```
# PHYSIQUE ATOMIQUE ET NUCLÉAIRE
# DEVOIR #4 - NUMÉRO 5
# CODE PYTHON

class PB:
    def __init__(self):
        self.A = 208                        # Nombre de masse
        self.Z = 82                         # Nombre atomique

        self.Vo = 50                        # MeV
        self.hw = 41 * self.A**(-1/3)       # MeV
        self.D = 0.0225 * self.hw
        self.C = 0.1 * self.hw

        self.protons = [                    # couches complètées pour 82 protons
                [1, 0, 0.5],
                [1, 1, 1.5],
                [1, 1, 0.5],
                [1, 2, 2.5],
                [2, 0, 0.5],
                [1, 2, 1.5],
                [1, 3, 3.5],
                [2, 1, 1.5],
                [1, 3, 2.5],
                [2, 1, 0.5],
                [1, 4, 4.5],
                [2, 2, 2.5],
                [1, 4, 3.5],
                [3, 0, 0.5],
                [2, 2, 1.5],
                [1, 5, 5.5],                # 82 protons
                ]

        self.neutrons = [                   # couches complétées pour 126 neutrons
                [1, 0, 0.5],
                [1, 1, 1.5],
                [1, 1, 0.5],
                [1, 2, 2.5],
                [2, 0, 0.5],
                [1, 2, 1.5],
                [1, 3, 3.5],
                [2, 1, 1.5],
                [1, 3, 2.5],
                [2, 1, 0.5],
                [1, 4, 4.5],
                [2, 2, 2.5],
                [1, 4, 3.5],
                [3, 0, 0.5],
                [2, 2, 1.5],
                [1, 5, 5.5],                # 82 neutrons

                [2, 3, 3.5],
                [1, 5, 4.5],
                [1, 6, 6.5],
```

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                [3, 1, 1.5],
                [2, 3, 2.5],
                [3, 1, 0.5]                         # 126 neutrons
                ]

    def Enlsj(self,n,l,s,j):                        # Énergie d'un nucléon selon nlsj
        return - self.Vo + self.hw * (2 * (n - 1) + l + 3/2) - self.D * l * (l + 1) - self.C * (j * (j + 1) - l * (l + 1) - s * (s
+ 1)) / 2

    def bindingEnergy(self):                        # Énergie de liaison
        protonsEnergy = 0
        for shell in self.protons:
            n, l, s, j = shell[0], shell[1], 0.5, shell[2]
            protonsEnergy += self.Enlsj(n, l, s, j) * (2 * j + 1)
                                    # Ajout de l'énergie d'un proton multipliée par le degré de dégénérescence
        neutronsEnergy = 0
        for shell in self.neutrons:
            n, l, s, j = shell[0], shell[1], 0.5, shell[2]
            neutronsEnergy += self.Enlsj(n, l, s, j)  * (2 * j + 1)
                                    # Ajout de l'énergie d'un neutron multipliée par le degré de dégénérescence
        return - (protonsEnergy + neutronsEnergy)            # Somme de toutes les énergies

pb = PB()
print('The binding energy is', pb.bindingEnergy(), 'MeV.')
```

Output :

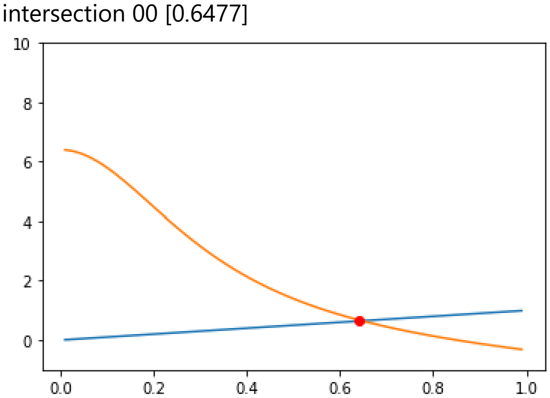
The binding energy is 3422.517322322542 MeV.

```python
# PHYSIQUE ATOMIQUE ET NUCLÉAIRE
# DEVOIR #4 - NUMÉRO 3
# CODE PYTHON

import numpy as np
from matplotlib import pyplot as plt
import scipy.special as ss
import scipy


def f(x):
	return x

def f0(x, Omega2):
   return - (1 - x**2)**0.5 * (np.tan((Omega2 * (1 - x**2))**0.5))**-1

def F(L, x, Omega2):
    a = scipy.sqrt((Omega2 * (1 - x**2)))
    b = 1j * Omega2**0.5 * x
    coeff = -1j * scipy.sqrt((1 - x**2))
    firstTerm = ss.spherical_jn(L - 1,a) / ss.spherical_jn(L,a)
    secdTerm = (ss.spherical_jn(L,b) + 1j*ss.spherical_yn(L,b)) / (ss.spherical_jn(L-1,b) + 1j * ss.spherical_yn(L-
1,b))
    return coeff * firstTerm * secdTerm

# Omega^2 values
singlet = 2.23 * 4
triplet = 3.57 * 4

# w values knowing w range is [0,1]
w = np.array([(i + 1)/100 for i in range(99)])

# left term of the transcendant equation
f = np.array([f(i) for i in w])

# right term of the transcendant equation
f_00 = np.array([f0(i, singlet) for i in w])       # when (L,S) = (0,0)
f_01 = np.array([f0(i, triplet) for i in w])       # when (L,S) = (0,1)
F_10 = np.array([F(1,i, singlet) for i in w])      # when (L,S) = (1,0)
F_11 = np.array([F(1,i, triplet) for i in w])      # when (L,S) = (1,1)

# when (L,S) = (0,0)
plt.figure()
plt.plot(w,f)
plt.plot(w,f_00)
idx = np.argwhere(np.diff(np.sign(f_00 - f))).flatten()
print('intersection', w[idx])
plt.plot(w[idx], f[idx], 'ro')
plt.ylim([-1,10])
plt.savefig('00', bbox_inches = 'tight')

# when (L,S) = (0,1)
plt.figure()
plt.plot(w,f)
```

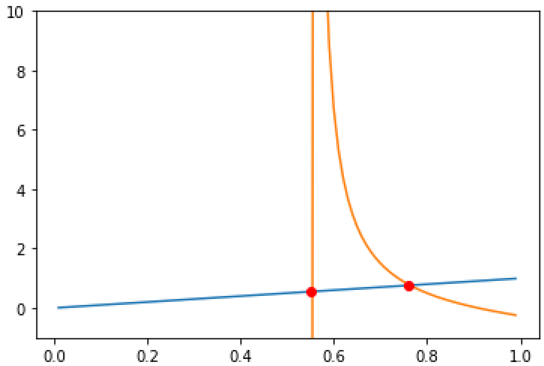
```
plt.plot(w,f_01)
idx = np.argwhere(np.diff(np.sign(f_01 - f))).flatten()
print('intersection', w[idx])
plt.plot(w[idx], f[idx], 'ro')
plt.ylim([-1,10])
plt.savefig('01', bbox_inches = 'tight')

# when (L,S) = (1,0)
plt.figure()
plt.plot(w,f)
plt.plot(w,np.real(F_10))
idx = np.argwhere(np.diff(np.sign(F_10 - f))).flatten()
print('intersection', w[idx])
plt.plot(w[idx], f[idx], 'ro')
plt.ylim([-10,10])
plt.savefig('10', bbox_inches = 'tight')

# when (L,S) = (1,1)
plt.figure()
plt.plot(w,f)
plt.plot(w,np.real(F_11))
idx = np.argwhere(np.diff(np.sign(F_11 - f))).flatten()
print('intersection', w[idx])
plt.plot(w[idx], f[idx], 'ro')
plt.ylim([-1,10])
plt.savefig('11', bbox_inches = 'tight')
```

Output :

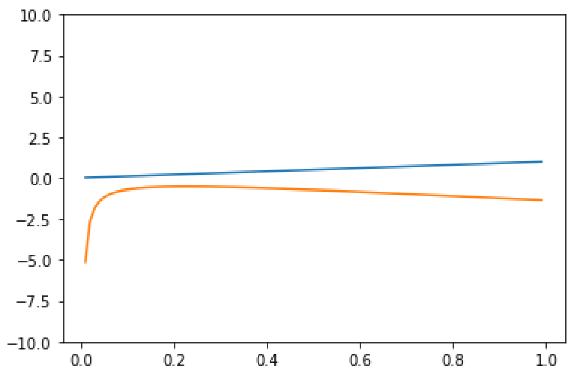
intersection 00 [0.6477]



intersection 01 [0.5557 0.7636]



intersection 10 []



intersection 11 [0.4319]