P20.29 (a) $E = \boxed{0}$;

$$V = \frac{k_e q}{R} = \frac{\left(8.99\times10^{9}\right)\left(26.0\times10^{-6}\right)}{0.140} = \boxed{1.67\text{ MV}}$$

(b) $$E = \frac{k_e q}{r^2} = \frac{\left(8.99\times10^{9}\right)\left(26.0\times10^{-6}\right)}{(0.200)^2} = \boxed{5.84\text{ MN/C}}\text{ away}$$

$$V = \frac{k_e q}{R} = \frac{\left(8.99\times10^{9}\right)\left(26.0\times10^{-6}\right)}{0.200} = \boxed{1.17\text{ MV}}$$

(c) $$E = \frac{k_e q}{R^2} = \frac{\left(8.99\times10^{9}\right)\left(26.0\times10^{-6}\right)}{(0.140)^2} = \boxed{11.9\text{ MN/C}}\text{ away}$$

$$V = \frac{k_e q}{R} = \boxed{1.67\text{ MV}}$$

P20.30 (a) Both spheres must be at the same potential according to $\frac{k_e q_1}{r_1} = \frac{k_e q_2}{r_2}$

where also $q_1 + q_2 = 1.20\times10^{-6}\text{ C}$.

Then $q_1 = \frac{q_2 r_1}{r_2}$

$$\frac{q_2 r_1}{r_2} + q_2 = 1.20\times10^{-6}\text{ C}$$

$$q_2 = \frac{1.20\times10^{-6}\text{ C}}{1 + 6\text{ cm}/2\text{ cm}} = 0.300\times10^{-6}\text{ C on the smaller sphere}$$

$$q_1 = 1.20\times10^{-6}\text{ C} - 0.300\times10^{-6}\text{ C} = 0.900\times10^{-6}\text{ C}$$

$$V = \frac{k_e q_1}{r_1} = \frac{\left(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(0.900\times10^{-6}\text{ C}\right)}{6\times10^{-2}\text{ m}} = \boxed{1.35\times10^{5}\text{ V}}$$

continued on next page

(b) Outside the larger sphere,

$$\vec{\mathbf{E}}_1 = \frac{k_e q_1}{r_1^2}\hat{\mathbf{r}} = \frac{V_1}{r_1}\hat{\mathbf{r}} = \frac{1.35\times 10^5 \text{ V}}{0.06 \text{ m}}\hat{\mathbf{r}} = \boxed{2.25\times 10^6 \text{ V/m away}}.$$

Outside the smaller sphere,

$$\vec{\mathbf{E}}_2 = \frac{1.35\times 10^5 \text{ V}}{0.02 \text{ m}}\hat{\mathbf{r}} = \boxed{6.74\times 10^6 \text{ V/m away}}.$$

The smaller sphere carries less charge but creates a much stronger electric field than the larger sphere.

P20.31 (a) $Q = C\Delta V = \left(4.00\times 10^{-6} \text{ F}\right)(12.0 \text{ V}) = 4.80\times 10^{-5} \text{ C} = \boxed{48.0\ \mu\text{C}}$

(b) $Q = C\Delta V = \left(4.00\times 10^{-6} \text{ F}\right)(1.50 \text{ V}) = 6.00\times 10^{-6} \text{ C} = \boxed{6.00\ \mu\text{C}}$

P20.35 (a) $\Delta V = Ed$

$$E = \frac{20.0 \text{ V}}{1.80\times 10^{-3} \text{ m}} = \boxed{11.1 \text{ kV/m}}$$

(b) $E = \dfrac{\sigma}{\epsilon_0}$

$$\sigma = \left(1.11\times 10^4 \text{ N/C}\right)\left(8.85\times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2\right) = \boxed{98.3 \text{ nC/m}^2}$$

(c) $$C = \frac{\epsilon_0 A}{d} = \frac{\left(8.85\times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2\right)\left(7.60 \text{ cm}^2\right)(1.00 \text{ m}/100 \text{ cm})^2}{1.80\times 10^{-3} \text{ m}} = \boxed{3.74 \text{ pF}}$$

(d) $\Delta V = \dfrac{Q}{C}$

$$Q = (20.0 \text{ V})\left(3.74\times 10^{-12} \text{ F}\right) = \boxed{74.7 \text{ pC}}$$

P20.36 (a) $$C = \frac{\ell}{2k_e \ln\left(\frac{b}{a}\right)} = \frac{50.0}{2\left(8.99\times 10^9\right)\ln\left(\frac{7.27}{2.58}\right)} = \boxed{2.68 \text{ nF}}$$

(b) Method 1: $\Delta V = 2k_e\lambda \ln\left(\dfrac{b}{a}\right)$

$$\lambda = \frac{q}{\ell} = \frac{8.10\times 10^{-6} \text{ C}}{50.0 \text{ m}} = 1.62\times 10^{-7} \text{ C/m}$$

$$\Delta V = 2\left(8.99\times 10^9\right)\left(1.62\times 10^{-7}\right)\ln\left(\frac{7.27}{2.58}\right) = \boxed{3.02 \text{ kV}}$$

Method 2: $$\Delta V = \frac{Q}{C} = \frac{8.10\times 10^{-6}}{2.68\times 10^{-9}} = \boxed{3.02 \text{ kV}}$$

P20.39 (a) Capacitors in parallel add. Thus, the equivalent capacitor has a value of

$$C_{eq} = C_1 + C_2 = 5.00\ \mu\text{F} + 12.0\ \mu\text{F} = \boxed{17.0\ \mu\text{F}}\ .$$

(b) The potential difference across each branch is the same and equal to the voltage of the battery.

$$\Delta V = \boxed{9.00\ \text{V}}$$

(c) $Q_5 = C\Delta V = (5.00\ \mu\text{F})(9.00\ \text{V}) = \boxed{45.0\ \mu\text{C}}$

and $Q_{12} = C\Delta V = (12.0\ \mu\text{F})(9.00\ \text{V}) = \boxed{108\ \mu\text{C}}$

P20.40 (a) In series capacitors add as

$$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2}=\frac{1}{5.00\ \mu\text{F}}+\frac{1}{12.0\ \mu\text{F}}$$

and $$C_{eq}=\boxed{3.53\ \mu\text{F}}.$$

(c) The charge on the equivalent capacitor is

$$Q_{eq}=C_{eq}\Delta V=(3.53\ \mu\text{F})(9.00\ \text{V})=31.8\ \mu\text{C}.$$

Each of the series capacitors has this same charge on it.

So $$Q_1=Q_2=\boxed{31.8\ \mu\text{C}}.$$

(b) The potential difference across each is $$\Delta V_1=\frac{Q_1}{C_1}=\frac{31.8\ \mu\text{C}}{5.00\ \mu\text{F}}=\boxed{6.35\ \text{V}}$$

and

$$\Delta V_2=\frac{Q_2}{C_2}=\frac{31.8\ \mu\text{C}}{12.0\ \mu\text{F}}=\boxed{2.65\ \text{V}}$$

.

P20.41 (a) $$\frac{1}{C_s}=\frac{1}{15.0}+\frac{1}{3.00}$$

$$C_s=2.50\ \mu\text{F}$$
$$C_p=2.50+6.00=8.50\ \mu\text{F}$$
$$C_{eq}=\left(\frac{1}{8.50\ \mu\text{F}}+\frac{1}{20.0\ \mu\text{F}}\right)^{-1}=\boxed{5.96\ \mu\text{F}}$$

(b) $$Q=C\Delta V=(5.96\ \mu\text{F})(15.0\ \text{V})=\boxed{89.5\ \mu\text{C}}\ \text{on}\ 20.0\ \mu\text{F}$$

$$\Delta V=\frac{Q}{C}=\frac{89.5\ \mu\text{C}}{20.0\ \mu\text{F}}=4.47\ \text{V}$$
$$15.0-4.47=10.53\ \text{V}$$
$$Q=C\Delta V=(6.00\ \mu\text{F})(10.53\ \text{V})=\boxed{63.2\ \mu\text{C}}\ \text{on}\ 6.00\ \mu\text{F}$$

$$89.5-63.2=\boxed{26.3\ \mu\text{C}}\ \text{on}\ 15.0\ \mu\text{F}\ \text{and}\ 3.00\ \mu\text{F}$$

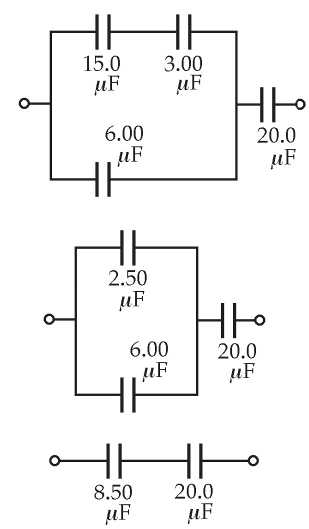

FIG. P20.41

P20.39 (a) Capacitors in parallel add. Thus, the equivalent capacitor has a value of

$$C_{eq}=C_1+C_2=5.00\ \mu\text{F}+12.0\ \mu\text{F}=\boxed{17.0\ \mu\text{F}}.$$

(b) The potential difference across each branch is the same and equal to the voltage of the battery.

$$\Delta V = \boxed{9.00\ \text{V}}$$

(c) $Q_5 = C\Delta V = (5.00\ \mu\text{F})(9.00\ \text{V}) = \boxed{45.0\ \mu\text{C}}$

and $Q_{12} = C\Delta V = (12.0\ \mu\text{F})(9.00\ \text{V}) = \boxed{108\ \mu\text{C}}$

P20.40 (a) In series capacitors add as

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{5.00\ \mu\text{F}} + \frac{1}{12.0\ \mu\text{F}}$$

and $C_{eq} = \boxed{3.53\ \mu\text{F}}$.

(c) The charge on the equivalent capacitor is

$Q_{eq} = C_{eq}\Delta V = (3.53\ \mu\text{F})(9.00\ \text{V}) = 31.8\ \mu\text{C}$.

Each of the series capacitors has this same charge on it.

So $Q_1 = Q_2 = \boxed{31.8\ \mu\text{C}}$.

(b) The potential difference across each is $\Delta V_1 = \frac{Q_1}{C_1} = \frac{31.8\ \mu\text{C}}{5.00\ \mu\text{F}} = \boxed{6.35\ \text{V}}$

and

$\Delta V_2 = \frac{Q_2}{C_2} = \frac{31.8\ \mu\text{C}}{12.0\ \mu\text{F}} = \boxed{2.65\ \text{V}}$

.

P20.41 (a) $\frac{1}{C_s} = \frac{1}{15.0} + \frac{1}{3.00}$

$C_s = 2.50\ \mu\text{F}$

$C_p = 2.50 + 6.00 = 8.50\ \mu\text{F}$

$$C_{eq} = \left(\frac{1}{8.50\ \mu\text{F}} + \frac{1}{20.0\ \mu\text{F}}\right)^{-1} = \boxed{5.96\ \mu\text{F}}$$

(b) $Q = C\Delta V = (5.96\ \mu\text{F})(15.0\ \text{V}) = \boxed{89.5\ \mu\text{C}}$ on $20.0\ \mu\text{F}$

$\Delta V = \frac{Q}{C} = \frac{89.5\ \mu\text{C}}{20.0\ \mu\text{F}} = 4.47\ \text{V}$

$15.0 - 4.47 = 10.53\ \text{V}$

$Q = C\Delta V = (6.00\ \mu\text{F})(10.53\ \text{V}) = \boxed{63.2\ \mu\text{C}}$ on $6.00\ \mu\text{F}$

$89.5 - 63.2 = \boxed{26.3\ \mu\text{C}}$ on $15.0\ \mu\text{F}$ and $3.00\ \mu\text{F}$

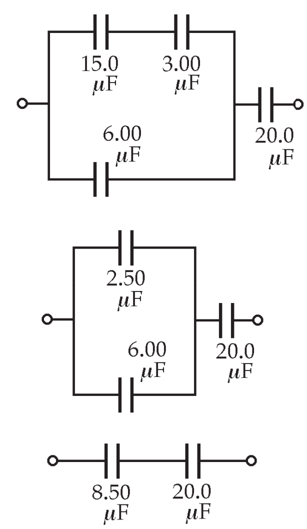

FIG. P20.41

P20.43 $C = \dfrac{Q}{\Delta V}$ so $\quad 6.00 \times 10^{-6} = \dfrac{Q}{20.0}$

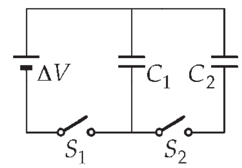

FIG. P20.43

and $\quad Q = \boxed{120\ \mu\text{C}}$

$Q_1 = 120\ \mu\text{C} - Q_2$

and $\quad \Delta V = \dfrac{Q}{C}: \quad \dfrac{120 - Q_2}{C_1} = \dfrac{Q_2}{C_2}$

or $\quad \dfrac{120 - Q_2}{6.00} = \dfrac{Q_2}{3.00}$

$(3.00)(120 - Q_2) = (6.00)Q_2$

$Q_2 = \dfrac{360}{9.00} = \boxed{40.0\ \mu\text{C}} \qquad Q_1 = 120\ \mu\text{C} - 40.0\ \mu\text{C} = \boxed{80.0\ \mu\text{C}}$

P20.48 $U = \dfrac{1}{2} C \Delta V^2$

$$\Delta V = \sqrt{\frac{2U}{C}} = \sqrt{\frac{2(300\ \text{J})}{30 \times 10^{-6}\ \text{C/V}}} = \boxed{4.47 \times 10^3\ \text{V}}$$

P20.49 $U = \dfrac{1}{2} C (\Delta V)^2$

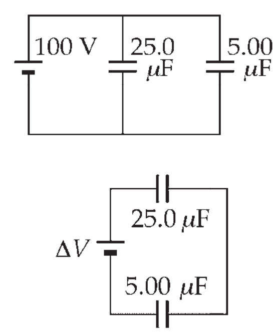

FIG. P20.49

The circuit diagram is shown at the right.

(a) $\quad C_p = C_1 + C_2 = 25.0\ \mu\text{F} + 5.00\ \mu\text{F} = 30.0\ \mu\text{F}$

$$U = \frac{1}{2}(30.0 \times 10^{-6})(100)^2 = \boxed{0.150\ \text{J}}$$

(b) $$C_s = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \left(\frac{1}{25.0\ \mu\text{F}} + \frac{1}{5.00\ \mu\text{F}}\right)^{-1} = 4.17\ \mu\text{F}$$

$$U = \frac{1}{2} C (\Delta V)^2$$

$$\Delta V = \sqrt{\frac{2U}{C}} = \sqrt{\frac{2(0.150)}{4.17 \times 10^{-6}}} = \boxed{268\ \text{V}}$$

P20.53 (a)

$$C = \frac{\kappa \epsilon_0 A}{d} = \frac{2.10(8.85 \times 10^{-12}\ \text{F/m})(1.75 \times 10^{-4}\ \text{m}^2)}{4.00 \times 10^{-5}\ \text{m}} = 8.13 \times 10^{-11}\ \text{F} = \boxed{81.3\ \text{pF}}$$

(b) $\Delta V_{\max} = E_{\max} d = \left(60.0 \times 10^{6} \text{ V/m}\right)\left(4.00 \times 10^{-5} \text{ m}\right) = \boxed{2.40 \text{ kV}}$

P20.59 The energy transferred is $T_{ET} = \frac{1}{2} Q \Delta V = \frac{1}{2}(50.0 \text{ C})\left(1.00 \times 10^{8} \text{ V}\right) = 2.50 \times 10^{9} \text{ J}$

and 1% of this (or $\Delta E_{\text{int}} = 2.50 \times 10^{7} \text{ J}$) is absorbed by the tree. If m is the amount of water boiled away,

then

$$\Delta E_{\text{int}} = m(4\,186 \text{ J/kg} \cdot {}^{\circ}\text{C})(100^{\circ}\text{C} - 30.0^{\circ}\text{C}) + m\left(2.26 \times 10^{6} \text{ J/kg}\right) = 2.50 \times 10^{7} \text{ J}$$

giving $m = \boxed{9.79 \text{ kg}}$.