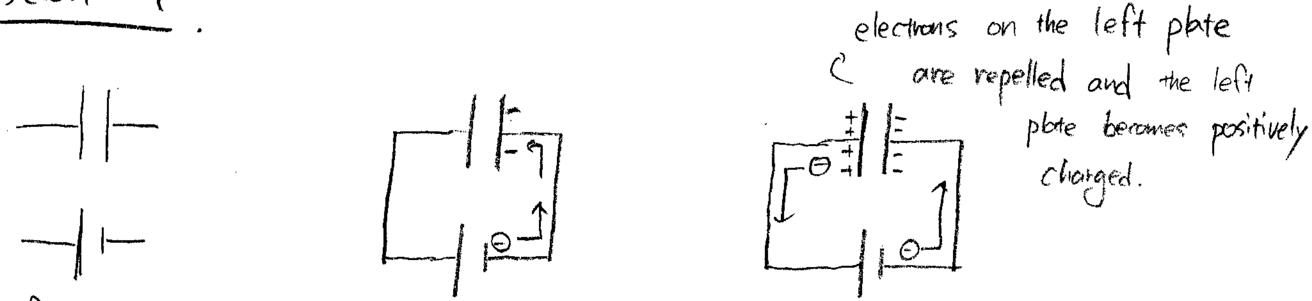
PHY122 Workshop #3

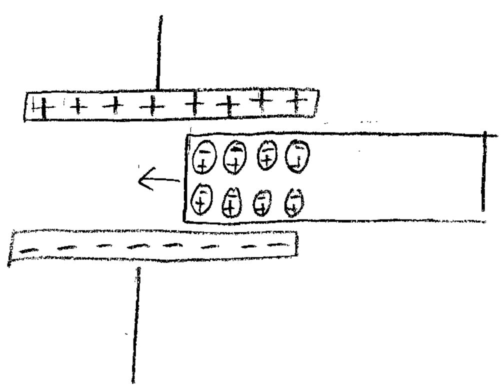
Question 4



Before connecting — Just after connecting — Some time later

When a capacitor is first connected to a battery, charge flows to one plate. Because the plates are separated by an insulating material, charge cannot cross the gap. An equal amount of charge is therefore repelled from the opposite plate, leaving it with a charge that is equal and opposite to the charge on the first plate. The two conductors of a capacitor will have equal and opposite charges even if they have different sizes or shapes.

Q11



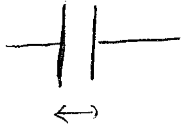
⇐ Refer Fig 24-17

The dielectric will be pulled into the capacitor by the electrostatic attractive forces btwn the charges on the capacitor plates and the polarized charges on the dielectric's surface. (Note that the addition of the dielectric decreases the energy of the system.)

P8

(a)

$+Q_{1i}\ -Q_{1i}$

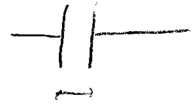


$V_{1i} = 475\,V$

$C_1 = 2.70\,\mu F$

$Q_{1i} = C_1 V_{1i}$

$+Q_{2i}\ -Q_{2i}$



$V_{2i} = 525\,V$

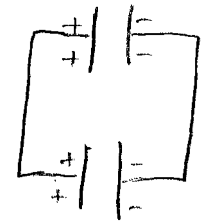
$C_2 = 4.00\,\mu F$

$Q_{2i} = C_2 V_{2i}$

$\Rightarrow$

Q_{1f}

C_1, V_{1f}



C_2, V_{2f}

Q_{2f}

The total charge on the combination of capacitors is the sum of the charges on the two individual capacitors, since there is no battery connected to them to supply additional charge, and there is no neutralization of charge by combining positive and negative charges.

$$Q_{total} = Q_{1i} + Q_{2i} = Q_{1f} + Q_{2f} \quad -①$$

The voltage across each capacitor must be the same after they are connected, since each capacitor plate is connected to a corresponding plate on the other capacitor by a constant-potential wire.

$$V_{1f} = V_{2f} = V \quad -②$$

Since this is a case of capacitors in parallel,

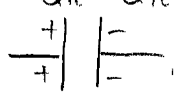
$$V = \frac{Q_{total}}{C_1 + C_2} = \frac{Q_{1i} + Q_{2i}}{C_1 + C_2} = \frac{(2.70\times10^{-6}F)(475V) + (4.00\times10^{-6}F)(525V)}{(6.70\times10^{-6}F)}$$

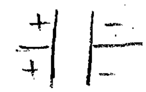
$$= 504.85V \approx \boxed{505\,V}$$

$\therefore\ Q_{1f} = C_1 V_{1f} = C_1 V = (2.70\times10^{-6}F)(505V) \cong \boxed{1.36\times10^{-3}C}$

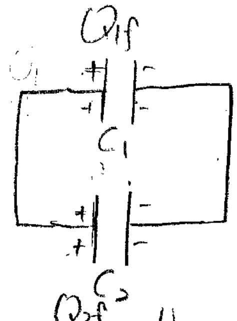
$Q_{2f} = C_2 V_{2f} = C_2 V = (4.00\times10^{-6}F)(505V) = \boxed{2.02\times10^{-3}C}$

(b) $+Q_{1i}\ -Q_{1i}$ $+Q_{2i}\ -Q_{2i}$





$\Rightarrow$



$Q_{1i} = 1.28\times10^{-3}C$, $Q_{2i} = 2.1\times10^{-3}C$

By connecting plates of opposite charge, the total charge will be the difference of the charges on the two individual capacitors.

$Q_{total} = |Q_{1i} - Q_{2i}| = |2.1\times10^{-3}C - 1.28\times10^{-3}C| = \underline{0.82\times10^{-3}C}$

As in (a), $V_{1f} = V_{2f} = V$

$$V = \frac{Q_{total}}{C_1 + C_2} = \frac{0.82\times10^{-3}C}{6.70\times10^{-6}F} = \boxed{122V}$$

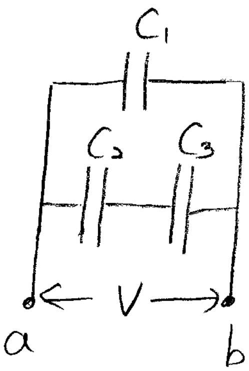
$\therefore\ Q_{1f} = C_1 V_{1f} = C_1 V_1 = (2.70\times10^{-6}F)(122V) = 329.4\times10^{-6}C$

$= \boxed{3.3\times10^{-4}C}$

$Q_{2f} = C_2 V_{2f} = C_2 V_2 = (4.00\times10^{-6}F)(122V) = 488\times10^{-4}C$

$= \boxed{4.9\times10^{-6}C}$

P37 (a)



The series capacitors add reciprocally, and then the parallel combination is found by adding linearly.

$$C_{eq} = C_1 + \left(\frac{1}{C_2} + \frac{1}{C_3}\right)^{-1} = C_1 + \left(\frac{C_3 + C_2}{C_2 C_3}\right)^{-1}$$

$$= \boxed{C_1 + \frac{C_2 C_3}{C_2 + C_3}}$$

(b) For C_1, the full 35.0 V is across the capacitance,

$$Q_1 = C_1 V = (24.0 \times 10^{-6} F)(35.0 V) = \boxed{8.4 \times 10^{-4} C}$$

The charges on the series combination is the same as the charge on each of the individual capacitors.

$$C_{eq} = \left(\frac{1}{C_2} + \frac{1}{C_3}\right)^{-1} = \left(\frac{1}{24 \mu F} + \frac{1}{12 \mu F}\right)^{-1} = \left(\frac{3}{\underset{8}{\cancel{24}} \mu F}\right)^{-1} = 8 \mu F$$

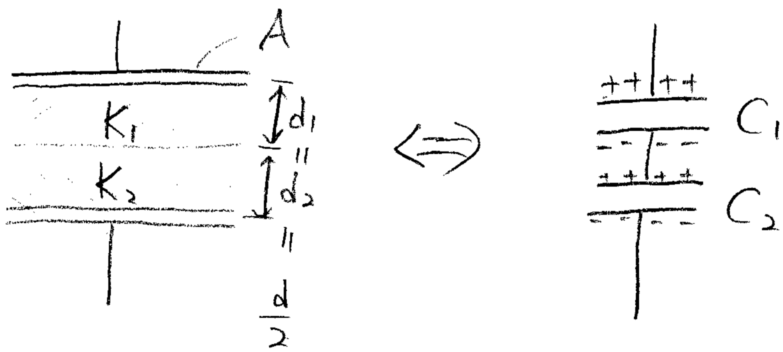
$$Q_2 = Q_3 = C_{eq} V = (8 \mu F) \times (35.0 V) = \boxed{2.8 \times 10^{-4} C}$$

$\boxed{P45}$ As we obtained in Prob 37,

$$C_{eq} = C_1 + \frac{C_2 C_3}{C_2 + C_3} = C + \frac{CC}{2C} = \frac{3}{2}C$$

$$U = \frac{1}{2} C_{eq} V^2 = \frac{1}{2} \times \frac{3}{2} C V^2 = \frac{3}{4}(22.6 \times 10^{-6} F)(10.0 V)^2 = \boxed{1.70 \times 10^{-3} J}$$

$\boxed{\text{Prob. 60}}$



The intermediate potential at the boundary of the two dielectrics can be treated as the "low" potential plate of one half and the "high" potential plate of the other half, so we treat it as two capacitors in series.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{K_1 \frac{\varepsilon_0 A}{d/2}} + \frac{1}{K_2 \frac{\varepsilon_0 A}{d/2}} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

$$= \frac{d}{2\varepsilon_0 A} \frac{K_1 + K_2}{K_1 K_2}$$

$$\Leftrightarrow \boxed{C_{eq} = \frac{2\varepsilon_0 A}{d} \frac{K_1 K_2}{K_1 + K_2}}$$