1. An electron is released at the negative plate of a parallel plate capacitor and accelerates to the positive plate (see the drawing).

(a) As the electron gains kinetic energy, does its electric potential energy increase or decrease? Why?

(b) The difference in the electron’s electric potential energy between the positive and negative plates is \( E_{P_{positive}} - E_{P_{negative}} \). How is this difference related to the charge on the electron \( e \) and to the difference in the electric potential between the plates?

(c) How is the potential difference related to the electric field within the capacitor and the displacement of the positive plate relative to the negative plate?

(d) The plates of a parallel plate capacitor are separated by a distance of 1.2 cm, and the electric field within the capacitor has a magnitude of \( 2.1 \times 10^6 \text{ V/m} \). An electron starts from rest at the negative plate and accelerates to the positive plate. What is the kinetic energy of the electron just as the electron reaches the positive plate?

(a) The electric potential energy decreases. The electric force \( F \) is a conservative force, so the total energy (kinetic energy plus electric potential energy) remains constant as the electron moves across the capacitor. Thus, as the electron accelerates and its kinetic energy increases, its electric potential energy decreases.

(b) According to Equation 19.4, the change in the electron’s electric potential energy is equal to the charge on the electron \( (-e) \) times the potential difference between the plates, or
\[
E_{P_{positive}} - E_{P_{negative}} = (-e) (V_{positive} - V_{negative})
\]

(c) The electric field \( E \) is related to the potential difference between the plates and the displacement \( \Delta s \) by
\[
E = \frac{V_{positive} - V_{negative}}{\Delta s} \quad \text{(Equation 19.7a)}
\]
Note that \( V_{positive} - V_{negative} \) and \( \Delta s \) are positive numbers, so the electric field is a negative number, denoting that it points to the left in the drawing.

(d) The total energy of the electron is conserved, so its total energy at the positive plate is equal to its total energy at the negative plate:
\[
KE_{positive} + E_{P_{positive}} = KE_{negative} + E_{P_{negative}}
\]
Since the electron starts from rest at the negative plate, \( KE_{negative} = 0 \). Thus, the kinetic energy of the electron at the positive plate is
\[
KE_{positive} = E_{P_{positive}} = (V_{positive} - V_{negative})
\]
We know from the discussion in our answer to Concept Question 4 that
\[
E_{P_{positive}} = e (V_{positive} - V_{negative})
\]
so the kinetic energy can be written as
\[
KE_{positive} = - (E_{P_{positive}} - E_{P_{negative}}) = e (V_{positive} - V_{negative})
\]
Since the potential difference is related to the electric field \( E \) and the displacement \( \Delta s \) by (Equation 19.7a), we have that
\[
KE_{positive} = - (E_{P_{positive}} - E_{P_{negative}}) = e (-E \Delta s) = (1.60 \times 10^{-19})/(-2.1 \times 10^6)(0.012) = 4.8 \times 10^{-15} \text{ J}
\]
2. Each of the four circuits in the drawing consists of a single resistor whose resistance is either \( R \) or \( 2R \), and a single battery whose voltage is either \( V \) or \( 2V \).

(a) Rank the circuits according to the power, largest to smallest.

(b) Rank the circuits according to the current delivered to the resistor, largest to smallest.

(c) The unit of voltage in each circuit is \( V = 12.0 \, V \) and the unit of resistance is \( R = 6.00 \, \Omega \). Determine the power supplied to each resistor.

(d) Determine the current delivered to each resistor.

(a) The power delivered to a resistor is given by Equation 20.6c as \( P = \frac{V^2}{R} \), where \( V \) is the voltage and \( R \) is the resistance. Because of the dependence of the power on \( V^2 \), doubling the voltage has a greater effect in increasing the power than halving the resistance. The table shows the power for each circuit, given in terms of these variables:

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Power</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>( P = \frac{V^2}{R} )</td>
<td>3</td>
</tr>
<tr>
<td>b</td>
<td>( P = \frac{V}{2R} )</td>
<td>4</td>
</tr>
<tr>
<td>c</td>
<td>( P = \frac{(2V)^2}{2R} = \frac{4V^2}{R} )</td>
<td>1</td>
</tr>
<tr>
<td>d</td>
<td>( P = \frac{(2V)^2}{2R} = \frac{2V^2}{R} )</td>
<td>2</td>
</tr>
</tbody>
</table>

(b) The current is given by Equation 20.2 as \( I = \frac{V}{R} \). Note that the current, unlike the power, depends linearly on the voltage. Therefore, either doubling the voltage or halving the resistance has the same effect on the current. The table shows the current for the four circuits:

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Current</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>( I = \frac{V}{R} )</td>
<td>2</td>
</tr>
<tr>
<td>b</td>
<td>( I = \frac{V}{2R} )</td>
<td>3</td>
</tr>
<tr>
<td>c</td>
<td>( I = \frac{2V}{R} )</td>
<td>1</td>
</tr>
<tr>
<td>d</td>
<td>( I = \frac{V}{R} )</td>
<td>2</td>
</tr>
</tbody>
</table>

(c) Using the results from part (a) and the values of \( V = 12.0 \, V \) and \( R = 6.00 \, \Omega \), the power dissipated in each resistor is

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Power</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>( P = \frac{V^2}{R} = 24.0 , W )</td>
<td>3</td>
</tr>
<tr>
<td>b</td>
<td>( P = \frac{V}{2R} = 12.0 , W )</td>
<td>4</td>
</tr>
<tr>
<td>c</td>
<td>( P = \frac{4V^2}{R} = 96.0 , W )</td>
<td>1</td>
</tr>
<tr>
<td>d</td>
<td>( P = \frac{2V^2}{R} = 48.0 , W )</td>
<td>2</td>
</tr>
</tbody>
</table>

(d) Similarly, using the results from part (b), the current in each circuit is

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Current</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>( I = \frac{V}{R} = 2.00 , A )</td>
<td>2</td>
</tr>
<tr>
<td>b</td>
<td>( I = \frac{V}{2R} = 1.00 , A )</td>
<td>3</td>
</tr>
<tr>
<td>c</td>
<td>( I = \frac{2V}{R} = 4.00 , A )</td>
<td>1</td>
</tr>
<tr>
<td>d</td>
<td>( I = \frac{V}{R} = 2.00 , A )</td>
<td>2</td>
</tr>
</tbody>
</table>
3. The drawing shows three different resistors in two different circuits. The resistances are such that \( R_1 > R_2 > R_3 \).

(a) For the circuit on the top, rank the current through each resistor and the voltage across each one, largest first.

(b) Repeat part (a) for the circuit on the bottom.

(c) The battery has a voltage of \( V = 24.0 \text{ V} \), and the resistors have values of \( R_1 = 50.0 \Omega \), \( R_2 = 25.0 \Omega \), and \( R_3 = 10.0 \Omega \). For the circuit on the top, determine the current through and the voltage across each resistor.

(d) Repeat part (c) for the circuit on the bottom.

(a) The three resistors are in series, so the same current goes through each resistor: \( I_1 = I_2 = I_3 \). The voltage across each resistor is given by Equation 20.2 as \( V = IR \). Because the current through each resistor is the same, the voltage across each is proportional to the resistance. Since \( R_1 > R_2 > R_3 \), the ranking of the voltages is \( V_1 > V_2 > V_3 \).

(b) The three resistors are in parallel, so the same voltage exists across each: \( V_1 = V_2 = V_3 \). The current through each resistor is given by Equation 20.2 as \( I = V/R \). Because the voltage across each resistor is the same, the current through each is inversely proportional to the resistance. Since \( R_1 > R_2 > R_3 \), the ranking of the currents is \( I_3 > I_2 > I_1 \).

(c) The current through the three resistors is given by \( I = V/R_s \), where \( R_s \) is the equivalent resistance of the series circuit. From Equation 20.16, the equivalent resistance is \( R_s = 50.0 + 25.0 + 10.0 = 85.0 \Omega \). The current through each resistor is

\[
I_1 = I_2 = I_3 = \frac{V}{R_s} = \frac{24.0}{85.0} = 0.282 \text{ A}
\]

The voltage across each resistor is

\[
V_1 = IR_1 = 0.282 \times 50.0 = 14.1 \text{ V}, \quad V_2 = IR_2 = 0.282 \times 25.0 = 7.05 \text{ V}, \quad V_3 = IR_3 = 0.282 \times 10.0 = 2.82 \text{ V}
\]

(d) The resistors are in parallel, so the voltage across each is the same as the voltage of the battery:

\[
V_1 = V_2 = V_3 = 24.0 \text{ V}
\]

The current through each resistor is equal to the voltage across each divided by the resistance:

\[
I_1 = \frac{V}{R_1} = \frac{24.0}{50.0} = 0.480 \text{ A}, \quad I_2 = \frac{V}{R_2} = \frac{24.0}{25.0} = 0.960 \text{ A}, \quad I_3 = \frac{V}{R_3} = \frac{24.0}{10.0} = 2.40 \text{ A}
\]
The circuit in the drawing contains three identical resistors.

(a) Consider the equivalent resistance between the two points $a$ and $b$, $b$ and $c$, and $a$ and $c$. Rank the equivalent resistances in decreasing order.

(b) Each resistor has a value of $R = 10.0 \, \Omega$. Determine the equivalent resistance between the points $a$ and $b$, $b$ and $c$, and $a$ and $c$.

(a) Between points $a$ and $b$ there is only one resistor, so the equivalent resistance is $R_{ab} = R$. Between points $b$ and $c$ the two resistors are in parallel. The equivalent resistance can be found from Equation 20.17:

$$\frac{1}{R_{bc}} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \quad \rightarrow \quad R_{bc} = \frac{1}{2}R$$

The equivalent resistance between $a$ and $b$ is in series with the equivalent resistance between $b$ and $c$, so the equivalent resistance between $a$ and $c$ is

$$R_{ac} = R_{ab} + R_{bc} = R + \frac{1}{2}R = \frac{3}{2}R.$$ 

Thus, we see that $R_{ac} > R_{ab} > R_{bc}$.

(b) Since the resistance is $R = 10.0 \, \Omega$, the equivalent resistances are:

$$R_{ab} = R = 10.0 \, \Omega, \quad R_{bc} = \frac{1}{2}R = 5.00 \, \Omega, \quad R_{ac} = \frac{3}{2}R = 15.0 \, \Omega.$$