Physics 180E Homework #1

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Problem 0.1.

(a) We derived in the first lecture that

$$\alpha = Ap \exp\left(-\frac{Bp}{E}\right).$$

Comparing that with the equation

$$\alpha = \frac{C}{\lambda_{mfp}} \exp\left(-\frac{W_{ion}}{E\lambda_{mfp}}\right),$$

we see that $Ap\lambda_{mfp} = C$ and $Bp\lambda_{mfp} = W_{ion}$. In order to get the equation

$$E = \frac{V_b}{d} = \frac{Bp}{\ln(Apd) - \ln(\ln(1 + 1/\gamma_{se}))},$$

start by taking the log of both sides of

$$\alpha d = \ln\left(1 + \frac{1}{\gamma_{se}}\right) = Apd \exp\left(-\frac{Bp}{E}\right)$$

to get

$$\ln(\ln(1 + 1/\gamma_{se})) = \ln(Apd) - \frac{Bp}{E}$$

which can be rewritten as

$$E = \frac{Bp}{\ln(Apd) - \ln(\ln(1 + 1/\gamma_{se}))}.$$

So the answer is

$$A = \frac{C}{p\lambda_{mfp}} = \frac{Cn\sigma}{p}$$
$$B = \frac{W_{ion}}{p\lambda_{mfp}} = \frac{W_{ion}n\sigma}{p}.$$

(b) Let $x = pd$. Then V_b is a function of x, and the minimum occurs when

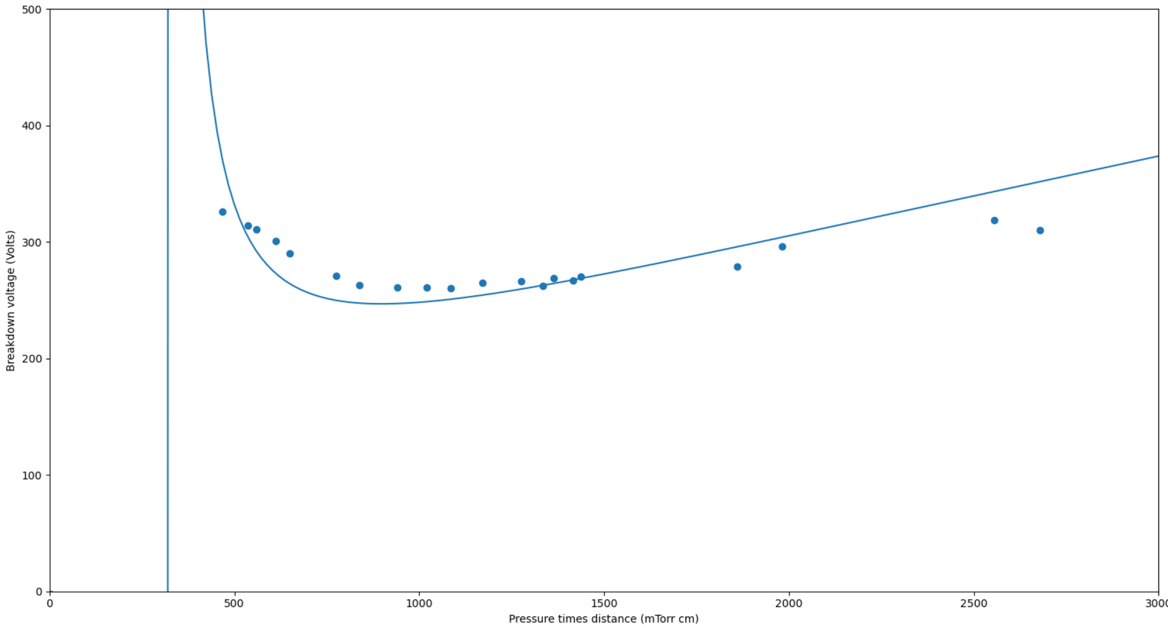
$$0 = \frac{\partial V_b}{\partial x} = \frac{B(\ln(Ax) - \ln(\ln(1 + 1/\gamma_{se}))) - Bx\left(\frac{A}{Ax}\right)}{(\ln(Ax) - \ln(\ln(1 + 1/\gamma_{se})))^2}$$
$$0 = B(\ln(Ax) - \ln(\ln(1 + 1/\gamma_{se}))) - Bx^2$$
$$x = \sqrt{\ln(Ax) - \ln(\ln(1 + 1/\gamma_{se}))}$$

It seems I messed up, so I plugged the expression into Wolfram Alpha and got

$$x = \frac{e \ln(1 + 1/\gamma_{se})}{A}.$$

Problem 0.2.

Here is the data for argon. I believe the curve fit will become much better once I account for systematic error in the distance measurement.



PHYSICS 180E, WINTER 2025

HOMEWORK 2
(DUE WEDNESDAY JAN. 29 BY MIDNIGHT ON GRADESCOPE)

1. In lecture, we derived the breakdown condition:

$$\alpha d = \ln\left(1 + \frac{1}{\gamma_{se}}\right)$$

where d is the plate separation, γ_{se} is the secondary emission coefficient, and α is the first Townsend coefficient:

$$\alpha = \frac{C}{\lambda_{mfp}} \exp\left(-\frac{W_{ion}}{E\lambda_{mfp}}\right)$$

(C is an experimentally determined constant, W_{ion} is the ionization potential of the gas, and $\lambda_{mfp} = 1/n\sigma$ is the mean free path for electron collisions with neutrals). In class, I showed this can be rewritten in terms of the breakdown voltage V_b as:

$$V_b = \frac{Bpd}{\ln(Apd) - \ln(\ln(1 + 1/\gamma_{se}))}$$

   (a) Write down expressions for A and B in terms of physical parameters (and the unknown constant C).

   (b) Determine an expression for the *minimum* breakdown voltage, again expressed in terms of physical parameters. Which physical parameter is this minimum most sensitive to?

2. Using your data, produce a Paschen curve plot for at least one gas/pressure and turn it in as part of this homework. If you were able to take data for more than one gas, what is the ordering of the gases with respect to minimum breakdown voltages? Does this order make sense?