Halliday/Resnick/Walker 7e
Chapter 25 – Capacitance

2. (a) The capacitance of the system is

$$C = \frac{q}{\Delta V} = \frac{70\,\text{pC}}{20\,\text{V}} = 3.5\,\text{pF}.$$

(b) The capacitance is independent of q; it is still 3.5 pF.

(c) The potential difference becomes

$$\Delta V = \frac{q}{C} = \frac{200\,\text{pC}}{3.5\,\text{pF}} = 57\,\text{V}.$$

3. (a) The capacitance of a parallel-plate capacitor is given by $C = \varepsilon_0 A/d$, where A is the area of each plate and d is the plate separation. Since the plates are circular, the plate area is $A = \pi R^2$, where R is the radius of a plate. Thus,

$$C = \frac{\varepsilon_0 \pi R^2}{d} = \frac{\left(8.85\times10^{-12}\,\text{F/m}\right)\pi\left(8.2\times10^{-2}\,\text{m}\right)^2}{1.3\times10^{-3}\,\text{m}} = 1.44\times10^{-10}\,\text{F} = 144\text{pF}.$$

(b) The charge on the positive plate is given by $q = CV$, where V is the potential difference across the plates. Thus,

$$q = (1.44 \times 10^{-10}\text{ F})(120\text{ V}) = 1.73 \times 10^{-8}\text{ C} = 17.3\text{ nC}.$$

5. Assuming conservation of volume, we find the radius of the combined spheres, then use $C = 4\pi\varepsilon_0 R$ to find the capacitance. When the drops combine, the volume is doubled. It is then $V = 2(4\pi/3)R^3$. The new radius R' is given by

$$\frac{4\pi}{3}\left(R'\right)^3 = 2\frac{4\pi}{3}R^3 \quad \Rightarrow \quad R' = 2^{1/3}R.$$

The new capacitance is

$$C' = 4\pi\varepsilon_0 R' = 4\pi\varepsilon_0 2^{1/3} R = 5.04\pi\varepsilon_0 R.$$

With R = 2.00 mm, we obtain $C = 5.04\pi\left(8.85\times10^{-12}\,\text{F/m}\right)\left(2.00\times10^{-3}\,\text{m}\right) = 2.80\times10^{-13}\,\text{F}$.

7. The equivalent capacitance is given by $C_{eq} = q/V$, where q is the total charge on all the capacitors and V is the potential difference across any one of them. For N identical capacitors in parallel, $C_{eq} = NC$, where C is the capacitance of one of them. Thus, $NC = q/V$ and

$$N = \frac{q}{VC} = \frac{1.00\,\text{C}}{(110\,\text{V})\,(1.00\times10^{-6}\,\text{F})} = 9.09\times10^{3}\,.$$

9. The equivalent capacitance is

$$C_{\text{eq}} = \frac{(C_1 + C_2)C_3}{C_1 + C_2 + C_3} = \frac{(10.0\,\mu\text{F} + 5.00\,\mu\text{F})(4.00\,\mu\text{F})}{10.0\,\mu\text{F} + 5.00\,\mu\text{F} + 4.00\,\mu\text{F}} = 3.16\,\mu\text{F}.$$

10. The charge that passes through meter A is

$$q = C_{\text{eq}}V = 3CV = 3(25.0\,\mu\text{F})(4200\,\text{V}) = 0.315\,\text{C}.$$

11. (a) and (b) The original potential difference V_1 across C_1 is

$$V_1 = \frac{C_{\text{eq}}V}{C_1 + C_2} = \frac{(3.16\,\mu\text{F})(100.0\,\text{V})}{10.0\,\mu\text{F} + 5.00\,\mu\text{F}} = 21.1\,\text{V}.$$

Thus $\Delta V_1 = 100.0\text{ V} - 21.1\text{ V} = 78.9\text{ V}$ and

$$\Delta q_1 = C_1\Delta V_1 = (10.0\,\mu\text{F})(78.9\text{ V}) = 7.89\times10^{-4}\text{ C}.$$

12. (a) The potential difference across C_1 is $V_1 = 10.0$ V. Thus,

$$q_1 = C_1V_1 = (10.0\,\mu\text{F})(10.0\text{ V}) = 1.00\times10^{-4}\text{ C}.$$

(b) Let $C = 10.0\,\mu$F. We first consider the three-capacitor combination consisting of C_2 and its two closest neighbors, each of capacitance C. The equivalent capacitance of this combination is

$$C_{\text{eq}} = C + \frac{C_2C}{C + C_2} = 1.50\ C.$$

Also, the voltage drop across this combination is

$$V = \frac{CV_1}{C + C_{eq}} = \frac{CV_1}{C + 1.50\ C} = 0.40V_1.$$

Since this voltage difference is divided equally between C_2 and the one connected in series with it, the voltage difference across C_2 satisfies $V_2 = V/2 = V_1/5$. Thus

$$q_2 = C_2V_2 = (10.0\,\mu\text{F})\left(\frac{10.0\,\text{V}}{5}\right) = 2.00\times10^{-5}\,\text{C}.$$

13. The charge initially on the charged capacitor is given by $q = C_1V_0$, where $C_1 = 100$ pF is the capacitance and $V_0 = 50$ V is the initial potential difference. After the battery is disconnected and the second capacitor wired in parallel to the first, the charge on the first capacitor is $q_1 = C_1V$, where $V = 35$ V is the new potential difference. Since charge is conserved in the process, the charge on the second capacitor is $q_2 = q - q_1$, where C_2 is the capacitance of the second capacitor. Substituting C_1V_0 for q and C_1V for q_1, we obtain $q_2 = C_1 (V_0 - V)$. The potential difference across the second capacitor is also V, so the capacitance is

$$C_2 = \frac{q_2}{V} = \frac{V_0 - V}{V} C_1 = \frac{50\,\text{V} - 35\,\text{V}}{35\,\text{V}} (100\,\text{pF}) = 43\,\text{pF}.$$

14. The two 6.0 μF capacitors are in parallel and are consequently equivalent to $C_{eq} = 12\ \mu\text{F}$. Thus, the total charge stored (before the squeezing) is

$$q_{\text{total}} = C_{eq}V_{\text{battery}} = 120\ \mu\text{C}\ .$$

(a) and (b) As a result of the squeezing, one of the capacitors is now 12 μF (due to the inverse proportionality between C and d in Eq. 25-9) which represents an increase of 6.0 μF and thus a charge increase of

$$\Delta q_{\text{total}} = \Delta C_{eq}V_{\text{battery}} = (6.0\ \mu\text{F})(10\ \text{V}) = 60\ \mu\text{C}\ .$$

15. (a) First, the equivalent capacitance of the two 4.00 μF capacitors connected in series is given by 4.00 μF/2 = 2.00 μF. This combination is then connected in parallel with two other 2.00-μF capacitors (one on each side), resulting in an equivalent capacitance $C = 3(2.00\ \mu\text{F}) = 6.00\ \mu\text{F}$. This is now seen to be in series with another combination, which consists of the two 3.0-μF capacitors connected in parallel (which are themselves equivalent to $C' = 2(3.00\ \mu\text{F}) = 6.00\ \mu\text{F}$). Thus, the equivalent capacitance of the circuit is

$$C_{eq} = \frac{CC'}{C + C'} = \frac{(6.00\,\mu\text{F})\,(6.00\,\mu\text{F})}{6.00\,\mu\text{F} + 6.00\,\mu\text{F}} = 3.00\,\mu\text{F}.$$

(b) Let $V = 20.0$ V be the potential difference supplied by the battery. Then

$$q = C_{eq}V = (3.00\ \mu\text{F})(20.0\ \text{V}) = 6.00 \times 10^{-5}\ \text{C}.$$

(c) The potential difference across C_1 is given by

$$V_1 = \frac{CV}{C + C'} = \frac{(6.00\,\mu\text{F})\,(20.0\,\text{V})}{6.00\,\mu\text{F} + 6.00\,\mu\text{F}} = 10.0\,\text{V}.$$

(d) The charge carried by C_1 is $q_1 = C_1V_1 = (3.00\ \mu\text{F})(10.0\ \text{V}) = 3.00 \times 10^{-5}$ C.

(e) The potential difference across C_2 is given by $V_2 = V - V_1 = 20.0\text{ V} - 10.0\text{ V} = 10.0\text{ V}$.

(f) The charge carried by C_2 is $q_2 = C_2V_2 = (2.00\ \mu\text{F})(10.0\text{ V}) = 2.00 \times 10^{-5}$ C.

(g) Since this voltage difference V_2 is divided equally between C_3 and the other 4.00-μF capacitors connected in series with it, the voltage difference across C_3 is given by $V_3 = V_2/2 = 10.0\text{ V}/2 = 5.00\text{ V}$.

(h) Thus, $q_3 = C_3V_3 = (4.00\ \mu\text{F})(5.00\text{ V}) = 2.00 \times 10^{-5}$ C.

18. Eq. 23-14 applies to each of these capacitors. Bearing in mind that $\sigma = q/A$, we find the total charge to be

$$q_{\text{total}} = q_1 + q_2 = \sigma_1 A_1 + \sigma_2 A_2 = \varepsilon_0 E_1 A_1 + \varepsilon_0 E_2 A_2 = 3.6\text{ pC}$$

where we have been careful to convert cm^2 to m^2 by dividing by 10^4.

21. The charges on capacitors 2 and 3 are the same, so these capacitors may be replaced by an equivalent capacitance determined from

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{C_2 + C_3}{C_2C_3}.$$

Thus, $C_{\text{eq}} = C_2C_3/(C_2 + C_3)$. The charge on the equivalent capacitor is the same as the charge on either of the two capacitors in the combination and the potential difference across the equivalent capacitor is given by q_2/C_{eq}. The potential difference across capacitor 1 is q_1/C_1, where q_1 is the charge on this capacitor. The potential difference across the combination of capacitors 2 and 3 must be the same as the potential difference across capacitor 1, so $q_1/C_1 = q_2/C_{\text{eq}}$. Now some of the charge originally on capacitor 1 flows to the combination of 2 and 3. If q_0 is the original charge, conservation of charge yields $q_1 + q_2 = q_0 = C_1 V_0$, where V_0 is the original potential difference across capacitor 1.

(a) Solving the two equations

$$\frac{q_1}{C_1} = \frac{q_2}{C_{\text{eq}}} \qquad \text{and} \qquad q_1 + q_2 = C_1V_0$$

for q_1 and q_2, we obtain

$$q_1 = \frac{C_1^2V_0}{C_{\text{eq}} + C_1} = \frac{C_1^2V_0}{\dfrac{C_2C_3}{C_2 + C_3} + C_1} = \frac{C_1^2\left(C_2 + C_3\right)V_0}{C_1C_2 + C_1C_3 + C_2C_3}.$$

With V_0 = 12.0 V, C_1= 4.00 μF, C_2= 6.00 μF and C_3 =3.00 μF, we find C_{eq} = 2.00 μF and q_1 = 32.0 μC.

(b) The charge on capacitors 2 is

$$q_2 = C_1V_0 - q_1 = (4.00\mu\text{F})(12.0\text{V}) - 32.0\mu\text{F} = 16.0\mu\text{F}$$

(c) The charge on capacitor 3 is the same as that on capacitor 2:

$$q_3 = C_1V_0 - q_1 = (4.00\mu\text{F})(12.0\text{V}) - 32.0\mu\text{F} = 16.0\mu\text{F}$$

24. Let $\mathcal{V}$ = 1.00 m^3. Using Eq. 25-25, the energy stored is

$$U = u\mathcal{V} = \frac{1}{2}\varepsilon_0 E^2\mathcal{V} = \frac{1}{2}\left(8.85\times10^{-12}\,\frac{\text{C}^2}{\text{N}\cdot\text{m}^2}\right)(150\,\text{V/m})^2\left(1.00\,\text{m}^3\right) = 9.96\times10^{-8}\ \text{J}.$$

27. The total energy is the sum of the energies stored in the individual capacitors. Since they are connected in parallel, the potential difference V across the capacitors is the same and the total energy is

$$U = \frac{1}{2}\left(C_1 + C_2\right)V^2 = \frac{1}{2}\left(2.0\times10^{-6}\,\text{F} + 4.0\times10^{-6}\,\text{F}\right)\left(300\,\text{V}\right)^2 = 0.27\,\text{J}.$$

28. (a) The potential difference across C_1 (the same as across C_2) is given by

$$V_1 = V_2 = \frac{C_3V}{C_1 + C_2 + C_3} = \frac{(15.0\mu\text{F})(100\text{V})}{10.0\mu\text{F}+5.00\mu\text{F}+15.0\mu\text{F}} = 50.0\text{V}.$$

Also, $V_3 = V - V_1 = V - V_2$ = 100 V – 50.0 V = 50.0 V. Thus,

$$q_1 = C_1V_1 = (10.0\mu\text{F})(50.0\text{V}) = 5.00\times10^{-4}\,\text{C}$$
$$q_2 = C_2V_2 = (5.00\mu\text{F})(50.0\text{V}) = 2.50\times10^{-4}\,\text{C}$$
$$q_3 = q_1 + q_2 = 5.00\times10^{-4}\,\text{C} + 2.50\times10^{-4}\,\text{C} = 7.50\times10^{-4}\,\text{C}.$$

(b) The potential difference V_3 was found in the course of solving for the charges in part (a). Its value is V_3 = 50.0 V.

(c) The energy stored in C_3 is

$$U_3 = \frac{1}{2}C_3V_3^2 = \frac{1}{2}(15.0\mu\text{F})(50.0\text{V})^2 = 1.88\times10^{-2}\,\text{J}.$$

(d) From part (a), we have $q_1 = 5.00\times10^{-4}\,\text{C}$, and

(e) V_1 = 50.0 V.

(f) The energy stored in C_1 is

$$U_1 = \frac{1}{2}C_1V_1^2 = \frac{1}{2}(10.0\,\mu\text{F})(50.0\,\text{V})^2 = 1.25\times10^{-2}\,\text{J}.$$

(g) Again, from part (a), $q_2 = 2.50\times10^{-4}\,\text{C}$, and

(h) V_2 = 50.0 V.

(i) The energy stored in C_2 is

$$U_2 = \frac{1}{2}C_2V_2^2 = \frac{1}{2}(5.00\,\mu\text{F})(50.0\,\text{V})^2 = 6.25\times10^{-3}\,\text{J}.$$

31. (a) Let q be the charge on the positive plate. Since the capacitance of a parallel-plate capacitor is given by $\varepsilon_0 A/d_i$, the charge is $q = CV = \varepsilon_0 AV_i/d_i$. After the plates are pulled apart, their separation is d_f and the potential difference is V_f. Then $q = \varepsilon_0 AV_f/2d_f$ and

$$V_f = \frac{d_f}{\varepsilon_0 A}q = \frac{d_f}{\varepsilon_0 A}\frac{\varepsilon_0 A}{d_i}V_i = \frac{d_f}{d_i}V_i.$$

With $d_i = 3.00\times10^{-3}\,\text{m}$, $V_i = 6.00$ V and $d_f = 8.00\times10^{-3}\,\text{m}$, we have $V_f = 16.0\,\text{V}$.

(b) The initial energy stored in the capacitor is (in SI units)

$$U_i = \frac{1}{2}CV_i^2 = \frac{\varepsilon_0 AV_i^2}{2d_i} = \frac{(8.85\times10^{-12})(8.50\times10^{-4})(6.00)^2}{2(3.00\times10^{-3})} = 4.51\times10^{-11}\ \text{J}.$$

(c) The final energy stored is

$$U_f = \frac{1}{2}\frac{\varepsilon_0 A}{d_f}V_f^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d_f}\left(\frac{d_f}{d_i}V_i\right)^2 = \frac{d_f}{d_i}\left(\frac{\varepsilon_0 AV_i^2}{d_i}\right) = \frac{d_f}{d_i}U_i.$$

With $d_f/d_i = 8.00/3.00$, we have $U_f = 1.20\times10^{-10}$ J.

(d) The work done to pull the plates apart is the difference in the energy:

$$W = U_f - U_i = 7.52\times10^{-11}\ \text{J}.$$

34. If the original capacitance is given by $C = \varepsilon_0 A/d$, then the new capacitance is $C' = \varepsilon_0 \kappa A/2d$. Thus $C'/C = \kappa/2$ or

$$\kappa = 2C'/C = 2(2.6\ \text{pF}/1.3\ \text{pF}) = 4.0.$$

35. The capacitance with the dielectric in place is given by $C = \kappa C_0$, where C_0 is the capacitance before the dielectric is inserted. The energy stored is given by $U = \frac{1}{2}CV^2 = \frac{1}{2}\kappa C_0 V^2$, so

$$\kappa = \frac{2U}{C_0V^2} = \frac{2(7.4\times10^{-6}\,\text{J})}{(7.4\times10^{-12}\,\text{F})(652\text{V})^2} = 4.7.$$

According to Table 25-1, you should use Pyrex.

38. Each capacitor has 12.0 V across it, so Eq. 25-1 yields the charge values once we know C_1 and C_2. From Eq. 25-9,

$$C_2 = \frac{\varepsilon_0 A}{d} = 2.21\times10^{-11}\ \text{F}\ ,$$

and from Eq. 25-27,

$$C_1 = \frac{\kappa\varepsilon_0 A}{d} = 6.64\times10^{-11}\ \text{F}\ .$$

This leads to $q_1 = C_1V_1 = 8.00\times10^{-10}$ C and $q_2 = C_2V_2 = 2.66\times10^{-10}$ C. The addition of these gives the desired result: $q_{\text{tot}} = 1.06\times10^{-9}$ C. Alternatively, the circuit could be reduced to find the q_{tot}.

39. The capacitance is given by $C = \kappa C_0 = \kappa\varepsilon_0 A/d$, where C_0 is the capacitance without the dielectric, κ is the dielectric constant, A is the plate area, and d is the plate separation. The electric field between the plates is given by $E = V/d$, where V is the potential difference between the plates. Thus, $d = V/E$ and $C = \kappa\varepsilon_0 AE/V$. Thus,

$$A = \frac{CV}{\kappa\varepsilon_0 E}.$$

For the area to be a minimum, the electric field must be the greatest it can be without breakdown occurring. That is,

$$A = \frac{(7.0\times10^{-8}\,\text{F})(4.0\times10^{3}\,\text{V})}{2.8(8.85\times10^{-12}\,\text{F/m})(18\times10^{6}\ \text{V/m})} = 0.63\ \text{m}^2.$$

43. We assume there is charge q on one plate and charge $-q$ on the other. The electric field in the lower half of the region between the plates is

$$E_1 = \frac{q}{\kappa_1 \varepsilon_0 A},$$

where A is the plate area. The electric field in the upper half is

$$E_2 = \frac{q}{\kappa_2 \varepsilon_0 A}.$$

Let $d/2$ be the thickness of each dielectric. Since the field is uniform in each region, the potential difference between the plates is

$$V = \frac{E_1 d}{2} + \frac{E_2 d}{2} = \frac{qd}{2\varepsilon_0 A}\left[\frac{1}{\kappa_1} + \frac{1}{\kappa_2}\right] = \frac{qd}{2\varepsilon_0 A}\frac{\kappa_1 + \kappa_2}{\kappa_1 \kappa_2},$$

so

$$C = \frac{q}{V} = \frac{2\varepsilon_0 A}{d}\frac{\kappa_1 \kappa_2}{\kappa_1 + \kappa_2}.$$

This expression is exactly the same as that for C_{eq} of two capacitors in series, one with dielectric constant κ_1 and the other with dielectric constant κ_2. Each has plate area A and plate separation $d/2$. Also we note that if $\kappa_1 = \kappa_2$, the expression reduces to $C = \kappa_1 \varepsilon_0 A/d$, the correct result for a parallel-plate capacitor with plate area A, plate separation d, and dielectric constant κ_1.

With $A = 7.89 \times 10^{-4}\,\text{m}^2$, $d = 4.62 \times 10^{-3}\,\text{m}$, $\kappa_1 = 11.0$ and $\kappa_2 = 12.0$, the capacitance is, (in SI units)

$$C = \frac{2(8.85\times10^{-12})(7.89\times10^{-4})}{4.62\times10^{-3}}\frac{(11.0)(12.0)}{11.0+12.0} = 1.73\times10^{-11}\,\text{F}.$$

51. One way to approach this is to note that – since they are identical – the voltage is evenly divided between them. That is, the voltage across each capacitor is $V = (10/n)$ volt. With $C = 2.0 \times 10^{-6}$ F, the electric energy stored by each capacitor is $\frac{1}{2}CV^2$. The total energy stored by the capacitors is n times that value, and the problem requires the total be equal to 25×10^{-6} J. Thus,

$$\frac{n}{2}(2.0 \times 10^{-6})\left(\frac{10}{n}\right)^2 = 25 \times 10^{-6}$$

leads to $n = 4$.

52. Initially the capacitors C_1, C_2, and C_3 form a series combination equivalent to a single capacitor which we denote C_{123}. Solving the equation

$$\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{C_{123}} ,$$

we obtain $C_{123} = 2.40$ μF. With $V = 12.0$ V, we then obtain $q = C_{123}V = 28.8$ μC. In the final situation, C_2 and C_4 are in parallel and are thus effectively equivalent to $C_{24} = 12.0\ \mu\text{F}$. Similar to the previous computation, we use

$$\frac{1}{C_1} + \frac{1}{C_{24}} + \frac{1}{C_3} = \frac{1}{C_{1234}}$$

and find $C_{1234} = 3.00$ μF. Therefore, the final charge is $q = C_{1234}V = 36.0$ μC.

(a) This represents a change (relative to the initial charge) of $\Delta q = 7.20$ μC.

(b) The capacitor C_{24} which we imagined to replace the parallel pair C_2 and C_4 is in series with C_1 and C_3 and thus also has the final charge $q = 36.0$ μC found above. The voltage across C_{24} would be $V_{24} = q/C_{24} = 36.0/12.0 = 3.00$ V. This is the same voltage across each of the parallel pair. In particular, $V_4 = 3.00$ V implies that $q_4 = C_4 V_4 = 18.0$ μC.

(c) The battery supplies charges only to the plates where it is connected. The charges on the rest of the plates are due to electron transfers between them, in accord with the new distribution of voltages across the capacitors. So, the battery does not directly supply the charge on capacitor 4.

54. We note that the voltage across C_3 is $V_3 = (12\text{ V} - 2\text{ V} - 5\text{ V}) = 5$ V. Thus, its charge is $q_3 = C_3 V_3 = 4$ μC.

(a) Therefore, since C_1, C_2 and C_3 are in series (so they have the same charge), then

$$C_1 = \frac{4\ \mu\text{C}}{2\text{ V}} = 2.0\ \mu\text{F} .$$

(b) Similarly, $C_2 = 4/5 = 0.80$ μF.

55. (a) The number of (conduction) electrons per cubic meter is $n = 8.49 \times 10^{28}\ \text{m}^3$. The volume in question is the face area multiplied by the depth: $A{\cdot}d$. The total number of electrons which have moved to the face is

$$N = \frac{-3.0 \times 10^{-6}\text{ C}}{-1.6 \times 10^{-19}\text{ C}} \approx 1.9 \times 10^{13} .$$

Using the relation $N = nAd$, we obtain $d = 1.1 \times 10^{-12}$ m, a remarkably small distance!

57. (a) Put five such capacitors in series. Then, the equivalent capacitance is 2.0 μF/5 = 0.40 μF. With each capacitor taking a 200-V potential difference, the equivalent capacitor can withstand 1000 V.

(b) As one possibility, you can take three identical arrays of capacitors, each array being a five-capacitor combination described in part (a) above, and hook up the arrays in parallel. The equivalent capacitance is now $C_{eq} = 3(0.40\ \mu\text{F}) = 1.2\ \mu\text{F}$. With each capacitor taking a 200-V potential difference the equivalent capacitor can withstand
1000 V.

62. We do not employ energy conservation since, in reaching equilibrium, some energy is dissipated either as heat or radio waves. Charge is conserved; therefore, if $Q = C_1 V_{bat} = 100\ \mu\text{C}$, and q_1, q_2 and q_3 are the charges on C_1, C_2 and C_3 after the switch is thrown to the right and equilibrium is reached, then

$$Q = q_1 + q_2 + q_3 \ \ .$$

Since the parallel pair C_2 and C_3 are identical, it is clear that $q_2 = q_3$. They are in parallel with C_1 so that $V_1 = V_3$, or

$$\frac{q_1}{C_1} = \frac{q_3}{C_3}$$

which leads to $q_1 = q_3/2$. Therefore,

$$Q = \left(\frac{1}{2} q_3\right) + q_3 + q_3$$

which yields $q_3 = 40\ \mu\text{C}$ and consequently $q_1 = 20\ \mu\text{C}$.

63. The pair C_3 and C_4 are in parallel and consequently equivalent to 30 μF. Since this numerical value is identical to that of the others (with which it is in series, with the battery), we observe that each has one-third the battery voltage across it. Hence, 3.0 V is across C_4, producing a charge

$$q_4 = C_4 V_4 = (15\ \mu\text{F})(3.0\ \text{V}) = 45\ \mu\text{C} \ \ .$$