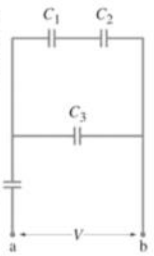
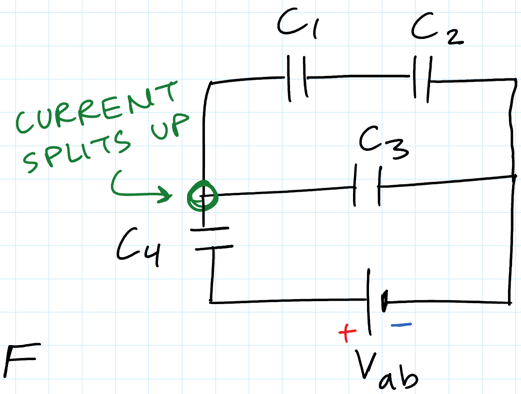
30. (II) Suppose in Fig. 24–23 that $C_1 = C_2 = C_3 = 16.0\,\mu F$ and $C_4 = 28.5\,\mu F$. If the charge on C_2 is $Q_2 = 12.4\,\mu C$, determine the charge on each of the other capacitors, the voltage across each capacitor, and the voltage V_{ab} across the entire combination.

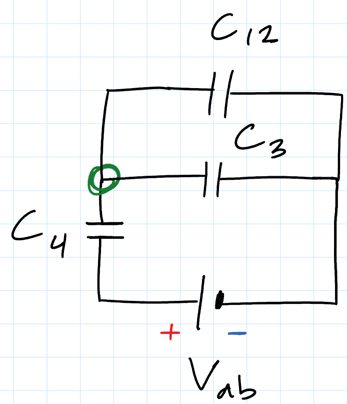


DISCLAIMER: THIS IS CH 24, 25 WHICH IS BEFORE KIRCHOFF'S LAW STUFF



FIND Q_1, Q_3, Q_4 & V_1, V_2, V_3, V_4

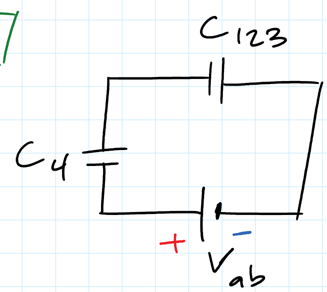
$$C_{12} = \left[\frac{1}{C_1} + \frac{1}{C_2}\right]^{-1} = \left[\frac{1}{16} + \frac{1}{16}\right]^{-1} = \left[\frac{2}{16}\right]^{-1} = 8\,\mu F$$



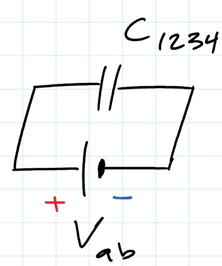
$$C_{123} = C_{12} + C_3 = 8 + 16 = 24\,\mu F$$

$$C_{1234} = \left[\frac{1}{C_{123}} + \frac{1}{C_4}\right]^{-1} = \left[\frac{1}{24} + \frac{1}{28.5}\right]^{-1} \cong 13\,\mu F$$

SINCE $Q_2 = 12.4\,\mu C$, $V_2 = \frac{Q_2}{C_2} = \frac{12.4}{16} = \boxed{0.775\,V}$



KEEP IN MIND:
- ↳ DEVICES IN PARALLEL ~ SAME V
- ↳ DEVICES IN SERIES ~ SAME Q



SINCE Q_1 & Q_2 IN SERIES: $Q_1 = Q_2$

$$\longrightarrow Q_1 = Q_2 = C_2 V_2 = (16)(0.775) = \boxed{12.4\,\mu C}$$

$$\longrightarrow V_2 = \frac{Q_2}{C_2} = \frac{12.4}{16} = \boxed{0.775\,V}$$ ~ $V_1 = V_2$ SINCE $C_1 = C_2$

ALSO: VOLTAGES IN SERIES ARE ADDED, SO $V_{12} = V_1 + V_2 = 2(0.775)$

$= 1.55\,V$

SINCE C_{12} & C_3 IN PARALLEL, $V_{12} = V_3$

$\longrightarrow V_3 = V_2 = \boxed{1.55\,V}$

IT TURNS OUT $V_{123} = V_{12} = V_3$ SINCE THESE ARE ALL PARALLEL

SINCE C_{123} & C_4 IN SERIES, $Q_{123} = Q_4 = Q_{1234} = Q_{TOTAL}$

$\longrightarrow Q_4 = Q_{123}$

$= C_{123} V_{123} = (24)(1.55) = \boxed{37.2\,\mu C}$

$\longrightarrow V_4 = \frac{Q_4}{C_4} = \frac{37.2}{28.5} = \boxed{1.305\,V}$

SINCE V_{123} & V_4 IN SERIES, $V_{1234} = V_{123} + V_4 = 1.55 + 1.305$

$= \boxed{2.855\,V}$

GOING FROM + TO − ON THE BATTERY, THE VOLTAGE GOES FROM V_{ab} TO ZERO SO $V_{ab} = V_4 + V_{123} = V_{1234}$

$= \boxed{2.855\,V}$

30. C_1 and C_2 are in series, so they both have the same charge. We then use that charge to find the voltage across each of C_1 and C_2. Then their combined voltage is the voltage across C_3. The voltage across C_3 is used to find the charge on C_3.

$$Q_1 = Q_2 = 12.4\mu C \; ; \; V_1 = \frac{Q_1}{C_1} = \frac{12.4\mu C}{16.0\mu F} = 0.775\,V \; ; \; V_2 = \frac{Q_2}{C_2} = \frac{12.4\mu C}{16.0\mu F} = 0.775\,V$$

$$V_3 = V_1 + V_2 = 1.55\,V \; ; \; Q_3 = C_3 V_3 = (16.0\mu F)(1.55\,V) = 24.8\mu C$$

From the diagram, C_4 must have the same charge as the sum of the charges on C_1 and C_3. Then the voltage across the entire combination is the sum of the voltages across C_4 and C_3.

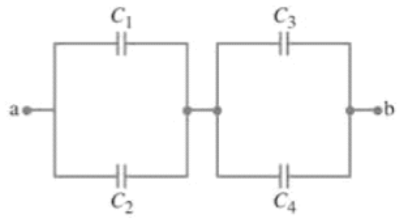
$$Q_4 = Q_1 + Q_3 = 12.4\mu C + 24.8\mu C = 37.2\mu C \; ; \; V_4 = \frac{Q_4}{C_4} = \frac{37.2\mu C}{28.5\mu F} = 1.31\,V$$

$$V_{ab} = V_4 + V_3 = 1.31\,V + 1.55\,V = 2.86\,V$$

Here is a summary of all results.

$$\boxed{\begin{array}{l} Q_1 = Q_2 = 12.4\mu C \; ; \; Q_3 = 24.8\mu C \; ; \; Q_4 = 37.2\mu C \\ V_1 = V_2 = 0.775\,V \; ; \; V_3 = 1.55\,V \; ; \; V_4 = 1.31\,V \; ; \; V_{ab} = 2.86\,V \end{array}}$$

33. (II) Suppose in Problem 32, Fig. 24–25, that $C_1 = C_3 = 8.0\,\mu F$, $C_2 = C_4 = 16\,\mu F$, and $Q_3 = 23\,\mu C$. Determine (*a*) the charge on each of the other capacitors, (*b*) the voltage across each capacitor, and (*c*) the voltage V_{ba} across the combination.



33. (*a*) The voltage across C_3 and C_4 must be the same, since they are in parallel.

$$V_3 = V_4 \rightarrow \frac{Q_3}{C_3} = \frac{Q_4}{C_4} \rightarrow Q_4 = Q_3\frac{C_4}{C_3} = (23\mu C)\frac{16\mu F}{8\mu F} = \boxed{46\mu C}$$

The parallel combination of C_3 and C_4 is in series with the parallel combination of C_1 and C_2, and so $Q_3 + Q_4 = Q_1 + Q_2$. That total charge then divides between C_1 and C_2 in such a way that $V_1 = V_2$.

$$Q_1 + Q_2 = Q_3 + Q_4 = 69\mu C \ ; \ V_1 = V_2 \rightarrow \frac{Q_1}{C_1} = \frac{Q_4}{C_4} = \frac{69\mu C - Q_1}{C_4} \rightarrow$$

$$Q_1 = \frac{C_1}{C_4 + C_1}(69\mu C) = \frac{8.0\mu F}{24.0\mu F}(69\mu C) = \boxed{23\mu C} \ ; \ Q_2 = 69\mu C - 23\mu C = \boxed{46\mu C}$$

Notice the symmetry in the capacitances and the charges.

(*b*) Use Eq. 24-1.

$$V_1 = \frac{Q_1}{C_1} = \frac{23\mu C}{8.0\mu F} = 2.875\,V \approx \boxed{2.9\,V} \ ; \ V_2 = V_1 = \boxed{2.9\,V}$$

$$V_3 = \frac{Q_3}{C_3} = \frac{23\mu C}{8.0\mu F} = 2.875\,V \approx \boxed{2.9\,V} \ ; \ V_4 = V_3 = \boxed{2.9\,V}$$

(*c*) $V_{ba} = V_1 + V_3 = 2.875\,V + 2.875\,V = 5.75\,V \approx \boxed{5.8\,V}$