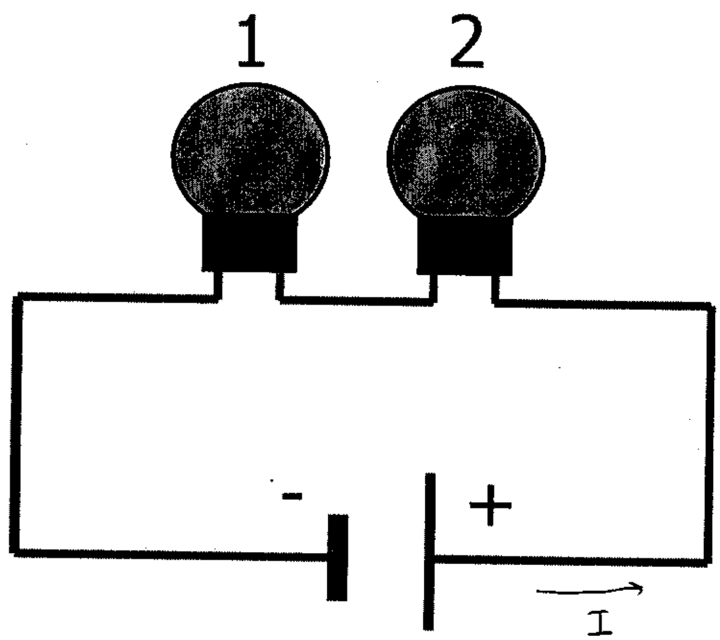
**Problem 1 (25 points)**

**Shown below is a circuit consisting of an ideal power supply with an output voltage $\Delta V$ 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?**

$P_1 = I^2 R_1$

$P_2 = I^2 R_2$

$P_1 < P_2 \implies R_1 < R_2$ 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 $\Delta V$ 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?**

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

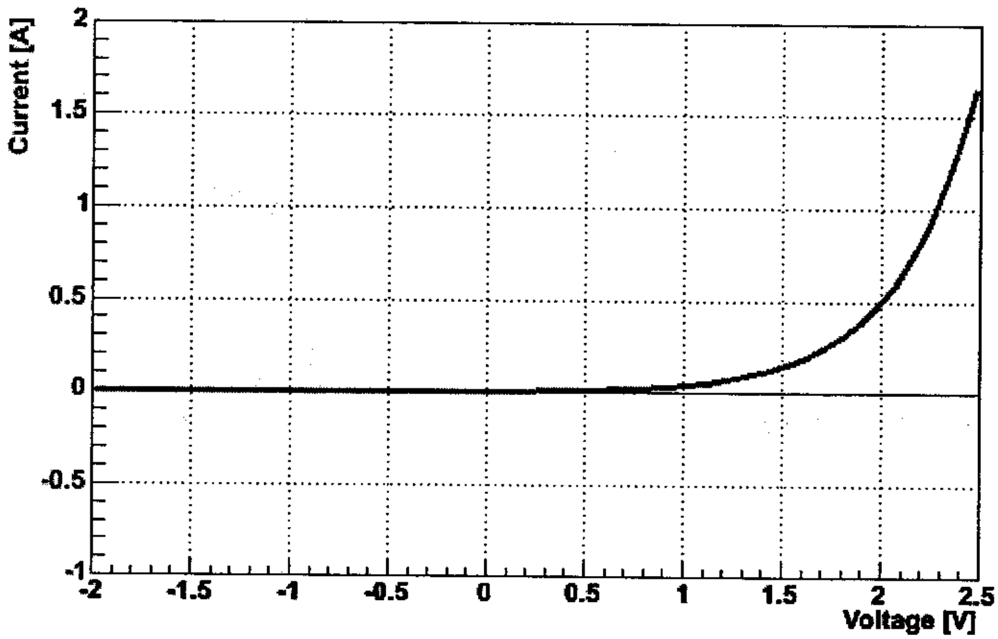
$P_2 = \frac{(\Delta V)^2}{R_2}$

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

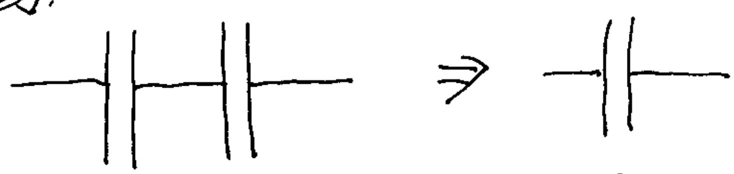
a) $U_0 = \frac{Q^2}{2C_0}$ Charge on plates remains fixed. Original energy $U_0 = 2\,J$.

After increase of spacing new capacitance is C

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

$$\therefore U\,(\text{After increase of spacing}) = \frac{Q^2}{2C} = \frac{Q^2}{C_0} = 2U_0 = 4J$$

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



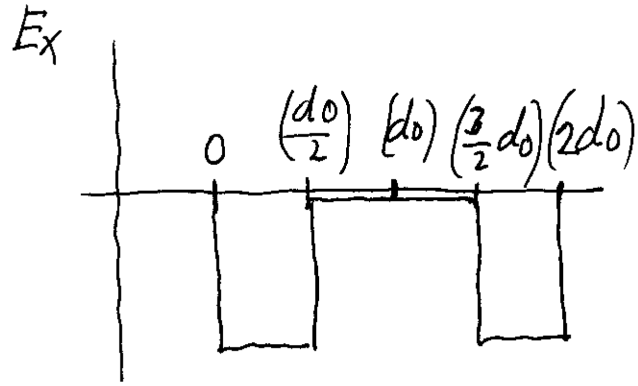
$C' = \epsilon_0 A/(d_0/2)$; $C_0'$ $C_0' = 2C_0$ $C_{eq}$

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

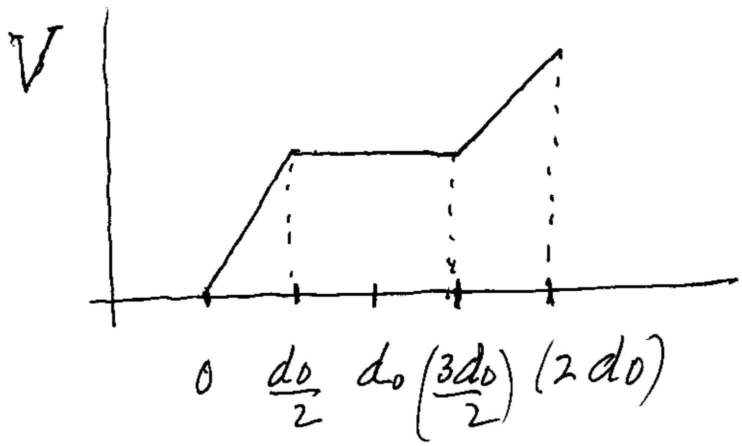
$$\therefore U\,(\text{after slab inserted}) = \frac{Q^2}{2C_{eq}} = \left(\frac{Q^2}{2C_0}\right) = U_0$$

$$= 2 \text{ Joules}$$

c)




Electric field points in the direction of $-x$ (so is **negative**)



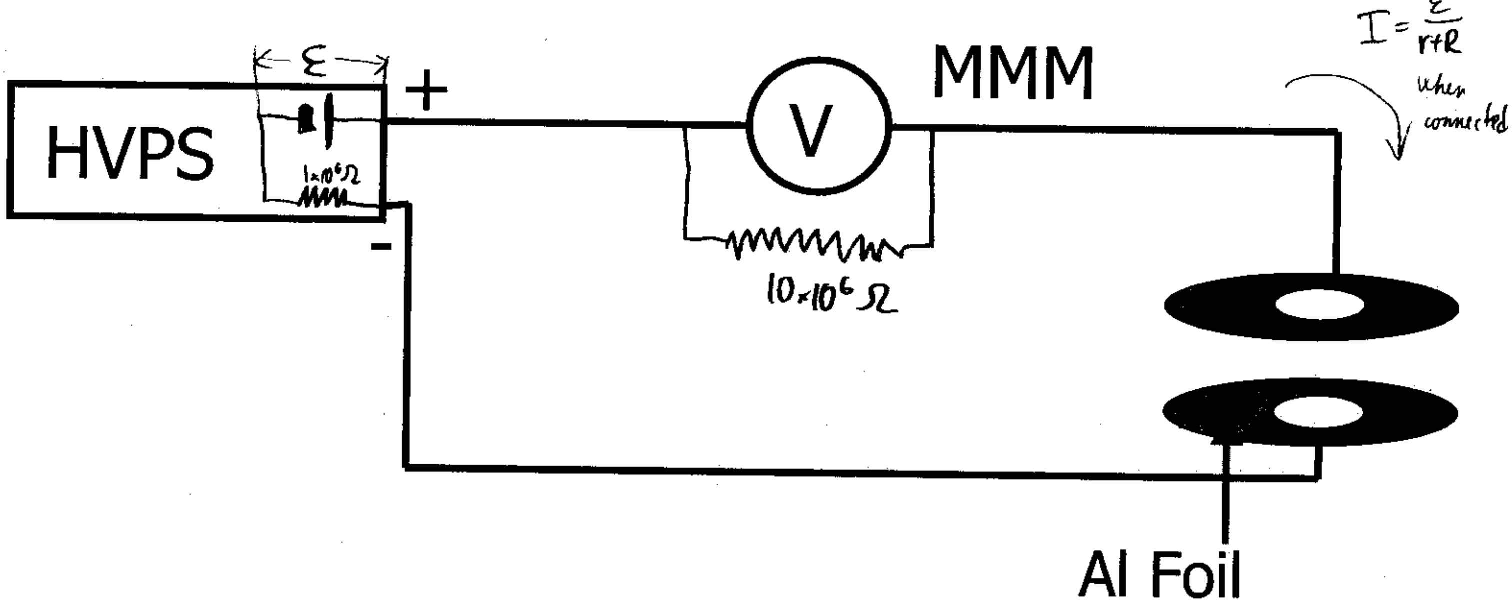

$$E = -\left(\frac{dV}{dx}\right)$$

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.**

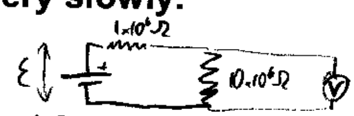



**(a) What is the approximate reading of the multimeter in Volts when the EMF of the HVPS has been adjusted to 400V and the foil has not jumped?**

Before the foil jumps, the circuit is disconnected ... $\boxed{V = 0V}$ (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 $\boxed{\text{less than } 500V}$ 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! $\boxed{\mathcal{E} = 500V}$ (10 pts)

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