1. (Electron Neutrino Scattering, H & M Ex. 12.16)
   If the weak current had a \((V + A)\) structure, \(\gamma^\mu (1 + \gamma^5)\), show that
   \[
   \frac{d\sigma}{d\Omega} = \frac{G_F^2}{4\pi^2} (1 + \cos \theta)^2
   \]
   for both \(\nu_e e\) and \(\bar{\nu}_e e\) scattering, and therefore we would have \(\sigma(\bar{\nu}_e) = \sigma(\nu_e e)\).

2. (Charm Quark Decay)
   Calculate the electron energy spectrum from \(c\)-quark semileptonic decay \(c \rightarrow s + e^+ + \nu_e\),
   ignoring the positron mass, but including the strange quark mass and show that it is given by:
   \[
   \frac{d\Gamma}{dx} = \frac{G_F^2}{16\pi^3} m_c^2 \frac{(x_m - x)^2}{(1 - x)},
   \]
   where \(x = \frac{2E_e}{m_c}\) and \(x_m = 1 - \frac{m_s^2}{m_c^2}\). Sketch or use a computer plot and compare it to what you
   found for the electron energy distribution from \(\mu\) decay.

3. (Charged current deeply inelastic neutrino scattering)
   The CDHS group at CERN in a classic experiment determined that the ratio of high-energy
   neutrino to antineutrino scattering on an isoscalar target was about 2.1. From this number
   deduce the ratio of the fraction of momentum carried by the sea quarks and antiquarks to
   that of the valence quarks under the assumption that:
   
   (a) that there are only \(u\) and \(d\) quarks and antiquarks in the sea; and
   
   (b) that the sea is SU(3)\(_f\) invariant (i.e., equal numbers of \(u\), \(d\), and \(s\) quarks and antiquarks
   in the sea).

4. (Very heavy lepton decay)
   
   (a) At a future \(e^+e^-\) linear collider, we may discover a fourth generation lepton \(L^-\) with a
   mass of 200 GeV. The only decay mode will be \(L^- \rightarrow W^- \nu_L\). Calculate the \(L^-\) width
   assuming that \(\nu_L\) is massless.
   
   (b) Now, just for fun, let’s go to CLIC (a proposed third generation \(e^+e^-\) linear collider)
   and take the mass of the \(L^-\) to be 5 TeV. What is the width now? Can you figure out
   what has gone wrong?

5. (Cabibbo issues)
   
   (a) Estimate the relative ratios for the decay rates \(D^0 \rightarrow K^-\pi^+, \pi^+\pi^-,\) and \(K^+\pi^-\).
   
   (b) Given \(\Gamma(K^+ \rightarrow \pi^0 e^+ \nu_e) = 4 \times 10^6\) sec\(^{-1}\), calculate the rate for \(\Gamma(D^0 \rightarrow K^- e^+ \nu_e)\) and
   hence estimate the lifetime of the \(D^0\) meson.