•••23 Figure 25-39 shows a 12.0 V battery and four uncharged capacitors of capacitances $C_1 = 1.00\ \mu F$, $C_2 = 2.00\ \mu F$, $C_3 = 3.00\ \mu F$, and $C_4 = 4.00\ \mu F$. If only switch S_1 is closed, what is the charge on (a) capacitor 1, (b) capacitor 2, (c) capacitor 3, and (d) capacitor 4? If both switches are closed, what is the charge on (e) capacitor 1, (f) capacitor 2, (g) capacitor 3, and (h) capacitor 4?

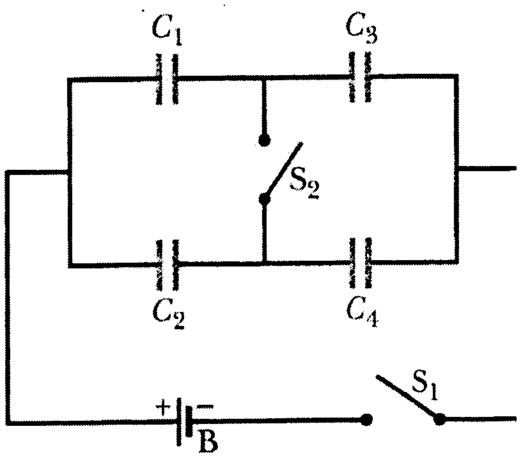
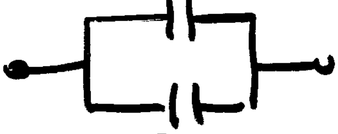


Fig. 25-39 Problem 23.

S_1 closed

$C_{13} = 0.75\ \mu F$



$C_{24} = 1.33\ \mu F$

$C_{eq} = 2.1\ \mu F$

$q_{eq} = 25\ \mu C$

$V_{24} = 12\ V = V_{13}$

$q_{24} = 1.33\ \mu F \times 12 = 15.96\ \mu C \approx 16\ \mu C$

$q_{13} = 0.75\ \mu F \times 12 = 9\ \mu C$

sum

$q_1 = q_3 = 9\ \mu C$

$q_2 = q_4 = 16\ \mu C$

S_1 closed + S_2 closed

C_1 & C_2 parallel

C_3 & C_4 parallel

do it at home!

•••21 Figure 25-37 displays a 12.0 battery and three uncharged capacitors of capacitances $C_1 = 4.00\ \mu F$, $C_2 = 6.00\ \mu F$, and $C_3 = 3.00\ \mu F$. The switch is thrown to the left side until capacitor 1 is fully charged. Then the switch is thrown to the right. What is the final charge on (a) capacitor 1, (b) capacitor 2, and (c) capacitor 3? **SSM**

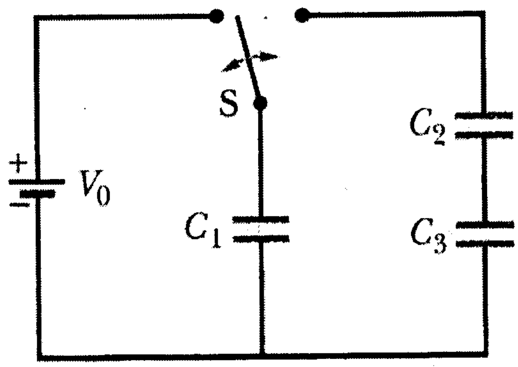
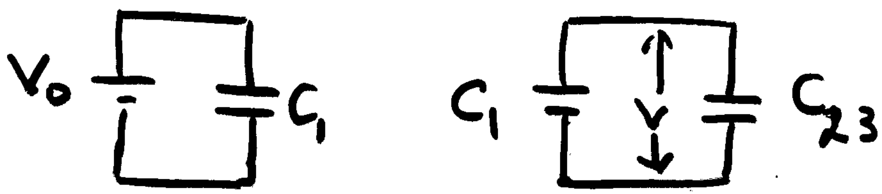


Fig. 25-37 Problem 21.

a) $q_2 = q_3$ (series)

$$\frac{1}{C_{23}} = \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow C_{23} = \frac{C_2 C_3}{C_2 + C_3} = 2\mu F$$



$$q_0 = C_1 V_0 = 48\mu C$$

$$q_0 = q_1 + q_2 = 48\mu C$$

$$\frac{q_1}{C_1} = \frac{q_2}{C_{23}}$$

$$q_0 = q_2 \frac{C_1}{C_{23}} + q_2 = q_2\left(\frac{C_1}{C_{23}} + 1\right)$$

$$\Rightarrow q_2 = 16\mu C$$

$$q_1 = \frac{C_1}{C_{23}} q_2 = 32\mu C$$

$$q_3 = q_2 = 16\mu C$$

(•26) A parallel-plate air-filled capacitor having area 40 cm^2 and plate spacing 1.0 mm is charged to a potential difference of 600 V. Find (a) the capacitance, (b) the magnitude of the charge on each plate, (c) the stored energy, (d) the electric field between the plates, and (e) the energy density between the plates.

a) $C = \frac{\varepsilon_0 A}{d} = 8.85 \times 10^{-12} \times \frac{40 \times 10^{-4}}{1 \times 10^{-3}} = 35 pF$

b) $q = CV = 35 \times 10^{-12} F \times 600 V$

$= 21 nC$

c) $U = \frac{1}{2} CV^2 = \frac{1}{2} (35 \times 10^{-12})^2 \times (600)^2$

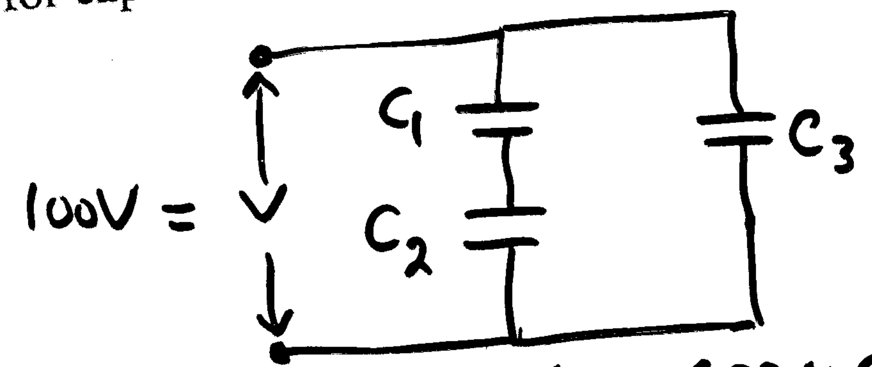
$= 6.3 \times 10^{-6} J = 6.3 pJ$

d) $E = \frac{V}{d} = \frac{600}{0.001} = 6 \times 10^5 \ V/m$

e) $u = \frac{U}{Volume} = \frac{U}{A \times d} = \frac{6.3 \times 10^{-6}}{40 \times 10^{-4} \times 10^{-3}}$

$u = 1.6 \ J/m^3$.

••30 In Fig. 25-27, a potential difference $V = 100\ V$ is applied across a capacitor arrangement with capacitances $C_1 = 10.0\ \mu F$, $C_2 = 5.00\ \mu F$, and $C_3 = 4.00\ \mu F$. What are (a) charge q_3, (b) potential difference V_3, and (c) stored energy U_3 for capacitor 3, (d) q_1, (e) V_1, and (f) U_1 for capacitor 1, and (g) q_2, (h) V_2, and (i) U_2 for capacitor 2?



a) $q_3 = C_3 \times V = 4\mu F \times 100V = 400\mu C$

b) $V_3 = V = 100V$

c) $U_3 = \frac{1}{2} C_3 V_3^2 = 2 \times 10^{-2} J$

d) $3.3\mu F = C_{12}$

$q_{12} = C_{12} V$

$= 330\mu C$

$\Rightarrow q_1 = q_2 = 330\mu C$

e) $V_1 = \frac{q_1}{C_1} = \frac{330\mu C}{10\mu F} = 33V$

f) $U_1 = \frac{1}{2} C_1 V_1^2 = 5550\mu J$

g) $q_2 = 330\mu C$

h) $V_2 = q_2/C_2 = 66V$

(•34) An air-filled parallel-plate capacitor has a capacitance of 1.3 pF. The separation of the plates is doubled, and wax is inserted between them. The new capacitance is 2.6 pF. Find the dielectric constant of the wax.

$$C_0 = \varepsilon_0 \frac{A}{d} = 1.3\,pF$$

double the separation $C_1 = \frac{C_0}{2} = 0.65\,pF$

Wax is inserted (dielectric) $C_2 = K C_1$

$$2.6\,pF = K \times 0.65\,pF$$

$$\boxed{K = 4}$$

•36 A parallel-plate air-filled capacitor has a capacitance of 50 pF. (a) If each of its plates has an area of 0.35 m^2, what is the separation? (b) If the region between the plates is now filled with material having $\kappa = 5.6$, what is the capacitance?

a) $C_0 = 50\,pF$

$A = 0.35\,m^2$

$$C_0 = \varepsilon_0 \frac{A}{d} \Rightarrow d = \frac{\varepsilon_0 A}{C_0}$$

$$d = \frac{8.85 \times 10^{-12} \times 0.35}{50 \times 10^{-12}} = \boxed{6.2 \times 10^{-2}\,m}$$

b)

$$C = \kappa C_0 = 5.6 \times 50\,pF$$

$$\boxed{C = 280\,pF}$$

••42 Figure 25-42 shows a parallel-plate capacitor with a plate area $A = 5.56\ cm^2$ and plate separation $d = 5.56$ mm. The left half of the gap is filled with material of dielectric constant $\kappa_1 = 7.00$; the right half is filled with material of dielectric constant $\kappa_2 = 12.0$. What is the capacitance?

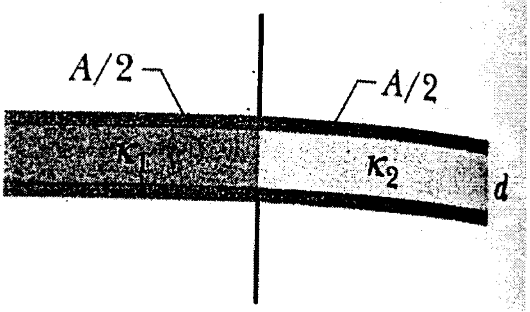
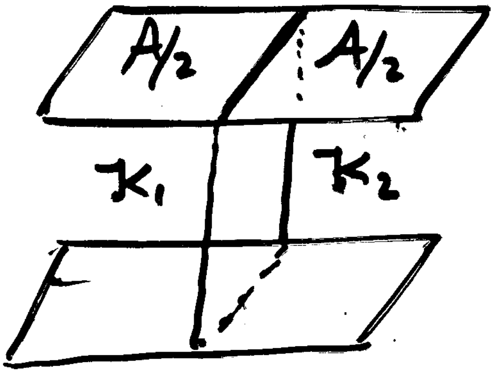
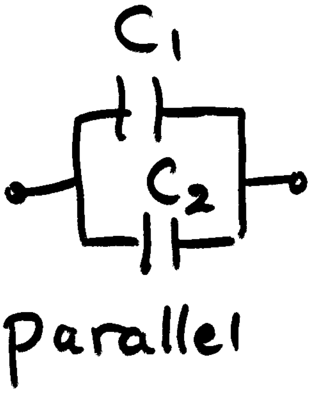


Fig. 25-42 Problem 42.

Same V!





$$C_{eq} = C_1 + C_2 = \kappa_1 \frac{\varepsilon_0 (A/2)}{d} + \kappa_2 \frac{\varepsilon_0 (A/2)}{d}$$

$$= \frac{\varepsilon_0 A}{d} \left(\frac{\kappa_1}{2} + \frac{\kappa_2}{2} \right)$$

$$= \frac{8.85\times 10^{-12} \times 5.56\times 10^{-4}}{5.56\times 10^{-3}} \left(\frac{7}{2} + \frac{12}{2} \right)$$

$$= 8.41\times 10^{-12}\ F$$

••43 Figure 25-43 shows a parallel-plate capacitor with a plate area $A = 7.89\ \text{cm}^2$ and plate separation $d = 4.62$ mm. The top half of the gap is filled with material of dielectric constant $\kappa_1 = 11.0$; the bottom half is filled with material of dielectric constant $\kappa_2 = 12.0$. What is the capacitance? **SSM**

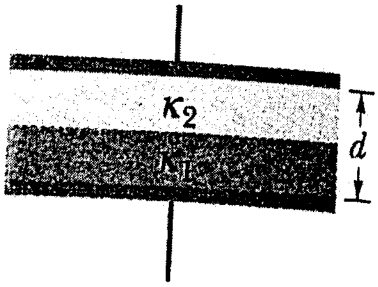
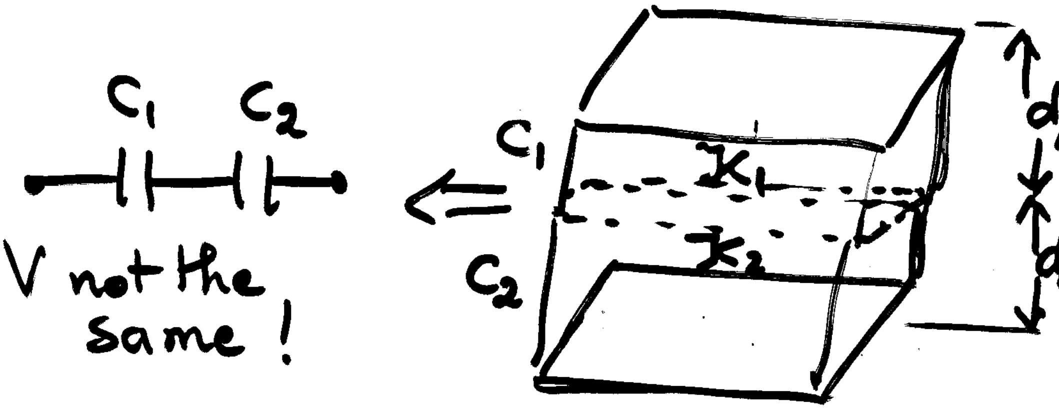


Fig. 25-43 Problem 43.

Series



V not the same!

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{\left(\kappa_1 \frac{\varepsilon_0 A}{d/2}\right)\left(\kappa_2 \frac{\varepsilon_0 A}{d/2}\right)}{\frac{\varepsilon_0 A}{d/2}(\kappa_1 + \kappa_2)}$$

$$= 2\varepsilon_0 A \frac{\kappa_1 \kappa_2}{\kappa_1 + \kappa_2}$$

$$= \frac{2 \times 8.85 \times 10^{-12} \times 7.89 \times 10^{-4} \times 11 \times 12}{23}$$

$$= 1.73 \times 10^{-11}\ \text{F}$$