1. Let's examine the scattering process $e^+e^- \to \mu^+\mu^-$ given on lecture pages 81' and 81". You can neglect the particle masses in the following calculations.

   a) In the case of spin-1/2 particles the invariant amplitude is $\overline{|\mathcal{M}|}^2 = 2e^4(t^2+u^2)/s^2$. What is the differential cross-section $\mathrm{d}\sigma/\mathrm{d}\Omega^*$ given as a function of the scattering angle θ^*?

   b) Show that the total cross-section is $\sigma = \frac{4\pi\alpha^2}{3s}$.

   c) If the muon was a spin-0 particle (but the electron a spin-1/2 particle) the invariant amplitude would be $\overline{|\mathcal{M}|}^2 = 8e^4(p_a \cdot p_d)(p_a \cdot p_c)/s^2$. Now calculate the differential and total cross-sections as above and compare the results.

2. The decay width $\Gamma(a \to cd)$ for a decay process $a \to cd$ was derived in the lecture notes on page 84. Go through the calculation in all details. (And correct the many typos in the lecture notes!)

3. The muon decay width Γ calculation is summarized on pages 86-87 in the lecture notes. Now following the pages from Halzen & Martin (262-263) (see KJE lecture notes pp. 86-88) do this calculation in detail. Show also the general result

$$\int \frac{\mathrm{d}^3p}{2E} = \int \mathrm{d}^4p\theta(E)\delta(p^2).$$

   For the invariant amplitude $\overline{|\mathcal{M}|}^2$ use the form given in equation (12.35) in Halzen & Martin, but do the exercise 12.10 suggested there. Note that now $m_e = m_\nu = 0$ and $m_\mu \equiv m$. **For this problem you get double points.**

4. Which of the following reactions can happen through the weak interaction? Draw the corresponding Feynman diagrams.
   (a) $\nu_\mu + \mathrm{p} \to \mu^+ + \mathrm{n}$
   (b) $\nu_e + \mathrm{p} \to \mathrm{e}^- + \pi^+ + \mathrm{p}$
   (c) $\Lambda \to \pi^+ + \mathrm{e}^- + \bar{\nu}_e$
   (d) $\mathrm{K}^+ \to \pi^0 + \mu^+ + \nu_\mu$

5. The following reactions are observed in nature. Determine the interaction involved in the reaction and draw the corresponding Feynman diagram.
   (a) $\pi^- + \mathrm{p} \to \pi^- + \pi^+ + \mathrm{n}$
   (b) $\gamma + \mathrm{p} \to \pi^+ + \mathrm{n}$
   (c) $\nu_\mu + \mathrm{n} \to \mu^- + \mathrm{p}$
   (d) $\pi^0 \to \mathrm{e}^+ + \mathrm{e}^- + \mathrm{e}^+ + \mathrm{e}^-$
   (e) $\mathrm{p} + \bar{\mathrm{p}} \to \pi^+ + \pi^- + \pi^0$
   (f) $\tau^- \to \pi^- + \nu_\tau$
   (g) $\mathrm{D}^- \to \mathrm{K}^+ + \pi^- + \pi^-$
   (h) $\pi^- \to \pi^0 + \mathrm{e}^- + \bar{\nu}_e$
   (i) $\Lambda + \mathrm{p} \to \mathrm{K}^- + \mathrm{p} + \mathrm{p}$