1. A capacitor is formed of two 1 mm thick parallel plates that are separated by 2 mm. An identical metal plate is then carefully inserted between the two plates so that a space of 0.5 mm is left on either side of the new plate, as shown in the figure.

A. [6 pts.] Does the capacitance of the capacitor change after the metal plate is inserted between the two original plates? Does it increase, decrease, or stay the same?
B. [6 pts.] Explain why a change does or does not occur.

A) Capacitance increases

B) The metal plate creates two capacitors in series, so the new capacitance is found by combining each new \( C \) that has the same area. 

\[
\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{(4\mu F)} + \frac{1}{(4\mu F)} = \frac{d}{2\varepsilon_0 A}
\]

\( C_{new} = 2C_{old} \)

2. Three capacitors are connected as shown in the figure. The capacitances shown are as follows: \( C_1 = 4 \mu F \), \( C_2 = 3 \mu F \), and \( C_3 = 5 \mu F \). The battery voltage is 6 V.

A. [11 pts.] What is the magnitude of the charge on capacitor \( C_2 \)?
B. [11 pts.] What is the potential difference across the plates of capacitor \( C_3 \)?

A) \( C = \frac{Q}{V} \)

\[ C_{23} = \left( \frac{1}{3} \frac{1}{5} \right) = 1.875 \mu F \]

\( C_1 \) and \( C_{23} \) both have 6V since they are parallel

\[ Q_{23} = C_{23} V_{23} = (1.875\mu F)(6V) = 11.25 \mu C \]

\( Q_2 = Q_3 = 11.25 \mu C \)

so \( Q_3 = 11.25 \mu C \)

B) \( Q_3 = Q_2 = 11.25 \mu C \) (series)

\[ V_3 = \frac{Q_3}{C_3} = \frac{11.25 \mu C}{5 \mu F} \]

\[ V_3 = 2.25 V \]
SHOW ALL WORK!

The figure applies to the following three problems.

A. [11 pts.] With the switch open, what is the current $I_1$? (A positive sign means that current flows in the direction of the arrow.)

B. [11 pts.] How much current passes through the switch after it is closed?

C. [11 pts.] With the switch closed, what is the voltage difference, $V(A) - V(B)$?

**Diagram:**

**A.**

\[
\begin{align*}
10V & \quad \text{10}\Omega \\
5\Omega & \quad 6V \\
5\Omega & \quad 15\Omega
\end{align*}
\]

**Loop rule:**

\[
0V = -10V + 10\Omega I_1 + 50\Omega I_1 + 15\Omega I_1 + 6V + 5\Omega I_1
\]

\[
4V = 80\Omega \cdot I_1 \Rightarrow I_1 = 50mA
\]

**B.**

\[
\begin{align*}
10V & \quad \text{10}\Omega \\
5\Omega & \quad 6V \\
15\Omega & \quad 5\Omega
\end{align*}
\]

\[
I_1 = \frac{10V}{10\Omega + 50\Omega} = \frac{1}{6}A
\]

\[
I_2 = \frac{6V}{5\Omega + 15\Omega} = \frac{3}{10}A
\]

\[
I_{\text{switch}} = I_1 + I_2 = \frac{1}{6}A + \frac{3}{10}A
\]

\[
I_{\text{switch}} = 0.58mA
\]

**C.**

\[
V(A) - V(B) = 6V - 15\Omega \cdot I_2 + 50\Omega \cdot I_1 \Rightarrow \\
\Delta V = 9.83V
\]

"There are other paths available."
The switches $S_1$ and $S_2$ in the figure are initially open (as shown), and the capacitors are initially uncharged. Then, at time $t = 0$, both switches are closed. Assume $V_B = 18 \text{ V}$, $R_1 = 10 \Omega$, $R_2 = 20 \Omega$, $R_3 = 30 \Omega$, $C_1 = 10 \mu\text{F}$, $C_2 = 20 \mu\text{F}$, and $C_3 = 30 \mu\text{F}$.

A. [11 pts.] What is the current through the resistor $R_1$ immediately after the switches are closed?

B. [11 pts.] What is the current through resistor $R_2$ a very long time after the switches are closed?

C. [11 pts.] What is the charge on the capacitor $C_2$ a very long time after the switches are closed?

**Solution**

A. $\Sigma V = V_B - I_1 R_1 - V_{C_2} = V_B - I_1 R_1 \rightarrow 0 = 0$  \( I_1 = 1.8 \text{ A} \)

At time $t = 0$, the charge on the capacitors is zero, so the voltage drop across the capacitors is zero. Since the 4 paths are in parallel, they must each have a voltage drop of zero and so current only flows through $C_2$ and $C_3$ paths.

B. As $t \rightarrow \infty$ the capacitor is full and no more current can flow through it. Since $R_2$ is in series with $C_1$, the current through $R_2$ is zero. Amps

C. For the Kirchhoff loop $\frac{V_B}{R_1} = \frac{V_{C_2}}{R_3}$

This is the only loop with current as $t \rightarrow \infty$ then $V_B - I_1 R_1 - I_3 R_3 = 0$  \( I = 0.45 \text{ A} \)

Since the path through $R_3$ is parallel to the $C_2$ path \( V_{R_3} = V_{C_2} \)

$V_{R_3} = I R_3 = 13.5 \text{ V} = V_{C_2}$  \( Q_{C_2} = C_2 V_{C_2} = 20 \mu\text{F} \times 13.5 \text{ V} = 2.7 \times 10^{-3} \text{ C} \)