1. In the circuit below calculate the current in each element and enter it in the table below. You must use the direction of currents shown on the figure. \( R_1 = 10 \) Ohms, \( R_2 = 25 \) Ohms, \( V_1 = 10 \) volts, \( V_2 = 20 \) volts, \( V_3 = 30 \) volts.

<table>
<thead>
<tr>
<th>( R_1 )</th>
<th>( V_1 )</th>
<th>( R_2 )</th>
<th>( V_2 )</th>
<th>( V_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0.4</td>
<td>0.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Left loop - move clockwise**

\[ V_2 + R_2 I_2 - V_3 = 0 \]
\[ 20 + 25 I_2 - 30 = 0 \]
\[ I_2 = 0.4 \text{ A} \]

**Right loop - move cw**

\[ V_3 - R_1 - V_1 = 0 \]
\[ 30 - 10 I_1 - 10 = 0 \]
\[ I_1 = 2 \text{ A} \]

**Current Rule**

\[ I_3 - I_2 - I_1 = 0 \]

\[ I_3 = I_1 + I_2 = 2 + 0.4 = 2.4 \text{ A} \]
2. In an RC circuit \( R = 10,000 \) Ohms, \( C = 0.1 \) microfarads, and the battery emf \( e = 10 \) volts. The capacitor is initially fully discharged.

a. What is the time constant of this circuit?

\[
\text{time const: } \tau = RC \\
\tau = 10^4 \times 0.1 \times 10^{-6} = 0.001 \text{ sec} = 1 \text{ m sec}
\]

b. Is this capacitor fully charged after one second? Your answer should be followed by the reasoning.

\[
q = CE \left( 1 - e^{-t/\tau} \right) \\
q_{\text{max}} = CE \\
q = q_{\text{max}} \left( 1 - e^{-t/\tau} \right) \\
q = q_{\text{max}} \left( 1 - e^{-1/0.001} \right) = q_{\text{max}} \left( 1 - e^{-1000} \right) \\
q = q_{\text{max}} \text{ since } e^{-1000} \approx 0
\]

The capacitor is fully charged after 1 sec.
3. Use Ampere's law to prove that magnetic field \( B \) at a distance \( X \) near a long wire with current \( I \) is given by

\[
B = \frac{\mu_0 I}{2\pi x}
\]

\[
\oint \overrightarrow{B} \cdot d\overrightarrow{l} = \int \mu_0 \overrightarrow{I} \cdot d\overrightarrow{l}, \quad B \parallel d\overrightarrow{l}
\]

\[
\int \overrightarrow{B} \cdot d\overrightarrow{l} = \int \overrightarrow{B} \cdot d\overrightarrow{l} = B \int \overrightarrow{d\alpha}
\]

\[
B = B(2\pi x) = \frac{\mu_0 I}{2\pi x}
\]

Two very long parallel wires with the distance of 0.1 mm from each other have a current \( I = 1.0 \) Amp each in the same direction.

i. What is the strength of the magnetic field at a distance 1 cm from one wire outside two wires?

\[
B_1 = \frac{\mu_0 I}{2\pi x_1} = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 10^{-2}} = 2 \times 10^{-5} T
\]

\[
B_2 = \frac{\mu_0 I}{2\pi x_2} = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times (1.0 + 0.1 \times 10^{-2}) \times 10^{-2}} \approx 2 \times 10^{-5} T
\]

\[
B = B_1 + B_2 = 2B_1 = 2 \times 10^{-5} T
\]

ii. What is the strength of the magnetic field halfway between these two wires?

The strength of \( \overrightarrow{B} \) at the center is zero since \( |B_1| = |B_2| \) but \( B_1 \) and \( B_2 \) have opposite directions.

iii. Do these wires attract or repel each other.

Attract
4. In the figures below show the directions of the vectors \( \vec{F}, \vec{a}, \vec{v}, \) and \( \vec{J} \) for a positive and negative charges shown. Also write down the formula you use for each vector.

\[
\vec{F} = q\vec{E} \\
\vec{a} = \frac{q\vec{E}}{m} = \frac{\vec{E}}{m} \\
\vec{v} = \int \vec{a} \, dt \\
\vec{J} = nq\vec{v}
\]
5. An alpha particle is accelerated by a voltage of 2000 volts from rest.

a. What is the speed of the alpha particle? Alpha particle consists of 2 protons and 2 neutrons.
\[ m_p = m_n = 1.67 \times 10^{-27} \text{ kg}, \quad q_p = 1.60 \times 10^{-19} \text{ C} \]

\[
\frac{1}{2} m v^2 = q V
\]

\[
\frac{1}{2} \times 4 \times 1.67 \times 10^{-27} \times v^2 = 2 \times 1.6 \times 10^{-19} \times 2 \times 10
\]

\[
v = 4.37 \times 10^5 \text{ m/s}
\]

b. The alpha particle enters a region with magnetic field \( B = 1.0 \) Tesla perpendicular to its velocity. Calculate the radius of the circular path.

\[
R = \frac{m v}{q B} = \frac{4 \times 1.67 \times 10^{-27} \times 4.37 \times 10^5}{2 \times 1.6 \times 10^{-19} \times 1}
\]

\[
R = 9.12 \times 10^{-3} \text{ m}
\]

c. Calculate the period of the circular motion of the alpha particle?
\[ m_p = m_n = 1.67 \times 10^{-27} \text{ kg}, \quad q_p = 1.60 \times 10^{-19} \text{ C} \]

\[
T = \frac{2 \pi R}{v} = \frac{2 \pi \times 9.12 \times 10^{-3} \text{ m}}{4.37 \times 10^5} = 1.31 \times 10^{-7} \text{ sec}
\]
6. Enter T (True) or F (False) before each statement below.
Correct answer: 2 points, no answer: 0 points, wrong answer: -1 points. Do not guess if you do not know the correct answer.

F Kilowatt-hour is the unit of power.
T A 2-Ohm resistor with a current 2 Amps dissipates a power of 8 watts.
F The equivalent resistance of series resistors is smaller than resistance of either one of two.
T A stiff rectangular loop with current I and area A is under the effect of a magnetic field B perpendicular to its plane. The force acting on this loop is zero.
T A stiff rectangular loop with current I and area A is under the effect of a magnetic field B perpendicular to its plane, the torque acting on the loop by the field is IAB.
F The magnetic field at the center of a square loop with current I is zero.