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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Fundamental particles

Quarks, beta decay and accelerator event records

35–40 minutes independent work + 15–20 minutes review

OCR A H556 | A-level physics | Module 6 | 35 marks

Specification points covered

6.4.2(a–g) Particles and antiparticles, hadrons and leptons, and the u d s quark model.

6.4.2(h–l) Beta-minus/beta-plus decay and charge conservation in quark transformations.

No Feynman diagrams, exchange-boson identification or strangeness-number calculations are required.

Use quark charges u = +⅔e, d = −⅓e, s = −⅓e. Each antiquark has the opposite electric charge to its corresponding quark. Neutrinos and antineutrinos are electrically neutral.

Use a calculator and your OCR A data booklet. Show working, units and directions where relevant.

1 Prepare the identity checks

An accelerator team must accept or reject particle identity cards and reconstruct beta-decay events before approving its calibration software. Use the supplied event information, charge and particle composition to justify decisions.

Other than the proton and neutron, any unfamiliar hadron composition needed is supplied. Do not assume that particles with the same electric charge must be the same particle.

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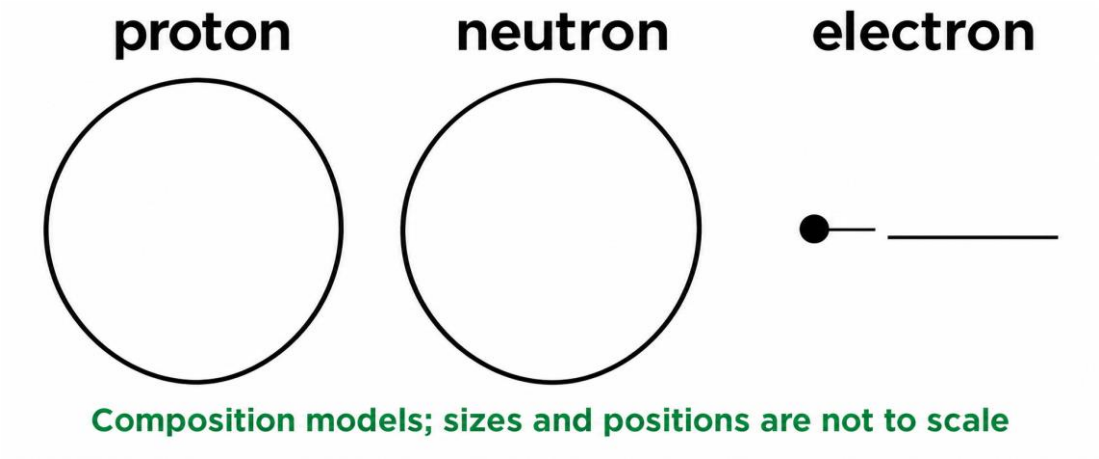


Figure 1 Particle-model reference panel; interiors deliberately unfilled

1(a) In blank space, draw a simple quark-content model for a proton and for a neutron. Label each quark. These are composition models, not drawings of fixed quark positions. **[2 marks]**

1(b) State one physical distinction between hadrons and leptons that the software should use, rather than comparing their masses. **[1 mark]**

2 Check antiparticle and interaction records

2(a) The software stores an electron's rest mass as m_e and charge as −e, and a proton's rest mass as m_p and charge as +e. Give the rest mass and charge of the corresponding positron and antiproton. **[2 marks]**

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2(b) An antineutron and a neutron have equal rest masses and are both electrically neutral. Can those two properties alone distinguish them? Explain. **[1 mark]**

2(c) A database labels a particle as an electron, but says that it experiences the strong nuclear force. Identify the error and state which nuclear interaction an electron can experience. **[2 marks]**

2(d) A programmer suggests classifying particles as hadrons whenever their mass is greater than an electron's mass. Explain why this is not an appropriate defining rule. **[1 mark]**

3 Audit quark-content cards

3(a) Card A gives a hadron with composition uds. Card B gives u and anti-s. Calculate the charge of each in units of e. **[2 marks]**

3(b) Card C has composition uus and charge +e. The software identifies it as a proton because its charge matches. Evaluate this identification. **[2 marks]**

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3(c) A neutral neon-22 calibration atom has Z = 10. Determine the total numbers of up quarks, down quarks and electrons in its simple constituent model. **[2 marks]**

3(d) Use those quark charges to check the nucleus's total charge. Then include the electrons to check the atom's net charge. **[2 marks]**

4 Reconstruct beta-minus events

4(a) Potassium-40 has proton number 19 and undergoes beta-minus decay to calcium. Write its complete nuclear equation, including the emitted lepton pair. **[2 marks]**

4(b) Write the quark-level beta-minus transformation and verify electric charge conservation in units of e. **[2 marks]**

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4(c) Explain why the nucleus's proton number increases but its nucleon number stays the same. **[2 marks]**

4(d) Name both emitted leptons in beta-minus decay. Distinguish the neutral one from the neutral lepton emitted in beta-plus decay. **[1 mark]**

5 Reconstruct beta-plus events

5(a) A suitable nitrogen-13 nucleus has Z = 7 and undergoes beta-plus decay to carbon. Write the complete nuclear equation, including the emitted lepton pair. **[2 marks]**

5(b) Write the quark-level beta-plus transformation and verify electric charge conservation. **[2 marks]**

5(c) A record says that the emitted positron was an electron already orbiting the nitrogen nucleus. Explain the error. **[1 mark]**

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5(d) State the changes in proton and neutron numbers during this beta-plus event and explain why A is unchanged. **[1 mark]**

6 Judge unfamiliar event records

6(a) A supplied model event has $s \rightarrow u + e^{-} + \bar{\nu}_e$ inside a suitable hadron. Check charge conservation and explain why the presence of a strange quark does not invalidate that check. **[2 marks]**

6(b) Record L describes a fundamental particle that experiences the weak interaction but not the strong interaction. Record H describes a quark-composite particle that experiences both. Classify each. **[1 mark]**

6(c) Correct both claims: “A neutrino cannot carry energy because it has zero charge” and “A neutron is fundamental because it has zero charge.” **[2 marks]**

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