

Lecture 15: Electric Circuits - Notes

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Transient Response in Circuits

- Before connection: No current flows, system in **equilibrium**.
- After connection: **Transient state** occurs where the electric field (**E-field**) disturbs the equilibrium.
- The **E-field** propagates at the **speed of light**, establishing the steady state within nanoseconds.

Resistors

- A **resistor** is a part of the circuit that opposes the flow of electrons.
- In steady state, current remains constant throughout the circuit, but **electric field (E-field)** differs based on material properties and geometry.
- **Energy Conservation** in a circuit follows **Kirchhoff's Loop Rule**:

$$\Delta V_1 + \Delta V_2 + \Delta V_3 + \dots = 0$$

- This is analogous to the principle that what goes up must come down.

Circuit with a Resistor

- Example 1: A narrow section of wire increases the **E-field** in that section.
- Example 2: A material with lower **mobility (u)** increases the **E-field** to maintain constant current.

Kirchhoff's Voltage Loop Law (Energy Conservation)

- The total voltage drop across all elements in a closed loop equals zero.

- Voltage differences are related to **energy per unit charge**:

$$\Delta V = \frac{\Delta U}{q}$$

Batteries

- **Electromotive force (emf)**: The battery's ability to maintain a potential difference between terminals.
- **emf** is the energy input per unit charge, measured in volts but can originate from chemical, nuclear, or gravitational energy.

Resistors in Series

- Increasing the length or cross-sectional area of a resistor affects the current.
- Doubling the length halves the current; doubling the cross-sectional area doubles the current.

Power in Circuits

- Power is the amount of **energy transferred** or **work done** per unit time.
- The **brightness** of a bulb is proportional to the **power dissipated**.
- Formula for power in a circuit:

$$P = IV = enAuE \times E \times L$$

- **Units of Power**: Watts (W), where 1 Watt = 1 Joule/sec.

Effect of Two Batteries in Series

- Two batteries in series double the **emf**, doubling the current and power.
- This increases the **brightness** of a light bulb.