each baryon consists of three quarks. ⬭

C The magnitude of the charge on every quark is $\frac{1}{3}$ ⬭

D A particle consisting of a single quark has not been observed. ⬭

(Total 1 mark)

Q3. (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		
	ud		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)

Q4. (a) Give the name of a particle that is a hadron.

.....

(1)

(b) Pions are mesons.

Give a possible quark structure for a pion.

.....

(1)
(Total 2 marks)

Q5. (a) The Σ^+ particle is a baryon with strangeness –1.

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

.....

.....

answer .....

(1)

(ii) How many of the quarks are strange?

.....

.....

answer .....

(1)

(b) The Σ^+ decays in the following reaction

$$\Sigma^+ \rightarrow \pi^+ + n$$

(i) State **two** quantities that are conserved in this reaction.

.....

.....

(2)

(ii) State a quantity that is not conserved in this reaction.

.....

(1)

(iii) What interaction is responsible for this reaction?

.....

(1)

(iv) Into what particle will the neutron formed in this reaction eventually decay?

.....

(1)

(Total 7 marks)

Q6. (a) Name **three** types (or *flavours*) of quark.

.....

.....

(2)

(b) By referring to the charges on quarks, explain why the neutron is uncharged.

.....

.....

(2)
(Total 4 marks)

Q7. Leptons, mesons and baryons are three classes of sub-atomic particles.

(a) Some classes of particles are fundamental; others are not. Circle the correct category for each of these three classes.

Leptons fundamental/not fundamental
Mesons fundamental/not fundamental
Baryons fundamental/not fundamental

(1)

(b) Name the class of particles of which the proton is a member.

.....

(1)

(c) By referring to the charges on up and down quarks, explain how the proton has a

charge of + 1*e*.

.....

.....

(2)
(Total 4 marks)

Q8. 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.

.....

.....

.....

.....

.....

(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)

Q9. (a) Give the number of nucleons and the number of electrons in an atom of $^{22}_{11}Na$.

nucleons .....

electrons .....

(2)

(b) The isotope $^{22}_{11}Na$ is a positron emitter. In positron emission an up quark undergoes the following change,

$u \rightarrow d + \beta^{+} + \nu_e$.

Show that charge, lepton number and baryon number are conserved in this decay.

charge .....

lepton number .....

baryon number .....

(3)

(c) Describe what happens when a positron collides with an electron.

.....

.....

.....

(2)
(Total 7 marks)

Q10. (a) Quarks may be combined together in a number of ways to form sub-groups of hadrons. Name **two** of these sub-groups and for each, state its quark composition.

sub-group 1 .....

.....

sub-group 2 .....

.....

(3)

(b) A free neutron is an unstable particle.

(i) Complete the following to give an equation that represents the decay of a neutron.

$n \rightarrow$

(ii) Describe the change that occurs to the quark structure when a neutron decays.

.....

.....

.....

.....

.....

(4)
(Total 7 marks)