

## Extended worksheet – Option J, Worksheet 1

- 1 Explain why the neutral meson  $d\bar{s}$  cannot be its own antiparticle. [1]
- 2 State the Pauli principle. [1]
- 3 In a laser, very many photons occupy the same quantum state. Explain why this does not violate the Pauli principle. [2]
- 4 A photon is exchanged between two electrons. The photon does not exist for more than  $10^{-12}$  s. Calculate by what amount energy conservation could be violated as a result of this exchange. [2]
- 5 State what is meant by a **virtual particle**. [2]
- 6 Assume that the quark content of the neutral pion is  $\pi^0 = u\bar{u}$ . The pion decays into two photons,  $\pi^0 \rightarrow \gamma + \gamma$ .
  - a Draw a Feynman diagram for this decay labelling all particles in the diagram. [1]
  - b State the name(s) of any virtual particle(s) appearing in your diagram. [1]
- 7 The positive pion  $\pi^+ = u\bar{d}$  decays into a muon and a neutrino according to  $\pi^+ \rightarrow \mu^+ + \nu$ .
  - a Draw a Feynman diagram for this decay. [2]
  - b State the name(s) of any virtual particle(s) appearing in your diagram. [1]
  - c (HL only) Explain why the produced neutrino must be a muon neutrino. [1]
- 8 Draw Feynman diagrams for the processes
  - a  $e^- + e^- \rightarrow e^- + e^-$  [1]
  - b  $e^- + e^+ \rightarrow e^- + e^+$  [1]
  - c  $\gamma + \gamma \rightarrow \gamma + \gamma$  [1]
  - d Suggest why the reaction in **c** occurs much more rarely than the other two. [1]
- 9 The range of the weak interaction is of order  $10^{-18}$  m. Estimate the mass of the exchange particles of the weak interaction in  $\text{GeV } c^{-2}$ . [3]
- 10 The K meson ( $K^- = s\bar{u}$ ) decays according to the reaction  $K^- \rightarrow \mu^- + \bar{\nu}_\mu$ .
  - a Explain how it may be deduced that the decay takes place through the weak interaction. [2]
  - b (HL only) Suggest whether the neutrino in this decay could have been an electron neutrino. [2]
- 11 State the types of particles that carry colour quantum numbers. [2]



- 12** By reference to the Pauli principle and the spin  $3/2$  baryon (uuu), explain the need for colour. [2]
- 13** State what is meant by the term **confinement**. [1]