11. Particle Physics

11.2 Fundamental particles

Paper 2

Question Paper

1 A particle Q and a particle R are each composed of one quark and one antiquark.

(a) State the name of the class (group) of particles that includes Q and R.

..... [1]

(b) Q has a charge of –1*e*, where *e* is the elementary charge. R has a charge of 0.

Complete Table 7.1 to show a possible second quark in each of Q and R.

Table 7.1

	charge	first quark	second quark
Q	–1*e*	strange	
R	0	anti-up	

[2]

2 **(a)** Potassium-40 ($^{40}_{19}K$) undergoes β^- decay to form a nuclide of element X. Particle Z is emitted during the decay. The equation for the decay is shown.

$$^{40}_{19}K \rightarrow {}^{P}_{Q}X + {}^{R}_{S}\beta^- + Z$$

(iii) State the name of the class of fundamental particle to which both the β^- particle and particle Z belong.

..... [1]

(b) Determine the quark composition of an alpha-particle.

quark composition ..... [3]

3 **(a)** Nucleus P and nucleus Q are isotopes of the same element.

Nucleus Q is unstable and emits a β^- particle to form nucleus R.

(ii) When nucleus Q decays to form nucleus R, the quark composition of a nucleon changes.

State the change to the quark composition of the nucleon.

..... [1]

(b) A hadron consists of two charm quarks and one bottom quark.

Determine, in terms of the elementary charge *e*, the charge of the hadron.

charge = ... *e* [2]

4 **(c)** Table 7.1 lists the names of three particles and possible classifications for them.

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			
neutron			
positron			

Complete Table 7.1 by placing ticks (✓) in the boxes to indicate the classifications that apply to each particle. [2]

(d) The discovery of a particle with an unusual charge was an important step in the development of the theory of quarks. The particle is a hadron with a mass of 2.19×10^{-27} kg and a charge of +2*e*, where *e* is the elementary charge.

(ii) Determine a possible quark composition of a hadron with a charge of +2*e*.
Explain your reasoning.

[2]

5 **(a)** In the following list, underline **all** the particles that are **not** fundamental.

antineutrino baryon nucleon positron [1]

(c) A meson has a charge of –1*e*, where *e* is the elementary charge. The quark composition of the meson includes a charm antiquark.

State and explain a possible flavour (type) of the other quark in the meson.

.....

..... [2]

6 **(b)** A particle P is composed of an up quark (u) and a down antiquark ($\bar{d}$).

(i) Calculate the charge q of particle P in terms of e, where e is the elementary charge.

Show your working.

q = ... e [2]

(ii) Particle P belongs to **two** classes (groups) of particles.

State the names of these two classes.

1 .....

2 .....
[2]

7 **(a)** A nucleus of caesium-137 ($^{137}_{55}Cs$) decays by emitting a β^- particle to produce a nucleus of an element X and an antineutrino. The decay is represented by

$$^{137}_{55}Cs \rightarrow {}^{Q}_{S}X + {}^{P}_{R}\beta^- + {}^{0}_{0}\overline{\nu}.$$

(ii) State the name of the class (group) of particles that includes the β^- particle and the antineutrino.

..... [1]

(b) A particle Y has a quark composition of ddd where d represents a down quark.

A particle Z has a quark composition of $\overline{u}d$ where $\overline{u}$ represents an up antiquark.

(i) Show that the charges of particles Y and Z are equal.

[2]

(ii) State and explain which particle is a meson and which particle is a baryon.

meson: .....

.....

baryon: .....

.....

[2]

8 **(a)** A lepton is an example of a fundamental particle.

State what is meant by fundamental particle.

.....

..... [1]

(b) A lambda particle Λ^0 is a hadron that consists of an up (u) quark, a down (d) quark and a strange (s) quark.

Show that the charge on the Λ^0 particle is zero.

[2]

(c) The Λ^0 particle is unstable. It can decay into a neutron (n) and a pion (π^0) as shown by

$$\Lambda^0 \longrightarrow n + \pi^0.$$

The π^0 particle consists of an up quark and an up antiquark.

(i) Compare the properties of an up quark and an up antiquark.

.....

.....

..... [2]

(ii) Explain why the neutron is classed as a baryon and the π^0 particle is classed as a meson.

.....

.....

..... [2]

9 **(c)** Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of +2*e*, where *e* is the elementary charge.

State the quark composition of:

(i) particle P

..... [1]

(ii) particle Q.

..... [1]

10 (a) A proton in a nucleus decays to form a neutron and a β^+ particle.

(iv) Use the quark model to show that the charge on the proton is $+e$, where e is the elementary charge.

[2]

(v) The quark composition of the proton is changed during the decay.

Describe the change to the quark composition.

.....

..... [1]

11 (b) An α-particle is made up of other particles. One of these particles is a proton.

State and explain whether a proton is a fundamental particle.

.....

..... [1]

12 (b) Carbon-14 is radioactive and decays by emission of β^- particles.

(i) Nuclei do not contain β^- particles.

Explain the origin of the β^- particle that is emitted from the nucleus during β^- decay.

.....

.....

..... [1]

(ii) State the change in the quark composition of a carbon-14 nucleus when it emits a β^- particle.

..... [1]

13 (b) A hadron is composed of three identical quarks and has a charge of $+2e$, where e is the elementary charge.

Determine a possible type (flavour) of the quarks.
Explain your working.

.....

..... [2]

14 (a) State a similarity and a difference between a down quark and a down antiquark.

similarity: .....

difference: .....
[2]

15 (a) State a similarity and a difference between an up quark and an up antiquark.

similarity: .....

difference: .....
[2]

16 (b) A hadron has an overall charge of $+e$, where e is the elementary charge. The hadron contains three quarks. One of the quarks is a strange (s) quark.

(i) State the charge, in terms of e, of the strange (s) quark.

charge = ... [1]

(ii) The other two quarks in the hadron have the same charge as each other.

By considering charge, determine a possible type (flavour) of the other two quarks. Explain your working.

.....

.....[2]

17 (c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....

.....[3]

18 (b) A hadron consists of two down quarks and one strange quark.

Determine, in terms of the elementary charge e, the charge of this hadron.

charge = ... [2]

19 A stationary nucleus X decays to form nucleus Y, as shown by the equation

$$X \longrightarrow Y + \beta^- + \bar{\nu}.$$

(a) In the above equation, draw a circle around all symbols that represent a lepton. [1]

(e) The quark composition of one nucleon in X is changed during the emission of a β^- particle. Describe this change to the quark composition.

.....

.....[1]

20 **(a)** In the following list, underline all particles that are leptons.

antineutrino positron proton quark [1]