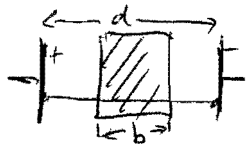
① (a) $C = \frac{\epsilon_0 A}{d} = \frac{(8.85\ pF/m)(0.12\ m^2)}{0.012\ m} = 89\ pF$

(b) $Q = C\Delta V = (89 \times 10^{-12}\ F)(120\ V) = 1.1 \times 10^{-8}\ C = 11\ nC$

same after dielectric is inserted.

(c) $E = \frac{Q/A}{\epsilon_0} = \frac{(1.1\times 10^{-8} C)/(0.12\ m^2)}{8.85 \times 10^{-12} F/m} = 10\ kV/m$

(d) $E' = E/K = 10\ kV/m / 4.8 = 2.1\ kV/m$

(e) 

Integrate along line:

$\Delta V = E(d-b) + E'(b)$

$= (10\ \frac{kV}{m})(0.008m) + (2.1\ \frac{kV}{m})(0.004m) = 88\ V$

(f) $C = \frac{Q}{\Delta V} = \frac{1.1 \times 10^{-8} C}{88V} \cong 120\ pF$

(g) Before: $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(1.1\times 10^{-8} C)^2}{89 \times 10^{-12} F} = 6.8 \times 10^{-7} J$

After: $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(1.1\times 10^{-8} C)^2}{120 \times 10^{-12} F} = 5.0 \times 10^{-7} J$

$W_{ext} = U_f - U_i = -1.8 \times 10^{-7} J$

② (a) Q remains the same. $C = \frac{\epsilon_0 A}{d} \rightarrow C' = \frac{\epsilon_0 A}{2d} = \frac{1}{2}C$

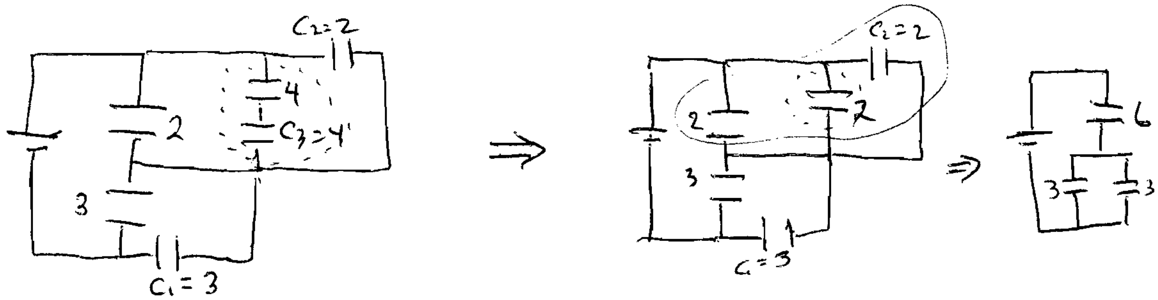
$\Delta V' = \frac{Q'}{C'} = \frac{Q}{\frac{1}{2}C} = 2\frac{Q}{C} = 2\Delta V$

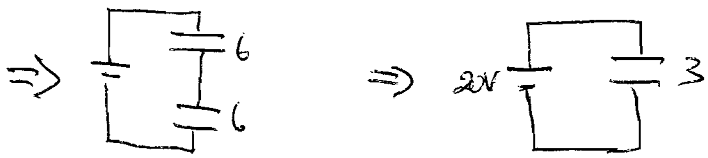
(b) Initial $U_i = \frac{1}{2}C(\Delta V)^2 = \frac{\epsilon_0 A}{2d}(\Delta V)^2$

Final. $U_f = \frac{1}{2}C'(\Delta V')^2 = \frac{1}{2}\frac{\epsilon_0 A}{2d}(2\Delta V)^2 = \frac{\epsilon_0 A (\Delta V)^2}{d}$

(c) $W_{ext} = U_f - U_i = \frac{\epsilon_0 A (\Delta V)^2}{d} - \frac{\epsilon_0 A (\Delta V)^2}{2d} = \frac{\epsilon_0 A (\Delta V)^2}{2d}$

③ (a)

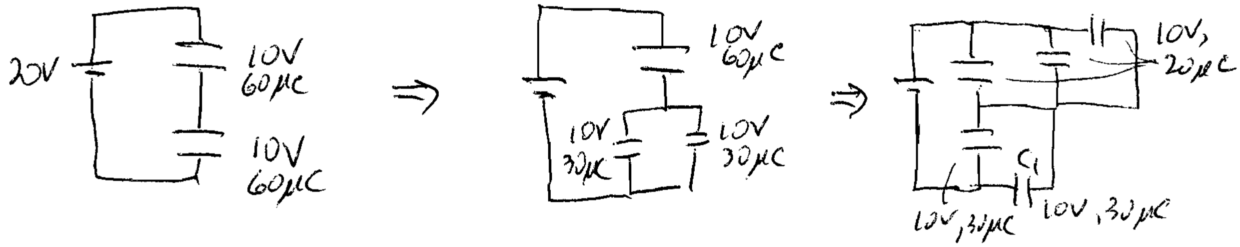




$C_{eq} = 3.0\ \mu F$

(b) $Q = C_{eq} \Delta V = C_{eq} \varepsilon = (3.0 \mu F)(20 V) = 60 \mu C$

(c) Work backwards to find Q and ΔV for each capacitor.



⇒ on C_1 : 10 V, 30 μC

(d) on C_2: 10 V, 20 μC

(e) on C_3: 5 V, 20 μC.

④ (a) $\Delta V_c = \varepsilon (1 - e^{-t/RC}) \Rightarrow e^{-t/RC} = 1 - \frac{\Delta V_c}{\varepsilon}$

$-\frac{t}{RC} = \ln\left(1 - \frac{\Delta V_c}{\varepsilon}\right)$

$RC = \frac{-t}{\ln\left(1 - \frac{\Delta V_c}{\varepsilon}\right)} = -\frac{1.3 \mu s}{\ln\left(1 - \frac{5V}{12V}\right)} = 2.41 \mu s$

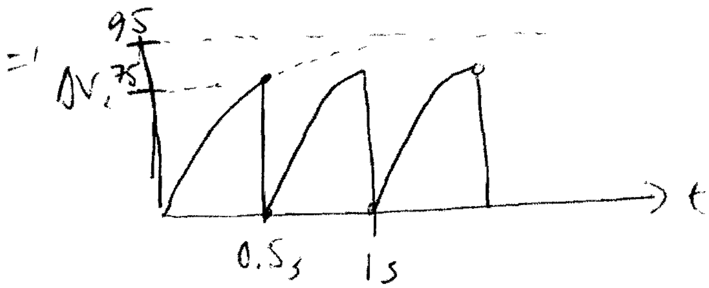
(b) $C = \frac{2.41 \mu s}{R} = \frac{2.41 \mu s}{15{,}000\ \Omega} = 161\ pF$

5. The charge on cap in RC circuit is

$$Q(t) = \mathcal{E}C(1 - e^{-t/RC})$$

$$\Delta V_c(t) = C \cdot Q(t) = \mathcal{E}(1 - e^{-t/RC})$$

at 75 volts, lamp fires & uses all charge (like camera flash)



$$\Rightarrow \Delta V_c(0.5s) = 75\text{ V} = 95\text{ V}(1 - e^{-t/RC})$$

or $\quad V_0 = \mathcal{E}(1 - e^{-t/RC})$ w/ $t = 0.5$ s

$$\Rightarrow e^{-t/RC} = 1 - \frac{V_0}{\mathcal{E}}$$

$$\frac{t}{RC} = -\ln\left(1 - \frac{V_0}{\mathcal{E}}\right)$$

$$R = \frac{t}{C} \frac{1}{-\ln(1 - \frac{V_0}{\mathcal{E}})}$$

$$= \frac{0.5s}{0.15\mu F} \frac{1}{-\ln(1 - \frac{75}{95})}$$

$$= \frac{0.5s}{0.15\mu F} \frac{1}{\ln \frac{95}{20}}$$

$$\boxed{R = 2.14 \times 10^6\ \Omega}$$