1) \( \frac{d\sigma}{dS} = \frac{1}{2} \frac{dn}{t} = \frac{J_0 r^2}{r} \): It is the number of scattered neutrons per unit solid angle per unit time.

2) We calculated a total neutron-proton scattering cross section of 4.6 barns. The experimentally measured value is 20.4 barns. The reason for this discrepancy is b/c neutron-proton interactions are spin dependent.

\[ S = S_n + S_p = \left\{ \begin{array}{ll} 1, & \text{triplet "parallel"} \\ 0, & \text{singlet "anti-parallel"} \end{array} \right. \]

\[ \sigma = \frac{3}{4} \sigma_t + \frac{1}{4} \sigma_\pi = 20.4 \text{ b} \]

\[ 4.66 \text{ b} \]

3) 1. Good moderator in reactors b/c of high scattering cross section and low mass number

2. It is commonly used to remove heat from the reactor and generate electricity by spinning a turbine

3. It is a source of Deuterium and Tritium for fusion experiments

4. It is effective in shielding neutrons.
6.2

\((n, n)\): elastic scattering, a neutron hits a target and a neutron is released with \(Q = 0\), can be potential or resonance scattering.

\((n, n')\): inelastic scattering, a neutron hits a target and a neutron, \(n'\), is released, \(Q \neq 0\).

\((n, \alpha), (n, p)\): particle emission, a neutron hits a target and a different particle is emitted.

\((n, \gamma)\): radiative capture, a neutron hits a target and is absorbed into the target. Energy is released with a gamma ray.

\((n, f)\): fission, a neutron hits a target and splits the nucleus into two smaller nuclei. More common with heavy atoms like \(^{235}\text{U}\). More neutrons can also be released during fission.

6.3

Conservation of energy: \((E_1 + m_1c^2) + (E_2 + m_3c^2) = (E_3 + m_3c^2) + (E_4 + m_4c^2)\) \(\text{(1)}\)

Conservation of Momentum: \(\vec{P}_1 + \vec{P}_2 = \vec{P}_3 + \vec{P}_4\) \(\text{(2)}\)

- Assume \(E_2 = 0\) \((E_1 \gg E_2)\), \(\vec{P}_2 = 0\)

\(\text{(2)}\)

\[\frac{\vec{P}_1 - \vec{P}_3}{\vec{P}_4}\]

\[|\vec{P}_1 - \vec{P}_3|^2 = |\vec{P}_4|^2\]

\[P_1^2 + P_3^2 - 2P_1P_3\cos\theta = P_4^2\]

\(\text{(1)}\)

\[Q = (m_1 + m_2 - m_3 - m_4)c^2 = E_3 + E_4 - E_1\]

\[E_4 = \frac{P_3^2}{2m_4} = \frac{1}{2m_4}(P_1^2 + P_3^2 - 2P_1P_3\cos\theta)\]

\(\text{(1)}\)

\[Q = E_3 - E_1 + \frac{1}{2m_4}(P_1^2 + P_3^2 - 2P_1P_3\cos\theta)\]

\[= E_3 - E_1 + \frac{1}{2m_4}(2m_1E_1 + 2m_3E_3 - 2\sqrt{m_1E_1m_3E_3}\cos\theta)\]

\[Q = E_3(1 + \frac{m_3}{m_4}) - E_1(1 - \frac{m_1}{m_4}) - \frac{2}{m_4}\sqrt{m_1m_3E_1E_3}\cos\theta\]