Problems 4.14

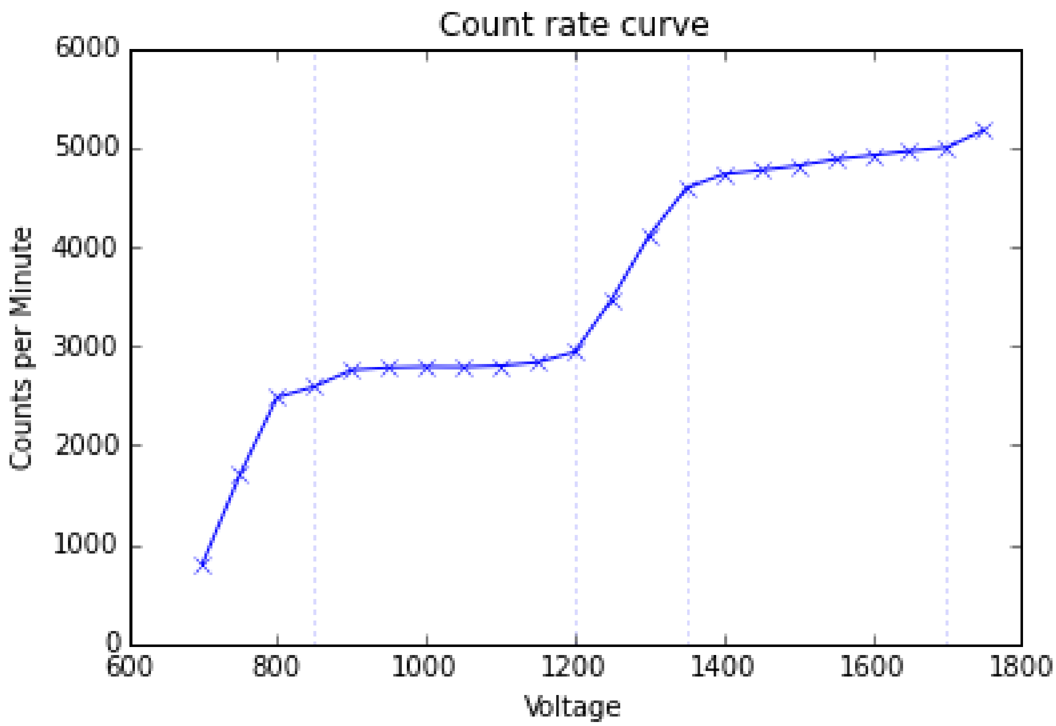
April 10, 2017

1 Section 4.14 Problems

```
In [62]: %matplotlib inline
         from __future__ import division
         import numpy as np
         import matplotlib.pyplot as plt
         from uncertainties import ufloat
         from uncertainties.umath import *
         import pandas as pd
```

1.1 Part A

```
In [4]: voltage = np.arange(700, 1800, 50)
        cpm = np.array([812, 1703, 2482, 2591,
                        2758, 2783, 2791, 2788,
                        2802, 2836, 2941, 3473,
                        4109, 4592, 4731, 4771,
                        4817, 4880, 4922, 4964,
                        4999, 5177])
        plt.plot(voltage, cpm, 'x-')
        for a in [850, 1200, 1350, 1700]:
            plt.axvline(x=a, linestyle='dotted', alpha=0.3)
        plt.xlabel("Voltage")
        plt.ylabel("Counts per Minute")
        plt.title("Count rate curve")
        plt.show()
```



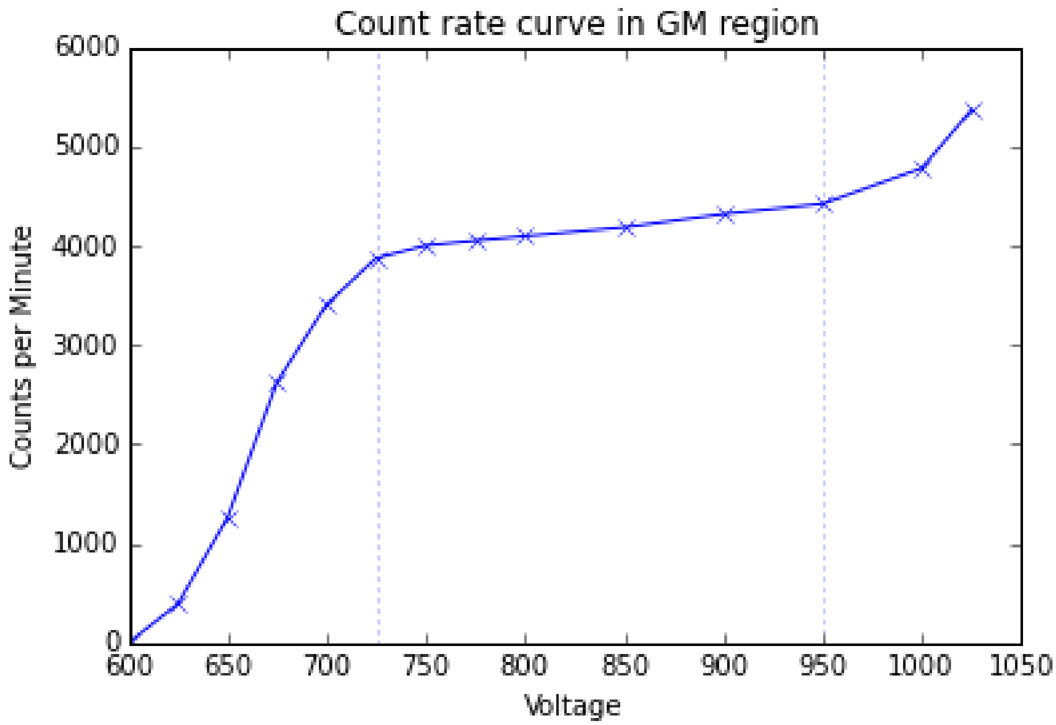
Note: I assume that there was a typo in the 4th data point–it should read "850, (2591)", not "850, (1591)"

From (0,800), the detector is counting ions that are formed close to the detector wire (most of the ion pairs recombine). In the (800,1200) range, the detector is in the ionization region, where all ions from the ionization event are collected but no cascade ions are produced. (1200, 1400) is the limited proportional region where increasing the voltage causes more cascade ionizations which are then collected by the detector. In (1350,1700), the detector is in the Geiger-Mueller region where it collects all ionizations in the cascade and the effects of increasing voltage are minor. Finally, above 1700V the self-discharge region begins, where the electric field is strong enough to cause ions to form without an incident particle.

1.2 Part B

```
In [5]: voltage = np.array([600, 625, 650, 675, 700,
                            725, 750, 775, 800, 850,
                            900, 950, 1000, 1025])
        cpm = np.array([0, 392, 1261, 2627, 3410, 3876,
                        4002, 4051, 4096, 4185, 4319,
                        4422, 4782, 5371])
        plt.axvline(x=725, linestyle='dotted', alpha=0.4)
        plt.axvline(x=950, linestyle='dotted', alpha=0.4)
        plt.plot(voltage, cpm, 'x-')
        plt.xlabel("Voltage")
        plt.ylabel("Counts per Minute")
```

```
plt.title("Count rate curve in GM region")
plt.show()
```



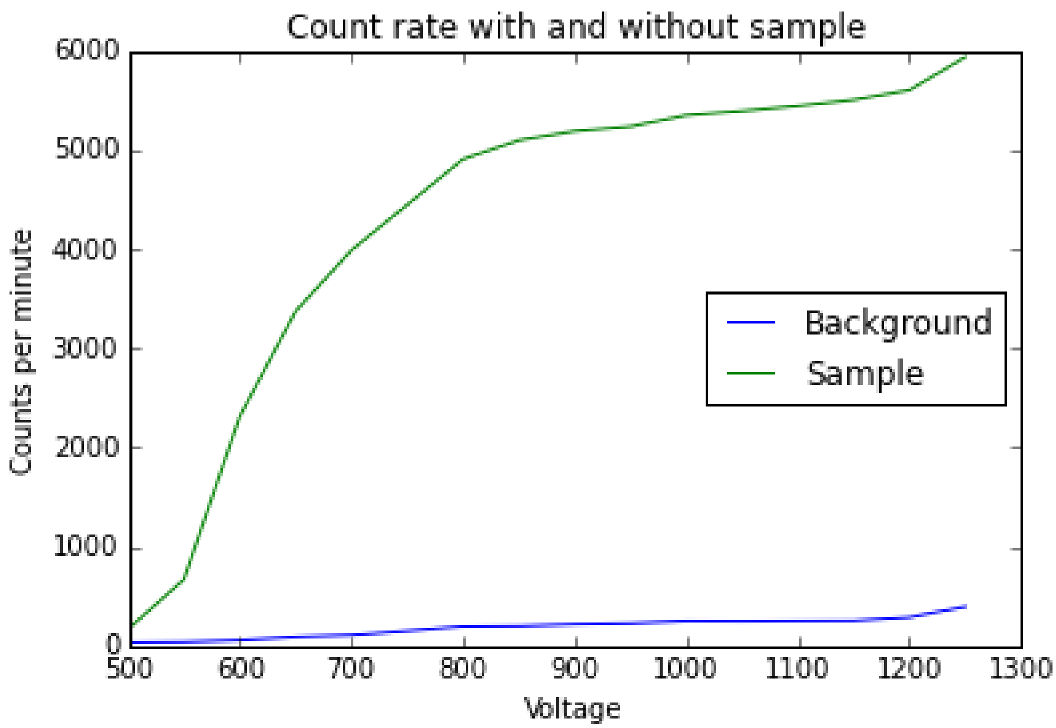
The operating voltage should be around 800-825V. Operating above 1025 is inadvisable because the detector will self-discharge even without radiation present.

1.3 Part C

```
In [6]: voltage_background = np.arange(500, 1300, 50)
        cpm_background = np.array([36, 41, 59, 91, 109,
                                   152, 196, 201, 219,
                                   228, 251, 249, 252,
                                   254, 289, 397])

        voltage_sample = np.array([500, 550, 600, 650,
                                   700, 800, 850, 900,
                                   950, 1000, 1050, 1100,
                                   1150, 1200, 1250])
        cpm_sample = np.array([171, 672, 2314, 3371, 3986,
                               4907, 5096, 5188, 5235,
                               5348, 5391, 5442, 5503,
                               5601, 5936])
        plt.plot(voltage_background, cpm_background, label="Background")
        plt.plot(voltage_sample, cpm_sample, label="Sample")
```

```
plt.xlabel("Voltage")
plt.ylabel("Counts per minute")
plt.legend(loc="center right")
plt.title("Count rate with and without sample")
plt.show()
```



The appropriate counting voltage is between 950-1050V.

1.4 Part D

```
In [7]: sc = ufloat(3270, 3270**0.5)
        st = 22.00
        bc = ufloat(331, 331**0.5)
        bt = 9.00
        activity = sc / st - bc / bt
        print(activity)
```

```
111.9+/-3.3
```

The count rate is 112±3 cpm

1.5 Part E

```
In [8]: dt = 9.00e-6 /60
        cr = ufloat(927420, 927420**0.5)
```

```
print(cr / (1 - cr * dt))
```

```
(1.0773+/-0.0013)e+06
```

The true count rate is 1.0773E6±1.3E3

1.6 Part F

$\tau = \frac{n_{12}-70n_1}{n_{12}n_1-70n_1n_{12}}$

```
In [9]: tau = ((147210. - 11.) - (70. * 2120.- 11.)) / ((147210. -11.)* (2120. - 11
```

```
In [10]: tau = tau * 60 # convert from minutes to seconds
```

```
In [11]: tau
```

```
Out[11]: 3.333248418129619e-06
```

The dead time is 3.33μs

1.7 Part G

```
In [53]: sample_no_cs = np.array([18921, 14632, 11985, 7337, 4511]) # cpm
         sample_with_cs = np.array([21026, 16746, 14092, 9439, 6621])  # cpm
         pure_no_cs = 181 # cpm
         pure_with_cs = 4732 # cpm
```

1.7.1 G.1

```
In [57]: quenched_sample_values = cr_with_cs - cr_no_cs
         print(quenched_sample_values)
```

```
[2105 2114 2107 2102 2110]
```

1.7.2 G.2

```
In [58]: non_quenched_standard_value = pure_with_cs - pure_no_cs
         print(non_quenched_standard_value)
```

```
4551
```

1.7.3 G.3

```
In [59]: quenching_factors = non_quenched_standard_value / quenched_sample_values
         print(quenching_factors)
```

```
[ 2.16199525  2.15279092  2.15994305  2.16508088  2.15687204]
```

1.7.4 G.4

```
In [60]: non_quenched_sample_counts = sample_no_cs * quenching_factors
         print(non_quenched_sample_counts)
```

```
[ 40907.11211401  31499.63670766  25886.91741813  15885.19838249
   9729.64976303]
```

1.7.5 G.5

```
In [61]: sample_activities = non_quenched_sample_counts - pure_no_cs
         print(sample_activities)
```

```
[ 40726.11211401  31318.63670766  25705.91741813  15704.19838249
   9548.64976303]
```

```
In [63]: answer = pd.DataFrame({
             "Quenched Sample Values": quenched_sample_values,
             "Quenching Factors": quenching_factors,
             "Non-quenched Counts": non_quenched_sample_counts,
             "Sample Activities": sample_activities
         })
         print(answer)
```

```
   Non-quenched Counts  Quenched Sample Values  Quenching Factors  \
0         40907.112114                    2105           2.161995
1         31499.636708                    2114           2.152791
2         25886.917418                    2107           2.159943
3         15885.198382                    2102           2.165081
4          9729.649763                    2110           2.156872

   Sample Activities
0       40726.112114
1       31318.636708
2       25705.917418
3       15704.198382
4        9548.649763
```

1.8 Part H

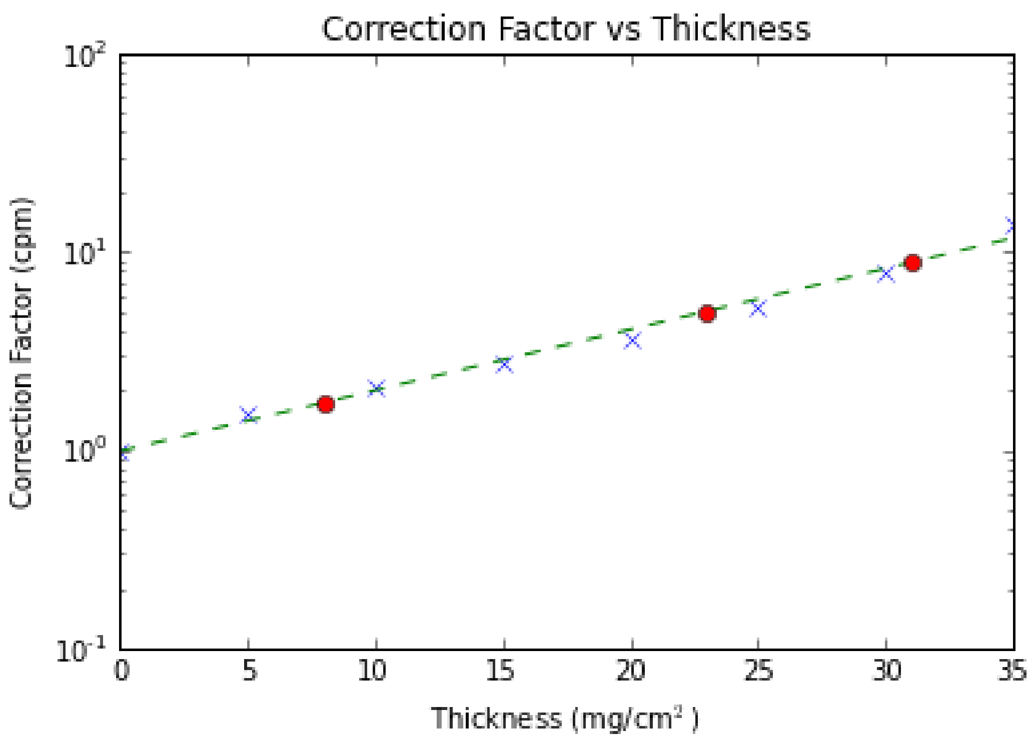
```
In [25]: thickness = np.array([0, 5, 10, 15, 20, 25, 30, 35])
         counts = np.array([5922, 3901, 2876, 2181, 1623, 1145, 752, 427])
         correction_factor = counts[0] / counts
         print(correction_factor)
```

```
[  1.           1.51807229   2.05910987   2.71526823   3.64879852
   5.1720524    7.875       13.86885246]
```

In [27]:
```
fit = np.polyfit(thickness, np.log(correction_factor), 1)
```

In [50]:
```
plt.plot(thickness, correction_factor, 'x', label="Data")

plt.ylabel('Correction Factor (cpm)')
plt.xlabel(r'Thickness (mg/cm$^2$)')
x = np.linspace(0, 35, 1000)
plt.plot(x, np.exp(fit[1] + fit[0] * x),
         linestyle='dashed', label="Fit")
plt.title("Correction Factor vs Thickness")
plt.yscale('log')
unknown_sample_thicknesses = np.array([8, 23, 31])
unknown_counts = np.array([3722, 9421, 875])
plt.plot(unknown_sample_thicknesses, np.exp(fit[1] + fit[0] * unknown_samp
plt.show()
```



In [49]:
```
print("Thickness\tCounts\t\tCF\t\t\tCorrected Counts")
print("---------\t------\t\t--\t\t\t----------------")
for i in range(len(unknown_sample_thicknesses)):
    print("{0}\t\t{1}\t\t{2}\t\t{3}".format(
        unknown_sample_thicknesses[i],
        unknown_counts[i],
        np.exp(fit[1] + fit[0] * unknown_sample_thicknesses[i]),
```

```
                np.exp(fit[1] + fit[0] * unknown_sample_thicknesses[i]) * unknown_
            ))
```

```
Thickness        Counts                CF                        Corrected Counts
---------        ------                --                        ----------------
8                3722                1.73234760334                6447.79777963
23                9421                5.00328331478                47135.9321086
31                875                8.80884819709                7707.74217246
```

1.9 Part I

In each case below indicate: 1. the best detection system and 2. corrections necessary to compare the counting results to a standard.

The form of the sample must not be altered.

1.9.1 1. An electroplated sample of ^{210}Po (5.30 MeV alpha) 7μ thick

Use a solid state detector. Correct for background, absorption and scattering.

1.9.2 2. A solid sample of $BaSO_4$ containing ^{35}S (0.17 MeV beta) 17 mg/cm^2 thick

Use a solid state detector. Correct for background, absorption and scattering.

1.9.3 3. A solid sample of ashed mammalian bone tissue containing ^{3}H (0.018 MeV beta) 4 mg/cm^2 thick

Use a solid state detector. Correct for background, absorption and scattering.

1.9.4 4. A solid sample of adenosine phosphate conatining ^{32}P (1.71 MeV beta) 22 mg/cm^2 thick

Use a solid state detector. Correct for background, absorption.

1.9.5 5. A solid sample of freeze-dried plant tissue containing ^{71}As (0.81 MeV positron and 0.175 MeV gamma) 42 mg/cm^2 thick

Use a solid state detector. Correct for background, absorption.

1.9.6 6. A solution of ashed bone marrow containing ^{55}Fe (6.4 keV X-ray) in dilute perchloric acid

Since this is a liquid, mix with a scintillating liquid in a 4π detector. Correct for background.

1.9.7 7. A solution of bovine liver tissue labeled with ^{64}Cu (1.34 MeV gamma, 0.57 MeV beta, 0.66 MeV positron) in hyamine

Use a solid state detector. Correct for background, absorption, scattering.

1.9.8 8. A solution of bartonella muris cell debris with ^{75}Zn (ec, 1.11 MeV gamma)

Use a liquid scintillator, correct for background.

1.9.9 9. A solution of pig urine containing ^{235}Pu (5.85 MeV alpha)

Use a liquid scintillator, correct for background.

1.9.10 10. A liquid dispersing agent containing colloidally-suspended funaria spores with ^{45}Ca (0.25 MeV beta)

Use a liquid scintillator, correct for background.

1.9.11 11. Gaseous BF$_3$ containing ^{18}F (0.65 MeV positron)

Use a proportional counter, correct for background.

1.10 Part J

1.10.1 1

^{32}P (1.71 MeV beta) in presence of ^{35}S (167 keV beta):

Use a solid state detector and set to only detect energies above 1MeV.

1.10.2 2

^{131}I (970 keV beta) in presence of ^{32}P (1710 keV beta):

Use a solid state detector and set to only detect energies below 1.2MeV

1.10.3 3

^{32}P (1.71 MeV beta) in presence of ^{131}I (970 keV beta):

Use a solid state detector and set to only detect energies above 1.2 MeV

1.10.4 4

^{226}Th (6.45 MeV alpha) in presence of ^{129}I (194 keV beta):

Count with beta only by placing a piece of paper as a shield between detector and source, then count beta and alpha without the piece of paper. Subtract the beta value from the beta plus alpha value.

Alternatively, set energy threshold to 2 MeV and count alpha only.

1.10.5 5

^{3}H (18.6 keV beta) in presence of ^{14}C (156 keV beta):

Allow the H gas to physically separate from the denser C-14 gas, then count the gas in the upper chamber (the ^3H) with a proportional counter.

```
In [ ]:
```