NE551 Homework 4 Addendum

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Problem 2 (Anderson 4.2)

In [255]:
```
%%javascript
MathJax.Extension["TeX/cancel"]={version:"2.4.0",ALLOWED:{color:1,math
color:1,background:1,mathbackground:1,padding:1,thickness:1}};MathJax.
Hub.Register.StartupHook("TeX Jax Ready",function(){var c=MathJax.Inpu
tJax.TeX,a=MathJax.ElementJax.mml,b=MathJax.Extension["TeX/cancel"];b.
setAttributes=function(h,e){if(e!==""){e=e.replace(/ /g,"").split(/,/)
;for(var g=0,d=e.length;g<d;g++){var f=e[g].split(/[:=]/);if(b.ALLOWED
[f[0]]){if(f[1]==="true"){f[1]=true}if(f[1]==="false"){f[1]=false}h[f[
0]]=f[1]}}}return h};c.Definitions.Add({macros:{cancel:["Cancel",a.NOT
ATION.UPDIAGONALSTRIKE],bcancel:["Cancel",a.NOTATION.DOWNDIAGONALSTRIK
E],xcancel:["Cancel",a.NOTATION.UPDIAGONALSTRIKE+" "+a.NOTATION.DOWNDI
AGONALSTRIKE],cancelto:"CancelTo"}},null,true);c.Parse.Augment({Cancel
:function(e,g){var d=this.GetBrackets(e,""),f=this.ParseArg(e);var h=b
.setAttributes({notation:g},d);this.Push(a.menclose(f).With(h))},Cance
lTo:function(e,g){var i=this.ParseArg(e),d=this.GetBrackets(e,""),f=th
is.ParseArg(e);var h=b.setAttributes({notation:a.NOTATION.UPDIAGONALST
RIKE+" "+a.NOTATION.UPDIAGONALARROW},d);i=a.mpadded(i).With({depth:"-.
1em",height:"+.1em",voffset:".1em"});this.Push(a.msup(a.menclose(f).Wi
th(h),i))}});MathJax.Hub.Startup.signal.Post("TeX cancel Ready")});Mat
hJax.Ajax.loadComplete("[MathJax]/extensions/TeX/cancel.js");
```

$$R = \frac{M \cancel{c^2} I^2}{32 z^2 \pi r_0^2 \left(m_e \cancel{c^2}\right)^3 N_A \left(Z/M_m\right) \rho} \left[\mathrm{Ei}(\ln u_0) - \cancel{\mathrm{Ei}(\ln u_1)}\right] + \cancel{R_1(T_1)}$$

and

$$u = \left(\frac{4 m_e c^2 \tau}{I}\right)^2 = \left(\frac{4 m_e \cancel{c^2}\, T}{I M \cancel{c^2}}\right)^2$$

In [256]:
```
import scipy.constants as const
from scipy.special import expi # Exponential integral function, Ei
from math import log, pi
import numpy as np
from scipy.interpolate import interp1d
```

In [257]:
```
# Constants!
I = 82 * 10 ** -6 # MeV
M = const.physical_constants['alpha particle mass energy equivalent in
MeV'][0] # 3727.379... MeV
z = 2 # incident alpha particle
m_e = const.physical_constants['electron mass energy equivalent in MeV
'][0]
r_0 = const.physical_constants['classical electron radius'][0] * 100 #
cm
N_A = const.physical_constants['Avogadro constant'][0]
Z = 14
M_m = 28.014 # g/mol
rho = 0.00125 # g/cm^3
```

In [258]:
```
def u(T):
    numerator = 4 * m_e * T
    denominator = I * M
    return (numerator / denominator) ** 2
```

In [259]:
```
u(5)
```

Out[259]:
```
1118.0599713539173
```

In [260]:
```
# Approximation of Exponential integral
u(5) / log(u(5))
```

Out[260]:
```
159.28254390194414
```

In [261]:
```
def R(T, approxEi=False):
    """ Gives predicted range
        Can optionally specify approxEi to use the log approximation f
or Ei(log(u))
    """
    numerator = M * I * I
    denominator = 32 * z ** 2 * pi * r_0 ** 2 * m_e ** 3 * N_A * Z * r
ho / M_m
    if not(approxEi):
        ei = expi(log(u(T)))
    else:
        ei = u(T) / log(u(T)) # Approximation as u >> 1
    return numerator * ei / denominator
```

```
In [262]: print R(5, approxEi=True)

2.49058984845
```

```
In [263]: print R(5, approxEi=False)

3.04222192314
```

Problem 4

```
In [279]: r_e = r_0 # Copying code from scratch sheet
          I_water = 75.0
          I_air = 85.7
          rho_water = 1.0
          rho_air = 0.0012
```

```
In [280]: def beta_squared(T, m):
              """ Gives value of beta^2 for a given Mass (MeV/c^2) and Kinetic E
          nergy (MeV)
              """
              numerator = T * (T + 2 * m)
              denominator = (T + m) ** 2
              return np.divide(numerator, denominator)
```

```
In [281]: def gamma_squared(T, m):
              """ Gives value of gamma^2 for a given mass (MeV/c^2) and Kinetic
          Energy (MeV)
              """
              return 1.0 / (1 - beta_squared(T, m)) ** 0.5
```

```
In [282]: def S_c(incident, target, T, M_b, density, I):
              """ Returns the stopping power in MeV/cm
                  T in MeV
                  density in g/cm^3
                  Output in MeV/cm
              """
              # Currently the incident is specified in Z number. Incident is ass
          umed to be fully ionized
              z = incident

              # Z is actually Z/A
              Z = target

              first = 4 * (z ** 2) * pi * (r_e ** 2) * m_e
              second = N_A * Z * density
              third = 1.0 / beta_squared(T, M_b)
              logpart = (2 * m_e * beta_squared(T, M_b) * gamma_squared(T, M_b))
          / (I * 10 ** -6)
              fourth = np.log(logpart) - beta_squared(T, M_b) + beta_squared(T,
          M_b)

              result = first * second * third * fourth

              return result
```

```
In [283]: S_c_chamber_one = S_c(1.0, 0.55, 250.0, 937.0, rho_air, I_air)
```

```
In [284]: T_array = np.linspace(-10.0, 300.0, 260000)
```

```
In [285]: interpolator = interp1d(
              T_array,
              np.piecewise(
                  T_array,
                  [T_array <= 0.001, T_array > 0],
                  [
                      lambda T_array: 0.0,
                      lambda T_array: S_c(1.0, 0.55, T_array, 937.0, rho_water,
          I_water)
                  ]
              )
          )
```

```
In [286]: S_c(1.0, 0.55, 250.0, 937.0, 1.0, 75.0)

Out[286]: 3.934864903456555
```

In [287]:
```
interpolator(250)
```

Out[287]:
```
array(3.9348649034678584)
```

In [311]:
```
def EofT(E0, t, step=1):
    if t<step:
        return E0
    else:
        e = EofT(E0, t-step, step=step)
        if e > E0:
            return E0
        elif e>=0:
            temp = e - step * interpolator(e)
            if temp >= 0.0:
                return temp
            else:
                return 0.0
```

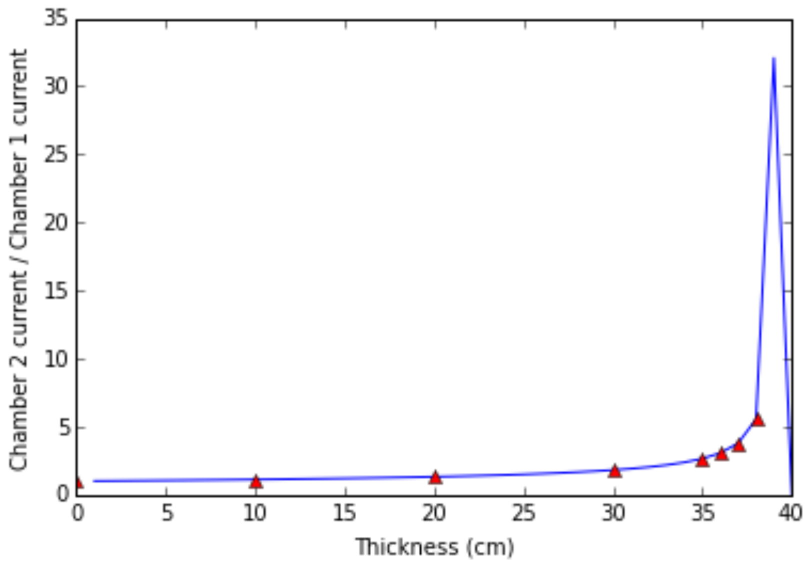
In [346]:
```
def bragg_curve(t, debug=False):
    S_c_chamber_one = S_c(1.0, 0.49918972273707857, 250.0, 937.0, rho_
air, I_air)
    E_after_chamber = EofT(250.0, t)
    if E_after_chamber > 0.0:
        S_c_chamber_two = S_c(1.0, 0.49918972273707857, E_after_chambe
r, 937.0, rho_air, I_air)
    else:
        S_c_chamber_two = 0.0
    if debug is True:
        print S_c_chamber_two
        print S_c_chamber_one
        print E_after_chamber
    return S_c_chamber_two / S_c_chamber_one
```

In [347]:
```
thickness = [0.0, 10.0, 20.0, 30.0, 35.0, 36.0, 37.0, 38.0]
```

In [348]:
```
%matplotlib inline
```

```
In [349]: import matplotlib.pyplot as plt

          plt.plot([i + 1.0 for i in range(40)], [bragg_curve(i + 1.0) for i in
          range(40)], 'b',
                   thickness, [bragg_curve(i) for i in thickness], 'r^'
                  )
          plt.xlabel("Thickness (cm)")
          plt.ylabel("Chamber 2 current / Chamber 1 current")
          plt.show()
```



```
In [ ]:
```