Problem 1. Anderson 8.3

Calculate the wavelength of a 1 MeV neutron in free space. If a total E of 1 MeV is a constant of the motion and the neutron is in a region of a potential well depth of 10 MeV, what is the wavelength?

Solution

Part (a)

$$\begin{aligned}
\lambda_{free} &= \frac{h}{\sqrt{2m_n T}} \\
&= \frac{4.14 \times 10^{-15}\,\text{eV s} \times \frac{1\,\text{MeV}}{1 \times 10^6\,\text{eV}}}{\sqrt{2 \times 939.6\,\text{MeV}\,{c_0}^{-2} \times 1\,\text{MeV}}} \\
&= 2.87 \times 10^{-14}\,\text{m} \\
&= 28.7\,\text{fm}
\end{aligned}$$

Part (b)

$$\begin{aligned}
\lambda_{well} &= \frac{h}{\sqrt{2m_n(T+V}} \\
&= \frac{4.14 \times 10^{-15}\,\text{eV s} \times \frac{1\,\text{MeV}}{1 \times 10^6\,\text{eV}}}{\sqrt{2 \times 939.6\,\text{MeV}\,{c_0}^{-2} \times 11\,\text{MeV}}} \\
&= 8.64\,\text{fm}
\end{aligned}$$

Problem 2.

Using the NNDC ENDF evaluations, find (and report) the elastic scattering cross sections for 0.5 MeV, 1 MeV, 5 MeV, and 10 MeV neutrons scattering in ^{207}Pb. Use those values to calculate the corresponding mean free paths for elastic scattering.

Solution

Calculations performed in attached code

T (MeV)	σ (cm^{-1})	Mean Free Path (cm)
0.5	5.810217	5.216310
1.0	4.876894	6.214590
5.0	4.896170	6.190124
10.0	2.483300	12.204686

Problem 3. Anderson 8.10, change deuterium to ^{7}Li and change uranium to ^{206}Pb

Find the number of collisions (nearest integer) necessary to thermalize a beam of 1 MeV neutrons with ^{7}Li, He, Be, C, and ^{206}Pb

Solution

Calculations performed in attached code

A	Target	Average Collisions to Thermalize
7	Li-7	67
4	Helium	41
9	Beryllium	85
12	Carbon	111
206	Pb-206	1809

Problem 4.

A 14 MeV neutron scatters elastically off of a ^{12}C nucleus. The energy given to the ^{12}C nucleus is 1 MeV. What is the scattered angle of the neutron?

Solution

$$\theta' = \cot^{-1} \frac{1 - A\cos 2\theta'_A}{A \sin 2\theta'_A}$$

$$T' = T \left[\frac{\cos\theta' + \left(A^2 - \sin^2\theta'\right)^{1/2}}{A+1} \right]^2$$

Substituting in $T = 14\,\text{MeV}$ and $T' = 13\,\text{MeV}$ and using wolframalpha to solve, we get:

$$\theta' = \pm 56.22^\circ$$

NE551_hw_08

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1 Problem 2

In [2]:
```
import pandas as pd
import numpy as np
import scipy.constants as const
```

In [3]:
```
def mean_free_path(sigma):
    # Define constants
    density = 11.34 # g/cm^3
    molar_mass = 206.9758969
    na = const.Avogadro

    # convert sigma from barns to cm^2
    sigma = sigma * 1e-24

    macroscopic_cross_section = sigma * na * density / molar_mass

    mean_free_path = macroscopic_cross_section ** -1

    return mean_free_path
```

In [4]:
```
endf_data = pd.DataFrame(
    {
        'T': [0.5, 1., 5., 10.],
        'sigma': [5.8102174, 4.8768945, 4.89617, 2.4833]
    }
)
```

In [5]:
```
endf_data['Mean Free Path'] = mean_free_path(endf_data['sigma'])
```

In [6]:
```
endf_data
```

Out[6]:

	T	sigma	Mean Free Path
0	0.5	5.810217	5.216310
1	1.0	4.876894	6.214590
2	5.0	4.896170	6.190124
3	10.0	2.483300	12.204686

In [15]:
```
endf_data.to_latex()
```

Out[15]:
```
u'\\begin{tabular}{lrrr}\n\\toprule\n{} &     T &     sigma &  Mean Free P
```

2 Problem 3

```
In [7]: materials = pd.DataFrame(
            {
                "Target": ["Li-7", "Helium", "Beryllium", "Carbon", "Pb-206"],
                "A": [7, 4, 9, 12, 206]
            }
        )
```

```
In [8]: def alpha(A):
            numerator = A - 1
            denominator = A + 1

            return (numerator / denominator)**2

        def average_logarithmic_energy_decrement_per_collision(A):
            a = alpha(A)
            numerator = a * np.log(a)
            denominator = 1 - a

            return 1 + numerator / denominator

        e_thermal = 0.025 # eV
        e_0 = 1e6 # eV

        def k(T, T_prime, A):
            ksi = average_logarithmic_energy_decrement_per_collision(A)

            return np.log(T / T_prime) / ksi
```

```
In [13]: materials['Average Collisions to Thermalize'] = np.round(k(e_0, e_thermal,
```

```
In [14]: materials
```

Out[14]:

	A	Target	Average Collisions to Thermalize
0	7	Li-7	67
1	4	Helium	41
2	9	Beryllium	85
3	12	Carbon	111
4	206	Pb-206	1809

```
In [16]: materials.to_latex()
```

```
Out[16]: u'\\begin{tabular}{lrlr}\n\\toprule\n{} &    A &     Target &  Average Col
```

```
In [ ]:
```