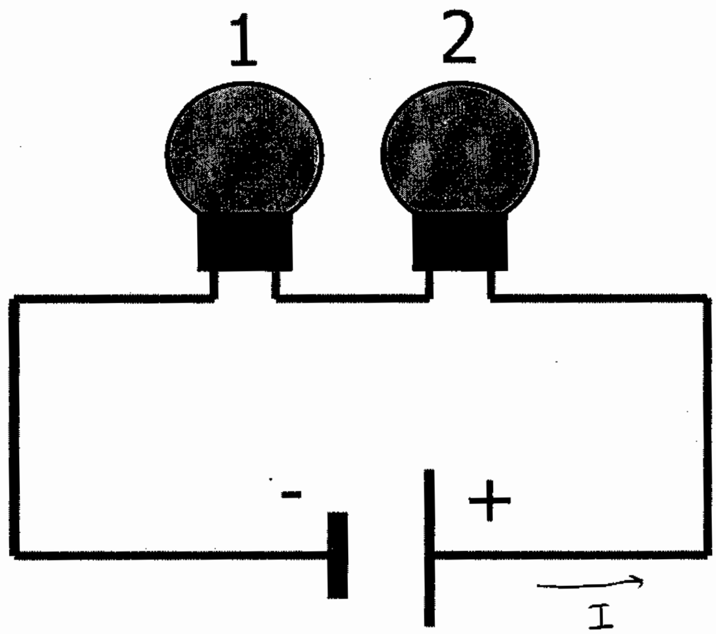
Problem 1 (25 points)

Shown below is a circuit consisting of an ideal power supply with an output voltage ΔV and two light bulbs connected in series. Bulb 2 is seen to burn brighter than bulb 1 in this circuit (i.e. it consumes more power). Approximate the bulbs as ohmic resistances.



(a) In this circuit, does current flow clockwise or counterclockwise?

counterclockwise

(b) Is the magnitude of the current through bulb 1 greater, the same or smaller than that of the current through bulb 2?

in series : the same

(c) Is the resistance of bulb 1 greater, smaller or the same as that of bulb 2?

$P_1 = I^2 R_1$

$P_2 = I^2 R_2$

$P_1 < P_2 \Rightarrow R_1 < R_2$ smaller

(d) Suppose the bulbs were connected in parallel, rather than in series. Would they burn brighter than before, dimmer than before or the same?

$P_1 = \frac{(\Delta V)^2}{R_1}$ since ΔV is greater than the voltage across Bulb 1 and Bulb 2 in series.

$P_2 = \frac{(\Delta V)^2}{R_2}$ both of them will burn brighter than before

(e) Suppose the bulbs were connected in parallel, rather than in series. Would bulb1 burn brighter, less bright or the same as bulb 2?

$P_1 = \frac{(\Delta V)^2}{R_1}$

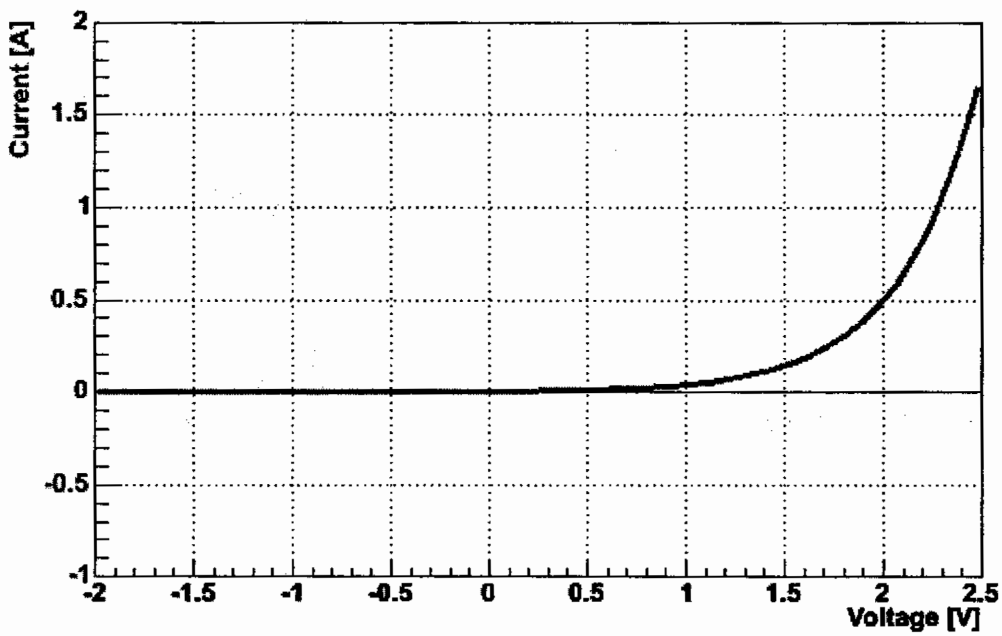
$P_2 = \frac{(\Delta V)^2}{R_2}$

since $R_1 < R_2 \Rightarrow P_1 > P_2$

i.e Bulb 1 burns brighter than Bulb 2

Problem 2 (25 points)

Shown below is a graph of current vs applied voltage for a diode, like the ones used in the HVPS experiment.



(a) Approximately, what is the resistance of the diode for an applied voltage of -2V?

$V = IR \quad I \sim 0 \Rightarrow R \sim \infty$

(b) Approximately, what is the resistance of the diode for an applied voltage of +2V?

$V = IR \quad V = 2V \quad I \sim 0.5A \Rightarrow R \sim 4\Omega$

(c) In one of the lecture demos, a long, resistive wire connecting a light bulb to a power supply was immersed in liquid nitrogen. Explain what happened (in a few sentences)

WIRE IS COOLED DOWN → LESS THERMAL EXCITATION OF METAL LATTICE → ELECTRONS MOVE THROUGH MORE EASILY → LESS RESISTIVITY → LESS RESISTANCE → MORE CURRENT → MORE POWER $P = I^2 R_{BULB}$

PROBLEM # 3

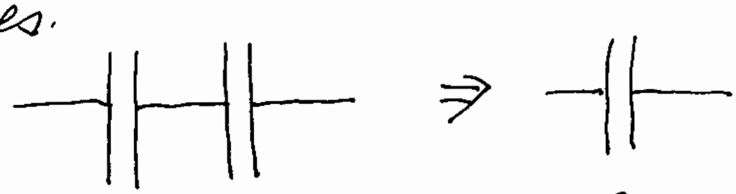
a) $U_0 = \dfrac{Q^2}{2C_0}$ Charge on plates remains fixed. Original energy $U_0 = 2\,J$.

After increase of spacing new capacitance is C

$$C = \left(\frac{\epsilon_0 A}{2d_0}\right) = \frac{C_0}{2} \qquad \text{Here } C_0 = \frac{\epsilon_0 A}{d_0}$$

$$\therefore\ U\left(\begin{smallmatrix}\text{After increase}\\ \text{of spacing}\end{smallmatrix}\right) = \frac{Q^2}{2C} = \frac{Q^2}{C_0} = 2U_0 = 4J$$

b) Remember that slab is a conductor. Under these conditions the system looks like 2 capacitors in series.



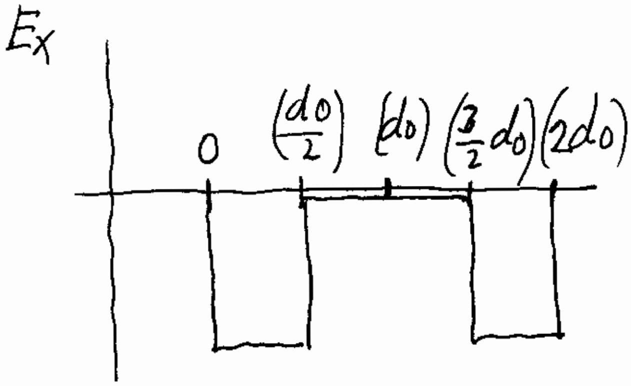
$C' = \epsilon_0 A/(d_0/2)$; C_0' $C_0' = 2C_0$ C_{eq}

$$\frac{1}{C_{eq}} = \frac{1}{C_0'} + \frac{1}{C_0'} \quad ; \quad C_{eq} = \frac{C_0'^2}{2C_0'} = \frac{1}{2}C_0' = C_0$$

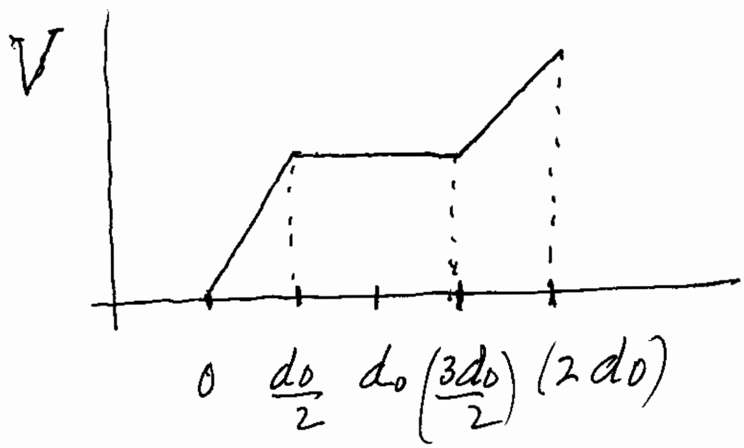
$$\therefore\ U\left(\begin{smallmatrix}\text{after slab}\\ \text{inserted}\end{smallmatrix}\right) = \frac{Q^2}{2C_{eq}} = \left(\frac{Q^2}{2C_0}\right) = U_0$$

$$= 2 \text{ Joules}$$

c)



Electric field points in the direction of $-x$ (so is <u>negative</u>)



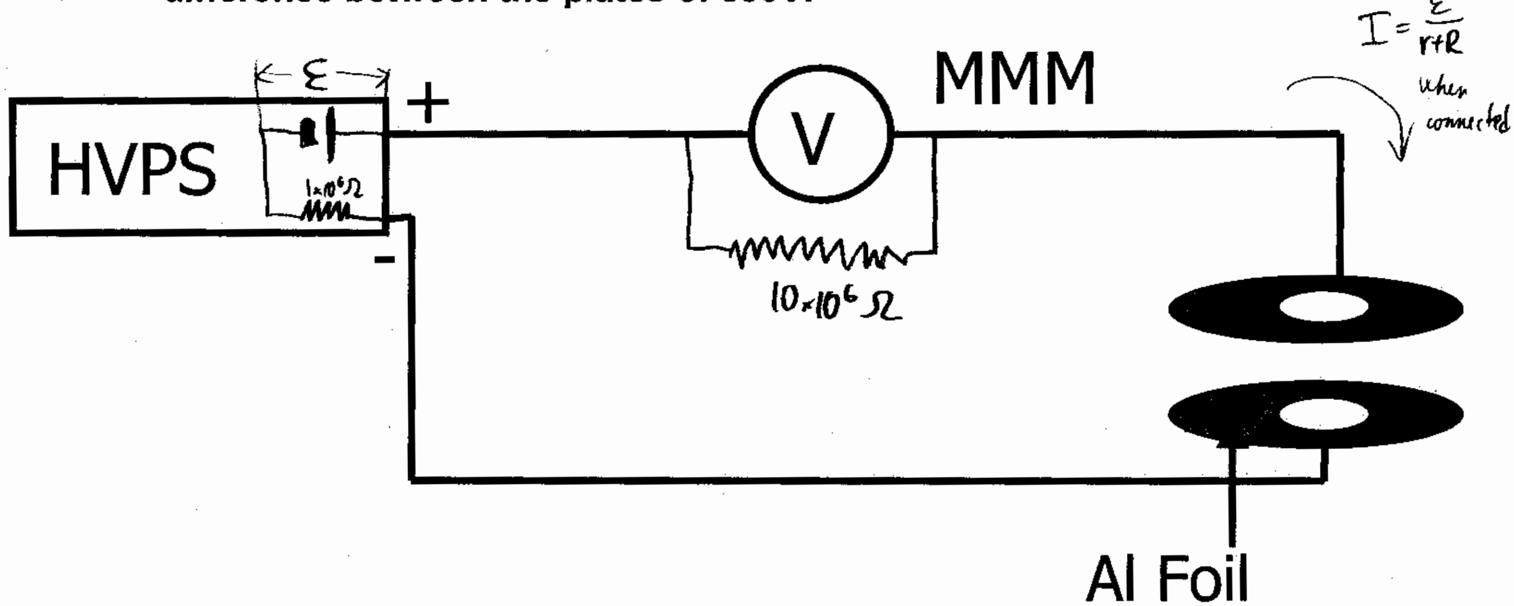
$E = -\left(\frac{dV}{dx}\right)$

or $V = -\int E\,dx$

Where the electric field is zero, the voltage remains constant $\left(\frac{d_0}{2} < x < \frac{3d_0}{2}\right)$

Problem 4 (25 points)

Shown below is a schematic view of experiment EF, but using only one multimeter. The multimeter has a resistance *R* of 10MΩ. Assume that in this setup, the foil jumps at a potential difference between the plates of 500V.

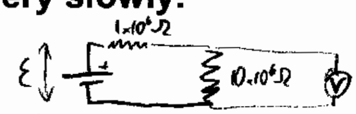


(a) What is the approximate reading of the multimeter in Volts when the EMF of the HVPS has been adjusted to 400V and the foil has not jumped?

Before the foil jumps, the circuit is disconnected ... $V = 0V$ (5 pts)

(b) What is the reading of the multimeter just after the foil has jumped and connected the two washers? Assume that the HVPS output was adjusted very slowly.

After the foil jumps, we have V something less than 500V because of the internal resistance $r = 1M\Omega$.



(10 pts)

(c) Assume that the HVPS has an internal resistance *r* of 1MΩ. What is the EMF of the HVPS just after the foil has jumped and connected the two washers?

The EMF of HVPS, $\mathcal{E}$, doesn't change! $\mathcal{E} = 500V$ (10 pts)

(The Voltmeter will show $V = \mathcal{E} - Ir = \mathcal{E} - \frac{\mathcal{E}}{r+R} r = \mathcal{E}\frac{R}{R+r} = 500 \cdot \frac{10}{11} = 450V$)