# Extended worksheet – Option J, Worksheet 2

**1** The momentum of a proton accelerated to a total energy of 7 TeV in the LHC is about $4\times10^{-15}$ Ns. Estimate the smallest size that can be resolved by such a proton. [3]

**2** State and explain a property of a particle that can be measured in a bubble chamber. [3]

**3** State and explain one advantage of a wire chamber over the bubble chamber. [2]

**4** State what is meant by **available energy** in a collision. [1]

**5** In a synchrotron protons are accelerated to a total energy of 7 TeV. They collide with protons of total energy 7 TeV that are moving in the opposite direction. Calculate the available energy in the collision. [1]

**6** A proton of rest mass $938\ \text{MeV}\,\text{c}^{-2}$ is accelerated from rest so that its final kinetic energy becomes 2500 MeV.

**a** State the total energy of the proton. [1]

**b** The proton in **a** collides with a proton at rest. Calculate the available energy in the collision. [2]

**7** Calculate the minimum total energy of an electron so that when it collides with a stationary electron the reaction $e^- + e^- \rightarrow e^- + e^- + e^- + e^+$ takes place. [3]

**8** State one advantage and one disadvantage of collisions in a synchrotron over collisions in a linear accelerator. [2]

**9** In a synchrotron, a proton is accelerated to a total energy *E*. The energy that must be provided to the proton is much greater than *E*. Explain this observation. [2]

**10** Quarks and leptons are divided into three families. State a difference between quarks and leptons that belong to different families. [1]

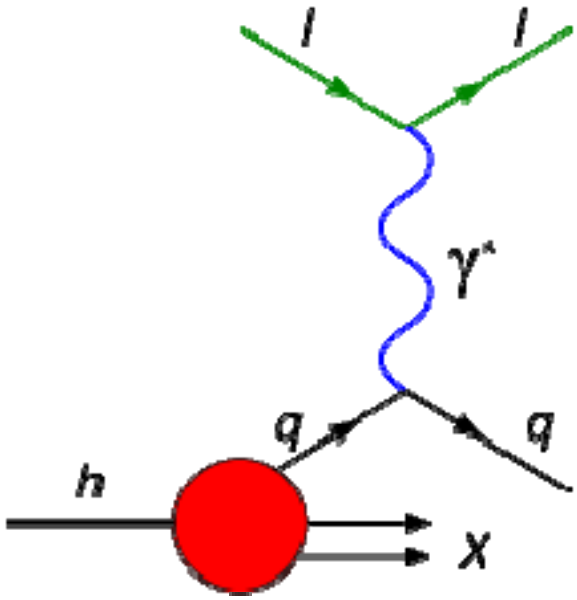
**11** The reaction $\mu^- \rightarrow \gamma + e^-$ does not occur because it violates two conservation laws. State the laws that would be violated if this reaction were to occur. [2]

**12** The muon does decay into an electron but not by the reaction above.

**a** State the correct reaction for this decay. [2]

**b** Draw a Feynman diagram for it. [3]

**13** The diagram below is a typical Feynman diagram for a deep inelastic process.




State the type of particle represented by

**a** the red circle. [1]

**b** the blue line. [1]

**c** the green line. [1]

**14** State three conclusions that may be reached from deep inelastic scattering experiments. [3]

**15** Discuss the experimental evidence for asymptotic freedom. [2]

**16** Calculate the lowest temperature at which production of an electron–positron pair becomes possible. [2]

**17** Describe a mechanism by which the present dominance of matter over antimatter is explained. [4]