1. The change in the potential energy of the proton is equal to the negative of the work done on it by the electric field. Thus,

\[ \Delta PE = -W = -qE_x(\Delta x) = -(+1.6 \times 10^{-19} \text{ C})(850 \text{ N/C})(2.5 \text{ m} - 0) = -3.4 \times 10^{-16} \text{ J} \]

and (b) is the correct choice for this question.

2. Because electric forces are conservative, the kinetic energy gained is equal to the decrease in electrical potential energy, or

\[ KE = -PE = -q(\Delta V) = -(1 \text{ e})(+1.0 \times 10^4 \text{ V}) = +1.0 \times 10^4 \text{ eV} \]

so the correct choice is (a).

3. From conservation of energy, \( KE_f + PE_f = KE_i + PE_i \), or \( \frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + qV_i - qV_f \)

or \( v_f = \sqrt{v_i^2 + \frac{2q(V_i - V_f)}{m}} \)

\[ = \sqrt{(6.20 \times 10^3 \text{ m/s})^2 + \frac{2(1.60 \times 10^{-19} \text{ C})(1.50 - 4.00) \times 10^3 \text{ V}}{6.63 \times 10^{-27} \text{ kg}}} = 3.78 \times 10^5 \text{ m/s} \]

Thus, the correct answer is choice (b).

4. In a uniform electric field, the change in electric potential is \( \Delta V = -E_x(\Delta x) \), giving

\[ E_x = -\frac{\Delta V}{\Delta x} = \frac{(V_f - V_i)}{(x_f - x_i)} = \frac{(190 \text{ V} - 120 \text{ V})}{(5.0 \text{ m} - 3.0 \text{ m})} = -35 \text{ V/m} = -35 \text{ N/C} \]

and it is seen that the correct choice is (d).

7. In a series combination of capacitors, the equivalent capacitance is always less than any individual capacitance in the combination, meaning that choice (a) is false. Also, for a series combination of capacitors, the magnitude of the charge is the same on all plates of capacitors in the combination, making both choices (d) and (e) false. The potential difference across the capacitance \( C_i \) is \( \Delta V_i = \frac{Q}{C_i} \), where \( Q \) is the common charge on each capacitor in the combination. Thus, the largest potential difference (voltage) appears across the capacitor with the least capacitance, making choice (b) the correct answer.

11. Capacitances connected in parallel all have the same potential difference across them and the equivalent capacitance, \( C_{eq} = C_1 + C_2 + C_3 + \cdots \), is larger than the capacitance of any one of the capacitors in the combination. Thus, choice (e) is a true statement. The charge on a capacitor is \( Q = C(\Delta V) \), so with \( \Delta V \) constant, but the capacitances different, the capacitors all store different charges that are proportional to the capacitances, making choices (a), (b), (d), and (e) all false. Therefore, (e) is the only correct answer.
12. For a series combination of capacitors, the magnitude of the charge is the same on all plates of capacitors in the combination. Also, the equivalent capacitance is always less than any individual capacitance in the combination. Therefore, choice (a) is true while choices (b) and (c) are both false. The potential difference across a capacitor is $\Delta V = Q/C$, so with $Q$ constant, capacitors having different capacitances will have different potential differences across them, with the largest potential difference being across the capacitor with the smallest capacitance. This means that choice (d) is false and choice (e) is true. Thus, both choices (a) and (e) are true statements.

4. Electric potential $V$ is a measure of the potential energy per unit charge. Electrical potential energy, $PE = QV$, gives the energy of the total charge $Q$.

8. There are eight different combinations that use all three capacitors in the circuit. These combinations and their equivalent capacitances are:

All three capacitors in series - $C_{eq} = \left( \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right)^{-1}$

All three capacitors in parallel - $C_{eq} = C_1 + C_2 + C_3$

One capacitor in series with a parallel combination of the other two:

$C_{eq} = \left( \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right)^{-1}$, $C_{eq} = \left( \frac{1}{C_3} + \frac{1}{C_2} \right)^{-1}$, $C_{eq} = \left( \frac{1}{C_3} + \frac{1}{C_1} \right)^{-1}$

One capacitor in parallel with a series combination of the other two:

$C_{eq} = \left( \frac{C_1 C_2}{C_1 + C_2} \right) + C_3$, $C_{eq} = \left( \frac{C_3 C_1}{C_3 + C_1} \right) + C_2$, $C_{eq} = \left( \frac{C_2 C_3}{C_2 + C_3} \right) + C_1$
16.1 (a) Because the electron has a negative charge, it experiences a force in the direction opposite to the field and, when released from rest, will move in the negative $x$ direction. The work done on the electron by the field is

$$W = F_x \Delta x = (qE_x) \Delta x = (-1.60 \times 10^{-19} \text{ C})(375 \text{ N/C})(-3.20 \times 10^{-2} \text{ m}) = 1.92 \times 10^{-18} \text{ J}$$

(b) The change in the electric potential energy is the negative of the work done on the particle by the field. Thus,

$$\Delta PE = -W = -1.92 \times 10^{-18} \text{ J}$$

(c) Since the Coulomb force is a conservative force, conservation of energy gives

$$\Delta KE + \Delta PE = 0,$$

or

$$KE_f = m_e \frac{v_f^2}{2} - \Delta PE = 0 - \Delta PE,$$

and

$$v_f = \sqrt{\frac{-2(\Delta PE)}{m_e}} = \sqrt{\frac{-2(-1.92 \times 10^{-18} \text{ J})}{9.11 \times 10^{-31} \text{ kg}}} = 2.05 \times 10^6 \text{ m/s in the } -x \text{ direction}$$

16.3 The work done by the agent moving the charge out of the cell is

$$W_{\text{inlet}} = -W_{\text{field}} = -(-\Delta PE_e) = +q(\Delta V)$$

$$= (1.60 \times 10^{-19} \text{ C})(+90 \times 10^{-3} \text{ J/C}) = 1.4 \times 10^{-20} \text{ J}$$

16.4 $\Delta PE_e = q(\Delta V) = q(V_f - V_i)$, so

$$g = \frac{\Delta PE_e}{V_f - V_i} = \frac{-1.92 \times 10^{-17} \text{ J}}{+60.0 \text{ J/C}} = -3.20 \times 10^{-10} \text{ C}$$
16.12 (a) At the origin, the total potential is

\[ V_{\text{origin}} = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} \]

\[ = \left( 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \right) \left[ \frac{4.50 \times 10^{-6} \text{ C}}{1.25 \times 10^{-2} \text{ m}} + \frac{(-2.24 \times 10^{-6} \text{ C})}{1.80 \times 10^{-2} \text{ m}} \right] = 2.12 \times 10^5 \text{ V} \]

(b) At point \( B \) located at \((1.50 \text{ cm}, 0)\), the needed distances are

\[ r_1 = \sqrt{|x_B - x_1|^2 + |y_B - y_1|^2} = \sqrt{(1.50 \text{ cm})^2 + (1.25 \text{ cm})^2} = 1.95 \text{ cm} \]

and

\[ r_2 = \sqrt{|x_B - x_2|^2 + |y_B - y_2|^2} = \sqrt{(1.50 \text{ cm})^2 + (1.80 \text{ cm})^2} = 2.34 \text{ cm} \]

giving

\[ V_B = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = \left( 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \right) \left[ \frac{4.50 \times 10^{-6} \text{ C}}{1.95 \times 10^{-2} \text{ m}} + \frac{(-2.24 \times 10^{-6} \text{ C})}{2.34 \times 10^{-2} \text{ m}} \right] = 1.21 \times 10^5 \text{ V} \]

16.26 (a) \[ C = \frac{Q}{\Delta V} = \frac{27.0 \mu \text{C}}{9.00 \text{ V}} = 3.00 \mu \text{F} \]

(b) \[ Q = C(\Delta V) = (3.00 \mu \text{F})(12.0 \text{ V}) = 36.0 \mu \text{C} \]

16.28 (a) \[ Q = C(\Delta V) = (4.00 \times 10^{-6} \text{ F})(12.0 \text{ V}) = 48.0 \times 10^{-6} \text{ C} = 48.0 \mu \text{C} \]

(b) \[ Q = C(\Delta V) = (4.00 \times 10^{-6} \text{ F})(1.50 \text{ V}) = 6.00 \times 10^{-6} \text{ C} = 6.00 \mu \text{C} \]
16.33 (a) Capacitors in a series combination store the same charge, \( Q = C_{eq}(\Delta V) \), where \( C_{eq} \) is the equivalent capacitance and \( \Delta V \) is the potential difference maintained across the series combination. The equivalent capacitance for the given series combination is

\[
\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}, \quad \text{or} \quad C_{eq} = \frac{C_1 C_2}{C_1 + C_2},
\]

so

\[
C_{eq} = \frac{(2.50 \, \mu F)(6.25 \, \mu F)}{2.50 \, \mu F + 6.25 \, \mu F} = 1.79 \, \mu F
\]

so the charge stored on each capacitor in the series combination is

\[
Q = C_{eq}(\Delta V) = (1.79 \, \mu F)(6.00 \, V) = 10.7 \, \mu C
\]

(b) When connected in parallel, each capacitor has the same potential difference, \( \Delta V = 6.00 \, V \), maintained across it. The charge stored on each capacitor is then

For \( C_1 = 2.50 \, \mu F \): \( Q_1 = C_1(\Delta V) = (2.50 \, \mu F)(6.00 \, V) = 15.0 \, \mu C \)

For \( C_2 = 6.25 \, \mu F \): \( Q_2 = C_2(\Delta V) = (6.25 \, \mu F)(6.00 \, V) = 37.5 \, \mu C \)

16.34 (a) When connected in series, the equivalent capacitance is

\[
\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}, \quad \text{or}
\]

\[
C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{(4.20 \, \mu F)(8.50 \, \mu F)}{4.20 \, \mu F + 8.50 \, \mu F} = 2.81 \, \mu F
\]

(b) When connected in parallel, the equivalent capacitance is

\[
C_{eq} = C_1 + C_2 = 4.20 \, \mu F + 8.50 \, \mu F = 12.7 \, \mu F
\]
16.35 (a) First, we replace the parallel combination between points b and c by its equivalent capacitance, \( C_{bc} = 2.00 \mu F + 6.00 \mu F = 8.00 \mu F \). Then, we have three capacitors in series between points a and d. The equivalent capacitance for this circuit is therefore

\[
\frac{1}{C_{eq}} = \frac{1}{C_{ab}} + \frac{1}{C_{bc}} + \frac{1}{C_{cd}} = \frac{3}{8.00 \mu F}
\]

giving \( C_{eq} = \frac{8.00 \mu F}{3} = 2.67 \mu F \)

(b) The charge stored on each capacitor in the series combination is

\[ Q_{ab} = Q_{bc} = Q_{cd} = C_{eq} (\Delta V_{ad}) = (2.67 \mu F)(9.00 V) = 24.0 \mu C \]

Then, note that \( \Delta V_{bc} = C_{bc} = \frac{24.0 \mu C}{8.00 \mu F} = 3.00 \text{ V} \). The charge on each capacitor in the original circuit is:

On the 8.00 \( \mu F \) between a and b: \( Q_8 = Q_{ab} = 24.0 \mu C \)

On the 8.00 \( \mu F \) between c and d: \( Q_8 = Q_{cd} = 24.0 \mu C \)

On the 2.00 \( \mu F \) between b and c: \( Q_2 = C_2 (\Delta V_{bc}) = (2.00 \mu F)(3.00 \text{ V}) = 6.00 \mu C \)

On the 6.00 \( \mu F \) between b and c: \( Q_6 = C_6 (\Delta V_{bc}) = (6.00 \mu F)(3.00 \text{ V}) = 18.0 \mu C \)

(c) Note that \( \Delta V_{ab} = Q_{ab}/C_{ab} = 24.0 \mu C/8.00 \mu F = 3.00 \text{ V} \), and that \( \Delta V_{cd} = Q_{cd}/C_{cd} = 24.0 \mu C/8.00 \mu F = 3.00 \text{ V} \). We earlier found that \( \Delta V_{bc} = 3.00 \text{ V} \), so we conclude that the potential difference across each capacitor in the circuit is

\[ \Delta V_8 = \Delta V_2 = \Delta V_6 = \Delta V_8 = 3.00 \text{ V} \]

16.45 Energy stored = \( \frac{Q^2}{2C} = \frac{1}{2} C (\Delta V)^2 = \frac{1}{2} (4.50 \times 10^{-6} \text{ F})(12.0 \text{ V})^2 = 3.24 \times 10^{-4} \text{ J} \)
16.48 The energy transferred to the water is

\[ W = \frac{1}{100} \left[ \frac{1}{2} Q (\Delta V) \right] = \frac{(50.0 \text{ C})(1.00 \times 10^8 \text{ V})}{200} = 2.50 \times 10^7 \text{ J} \]

Thus, if \( m \) is the mass of water boiled away,

\[ W = m \left[ c(\Delta T) + L_v \right] \]

becomes

\[ 2.50 \times 10^7 \text{ J} = m \left[ \left( 4186 \frac{\text{ J}}{\text{ kg} \cdot \text{K}} \right) (100^\circ \text{C} - 30.0^\circ \text{C}) + 2.26 \times 10^6 \text{ J/kg} \right] \]

\[ \text{giving} \quad m = \frac{2.50 \times 10^7 \text{ J}}{2.55 \text{ J/kg}} = 9.79 \text{ kg} \]