Questions on Particle Physics

1. The following strong interaction has been observed.

$$K^- + p \rightarrow n + X$$

The K^- is a strange meson of quark composition $\bar{u}s$.

The u quark has a charge of +2/3.

The d quark has a charge of –1/3.

Deduce the charge of the strange quark.

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(1)

Use the appropriate conservation law to decide whether particle X is positive, negative or neutral.

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(2)

Is particle X a baryon or a meson? Show how you obtained your answer.

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(2)

State the quark composition of X. Justify your answer.

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(3)
(Total 8 marks)

2. The strong force is one of the fundamental interactions. What exchange particle is associated with this force?

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List the other fundamental interactions. Circle the one for which the photon is the exchange particle.

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(Total 5 marks)

3. The Ω^- (omega minus), a particle with strangeness –3, was identified in 1964 in an experiment involving an interaction between a K^- meson of strangeness –1 and a proton.

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

Is the Ω^- particle a baryon or a meson? Give *two* reasons for your answer.

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(2)

Using the information in the table, deduce the quark composition of all particles in the equation.

Quark	Charge	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

p ……………………… Ω^- ..…………………………

K^- …………………….. K^+ …………………. K^0 …………………...

(4)
(Total 6 marks)

4. The theory of relativity established that all forms of energy possess mass and, conversely, that material particles are a form of energy. If enough energy is concentrated, new particles of matter will appear. Thus, the violent collision of two protons, for example, can produce more protons. Whenever matter is created this way in the laboratory it is always accompanied by an equivalent quantity of antimatter. Each lepton and quark possesses an antiparticle in which all the physical properties except mass are reversed. If an antiparticle encounters its mirror particle they annihilate each other, usually in the form of gamma radiation.

[Adapted from Paul Davies: *The particles and forces of nature*, in Revised NAS Physics, Longman 1986.]

(a) The collision between two protons is described as being a violent collision. Explain why the collision must be a violent one in order to produce more protons.

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(2)

(b) Whenever matter is created "*it is always accompanied by an equivalent quantity of antimatter*".

What conservation laws does this statement imply?

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(3)

(c) An electron encounters a positron. The rest mass of an electron and that of a positron is 0.000 55u.

Describe the outcome of the encounter.

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Support your description with relevant calculations.

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(4)
(Total 9 marks)

5. In 1995 scientists at CERN created, for the first time, anti-atoms of hydrogen. Each of these consisted of an anti-electron (a positron) in orbit around an antiproton. Each anti-atom produced survived for only about forty nanoseconds.

How do the properties of particles and antiparticles compare?

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(1)

Show that the energy required to produce an antiproton is about 1 GeV.

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(3)

Why did each anti-atom produced survive for only about forty nanoseconds?

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(2)

Tick appropriate boxes in the table below to show the nature of each of the named particles.

	Meson	Baryon	Lepton
proton			
antiproton			
electron			
positron			

(2)

A proton consists of two up quarks and a down quark. Describe the quark structure of an antiproton and show how this structure provides the correct charge.

(Charge of up quark = $+\frac{2}{3}e$)

(Charge of down quark = $-\frac{1}{3}e$)

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(2)
(Total 10 marks)

6. In 1989 the Large Electron Positron collider (LEP) at CERN was opened. It was used until 2000, when it was shut down to allow the construction of a new accelerator. At LEP, beams of electrons and positrons were accelerated to energies of 100 GeV in a huge ring with a circumference of 27 km before being made to collide with each other.

Just before LEP closed, scientists using it found some evidence for the proposed Higgs boson at a mass of 115 GeV/c^2.

Explain why 1 eV is equal to 1.6×10^{-19} J.

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(2)

Show how GeV/c^2 can be used as a unit of mass.

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(2)

If the Higgs boson has a mass of 115 GeV/c^2, find its mass in kg.

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Mass = ... kg

(2)

The positron is the antiparticle to the electron. What is an **antiparticle**?

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(1)

A description of LEP refers to '....the relatively small magnetic field required for LEP's gentle curvature....'.

Explain the need for a magnetic field and why it can be 'relatively small' in this case.

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(4)
(Total 11 marks)

7. The table below summarises some properties of some particles in the standard quark-lepton model.

Quarks			Leptons		
Name	Symbol	Charge	Name	Symbol	Charge
up	u	+2/3	electron	e^-	–1
down	d	–1/3	electron-neutrino	ν_e	0

Write bullet points to explain the composition of everyday matter using the information in the table.

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(Total 6 marks)

8. Describe the production of a beam of high energy **electrons** in a particle accelerator, and suggest why these electrons would be appropriate for investigating the fine structure of sub-atomic particles.

(Total 7 marks)