1. In high-energy physics a system of units in which $h = c = 1$ is sometimes used. In this system show that length $\propto 1/m$, time $\propto 1/m$, energy $\propto m$ and momentum $\propto m$. If $m$ is taken as the mass of a proton, what are the magnitudes of the units of length and of time?

2. In the elastic scattering of 200 MeV electrons through 11° by a gold foil, it is found that the scattered intensity is 70% of that expected for point nuclei. Calculate the r.m.s. radius of the gold nucleus.

3. An electron with energy $E$ scatters off a stationary target of mass $M$, transferring momentum $p$ and energy $\nu = E - E'$, where $E'$ is the electron's final energy. The 4-momentum transfer $q$ is given by $q^2 = p^2 - \nu^2/c^2$. Find an expression for $W$, the mass of the recoiling hadronic system in an inelastic collision in terms of $M$, $\nu$ and $q^2$. Show that for an elastic ($W = M$) collision $M = q^2/2\nu$. If the electron scattering angle is $\theta$, show that, neglecting the electron mass, $q^2c^2 = 4EE'\sin^2(\theta/2)$. In electron scattering off carbon at $E = 194$ MeV and $\theta = 135^\circ$ a peak at $\nu = 5.58$ MeV and a broad peak near $\nu = 51$ MeV are observed. Account for their origin and explain why the peak near 51 MeV is broad.

4. (a) Show that a negative muon captured in an $S$-state by a nucleus of charge $Ze$ and mass $A$ will spend a fraction $f \approx 0.25A(Z/137)^3$ of its time in nuclear matter, and that in time $t$ it will travel a total distance $fct(Z/137)$ in nuclear matter. (b) The law of radioactive decay of free muons is $dN/dt = -\lambda_d N$, where $\lambda_d = 1/\tau$ is the decay constant and the lifetime $\tau = 2.16 \mu$s. For a negative muon captured in an atom Z, the decay constant is $\lambda = \lambda_d + \lambda_c$, where $\lambda_c$ is the probability of nuclear capture per unit time. For aluminium ($Z = 13, A = 27$) the mean lifetime of negative muons is 0.88 $\mu$s. Calculate $\lambda_c$, and using the expression for $f$ in (a), compute the interaction mean free path $\Lambda$ for a muon in nuclear matter. (c) From the magnitude of $\Lambda$ in (b) estimate the magnitude of the coupling constant in the reaction $\mu^- + p \to n + \nu$, assuming that a coupling constant of unity corresponds to a mean free path equal to the range of nuclear forces.

5. The cross-section for the reaction $\pi^- + p \to \Lambda + K^0$ at 1-GeV/c incident momentum is approximately 1 mb (10^{-27} cm^2). Both $\Lambda$- and $K^0$-particles decay with a mean lifetime of about 10^{-10} s. From this information, estimate the relative magnitude of the couplings responsible for the production and decay, respectively, of the $\Lambda$- and $K^0$-particles.

(A simple estimate might be based on the fact that the sizes of the $\bar{u}, p, \Lambda, \bar{K}$ particles are all about 1 fermi.)