1. In natural units, one sets $c = 2.99792458 \times 10^8 \text{m/s} = 1$ and $\hbar = 1.05457 \times 10^{-34}$ Js $= 6.58212 \times 10^{-25}$ GeVs $= 1$, so that length, time, mass^{-1}, and energy^{-1} are all measured in the same units. Let us practice some unit conversions:

   a) Substitute the SI values of c and $\hbar$ into the relation $\hbar c = 1$, which is valid in natural units, and write the result in the form 1J = number $\times$ m^{-1}. The result provides a unit conversion formula valid in natural units for converting Joules into meters. Using in addition the relation $1\text{eV} = 1.602176634 \times 10^{-19}$J, write also the corresponding conversion formula between eV and m.

   b) The strong interaction between nucleons can be described effectively as a pion exchange process. In natural units, the pion mass is $m_\pi = 140\,\text{MeV}/c^2 = 140\,\text{MeV}$. What is the characteristic length scale m_π^{-1} of the interaction range in meters? What is the corresponding time scale m_π^{-1} in seconds?

2. A beam of Λ^0 particles produced in a particle accelerator is to be collided with a p^+ target located at a distance $\Delta x = 2.0$ m. The mean lifetime of the Λ^0 particles is $\tau = 2.6 \times 10^{-10}$ s. How large must the energy of the produced Λ^0 particles be in order for at least 50% of them to reach the p^+ target? Compare the result to the rest energy. (Hint: Remember that the particle lifetime is given in its rest frame, and note that the number of particles as a function of time follows a decay law similar to the one discussed in the lectures on p. 80.)

3. Draw the lowest order Feynman diagram(s) for the QED process $e^- + \mu^- \to e^- + \mu^-$. Determine how the electric charge and the lepton numbers associated with each flavour, (L_e, L_μ, L_τ where $L_e(e^\pm) = \pm 1$ etc.), change at each vertex.

4. Draw the lowest order Feynman diagrams for the following QED processes:

   a) $e^+ + e^+ \to e^+ + e^+$

   b) $e^- + \gamma \to e^- + \gamma$

   c) $\tau^+ + \tau^- \to \gamma + \gamma$