1. Srednicki, problem 89.2 (including problem 88.6).

2. (Extension of HW 2.2) Show that the PMNS matrix can be written in terms of three angles and two phases.

3. MSW effect: Consider mixing of the first two neutrino generations. Solar neutrinos are produced in weak eigenstates \( (\nu_e') \), but these are non-trivial mixtures of mass eigenstates, in a simplification of three-neutrino mixing described in class.

   a) Find an evolution equation for the weak eigenstates for monochromatic (fixed \( E \)) neutrinos as a function of propagation distance \( L \).

   b) Consider the four-Fermi interaction \( \propto J_\mu^+ J_\mu^- \). It is easy to show that a vacuum expectation value \( \langle \bar{e}_L \sigma^{\mu} e_L \rangle = \delta_0^\mu N_e/2 \), where \( N_e \) is the electron density in the sun, induces a correction to the evolution equation through the four-Fermi term. Using a Fierz rearrangement, find this correction.

   c) Parametrize the corrected evolution equation by a correction term in the equation from a), namely an additional contribution \( A\nu_e' \) to \( id\nu_e'/dL \). Suppose that in the center of the sun, where the neutrinos are produced, \( A \) is large as compared to \( \Delta m^2/E \), and that \( A \) varies “slowly” as a function of \( L \) (distance from the center of the sun), to \( A = 0 \) at the surface. What is the amplitude of the neutrino to be a \( \nu_e' \) when it reaches earth? (Justify any further approximations.)