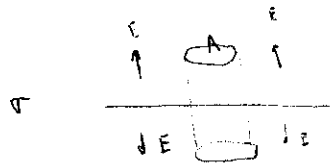
1.

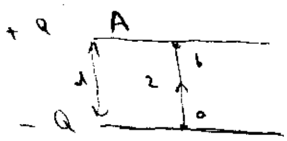
Quiz 2b



$$\oint E \cdot da = Q_{in}/\epsilon_0$$

$$E \cdot 2A = \sigma A/\epsilon_0$$

$$E = \frac{\sigma}{2\epsilon_0}$$



$\uparrow E_+ \downarrow E_- \Rightarrow \vec{E} = 0$

$\downarrow E_+ \downarrow E_- \Rightarrow E = \frac{\sigma}{\epsilon}$

$\downarrow E_+ \uparrow E_- \Rightarrow E = 0$

$$V_{ab} = -\int_a^b E \cdot ds = -\int_0^b \frac{\sigma}{\epsilon_0}(-\hat{z}) \cdot d\hat{z} = \frac{\sigma}{\epsilon_0} d = \frac{Q}{A\epsilon_0} d$$

$$Q = CV \Rightarrow C = \frac{A\epsilon_0}{d}$$

a) $d \to 2d$

$C \to C_0/2$

$Q \to Q$

$V \to 2\Delta V$

b) $P = IV = \frac{dQ}{dt} V$

$$U = \int P\, dV = \int_0^Q \frac{dQ'}{dt} \frac{Q'}{C} = \frac{1}{2}\frac{Q^2}{C}$$

$Q \to Q$

$C \to C/2$

$U \to 2U = \boxed{\frac{Q^2}{C_0}}$

c) Energy was added to the sytem by doing work against the electrical force to move the plates.

d) $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} C V^2$

$V \to V_0$

$C \to C_0/2$

$U = U_0/2 = \frac{Q^2}{4C_0}$

Notice: E remains the same in parts a-c but the volume it is affecting is doubled. In part d, E reduces to half its value.

Problem 2 (20 points)

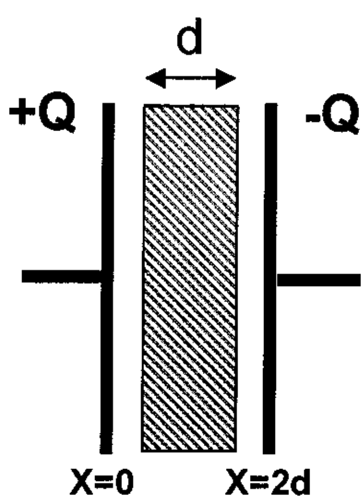
Shown below is the cross-section of a parallel plate capacitor with distance 2*d between the plates. The capacitor is given a charge Q using a power supply and then disconnected from the power supply. Then a dielectric with thickness d and dielectric constant K=2 is inserted between the plates.

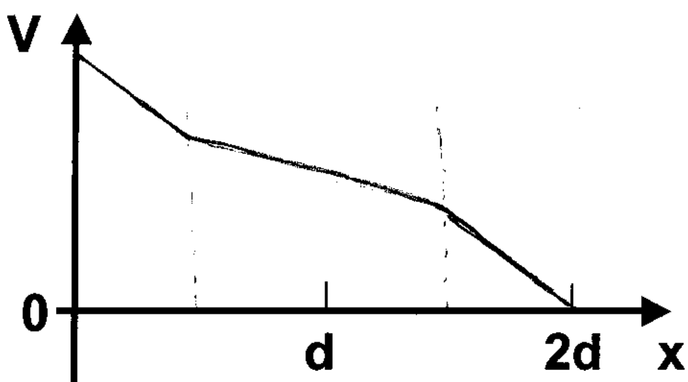
(a) Does the stored energy increase, decrease or stay the same when the dielectric is inserted?

$U = \frac{1}{2}\frac{Q^2}{C}$ $\qquad C = \frac{C_0}{2} + K\frac{C_0}{2}$

The energy decreases

(b) On the graph below, draw a qualitative sketch of the electric potential between the capacitor plates as a function of x between x=0 and x=2d. At which value of x did you choose to set V=0?





I chose x=2d as V=0

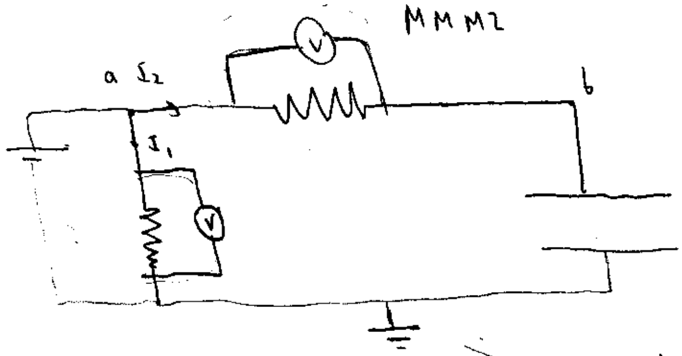
A different choice of V=0 would also give a correct result (By moving this sketch up or down)

3.

I will draw the multimeters as :

R = ∞ , ideal voltmeter

R = 20 MΩ



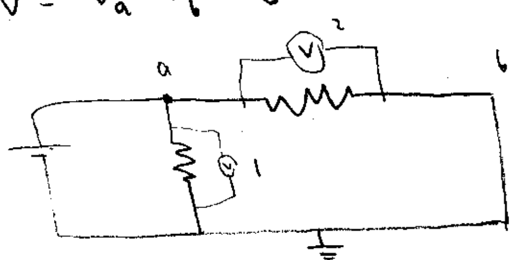
→ Ground shows any choice of V = 0

before : $I_2 = 0$ (circuit is open) , $V_a = V_b$

a) $V = 400V$

b) $\Delta V = V_a - V_b = 0$

c)



$V_b = 0$

d) $\Delta V = V_a - V_b = 380V$

e) The HVPS produces more current so there is a higher potential drop caused by the internal resistance of the HVPS

f) $V = E \cdot d = \frac{F}{m} d$

$$\left.\begin{array}{l} F \to F \\ m \to m \\ d \to 2d \end{array}\right\} V \to 2V$$

MMM1 would read 800V

4.

a) $P = IV = \frac{V^2}{R}$

$R_1 = \frac{V^2}{P} = \frac{144}{36} = 4\ \Omega$

b) $P = IV = I^2 R$

Since they have the same resistance and the same current flows through them, they would show <u>same</u> brightness

c) $R_2 = \frac{V^2}{P} = \frac{144}{72} = 2\ \Omega$

$P = I^2 R$

$I_1 = I_2$

$R_1 > R_2$

Bulb 1 would burn brighter.

Practice (a)

1.

(a) $I_1 = I_2 + I_3$

$I_1 > I_2$, $I_1 > I_3$

$P = I^2 R$

So bulb 1 is brightest

(b) bulb1 is brighter, bulb3 is less brighter.

the resistance of bulb 2 is reduced to 1/2,

Then , I_1 increases, U_1 increases, U_3 decreases.

$P_1 = I_1^2 R_1$, $P_3 = \frac{U_3^2}{R_3}$, So bulb1 is brighter, bulb3 is less brighter.

2.

(a) $C = \frac{2\varepsilon_0 A}{d_0}$

$E = \frac{1}{2}\frac{Q^2}{C} = \frac{d_0}{4\varepsilon_0 A} Q^2$

(b) $U = Q/C = \frac{d_0 Q}{2\varepsilon_0 A}$ is unchanged

After seperating,

$$\frac{1}{C'} = \frac{1}{C_{glass}} + \frac{2}{C_{air}} = \frac{d_0}{2\varepsilon_0 A} + \frac{2}{\frac{\varepsilon_0 A}{d_0/2}} = \frac{3 d_0}{2\varepsilon_0 A}$$

$$U_{stored} = \frac{1}{2} C' U^2$$
$$= \frac{1}{2} \frac{2\varepsilon_0 A}{3d_0} \left(\frac{d_0 Q}{2\varepsilon_0 A}\right)^2$$
$$= \frac{d_0}{12\varepsilon_0 A} Q^2$$

3.

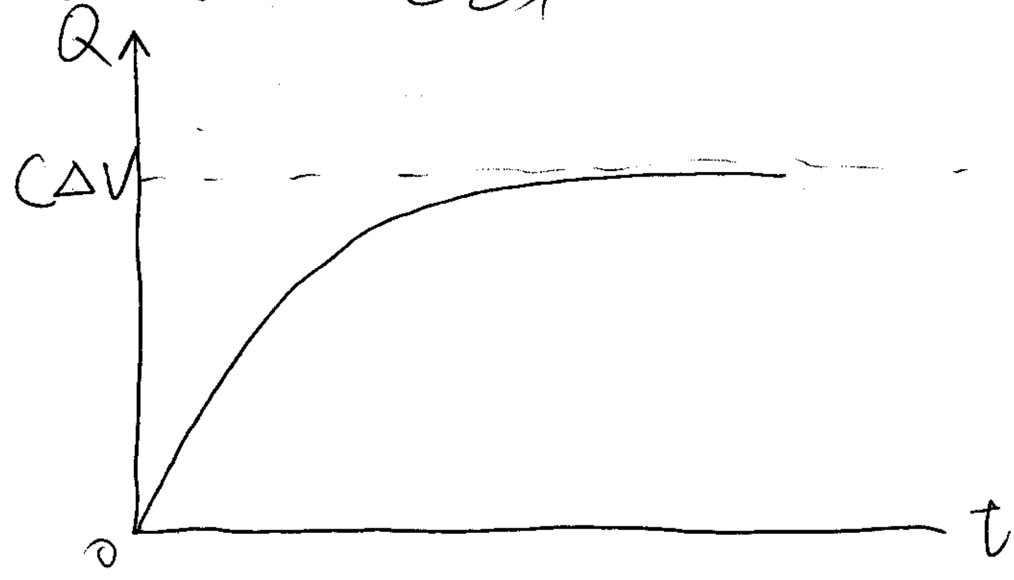
(a) $\cancel{\Delta V = U_c = -I_c r = -C\frac{dU}{dt} r}$

$$\Delta V - I_c r = U_c$$
$$\Delta V - C\frac{dU_c}{dt} r = U_c$$
$$\Rightarrow U_c = \Delta V\left(1 - e^{-\frac{t}{cr}}\right)$$
$$Q = CU_c = C\Delta V\left(1 - e^{-\frac{t}{cr}}\right)$$

$\cancel{\Rightarrow U_c = -I_c r}$

$\cancel{U_c = -C\frac{dU_c}{dt} r}$

$\cancel{\Rightarrow U_c = U_0(1 - e^{-\frac{1}{cr}t})}$



(b) $P = U_c I_c$

$$= \Delta V(1-e^{-\frac{t}{cr}})\frac{\Delta V}{r}e^{-\frac{t}{cr}}$$

So when $1-e^{-\frac{t}{cr}} = e^{-\frac{t}{cr}}$

P gets maximum.

$$\Rightarrow t = cr\ln 2$$

$$= 100\times10^{-6}\times 10\times10^{3}\ln 2$$

$$= \ln 2\ (s)$$

(c) $P_{max} = \frac{1}{4}\frac{\Delta V^2}{r} = \frac{1}{4}\frac{4000^2}{10\times10^3} = 400W$

4.

(a) $V_{mm_1} = 150V$

$V_{mm_2} = 150V$

(b) $V_{mm_1} = 300V$

$V_{mm_2} = 0V$

(C)

before foil jumps

$$E = \frac{\Delta V}{d}$$

$$F = QE = \frac{Q\Delta V}{d}$$