1. Considering Yukawa's hypothesis that the nuclear force should be due to the exchange of massive particles (that he called mesons), calculate the expected mass of this hypothetical meson. [5]

2. Draw a table showing all the elementary spin 1/2 anti-particles arranged in three families horizontally with the individual members of each family vertically. In the table give the names, symbols, electric charges, and approximate masses of each anti-particle. [6]

3. In a unit system where $c = \hbar = 1$, the Compton wavelength for an muon is given by $\lambda_\mu = m_\mu^{-1}$: calculate the numerical value.

   In the same system, the Bohr radius of a muonic hydrogen atom is given by $r_B = (\alpha m_\mu)^{-1}$, where α is the fine structure constant $\alpha = 1/137$: calculate the numerical value. [A muonic hydrogen atom is just equivalent to a regular hydrogen atom but the electron is substituted by a muon.] [6]

4. The weak interaction is assumed to be due to W or Z exchange. If the Z has a mass of 90 GeV/c^2, calculate the range of the weak interaction. How does this compare with the size of a nucleon? What are the consequences for the likelihood of nuclear β decay. [6]

5. Two protons are separated by a distance of 10^{-15}m. Calculate (a) the electric force and (b) the gravitational force on one proton due to the other. [4]

   Using the relative strengths of the strong, electromagnetic, weak and gravitational forces, estimate (c) the strong force and (d) the weak force between the two protons. [2]

   Summarise the four results in order of increasing strength. [1]