3.

$$a)\ C = \frac{\varepsilon_0 A}{d} = \frac{(8.85\times10^{-12})(.082^2\pi)}{.0013}$$

$$C = 144\times10^{-12}\,F = 144\,pF$$

$$b)\ Q = CV = (144pF)(120V) = 17.3\times10^{-9}\text{ coulombs}$$

$$\text{or } Q = 17.3\,nC$$

6.

$$a)\ C = \frac{\varepsilon_0 A}{d}$$

$$1F = \frac{(8.85\times10^{-12})(1m^2)}{d}$$

$$d = 8.85\times10^{-12}\,m$$

b) This is not possible. The plates would not stay separated.

10.

$$\frac{1}{C_{eq}} = \frac{1}{10+5} + \frac{1}{4} = \frac{4}{60} + \frac{15}{60}$$

$$C_{eq} = \frac{60}{19} = 3.2\mu\,F$$

11.

$$C = \frac{Q}{V} = \frac{1.0C}{110V} = .0091F$$

$$n(1\times10^{-6}F) = .0091F$$

$$n = 9100$$

13.

$$100 \times 10^{-12}\,\text{F} = \frac{Q}{50\text{V}}$$

$$Q = 5000 \times 10^{-12}\,\text{coulombs}$$

Charge must be conserved.

$$Q_0 = Q_1 + Q_2$$

$$C_1V_0 = C_1V + C_2V$$

$$V = \frac{C_1V_0}{C_1 + C_2} = 50\left(\frac{C_1}{C_1 + C_2}\right)$$

$$V = 35 = 50\left(\frac{100 \times 10^{-12}}{100 \times 10^{-12} + C_2}\right)$$

$$100 \times 10^{-12} + C_2 = \left(\frac{50}{35}\right)\left(100 \times 10^{-12}\right)$$

$$C_2 = 42 \times 10^{-12} = 42\text{pF}$$

17. **Refer back to problem #16. The subscripts match the capacitor's number.**

$$V_3 = \frac{320\mu\text{C}}{4\mu\text{F}} = 80\,\text{volts}$$

$$\therefore V_1 = V_2 = 20\,\text{volts}$$

Change in C_1:

$$\Delta V_1 = 100 - 20 = 80\,\text{volts}$$

$$Q = CV$$

final: $Q = (100\text{V})(10\mu\text{F}) = 1000\mu\text{C}$

initial: $Q = (20\text{V})(10\mu\text{F}) = 200\mu\text{C}$

$$\Delta Q = 1000 - 200 = 800\mu\text{C}$$

27.

a) S_1 closed. C_1 and C_3 are in series.

$$\frac{1}{C_{Top}} = \frac{1}{C_1} + \frac{1}{C_3} = \frac{1}{1} + \frac{1}{3} = \frac{4}{3}$$

$$C_{Top} = \frac{3}{4}\mu F$$

C_2 and C_4 are in series.

$$\frac{1}{C_{Bottom}} = \frac{1}{C_2} + \frac{1}{C_4} = \frac{1}{2} + \frac{1}{4} = \frac{3}{4}$$

$$C_{Bottom} = \frac{4}{3}\mu F$$

C_{Top} and C_{Bottom} are in parallel.

$$C_{Eq} = \frac{3}{4} + \frac{4}{3} = 2.1\,\mu F$$

$$Q = CV = 2.1(12\,V) = 25\,\mu C$$

$$Q = C_{Top} V = .75(12) = 9\,\mu C$$

$$Q = C_{Bottom} V = 1.33(12) = 16\,\mu C$$

C_1 and C_3 have $9\,\mu C$ charge each.

C_2 and C_4 have $16\,\mu C$ charge each.

b) S_2 closed, potentials now equal.

C_1 and C_2 are in parallel.

$$C_{1-2} = C_1 + C_2 = 3\,\mu F$$

C_3 and C_4 are in parallel.

$$C_{3-4} = C_3 + C_4 = 7\,\mu F$$

C_{1-2} and C_{3-4} are in series.

$$\frac{1}{C_{Eq}} = \frac{1}{C_{1-2}} + \frac{1}{C_{3-4}} = \frac{1}{3} + \frac{1}{7}$$

$$C_{Eq} = 2.1\,\mu F$$

$$Q = CV = 2.1(12) = 25\,\mu C$$

$$V_{1-2} = \frac{25}{3} = 8.3 \text{ and } V_{3-4} = \frac{25}{7} = 3.6$$

$$Q_1 = (1\mu F)(8.3V) = 8.3\,\mu C$$

$$Q_2 = (2\mu F)(8.3V) = 16.6\,\mu C$$

$$Q_3 = (3\mu F)(3.6V) = 10.8\,\mu C$$

$$Q_4 = (4\mu F)(3.6V) = 14.4\,\mu C$$

31.

$$U = \frac{1}{2}CV^2$$

$$C = C_1 + C_2 = 2 + 4 = 6\mu F$$

$$U = \frac{1}{2}(6\mu F)(300V)^2$$

$$U = .27 \text{joules}$$

33.

$$V = \frac{kq}{r}$$

$$8000 = \frac{kq}{.05m}$$

$$\therefore q = \frac{400}{k}$$

$$E = \frac{kq}{r^2} = \frac{k\left(\frac{400}{k}\right)}{(.05)^2}$$

$$E = 1.6 \times 10^5$$

$$U = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}(8.85 \times 10^{-12})(1.6 \times 10^5)^2$$

$$U = .1133 \frac{\text{joules}}{\text{meters}^3}$$

42.

a) $$C = \frac{\varepsilon_0 A}{d}$$

$$50 \times 10^{-12} = \frac{(8.85 \times 10^{-12})(.35)}{d}$$

$$d = 6.2cm$$

b) $$C = kC_0 = 5.6(50 \times 10^{-12})$$

$$C = 280 \times 10^{-12} = 280pF$$

43.

Got 7.4pF, want 7.4μ J.

$$U = \frac{1}{2}CV^2 = 7.4\mu\,J$$

$$\frac{1}{2}C(652)^2 = 7.4$$

$$C = 35pF$$

$$\frac{35pF}{7.4pF} = 4.7$$

Pyrex is a good choice.

51.

a) $$E = \frac{E_0}{k} = \frac{Q}{k\varepsilon_0 A}$$

$$Q = CV$$

$$E = \frac{CV}{k\varepsilon_0 A} = \frac{\left(100\times10^{-12}\right)(50)}{5.4\left(8.85\times10^{-12}\right)\left(.01m^2\right)}$$

$$E = \frac{5000\times10^{-12}}{.48\times10^{-12}} = 10{,}000\,\frac{\text{volts}}{\text{meter}}$$

b) **Free charge:**

$$q = C_0V_0 = \left(100\times10^{-12}\right)(50)$$

$$q = 5\times10^{-9}\,C$$

c) **Induced charge:**

$$q' = q\left(1-\frac{1}{k}\right) = \left(5\times10^{-9}\right)\left(1-\frac{1}{5.4}\right)$$

$$q' = 4.7\times10^{-9}\,C$$

53.

a) $C = \frac{\varepsilon_0 A}{d} = \frac{\left(8.85\times10^{-12}\right)\left(.12m^2\right)}{.012m} = 89pF$

b) Dielectric fills $\frac{1}{3}$ the space. $V = Ed$

$$V = E_0\left(\frac{2}{3}d\right) + \frac{E_0}{k}\left(\frac{1}{3}d\right) = E_0 d\left(\frac{2}{3}+\frac{1}{3k}\right) = V_0\left(\frac{2k+1}{3k}\right)$$

$$V = 120\left(\frac{10.6}{14.4}\right) = 88.3\text{volts}$$

need $Q = C_0V_0 = (89pF)(120V) = 10.7nC$

$$C = \frac{10.7nC}{88.3V} = 120pF$$

c) $Q = C_0V_0 = (89pF)(120V) = 10.7nC$

d) $E_0 = \frac{Q}{\varepsilon_0 A} = \frac{10.7\times10^{-9}}{\left(8.85\times10^{-12}\right)(.12)} = 10\frac{\text{kilovolts}}{\text{meter}}$

e) $E = \frac{Q}{k\varepsilon_0 A} = \frac{10.7\times10^{-9}}{(4.8)\left(8.85\times10^{-12}\right)(.12)} = 2083\frac{\text{volts}}{\text{meter}}$

f) From above V = 88.3volts, or $V = \frac{Q}{C}$ where C = 120pF.

g) $U_0 = \frac{1}{2}C_0V_0^2 = \frac{1}{2}(89)(120)^2 = .641\mu j$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}(120)(88.3)^2 = .468\mu j$$

$$W = .641 - .468 = .173\mu j$$

67. a) The charge must be the same for each capacitor.

$$\frac{1}{C} = \frac{1}{6}+\frac{1}{4} = \frac{2+3}{12} = \frac{5}{12}$$

$C = 2.4\mu F$

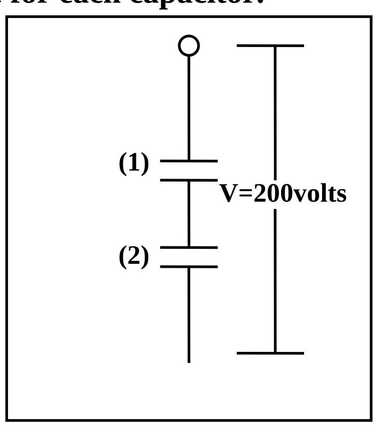
$$C = \frac{Q}{V} \Rightarrow Q = CV$$

$Q = 2.4(200) = 480\mu C$

$$V_1 = \frac{Q}{C_1} = \frac{480\mu C}{6\mu F} = 80\text{volts}$$

$$V_2 = \frac{Q}{C_2} = \frac{480\mu C}{4\mu F} = 120\text{volts}$$

Check: $120 + 80 = 200$volts



68. The potential across each is 200 volts.

$$C = 6 + 4 = 10\mu F$$

$$Q_1 = C_1 V_1 = 6(200) = 12 \times 10^{-4}\,C$$

$$Q_2 = C_2 V_2 = 4(200) = 8 \times 10^{-4}\,C$$

70.

$C = \frac{\varepsilon_0 A}{d}$, if capacitor is empty.

d is now reduced by b, the thickness of the metal.

a) $C = \frac{\varepsilon_0 A}{d-b}$

b) $W(\text{empty}) = \frac{1}{2} C_E V^2 = \frac{1}{2}\frac{Q^2}{C_E}$

$$W(\text{full}) = \frac{1}{2} C_F V^2 = \frac{1}{2}\frac{Q^2}{C_F}$$

$$\frac{W(\text{empty})}{W(\text{full})} = \frac{C_F}{C_E} = \frac{\left(\frac{\varepsilon_0 A}{d-b}\right)}{\left(\frac{\varepsilon_0 A}{d}\right)} = \frac{d}{d-b}$$

c) Must be the difference $W(\text{full}) - W(\text{empty})$.

$$\frac{1}{2}\frac{Q^2}{\left(\frac{\varepsilon_0 A}{d}\right)} - \frac{1}{2}\frac{Q^2}{\left(\frac{\varepsilon_0 A}{d-b}\right)} = \frac{1}{2}\frac{Q^2 d}{\varepsilon_0 A} - \frac{1}{2}\frac{Q^2(d-b)}{\varepsilon_0 A}$$

$$= \frac{1}{2}\frac{Q^2}{\varepsilon_0 A}\left(d-(d-b)\right) = \frac{1}{2}\frac{Q^2 b}{\varepsilon_0 A}$$

The slab is sucked in.

72.

a) $\frac{1}{C} = \frac{1}{2} + \frac{1}{8} = \frac{4+1}{8}$

$C_{eq} = 1.6\mu F$

$Q = CV = (1.6\mu F)(300V) = 480\mu C$

b) Now there is 2(480) = 960μC to divide up.

$\left(\frac{2}{10}\right)(960) = 192\mu C$

$\left(\frac{8}{10}\right)(960) = 770\mu C$

Voltages? $V = \frac{Q}{C}$

$V_2 = \frac{192\mu C}{2\mu F} = 96\text{volts}$

$V_8 = \frac{770\mu C}{8\mu F} = 96\text{volts}$

c) Now the charges cancel each other out.

$Q = V = 0$