**DC Circuits**

- Resistance Review
- Following the potential around a circuit
- Multiloop Circuits
- RC Circuits

**Homework for today:**
Read Chapters 26, 27
Chapter 26 Questions 1, 3, 10
Chapter 26 Problems 1, 17, 18, 35, 77

**Homework for tomorrow:**
Chapter 27 Questions 1, 3, 5
Chapter 27 Problems 7, 19, 49
WileyPlus assignment: Chapters 26, 27

**Review: Series and Parallel Resistors**

**Series:**
\[ R = R_1 + R_2 + R_3 \]

**Parallel:**
\[ \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]

**Following the Potential**

Study Fig. 27-4 in the text to see how the potential changes from point to point in a circuit.

Note the net change around the loop is zero.

**Q.27-1**

With the current \( i \) flowing as shown, which is at the **higher potential**, point \( b \) or point \( c \)?

1) \( b \) is higher
2) \( c \) is higher
3) They are the same
4) Not enough information

**Solution**

With the current \( i \) flowing as shown, which is at the **higher potential**, point \( b \) or point \( c \)?

**Solution:**
Current flows from high to low potential just like water flows down hill.

(1) \( b \) is higher
(2) \( c \) is higher
(3) They're the same
(4) Not enough info
Example: Problem 27-30

**Problem 27-30 (part a)**

\[ \mathcal{E} = 6.0 \, V \quad R_1 = 100 \, \Omega \]
\[ R_2 = R_3 = 50 \, \Omega \]
\[ R_4 = 75 \, \Omega \]

(a) Find the equivalent resistance of the network.

(b) Find the current in each resistor.

\[ \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{300} + \frac{1}{16} = \frac{19}{300} \]

\[ R_{eq} = 16 \, \Omega + 9 \, \Omega = 25 \, \Omega \]

\[ i_1 = \frac{\mathcal{E}}{R_{eq}} = \frac{6.0}{25} = 0.24 \, \text{mA} \]

\[ i_2 = \frac{V}{R_2} = \frac{0.95}{50} = 0.019 \, \text{mA} \]

\[ i_3 = \frac{V}{R_3} = \frac{0.95}{50} = 0.019 \, \text{mA} \]

\[ i_4 = \frac{V}{R_4} = \frac{0.95}{75} = 0.012 \, \text{mA} \]

Check: These three add up to \( i_1 = 0.24 \, \text{mA} \).

**Problem 27-30 (part b)**

(b) Find the current in each resistor.

First note that \( i_2 R_2 = i_3 R_3 = i_4 R_4 \).

\[ V = iR_{234} = 0.050 \times 19 \, \Omega = 0.95 \, V \]

So

\[ i_2 = V / R_2 = 0.95 / 50 = 0.019 \, \text{mA} \]

\[ i_3 = V / R_3 = 0.95 / 50 = 0.019 \, \text{mA} \]

\[ i_4 = V / R_4 = 0.95 / 75 = 0.012 \, \text{mA} \]

Check: These three add up to \( i_1 = 0.24 \, \text{mA} \).

Q.27-2

1) 1 A
2) 2 A
3) 3 A
4) 4 A
5) 5 A
6) 6 A
7) 7 A
8) 8 A
9) 9 A

\[ R_2 = 2 \, \Omega \]
\[ R_3 = 3 \, \Omega \]
\[ i_2 = 6 \, \text{A} \]
\[ i_3 = \text{?} \]

\[ V_b - V_c = i_2 R_2 = i_3 R_3 \]

\[ \therefore i_3 = \frac{i_2 R_2}{R_3} = \frac{2}{3} i_2 = 4 \, \text{A} \]
More Complicated Circuits

How do we solve a problem with more than one emf and several loops? We can’t do it just by series and parallel resistor combinations.

Rules for Multiloop Circuits

- **The net voltage change around any loop is zero.**
  “Energy conservation”
- **The net current into any junction is zero.**
  “Charge conservation”

Using these two rules we can always get enough equations to solve for the currents if we are given the emfs and resistances.

Example

\[ \mathcal{E}_1 = 24 \text{V} \]
\[ \mathcal{E}_2 = 12 \text{V} \]
\[ R_1 = 5 \Omega \]
\[ R_2 = R_3 = 30 \Omega \]

Find all currents!

First define unknowns: \( i_1, i_2, i_3 \)

Loop and junction equations:
\[
\mathcal{E}_1 - i_1 R_3 - i_1 R_1 = 0 \\
\mathcal{E}_2 - i_2 R_2 - i_1 R_1 = 0 \\
i_1 = i_2 + i_3 
\]

Put in the given numbers and also replace \( i_1 \) by \( i_2 + i_3 \):
\[
5i_1 + 30i_3 = 5i_2 + 30i_3 = 24 \\
5i_1 + 30i_2 = 35i_2 + 5i_3 = 12 
\]

Solve two equations in two unknowns to get:
\[ i_2 = 250 \text{ mA} \]
\[ i_3 = 650 \text{ mA} \]

Add to get
\[ i_1 = i_2 + i_3 = 900 \text{ mA} \]

Example (continued)

Left-hand loop:
\[ \mathcal{E}_1 - i_1 R_3 - i_1 R_1 = 0 \]
Right-hand loop:
\[ \mathcal{E}_2 - i_2 R_2 - i_1 R_1 = 0 \]
Junction:
\[ i_1 = i_2 + i_3 \]

Algebra: solve 3 equations for 3 unknowns \( i_1, i_2, i_3 \)

Check by using outer loop:
\[
\mathcal{E}_1 - i_1 R_3 + i_2 R_2 - \mathcal{E}_2 = 0 \\
24 - 30(0.65 - 0.25) - 12 \\
= 12 - 12 \\
= 0 
\]
Repeat with a different $R_1$

Exercise for the student: Same equations give **negative** $i_2$ in this case! This means current going downward through right-hand battery.

Back to Basics

- Examples that don’t involve so much algebra, but focus on the ideas of current and voltage.
- Even though you have a multiloop circuit so you need to write down the equations from the loop rule and the junction rule, you may not have to actually solve simultaneous equations.

**Simpler Examples**

Both these problems can be solved for **one unknown at a time**, without messy algebra.

**Discharging a Capacitor**

Capacitor has charge $Q_0$.
At time $t=0$, close switch.
What is charge $q(t)$ for $t>0$?

Obviously $q(t)$ is a function which decreases gradually, approaching zero as $t$ approaches infinity.
What function would do this?

$$ q(t) = Q_0 e^{-t/\tau} $$

But what is the **time constant** $\tau$?

Analyze circuit equation: find $\tau = RC$

**Charging a Capacitor**

$$ V $$

For small $t$, $q=0$ and $i=V/R$.
For large $t$, $q=CV$ and $i=0$.

$$ q(t) = CV \left[ 1 - e^{-t/\tau} \right] $$

$$ \tau = RC $$
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**Exam #1**

Exam #1

Ave = 65

18 F

12 A

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Ave = 65

12 A