1. Calculate the threshold kaon laboratory kinetic energy necessary for the reaction:

\[ \pi^- + p \to \Delta^0(1232) \]

where \( m_\Sigma = 1232 \text{ MeV}/c^2 \), \( m_p = 938 \text{ MeV}/c^2 \), and \( m_\pi = 139 \text{ MeV}/c^2 \).

2. Elastic \( p^{40}\text{Ca} \) scattering was studied at Los Alamos. A copy of one of the cross section plots is attached. The kinetic energy of incident protons is 497 MeV. The rest mass of the proton is 938 MeV/c^2. Let the nuclear density be parametrized as \( \rho(r) = \rho_0/(1 + e^{(r-c)/a}) \).
   
   (a) What is the incident laboratory momentum of the protons in MeV/c?
   
   (b) Find the half-density radius, \( c \), of \( ^{40}\text{Ca} \) from this data.
   
   (c) Find the diffusivity parameter, \( a \), of \( ^{40}\text{Ca} \) from this data.

3. Estimate the lifetime of a nucleon (proton/neutron) from the net geothermal heat flux (\( \phi_E = 0.1 \text{ W/m}^2 \)) of the earth. Assume that half the rest energy of the nucleon goes into heating and the remainder escapes via neutrino emission. (Data: \( M_N = 1.67 \times 10^{-27} \text{ kg} \), \( M_E = 6.0 \times 10^{24} \text{ kg} \), \( R_E = 6.4 \times 10^6 \text{ m} \).)

4. Consider the pionic break up of the deuteron which proceeds via the hadronic interaction,

\[ \pi^0 + d \to p + n. \]

At very low pion energy the relative angular momentum of the pion and deuteron in the initial state is zero (\( L_i = 0 \)). (Data: \( (J^T)_{\text{deuteron}} = 1^+ 0 \), \( (J^T)_{\text{pion}} = 0^- 1 \).) Use the generalized Pauli exclusion principle applied to the final proton and neutron (i.e. treating them as identical particles including isospin) to find the spin, isospin, and relative angular momentum of the final state.

5. Consider pion-nucleon scattering which proceeds via the strong interaction. The pion is an isospin triplet (\( t_\pi = 1 \)) and the nucleon is an isospin doublet (\( t_N = 1/2 \)); thus the total multiplicity is \( 3 \times 2 = 6 \).
   
   (a) Identify the values of the allowed total isospin and show that the total multiplicity is still six.
   
   (b) Use the Clebsch-Gordon tables to write the the \( |\pi^+ n\rangle\)-state and the \( |\pi^0 p\rangle\)-state in terms of the states of good total isospin. (Use bra-ket notation: \( |(t_1 t_2) t t_3\rangle \). For example, \( |\pi^+ p\rangle = |1 + 1|l_1 l_2 l_2 = |(1 1 0 0) + 1 2 2\rangle \).)
   
   (c) Assume the scattering amplitude is dominated by the \( T = 1/2\)-channel (a fictional case), find the cross section ratio,

\[ \frac{\sigma(\pi^+ + n \to \pi^0 + p)}{\sigma(\pi^+ + n \to \pi^+ + n)}. \]