Lecture

• Review: Resistors in Series and Parallel
• Kirchhoff’s Rules
• Capacitors in series and in parallel.
• Charging/Discharging capacitors.
The circuit shown is connected to a 25 A circuit breaker. If all devices are turned on at the same time will it trip the circuit breaker?

a) Yes
b) No
c) More information is needed.
In the circuit below, what is the current through $R_1$?

a) 10 A  
b) zero  
c) 5 A  
d) 2 A  
**e) 7 A**
Resistors in Series

From this we get the equivalent resistance (that single resistance that gives the same current in the circuit).

\[ R_{eq} = R_1 + R_2 + R_3. \]
Resistors in Series and in Parallel

Observation: In a parallel arrangement, each device (e.g. resistors) have the same potential difference across them.

\[
\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}
\]

\[
\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}
\]
What happens to the voltage across the resistor $R_4$ when the switch is closed?

a) increases  

b) decreases  

c) stays the same
Kirchhoff’s Rules

- Some circuits cannot be broken down into series and parallel connections.
- We can use conservation of energy and conservation of charge!
Kirchhoff’s Rules

Junction rule (conservation of charge): The sum of currents entering a junction equals the sum of the currents leaving it.

\[ \sum_{\text{in}} I = \sum_{\text{out}} I \]

Loop rule (conservation of energy): The sum of the changes in potential around a closed loop is zero.

\[ \sum_{\text{Closed Loop}} \Delta V = 0 \]
What is the current in branch P?

a) 2 A  
b) 3 A  
c) 5 A  
d) 6 A  
e) 10 A
Which of the equations is valid for the circuit below?

- a) $2 - I_1 - 2I_2 = 0$
- b) $2 - 2I_1 - 2I_2 - 4I_3 = 0$
- c) $2 - I_1 - 4 - 2I_2 = 0$
- d) $I_3 - 4 - 2I_2 + 6 = 0$
- e) $2 - I_1 - 3I_3 - 6 = 0$
Problem Solving Using Kirchhoff’s Rules

1. **Label each current** (if the label direction is wrong you will get a negative current value after solving the equations which means the current flows in the opposite direction).

2. **Identify unknowns.**

3. **Apply junction (conservation of charge) and loop (conservation of energy) rules** keeping in mind that for a full solution you will need as many independent equations as there are unknowns.

4. **Solve the equations, being careful with signs.**
Example: Find the current through each resistor

\[ \sum_{in} I = \sum_{out} I \]

At c: \[ I_1 + I_2 = I_3 \]

\[ \sum_{Closed\ Loop} \Delta V = 0 \]

\[ febadcf\ loop: \quad 14 + 4I_2 + 2I_3 = 0 \]

\[ bcdab\ loop: \quad 10 - 6I_1 - 2I_3 = 0 \]
Example:

What is the magnitude of the current through the 12V battery?

1. **Label each current** (if the label direction is wrong you will get a negative current after solving the equations which means the current flows in the opposite direction).

2. **Identify unknowns.** Unknown: $I_1, I_2, I_3$

3. **Apply junction (conservation of charge) and loop (conservation of energy) rules** (for a full solution you will need as many independent equations as there are unknowns).

4. **Solve the equations**, being careful with signs.
The lightbulbs in the circuit are identical. When the switch is closed, what happens?

a) both bulbs go out
b) intensity of both bulbs increases
c) intensity of both bulbs decreases
d) A gets brighter and B gets dimmer
e) nothing changes
Determine the power dissipated by the 40 Ω resistor.

a) 3.6 W  
b) 4.5 W  
c) 9.0 W  
d) 14 W  
e) 27 W
Capacitors in Parallel

\[ Q = C_{eq} V \]

\[ V = V_{ab} \]
We make two simple observations:

1. The potential across each capacitor is the same.

2. The total charge “Q” is equal to the sum of the charges: \[ Q = Q_1 + Q_2 + Q_3 \]

\[ C_{eq}V = C_1V + C_2V + C_3V \]

\[ C_{eq} = C_1 + C_2 + C_3 \] Capacitors in Parallel
Capacitors in Series

Observation:

- Any number of capacitors in a series arrangement will hold the same charge.
Observation:

- The sum of the potential drops across each capacitor must be equal to the potential across the battery: \( V = V_1 + V_2 + V_3 \)

\[ \frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \]

\[ \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \]
RC Circuits – Charging a Capacitor

Consider the circuit (a):

When the switch is closed, the capacitor will begin to charge.
Charging Capacitor

The voltage across the capacitor increases with time:

\[ V_C(t) = V_{\text{max}} \left(1 - e^{-t/RC}\right) \]

The charge follows a similar curve:

\[ Q(t) = Q_{\text{max}} \left(1 - e^{-t/RC}\right) \]

This curve has a characteristic time constant:

\[ \tau = RC \]
RC Circuits – Discharging Capacitor

- If an isolated charged capacitor is connected across a resistor, it discharges:

\[ Q(t) = Q_0 e^{-t/RC} \]
Example: Charging Capacitor

At time $t = 0s$, the charge on the capacitor plates is zero. How long, after the switch “$S$” is closed, does it take a capacitor with a capacitance $C = 2\mu F$ to be charged to 90% capacity? The resistance on the circuit is $R = 3\,k\Omega$