PROBLEM 2

The following diagrams show two views of a pair of parallel wires carrying currents \( I_1 \) and \( I_2 \). \( I_1 = 5.0 \, \text{A}, \) \( I_2 = 15.0 \, \text{A}, \) \( d = 4.0 \, \text{cm} \).

(a) At what point on a line between the two wires is the \( \vec{B} \) field zero? Measure distances from \( I_1 \). 

\[
\beta_{\text{net}} = \beta_1 + \beta_2 = 0 = \frac{\mu_0 I_1}{2\pi (d-x)} - \frac{\mu_0 I_2}{2\pi (d-x)} \quad \text{or} \quad \frac{I_1}{d} = \frac{3}{d-x} = 0
\]

\[ d - x = \frac{I_1}{\beta_1} = \frac{I_1}{I_1 + I_2} \times \frac{(5.0 \, \text{A})(4.0 \, \text{cm})}{20.0 \, \text{A}} \]

\[ d = 1.0 \, \text{cm} \]

(b) What is the magnitude and direction of the \( \vec{B} \) field at the point \( P \) located 3.0 cm directly below \( I_1 \)? 

\[
\beta_1 = \frac{\mu_0 I_1}{2\pi r_1} = \frac{\mu_0 I_1}{2\pi (0.03 \, \text{m})} = 3.3 \times 10^{-5} \, \text{T}
\]

\[
\beta_2 = \frac{\mu_0 I_2}{2\pi r_2} = \frac{\mu_0 I_2}{2\pi (0.05 \, \text{m})} \approx 6.0 \times 10^{-5} \, \text{T}
\]

\[
\beta_{\text{net}} = \beta_1 + \beta_2 = 6.9 \times 10^{-5} \, \text{T}
\]

\[
\phi = \tan^{-1} \left( \frac{-4.8}{6.9} \right) = \tan^{-1} \left( -0.696 \right) = -34.8^\circ \quad \text{(43.8^\circ \text{ below } B_1)}
\]

(c) At the point \( P \) a third wire is placed carrying current \( I_3 = 10.0 \, \text{A} \) parallel to both \( I_1 \) and \( I_2 \) but directed into the plane of the page from the edge view. What is the magnitude of the force this third wire feels?

\[
F = I_3 \beta_{\text{net}} = (10.0 \, \text{A})(2.0 \, \text{m})(6.9 \times 10^{-5} \, \text{T}) = 1.7 \times 10^{-2} \, \text{N}
\]
Problem 1.

A square wire loop of dimension 16.0 cm is supported vertically by a massless string attached to a spring scale as shown.

The mass of the loop is 150 g and a current of 5.00 A is established in the loop. A portion of the loop, inside the dashed rectangle, feels a uniform \( B \).

11 pts
A. What is the spring scale reading when \( B = 0 \)?

\[
W = mg = (0.150 \text{ kg})(9.8 \text{ m/s}^2) = 1.47 N
\]

12 pts
C. What is the magnitude and direction of the minimum \( B \) to reduce the spring scale reading to 0.0 N?

\[
F = I \times L \times B \quad \text{(on bottom segment only)}
\]

\[
B = \frac{F}{IL} = \frac{W}{IL} = \frac{1.47 N}{(5.00 \text{ A})(16 \text{ cm})} = \frac{1.47 N}{(5.00 \text{ A})(0.16 \text{ m})} = 1.84 T
\]

4 pts
DIR. of \( \vec{B} \) into plane of paper

34 pts
10-

6. Qualitative question: Suppose the uniform \( \vec{B} \) in the region shown were now made horizontal and pointing to the right. Describe how the loop would behave when the field is turned on.

\( \vec{B} \) IN THIS CASE THE MAGNETIC MOMENT \( \mu \) OF THE LOOP WOULD BE PERPENDICULAR TO \( \vec{B} \). THIS LOOP WOULD FEEL A \( \vec{F} \) THAT WOULD ROTATE \( \mu \) TOWARD DIRECTION OF \( \vec{B} \).
B. \(120\%\) The diagram shows a uniform \(\mathbf{B}\) directed down the page. Four objects are shown: \(q_1, q_2, q_3\), and \(q_4\) where \(q_1 = e^+, q_2 = p^+, q_3 = Li^+\) (singly charge lithium atom), and \(q_4 = He^+\) (helium atom). The motion of the objects shown is along the plane of the page at the instant shown. Use lines, curves (e.g., circles, spirals, etc.), and anything else to show subsequent motions. Assume all speeds are the same. If the field has no effect on the object, you may write next to that object "no change."  

C. \(15\%\) For the following, use arrows in each figure to indicate the direction of induced current flow in the secondary circuit based upon the described changes. (3 per each arrow)  

1. Variable resistor resistance is steadily reduced.

2. Switch on primary circuit is opened.

3. \(\mathbf{B}\) into the plane of the paper is suddenly turned off.

4. Bar magnet is moving to the right away from the secondary circuit. Secondary is stationary.

5. Bar magnet is moving toward the metal hoop along the axis of the hoop.
B. The diagrams below show a number of currents in wires sitting in \( \vec{B} \) fields. In each case draw an arrow showing the direction of the magnetic force the wire feels. If the wire feels no force, put the word "no force" next to the wire. Also, if the force is into the paper or out of the plane of the paper, next to the picture write words to state this.

1. [Diagram of a wire with an arrow pointing downward indicating the direction of the magnetic force.

2. [Diagram of a wire with an arrow pointing out of the plane of the paper indicating the direction of the magnetic force.

3. [Diagram of a wire with an arrow pointing into the plane of the paper indicating the direction of the magnetic force.

C. For the following use arrows in each figure to indicate the direction of the induced current flow in the secondary current.

1. [Diagram of a magnet with a coil, the magnet is chopped along the axis of the hoop.

2. [Diagram of a magnet with a coil, the \( \vec{B} \) initially out of the plane of the paper, reverses direction 2.0 s.

D. The following diagrams are two views of a rod on rails apparatus. The rails are inclined above the horizontal. The rod can then slide without friction along the rails under the influence of gravity. The rod and rails are resistanceless. All resistance is contained in \( R \). At the bottom of the page, describe how the rod slides down the rails. In your account of this motion also account for its causes.

Rod accelerates down rails initially due to \( W_a \). As it increases its velocity, down the rails, the rod and rails inductively induce \( F_i \) with a component opposite to the direction of motion subtracts from \( W_a = mg \sin \phi \).

Eventually the component of \( F_i \) up the rails equals \( W_a \) down the rails for which \( \phi = \text{const.} \) and \( \theta = 0 \).
EXAM 3

Name: ___________________________ Student ID #: ______________________

TA (circle one): Kirsten Larson Pierre Lacock

The diagram to the right shows two long wires carrying currents $I_1 = 10.0 \text{ A}$ and $I_2 = 8.00 \text{ A}$, respectively. The wires are in the plane of the paper. A, B, C, and D identify different regions (quadrants) near the wires.

A. $120^\circ$ 1. In this region the direction of the net $\vec{B}$ will always point into the plane of the paper.

   $D$ 2. In this region the direction of the net $\vec{B}$ will always point out of the plane of the paper.

   $A+C$ 3. There are points in this/these region(s) where the net $\vec{B}$ is zero.

B. Determine the net $\vec{B}$, magnitude and direction, at the point P shown in the diagram.

   $B_1 = \frac{\mu_0 I_1}{2\pi R_1} = \frac{(4\pi \times 10^{-7} \text{ T m/A})(10.0 \text{ A})}{2\pi (0.06 \text{ m})} = 3.33 \times 10^{-5} \text{ T}$ (62.5\°)

   $B_2 = \frac{\mu_0 I_2}{2\pi R_2} = \frac{(4\pi \times 10^{-7} \text{ T m/A})(8.00 \text{ A})}{2\pi (0.04 \text{ m})} = 4.80 \times 10^{-5} \text{ T}$ (66.3\°)

   $\vec{B}_{\text{net}} = \vec{B}_2 - \vec{B}_1 = 6.7 \times 10^{-5} \text{ T (out of plane of paper)}$

C. A proton ($q^+ = 1.6 \times 10^{-19} \text{ C}$) is seen to be moving at point P with a velocity of $2.0 \times 10^4 \text{ m/s}$ out of the plane of the paper. At the instant the proton passes P, what magnetic force does it feel?

   $\vec{F}_m = 0 \quad \vec{v} \text{ is parallel with } \vec{B}$
PROBLEM 3

(a) What is the equivalent capacitance of the collection of capacitors?

\[ \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2+C_3+C_4} + \frac{1}{C_4+C_5} = \frac{1}{8 \mu F} + \frac{1}{2 \mu F} + \frac{1}{8 \mu F} = \frac{1}{4 \mu F} \]

\[ C_{eq} = 2.0 \mu F \]

(b) What are the voltages across and the charges stored on capacitors C(1) and C(3)? Four answers are expected here.

\[ Q_{tot} = Q_{tot}(234) = \frac{4.8 \mu C}{2 \mu F} = 2.4 \mu C \]

\[ V_{112} = V_3 = \frac{Q_{tot}(234)}{C_{123}} = \frac{4.8 \mu C}{2 \mu F} = 2.4 \mu V \]

\[ V_1 = \frac{Q_{1}}{C_1} = \frac{4.8 \mu C}{2 \mu F} = 2.4 \mu V \]

\[ V_3 = \frac{Q_3 V_3}{C_3} = (2.0 \mu F)(12 \mu V) = 24 \mu V \]

(c) How much energy is stored in this capacitor collection?

\[ E_{tot} = \frac{1}{2} C_{eq} V^2 = \frac{1}{2}(15)(2.0 \mu F)(24 \mu V)^2 = 576 \mu J \]

(d) Suppose the section between 1 and 2 were removed and C(5) and C(6) disconnected from each other without losing any of their original charge. C(3) and C(6) are now reconnected with the + terminal of C(5) attached to the + terminal of C(6) and the - terminal of C(3) attached to the + terminal of C(6). Under these conditions what new total charge still resides on the C(5)-C(6) combination and what is the new voltage drop across each capacitor?

\[ Q_5 = Q_5 V_5 = (12 \mu V)(12 \mu V) = 12 \mu C \]

\[ Q_6 = Q_6 V_6 = (3 \mu F)(12 \mu V) = 36 \mu C \]

When the Cs are reconnected with opposite plates attached

\[ Q_{tot}(new) = 36 \mu C - 12 \mu C = 24 \mu C \]

\[ Q_{tot}(new) = C_5 V_{new} \]

\[ V_{new} = \frac{Q_{tot}(new)}{C_5} = \frac{24 \mu C}{3 \mu F} = 8 \mu V \]

\[ V_5 = V_6 = 8 \mu V \]

Note: This means \[ Q_5 = C_5 V_5 = 60 \mu C \]

\[ Q_6 = C_6 V_6 = 180 \mu C \]
Examine the following circuit. You may think of each resistor as a light bulb whose resistance is fixed at the value given. Assume that the brightness of the bulb is measured by the current that flows through it.

A. What is the equivalent resistance of the circuit and the net circuit current?

\[ R_{eq} = 2\Omega + 1\Omega + 3\Omega = 6\Omega \]

\[ I_{net} = \frac{V}{R_{eq}} = \frac{24V}{6\Omega} = 4.0A \]

B. What is the current through and the voltage drop across the 3.0\(\Omega\) resistor?

\[ I_{3\Omega} = 4.0A \]

\[ V_{3\Omega} = 24V \]

\[ I_3 = \frac{V_{3\Omega}}{3\Omega} = 8.0A \]

C. You have in your possession a DC ammeter and a DC voltmeter. Describe carefully how you would measure:

1. The current through the 12\(\Omega\) resistor; cut circuit between A + B on 12\(\Omega\) side and insert ammeter + terminal toward B, - terminal toward A.

2. The voltage drop across the 3.0\(\Omega\) - 6.0\(\Omega\) parallel resistance combination.

   PLACE + TERMINAL OR VOLTMETER AT D AND - TERMINAL AT C.

D. Now interchange the 4.0\(\Omega\) resistor with the 24.0 V source. Would the illumination of the 1.0\(\Omega\) resistor increase, decrease, or stay the same? You must justify your answer.

\[ V_2 = 4V \]

\[ I_2 = I_1 = \frac{24V}{7.5\Omega} = 3.4A < 4.0A \]

Illumination through 1.0\(\Omega\) resistor PALT.
Examine the following circuit. S is a switch.

\[ V \quad C_1 \quad C_2 \quad C_3 \]

- \( C_1 = 0.10 \mu F \)
- \( C_2 = 0.30 \mu F \)
- \( C_3 = 0.60 \mu F \)
- \( V = 12.0 \text{ volts} \)

A. \[ \text{10 PTs} \]

S is closed and the circuit is charged. What are (i) the equivalent capacitance of the circuit and (ii) the total charge the source delivers to this circuit?

\[
C_{eq} = C_1 + C_2 + \frac{1}{C_3} = 0.3 \mu F + 0.3 \mu F + \frac{1}{0.6 \mu F} = 1.3 \mu F
\]

\[
Q_{TOT} = C_{eq} \times V = (0.3 \mu F)(12 V) = 3.6 \mu C
\]

B. \[ \text{10 PTs} \]

With S closed, what are (i) the charge on \( C_2 \) and (ii) the voltage across \( C_3 \)?

- \( Q_{C_2} = C_2 \times V = (0.3 \mu F)(12 V) = 3.6 \mu C \)
- \( V_{C_3} = \frac{Q_{C_3}}{C_3} = \frac{2.4 \mu C}{0.6 \mu F} = 4.0 \text{ volts} \)

C. \[ \text{10 PTs} \]

With the circuit fully charged, open S. With S still open, add a dielectric to \( C_1 \) only so that its new capacitance is \( C_1\text{(new)} = 0.20 \mu F \). With S kept open, what are the new values of the (i) charge on \( C_1 \) and (ii) the voltage across \( C_3 \)?

- \( Q_{TOT} \text{ CANNOT CHANGE} \)
- \( Q_{C_1} = 3.6 \mu C \times \frac{V_{NRW}}{C_1} = \frac{3.6 \mu C}{0.20 \mu F} = 1.8 \mu C \)
- \( V_{NRW} = V_1 = \frac{Q_{TOT}}{C_1} = \frac{3.6 \mu C}{0.20 \mu F} = 18 \text{ volts} \)
- \( Q_3 = C_3 \times V_1 = (0.3 \mu F)(19.0 V) = 5.7 \mu C \)
A. Examine the six circuits below. All resistors are identical. In each case a 12.0 V source is connected between A and B.

For the statements below, enter one or more letters identifying the circuit. None or all are possible answers.

1. The circuit(s) for which the largest I passes point A.
2. The circuit(s) for which the smallest I passes A.
3. The circuit(s) consuming the largest amount of power.
4. The circuit(s) equivalent to \( A \rightarrow R \rightarrow B \) where the R value is the same as the individual resistance of the circuit elements above.
5. The circuit(s) in which zero current is passing through one or more resistors.
6. The circuit(s) in which the equivalent resistance is less than the resistance of one of the resistors in the circuit.

B. The \( -\frac{\Delta V}{\Delta t} \) in the circuit to the right reads 2.0 A. For this circuit find \( I_1 \) and \( I_2 \) for the source. Use Kirchhoff's Rules.

\[
\begin{align*}
\text{At A:} & \quad I_1 + I_2 = 0 \quad 2.0 \text{ A} \\
\text{upper loop:} & \quad -10V + 15V - 7I_1 = 0 \\
\text{lower loop:} & \quad -10V + \frac{5}{7}A - 2I_2 = 0 \\
I_2 & = 2.0A - \frac{5}{7}A \quad = \sqrt[3]{\frac{9}{7}A} \\
\end{align*}
\]

\[ I_1 = \frac{5}{7}A \]

\[ E = 10V + 2 \frac{5}{7}A = 10V + \frac{15}{7}B = 10V + 2.6V \]

\[ E = 12.6 \text{ V} \]
A. The current through the 4.0 Ω resistor is 1.71 A and travels from right to left. \( R_1 = 2.0 \, \Omega, \, R_2 = 4.0 \, \Omega, \, R_3 = 8.0 \, \Omega; \, V_1 = 6.0 \, V, \, V_2 = 6.0 \, V; \, V_3 = 6.0 \, V \). \[ I_2 \, R_2 = (1.71 \, A)(4.0 \, \Omega) = 6.84 \, V \]

1. [3 pts.] What is the difference in potential (voltage) between B and A in the drawing?

\[ \Delta V = V_B - V_A = -I_2 \, R_2 + V_2 \]
\[ = -6.84 \, V + 6.0 \, V \]
\[ \Delta V = -0.84 \, V \]

2. [12 pts.] What are the currents \( I_1 \) and \( I_2 \) through \( R_1 \) and \( R_3 \)? To get full credit you must give directions. Draw arrows on diagram for directions.

**Top Loop:** \( V_A - V_B = +0.847 \, V = 6.0 \, V - I_1 \, R_1 \)

\[ I_1 = \frac{6.16 \, V}{3.0 \, \Omega} = 2.056 \, A \]

**Bottom Loop:** \( V_A - V_B = +0.847 \, V = -6.0 \, V + I_2 \, R_3 \)

\[ I_2 = \frac{6.84 \, V}{8.0 \, \Omega} = 0.855 \, A \]

B. [15 pts.] A 200 V voltage is applied across the free terminals of a 3-capacitor combination shown. \( (C_1 = 2.0 \, \mu F; \, C_2 = 6.0 \, \mu F; \, C_3 = 8.0 \, \mu F) \)

1. What is the equivalent capacitance of the combination and the total charge supplied by the source?

\[ C_{123} = 4.0 \, \mu F \]

\[ C_{123} = C_1 + C_2 + \frac{1}{C_1} \cdot \frac{1}{C_2} \]

\[ Q_{123} = C_{123} \cdot V = (4.0 \, \mu F)(200 \, V) \]

\[ Q_{123} = 800 \, \mu C \]

2. What is the voltage drop across and the charge stored on \( C_1 \)?

\[ S_{IN} \, \quad Q_1 = Q_{123} = 800 \, \mu C \]

\[ V_1 = V_2 = \frac{800 \, \mu C}{8.0 \, \mu F} = 100 \, V \]

\[ Q_1 = C_1 \cdot V_1 = (6.0 \, \mu F)(100 \, V) = 600 \, \mu C \]
A. [12 pts.] Examine the combination of identical light bulbs connected to a source.

1. Which bulb(s) is/are brightest?
2. Through which bulb(s) is/are the largest current(s) flowing?
3. What happens to bulb 1 if bulb 3 is unscrewed and removed? (a) no change; (b) gets brighter; (c) gets dimmer; (d) cannot tell (e) goes out
4. What happens to bulb 2 if bulb 1 is unscrewed and removed? (a) no change; (b) gets brighter; (c) gets dimmer; (d) cannot tell (e) goes out

B. [12 pts.] Examine the combination of identical capacitors.

1. Which capacitor(s) store(s) the largest charge?
2. Which capacitor(s) experiences the largest potential difference?
3. While the source voltage remains connected a dielectric material is inserted between the plates of $C_3$ that doubles it capacitance. As a result the charge stored on $C_3$ (a) increases; (b) decreases; (c) stays the same; (d) cannot tell.
4. Because of inserting the dielectric between the plates of $C_3$ as in #3 above, the overall charge delivered by the source to the circuit (a) increases; (b) decreases; (c) stays the same; (d) cannot tell.

C. [10 pts.] The following figure shows 4 charged particles labeled 1-4 with identical speeds. The following items ask you to identify the particle. The charge on the particle is shown next to the particle. None is a possible answer.

1. The particle(s) feeling zero magnetic force.
2. The particle(s) on which the magnitude of the magnetic force is largest.
3. The particle(s) on which the direction of the magnetic force is up out of the plane of the paper.
4. The particle whose motion is entirely circular.
EXAM 3

Name: ___________________________________ Student ID #: _________________________

TA (circle one): Costello Flitcroft Murray Young

A. Examine the following circuit. 
\[ C_{12} = \frac{1}{3 \mu F} + \frac{1}{6 \mu F} \] 
\[ C_{12} = 2.0 \mu F \] 
\[ C_1 = 3.0 \mu F; C_2 = 6.0 \mu F; C_3 = 10.0 \mu F; C_4 = 4.0 \mu F; V = 24.0 \text{ V} \]

1. [6 pts.] Calculate the total equivalent capacitance of this circuit.
\[ \frac{1}{C_{eq}} = \frac{1}{C_{12}} + \frac{1}{C_4} = \frac{1}{12 \mu F} + \frac{1}{4 \mu F} \]
\[ C_{eq} = 3.0 \mu F \]

2. [6 pts.] Calculate the total charge delivered by the source to the collection of capacitors.
\[ Q_{tot} = C_{eq} V = (3.0 \mu F)(24 \text{ V}) \]
\[ Q_{tot} = 72.0 \mu C \]

3. [6 pts.] What are (a) the charge on and (b) the voltage drop across \( C_4 \)?
\[ Q_4 = 72.0 \mu C \]
\[ V_4 = \frac{Q_4}{C_4} = \frac{72.0 \mu C}{4.0 \mu F} = 18.0 \text{ V} \]

B. Examine the following circuit.
\[ R_1 = 100 \Omega; R_2 = 150 \Omega; R_3 = 140 \Omega; R_4 = 600 \Omega; V = 30.0 \text{ V} \]
\[ R_{12} = 60 \Omega \]

1. [6 pts.] What is the equivalent resistance of this combination of resistors?
\[ R_{eq} = R_{12} + R_3 = 240 \Omega \]
\[ \frac{1}{R_{eq}} = \frac{1}{R_{12}} + \frac{1}{R_3} = \frac{1}{60 \Omega} + \frac{1}{140 \Omega} = \frac{1}{60 \Omega} \]
\[ R_{eq} = 150 \Omega \]

2. [6 pts.] What is the total circuit current delivered by the source?
\[ I_{tot} = \frac{V}{R_{eq}} = \frac{30 \text{ V}}{150 \Omega} = 0.200 \text{ A} \]

3. [6 pts.] What are (a) the current through \( R_3 \) and the voltage drop across \( R_3 \)?
\[ I_3 = I_{tot} = \frac{V}{R_{12}} = \frac{30 \text{ V}}{240 \Omega} = 0.125 \text{ A} \]
\[ V_3 = I_3 R_3 = (0.125 \text{ A})(140 \Omega) = 17.5 \text{ V} \]

4. [2 pts.] Place an x in the circuit where a fuse should be placed to protect the source.
A. Examine the following circuit. At $t = 0$, $S_I$ and $S_2$ are open and $C$ is completely uncharged. For the following you will be asked questions about various circuit values, e.g., current through $R_4$ or charge on $C$. In each case the answer may be zero or something that can be expressed in terms of $V$, $R_1$, $R_2$, and/or $C$.

1. [2 pts.] Close $S_1$, leaving $S_2$ open. What initial current flows through $R_1$?

\[ I_{INITIAL} = \frac{V}{R_1} \]

2. [2 pts.] After 10 "RC time constants," what is the voltage drop across $R_2$?

\[ \Theta \]

3. [2 pts.] After 10 "RC time constants," what charge is stored in the capacitor?

\[ Q = Q_{MAX} = CV \]

4. [2 pts.] What is the voltage drop across $R_1$ with $S_1$ closed and $S_2$ open?

\[ \Theta \]

5. [2 pts.] Now open $S_1$ and close $S_2$. What initial current flows through the resistors?

\[ I_{INITIAL} = \frac{V}{R_1 + \frac{1}{R_2}} \]

B. [18 pts.] Two long parallel wires in the plane of the page are carrying currents, not necessarily equal, in opposite directions. A, B, C, D, and E are points along a perpendicular horizontal line. In the spaces provided enter none, or one, or more of the letters that best fit the statements.

(4 pts) 1. \[ B \quad E \]

At this/these point(s) the magnitude of $\vec{B}$ could be zero.

(6 pts) 2. \[ B \quad C \quad D \]

At this/these point(s) the magnitude of $\vec{B}$ will never be zero.

(4 pts) 3. \[ A \quad E \]

If $I_1 = I_2$, $\vec{B}$ at this/these points will point toward you out of the plane of the page.

(4 pts) 4. At C draw an arrow showing the magnetic force an electron would feel if it were at C moving upward and parallel to the two wires.

(1 pt) 5. A proton is traveling perpendicular to the plane of the paper with speed $v$. Describe the magnetic force it feels at E with the instantaneous motion described.

There is no $\vec{F}_M$ as $\vec{v}$ is parallel to $\vec{B}$.
EXAM 2

A. Examine the following collection of resistors.

1. [10 pts.] What is the equivalent resistance of this collection of resistors?

\[
\frac{1}{R_{\text{eq}}} = \frac{1}{12\Omega} + \frac{1}{4\Omega} = \frac{4\Omega \cdot 12\Omega}{16\Omega} = 3\Omega
\]

2. Suppose the current through the 8 Ω resistor is 0.50 A.

a. [8 pts.] What must be the battery voltage whose terminals are connected to A and B for this to be the case?

\[
\begin{align*}
I_{\text{top}} &= 0.5A + 0.25A + 0.25A = 1.00A \\
V_{\text{top}} &= V_{\text{source}} = I_{\text{top}}R_{\text{top}} = 3V = 3V
\end{align*}
\]

b. [3 pts.] What constant power is dissipated by the 20 Ω resistor?

\[
P_{20} = I_{20}^2 \times 20\Omega = (1.00A)^2 \times 20\Omega
\]

B. Examine the following network. The directions of the 1A and 2A currents are correct.

1. [3 pts.] What current flows through the 4 Ω resistor?

\[
I_4 = 1.0A
\]

2. [12 pts.] Use Kirchhoff's Rules to determine \( \varepsilon_1 \) and \( \varepsilon_2 \).

**Top Loop (ccw):**

\[
-6V + 200V + 4V - \varepsilon_1 = 0 \quad (4\text{pts})
\]

\[
\varepsilon_1 = 12V \quad (4\text{pts})
\]

**Bottom Loop (ccw):**

\[
18V - 9V - \varepsilon_2 - 9V = 0 \quad (4\text{pts})
\]

\[
\varepsilon_2 = 10V \quad (4\text{pts})
\]
A. [18 pts.] For the items below enter all options that answer the questions. Credit will be given for each correct answer. In some cases there are multiple correct answers. Points a, b, c, d, and e identify locations in the circuit.

1. \( \frac{R_3}{R_2} \) Through which resistors does the largest current flow?
2. \( \frac{R_1}{R_2} \) Across which resistors is the voltage drop the largest?
3. \( \frac{R_3}{R_2} \) To measure the terminal voltage of the source, place the leads of voltmeter on this pair of points.
4. \( \frac{R_3}{R_2} \) To read the current through \( R_3 \), place an ammeter in the circuit at this point.
5. \( \frac{R_3}{R_2} \) To read the current through \( R_2 \), place an ammeter in the circuit at this point.
6. \( \frac{R_3}{R_2} \) To read the voltage drop across \( R_3 \), place the leads from a voltmeter at these points.
7. \( \frac{R_3}{R_2} \) To protect the circuit from a current overload, place a circuit breaker at any of these points.
8. \( \frac{R_3}{R_2} \) The equivalent resistance of the circuit in terms of any of the resistance in the circuit.
9. \( \frac{R_3}{R_2} \) Suppose a zero-resistance wire were connected between points c and d. As a result the current though \( R_2 \) would increase, decrease or stay the same.
10. \( \frac{R_3}{R_2} \) When the leads of a voltmeter are placed at these two points, the voltmeter reading will be zero.

B. [8 pts.] Two wires carry identical currents as shown. The dashed line shown is midway between the wires, and points a, b, c, d, and e are selected points in space. Note: Points e and d are, respectively, equal distances above the top and bottom wires and point b is the same distance below the top wire and above the lower wire. Enter a, b, c, d, and/or e, as the case may be, for the items below. The two wires, the dashed line, and all the points a, b, c, d, and e, are all in the same plane.

1. \( \frac{R_3}{R_2} \) The point(s) at which the net \( \vec{B} \) from the two wires is zero.
2. \( \frac{R_3}{R_2} \) The point(s) at which the net \( \vec{B} \) from the two wires point out of the plane of the paper.
3. \( \frac{R_3}{R_2} \) The point(s) at which the net \( \vec{B} \) from the two wires point into the plane of the paper.
4. \( \frac{R_3}{R_2} \) The point(s) at which the field due to the lower wire is maximum.
5. \( \frac{R_3}{R_2} \) The point(s) at which the direction of \( \vec{B} \) from the separate wires is/are in the same direction.
A. Examine the drawing with the following collection of capacitors.

1. [6 pts.] What is the equivalent capacitance of the entire collection of capacitors? \( C_{eq} = \frac{C_{12}C_{34}}{C_{12} + C_{34}} \)

\[ C_{12} = 4.0 \mu F, \quad C_{34} = 12.0 \mu F \]

\[ C_{eq} = \frac{4.0 \mu F \times 12.0 \mu F}{4.0 \mu F + 12.0 \mu F} = \frac{48 \mu F \mu F}{16 \mu F} = 3.0 \mu F \]

2. [4 pts.] Suppose a 16.0 V potential is applied between points x and y. What is the total charge delivered by this source to the capacitor collection?

\[ Q_{total} = C_{eq} \cdot V = (8.0 \mu F)(16V) = 128 \mu C \]

3. [8 pts.] What is the charge delivered to the 8.0 \( \mu F \) capacitor, and what is the voltage applied across its plates? \( Q_{C1} = Q_{eq} \cdot \frac{C_{1}}{C_{1} + C_{eq}} \)

\[ V_{C1} = \frac{Q_{C1}}{C_{1}} = \frac{128 \mu C}{10 \mu F} = 12.8 \mu V \]

\[ Q_{eq} = C_{eq} \cdot V_{eq} = (3.0 \mu F)(10.7 \mu V) = 32.1 \mu C \]

B. Examine the following circuit. The current I flowing through the 10.0 \( \Omega \) resistor is 1.58 A. Note: The polarity of the source V may or may not be in the direction shown.

1. [10 pts.] What currents flow through the 18.0 \( \Omega \) and 5.00 \( \Omega \) resistors? Make sure you indicate the directions of these currents.

\[ I_R = I_L + 1.55 A \] (AT A)

\[ I_L = \frac{10 \times 3 \times 10^4 - (1.55 A)(10 \times 3 \times 10^4)}{18 \times 10^3} = 0.838 A \]

\[ I_R = 0 + 1.55 A = 1.55 A \]

2. [6 pts.] What is the value and the polarity of the unknown source voltage V? If the polarity is correct as shown, say so.

\[ V = \frac{-10 \times 3 \times 10^4}{10 \times 3 \times 10^4} + 10 \times 3 \times 10^4 = 0 \]

\[ V = 18.1 V \] THE POLARITY IS CORRECT AS SHOWN.
The pair of parallel wires shown in the drawing lie in the same plane and carry equal but oppositely directed currents of 15.0 A. Points A and B lie in the plane of the wires.

A. [14 pts.] What is the net \( B \) at magnitude and direction, at points A and B due to the currents flowing in each wire?

\[
0_b = \left( 4\pi \times 10^{-7} \frac{T \cdot m}{A} \right) \left( 15A \right) \left( 0.030 \right) = 0.00105 T
\]
\( \text{m} \) \text{m} \text{r}
\( \left( 0.060 \right) \)
\( \text{down into plane} \)
\( \text{up out of plane} \)

B. [6 pts.] Suppose a potassium ion \( K^+ \) was seen at point B in the figure. When the ion was at point B, it was moving with a speed of \( 2.4 \times 10^6 \text{ m/s} \) along a line in the plane of the two wires parallel to both in the direction in which the current in the wire on the lower right was moving. At the instant \( K^+ \) was at point B, what is the magnitude of the magnetic force it feels? At point B on the picture, draw an arrow showing the direction of this force. \( \text{(Note: The charge on this ion is } 1.6 \times 10^{-19} \text{ C}) \)

\[
F_{K^+} = qvB \sin 90^\circ = (1.6 \times 10^{-19} \text{ C})(2.4 \times 10^6 \text{ m/s})(1.00 \times 10^{-7} \text{ T}) = 3.8 \times 10^{-19} \text{ N}
\]

C. [6 pts.] Suppose a second \( K^+ \) ion was at point A in the drawing, and was moving with a speed of \( 2.4 \times 10^6 \text{ m/s} \) along a line perpendicular to the plane of the two wires and in a direction into the page. What magnetic force would this \( K^+ \) feel?

\[
F_{K^+} = 0
\]

D. [4 pts.] Assuming the segments of wire shown in the drawing are portions of much longer current carrying wires, do these short wire segments interact with each, i.e., do they attract or repel each other or do they not interact. Explain. They do interact. They repel. The force each wire feels sitting in the B field of the other wire, according to right hand rule 1 points away from the other wire.
EXAM 3

Name: ___________________________  Student ID #: ___________________________

TA (circle one): Alex  Ben  Brigham  Dan  Elspeth  Eric  Geoff

A. [20 pts.] Examine the circuit to the right. Assume the switch S is initially open and the capacitor is uncharged. Points B and C represent the positive and negative terminal of a fixed voltage battery. In the spaces below, enter the appropriate letter to best complete the statements: I (for increases), D (for decreases) or S (for stays the same). Assume the ammeter —○— offers zero resistance. Also, the capacitor plays no role in the circuit until the switch S is closed.

1. If R₁ increases, the potential difference between B and C —○—. Assume the battery does have an internal resistance, i.e., some resistance r between the terminals B and C.
2. For this item and all that follow, assume the internal resistance of the battery, r, is zero. If R₁ increases, the potential difference between B and C —○—.
3. If R₂ decreases the equivalent circuit resistance —Δ—.
4. If R₂ decreases the current through the ammeter —○—.
5. If R₃ decreases the voltage drop across R₁ —○—.
6. If R₂ decreases the voltage drop across R₄ —○—.
7. If R₁ and R₄ both increase, ε —○—.
8. With R₁ and R₄ fixed, close the switch S. Just after S is closed the reading on the ammeter —○—.
9. Relative to the ammeter reading before the switch S was closed, the ammeter reading after the switch has been closed a very long time (at least 5 R₄C time constants) —○—.
10. Relative to the ammeter reading before the switch S was closed, the ammeter reading after the switch S is opened after the capacitor had become fully charged —○—.

B. [10 pts.] The figures below show the motion of an proton given by an arrow, ⊗, or ⊙, all labeled  \( \vec{v} \), in a magnetic field \( \vec{B} \) (given by an arrow, ⊗ or ⊙). ⊗ denotes directly out of the plane of the paper and ⊙ denotes directly into the plane of the paper. For each case (a-e), draw an arrow from the charge representing the magnetic force the electron feels. If the force is zero, write the word zero next to the figure.

(a)  (b)  (c)  (d)  (e)
EXAM 3

A. [12 pts.] The figure to the right shows four identical light bulbs behaving as resistors and connected as shown to a voltage source. The level of illumination (brightness) of a given bulb depends upon the amount of current flowing through the bulb.

1. A and D What bulb(s) is/are the brightest in the circuit?
2. 2.5R is the equivalent resistance of the circuit assuming each bulb has a resistance of R. Enter a number which, when multiplied by R, gives R_eq.

Complete the following statements by entering either increase (I), decrease (D), or stays the same (S).

3. D If bulb A is removed the brightness of D will
4. B If bulb C is removed the brightness of C will
5. D If bulb C is removed the brightness of D will
6. B If bulb C is removed the brightness of A will

B. [12 pts.] Three simple RC circuits have source voltages (V), resistance (R), and capacitance (C) shown in the table below. Initially the switch is open and the capacitor is uncharged (circuit diagram to the right).

<table>
<thead>
<tr>
<th>Circuit</th>
<th>V</th>
<th>R</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>24 V</td>
<td>8.0 Ω</td>
<td>6.0 μF</td>
</tr>
<tr>
<td>B</td>
<td>18 V</td>
<td>6.0 Ω</td>
<td>1.0 μF</td>
</tr>
<tr>
<td>C</td>
<td>18V</td>
<td>18 Ω</td>
<td>4.0 μF</td>
</tr>
</tbody>
</table>

For the statements below, enter A, B and/or C as appropriate.

1. C immediately after S is closed the circuit with the smallest initial current.
2. A and B Immediately after S is closed the circuit with the largest initial current.
3. A After all the capacitors are fully charged the circuit capacitor with the largest charge.
4. C The circuit taking the longest time to fully charge.
5. A The circuit with the largest amount of charge on the capacitor after one RC time constant for that circuit has elapsed.
6. A The circuit capacitor capable of storing the largest amount of energy.

C. [10 pts.] Four particles are traveling in a region of a uniform magnetic field coming directly out of the page. See drawing. For the questions below assume the particles masses are the same and the particles charges are the same although the signs of the charge may be opposite.

1. B The particle with no charge.
2. C and D The particle(s) with negative charge.
A. Examine the following circuit.

1. \[8\text{ pts.}]\] What is the equivalent resistance of this circuit?
\[
R_{\text{eq}} = R_1 + R_2 + R_{3456}
\]
\[
= 25.0\, \Omega
\]

2. \[12\text{ pts.}]\] The current through the 4.00 \, \Omega resistor is measured to be 1.00 A. What is \(V\)?

In 1.00 A flows through 4.00 \, \Omega resistor, it also flows through \(R_{34}\) combination because \(R_{34} = R_{56}\). That means current through \(R_{3456}\) combination is 0.00A. This is also the circuit current. This

\[
V = \sum_{\text{circuit}} R_{\text{eq}} = (2.00\, \text{A})(25.0\, \Omega)
\]
\[
= 50.0\, \text{V}
\]

B. Three capacitors are connected as shown.

\(C_1 = 20.0\, \mu\text{F};\, C_2 = 15.0\, \mu\text{F};\, C_3 = 30.0\, \mu\text{F};\, V = 60.0\, \text{V}\)

1. \[4\text{ pts.}]\] What is the equivalent capacitance for this circuit?
\[
C_{eq} = C_1 + C_2 = 30.0\, \mu\text{F}
\]

2. \[8\text{ pts.}]\] What charge is stored in \(C_2\)?

\[
Q_{C_2} = C_2 V = (10.0\, \mu\text{F})(60.0\, \text{V}) = 600.\, \mu\text{C}
\]

\[
Q_{C_2} = Q_2 = 600.\, \mu\text{C}
\]
Two long straight wires, oriented perpendicular to the page, carry currents of $I_{\text{left}} = 10.0 \, \text{A}$ and $I_{\text{right}} = 15.0 \, \text{A}$. $I_{\text{left}}$ is into the page and $I_{\text{right}}$ is coming out of the page. The wires are separated by a distance of 12.0 cm.

A. [15 pts.] At point P determine the magnitude of the magnetic field due to the two currents. Draw the vector for that $\vec{B}$ at P.

\[
B_0(\text{RIGHT}) = \frac{\mu_0 I_{\text{RIGHT}}}{2\pi R_{\text{RIGHT}}} = \left(\frac{4\pi \times 10^{-7} \, \text{T} \cdot \text{m}}{A}\right) \left(15 \, \text{A}\right) = 5.00 \times 10^{-5} \, \text{T}
\]

\[
B_0(\text{LEFT}) = \frac{\mu_0 I_{\text{LEFT}}}{2\pi R_{\text{LEFT}}} = \left(\frac{4\pi \times 10^{-7} \, \text{T} \cdot \text{m}}{A}\right) \left(10 \, \text{A}\right) = 1.11 \times 10^{-5} \, \text{T}
\]

\[
B_0(\text{NET}) = B_0(\text{RIGHT}) - B_0(\text{LEFT}) = 3.89 \times 10^{-5} \, \text{T}
\]

B. [15 pts.] Suppose a third wire carrying a 4.00 A current is placed 6.00 cm to the right of the right wire that is carrying the 15.0 A current. It is situated perpendicular to the plane of the page and passes through point P. The current flowing in this wire goes into the plane of the page. What magnetic force, magnitude and direction, does a 20.0 cm length of this wire feel?

\[
F = ILLB \sin \Phi = (4.00 \, \text{A}) (0.06 \, \text{m}) (3.89 \times 10^{-5} \, \text{T}) (1) = 3.11 \times 10^{-5} \, \text{N}
\]

The force points to right away from $I_{\text{RIGHT}}$.

C. [4 pts.] Without the third wire present, are there any locations where the total $\vec{B}$ from $I_{\text{left}}$ and $I_{\text{right}}$ will be zero? If so, sketch approximately where these locations are. No calculation is required here.