CHAPTERS 13-23

OVERVIEW

FINAL EXAM

- **When:** Tuesday, Dec 14 8am-5pm
- **Content:** Cumulative (Chs 13-23*)
    - Only conceptual questions from chapter 23, no math
- **Style:** Take-home
    - Pick up physical copy from me
    - Do exam on your own time (open note + open book, **no internet, no collaboration**)
    - Turn physical copy back in to me **by 5pm on Tuesday**

THE PAST 15 WEEKS

- Chapter 13: Electric fields and force
- Chapter 14: Electric fields, charges, and matter
- Chapter 15: Electric fields of distributed charges
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CHAPTER 13

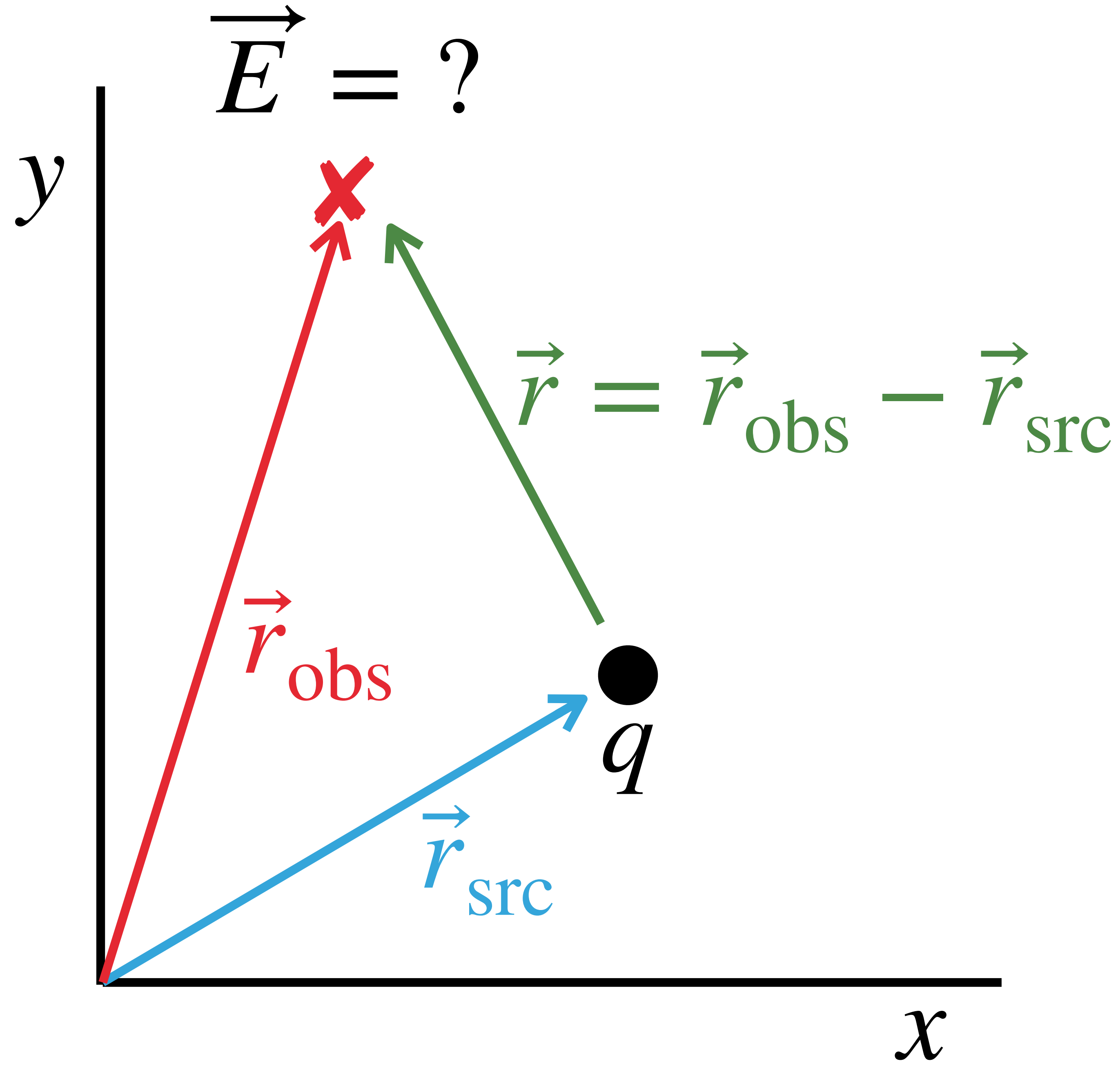
Most important concepts:

- Coulomb's Law (electric field of a single point charge)

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$

- Electric force:

$$\vec{F} = q\vec{E}$$

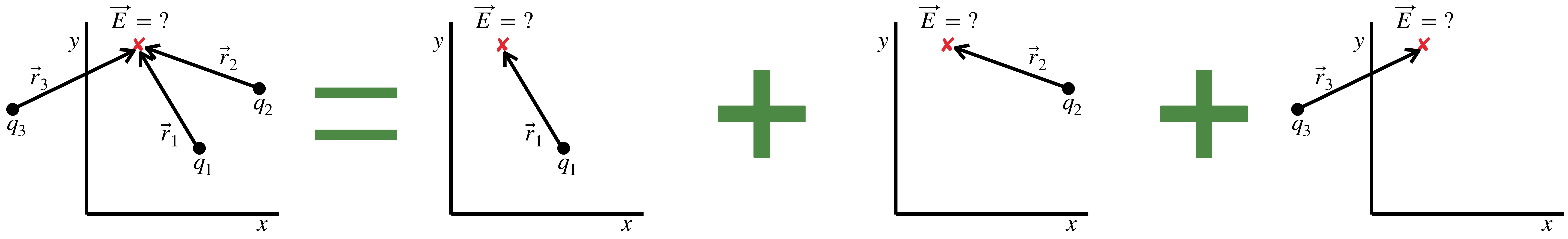


CHAPTER 13

Most important concepts:

- Superposition (electric field of multiple point charges)

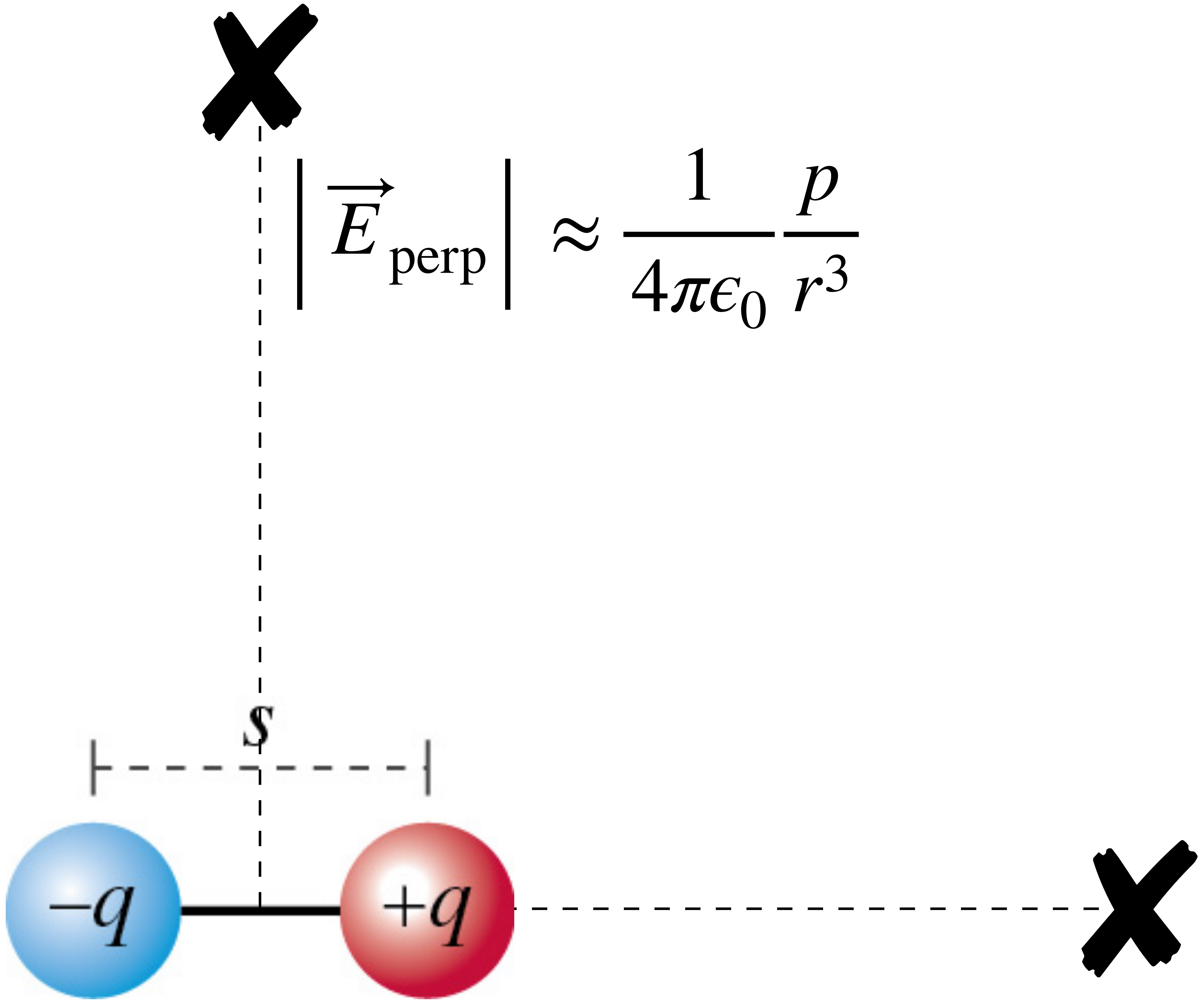
$$\vec{E}_{\text{tot}} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots$$



You should also know:

- Electric dipoles

Dipole moment: $p = qs$



$$\left|\vec{E}_{\text{perp}}\right| \approx \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$$

$$\left|\vec{E}_{\text{axis}}\right| \approx \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$$

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CHAPTER 14

Most important concepts

- How matter becomes “charged”
    - Conservation of charge
        - Charge is not “created” but transferred
        - More + than - charge –> “excess charge”

CHAPTER 14

Most important concepts

- How matter responds to external electric fields
  - Insulators become polarized: $\vec{p}_{\text{ind}} = \alpha \vec{E}$
  - Conductors experience charge motion: $\bar{v} = uE_{\text{net}}$
    - Charges move until the conductor reaches **static equilibrium**
      - $\bar{v} = E_{\text{net}} = 0$

Most important concepts

- Important differences between conductors and insulators

	Insulator	Conductor
Mobile Charges?	No	Yes
Location of excess charge? charge?	Anywhere	Only on surface
Charge spreading?	No	Yes
Electric field inside (in equilibrium)?	Can be non-zero	Must be zero
Response to external field?	Induced dipole (p=alpha x E)	Moving charges (v=uE)

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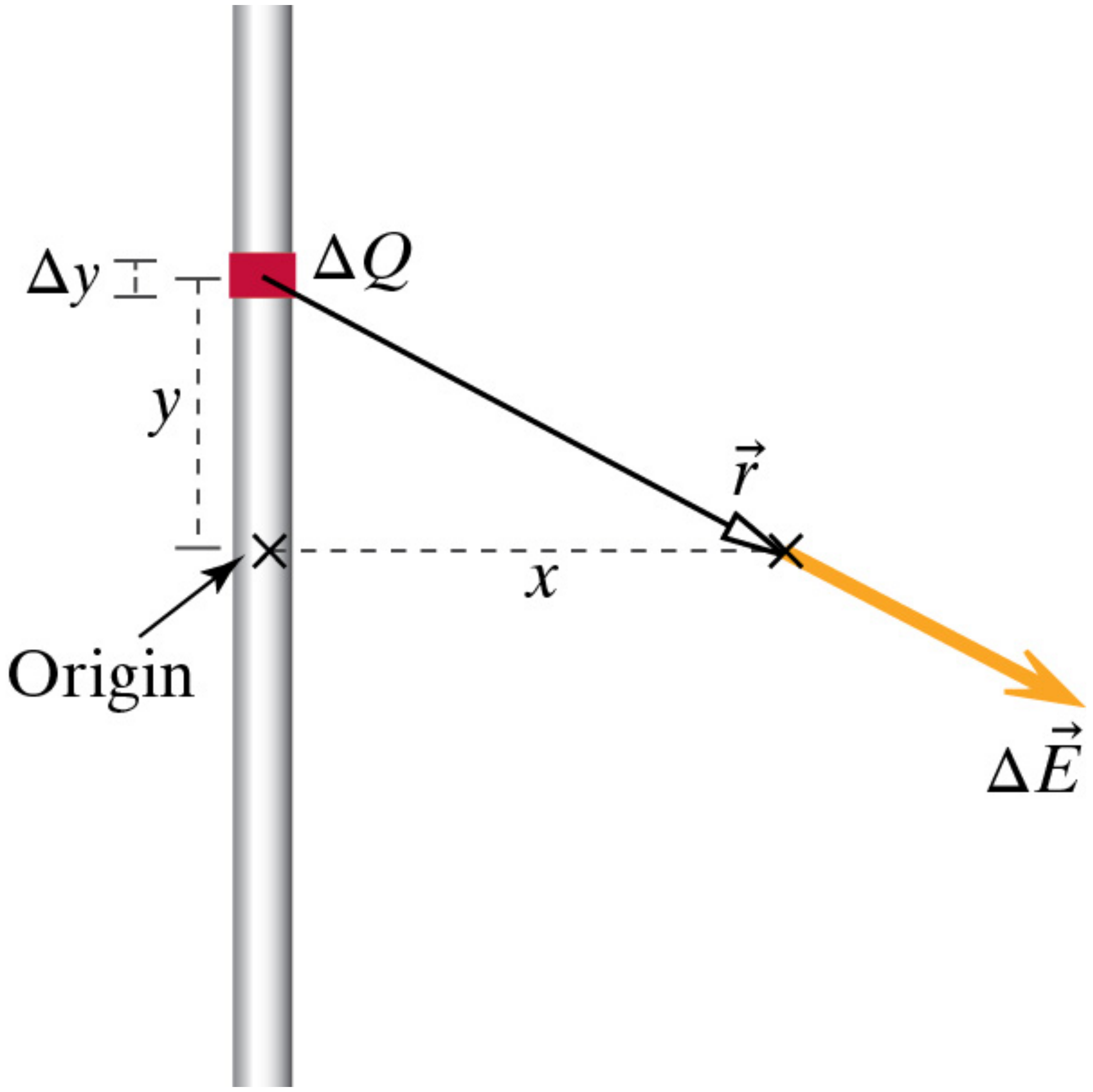
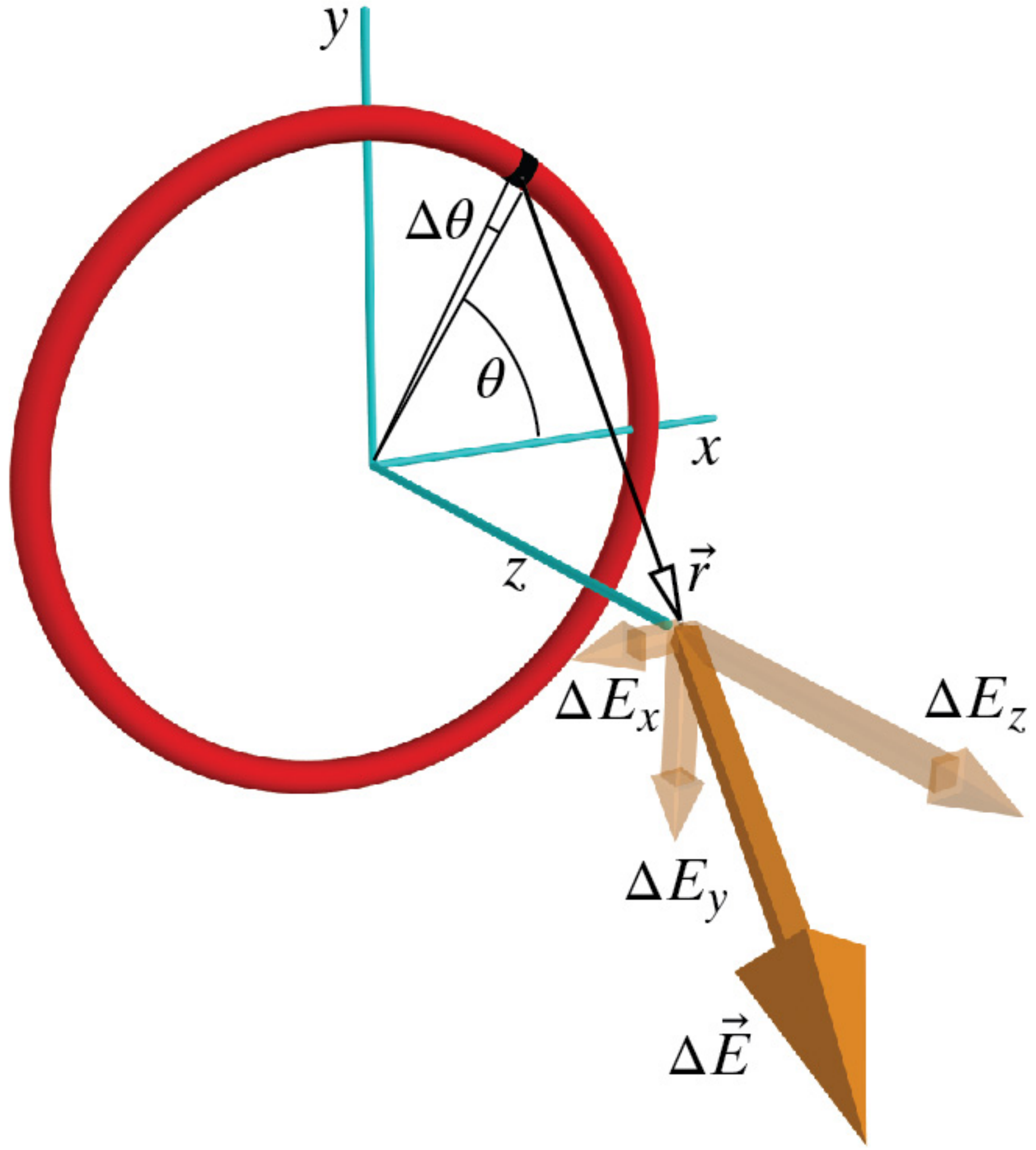
CHAPTER 15

Most important concepts:

- Setup an integral to find the electric field of common continuous charge distributions

1. Cut into tiny pieces
2. Write ΔQ and ΔE for a single piece
3. Add up all pieces (integrate)

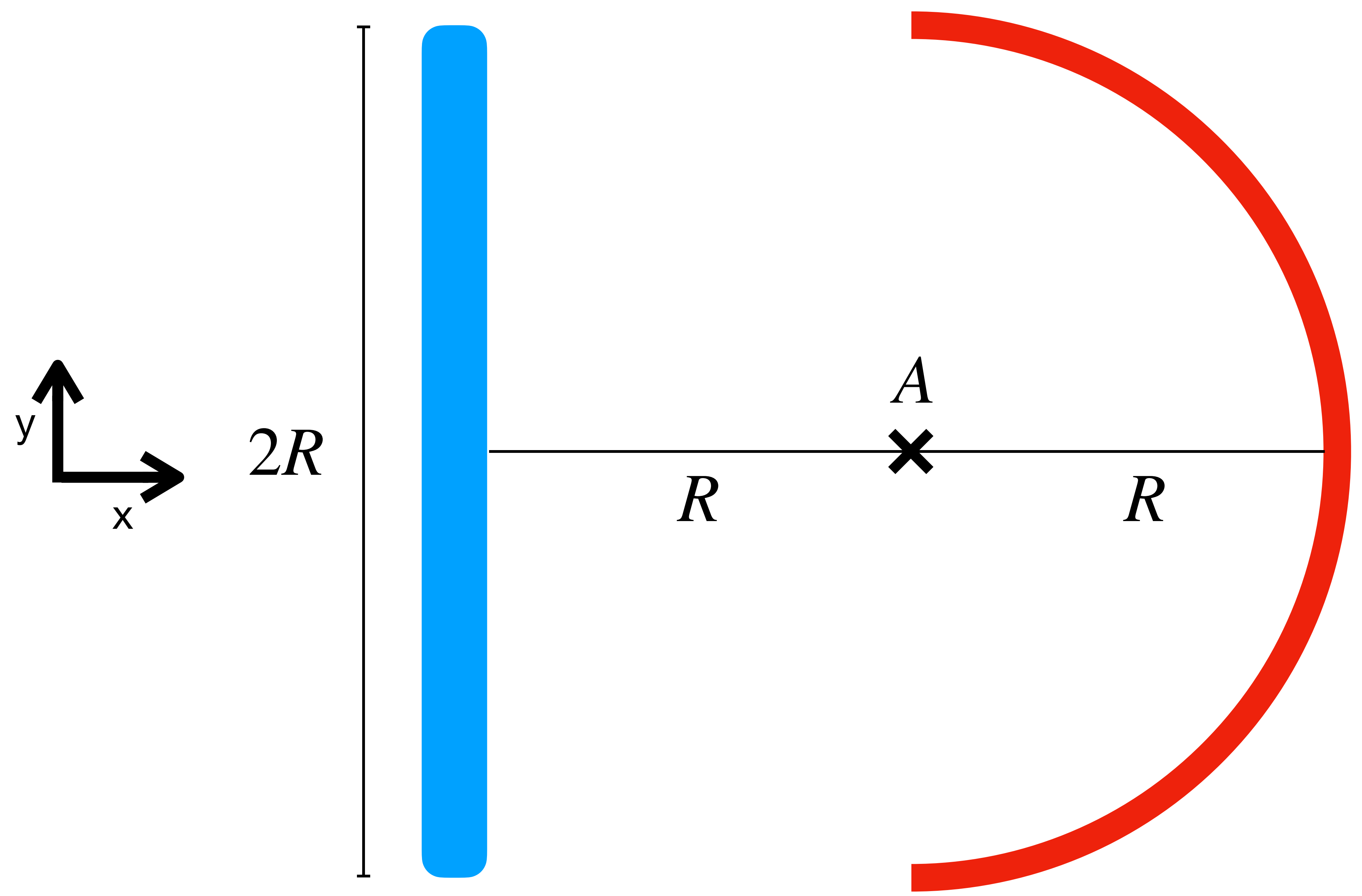


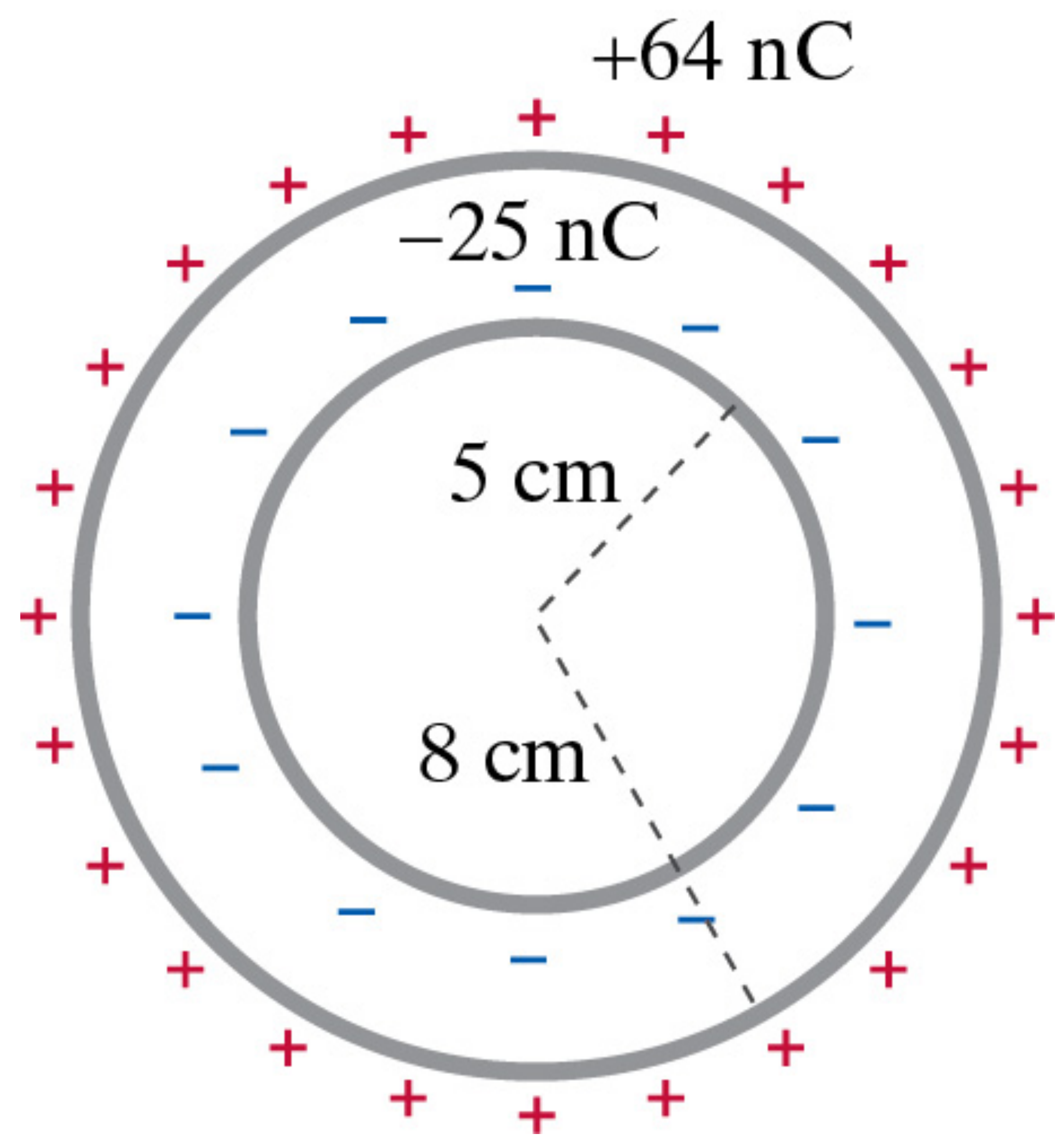


CHAPTER 15

Most important concepts:

- Use superposition to find the net field of multiple charge distributions





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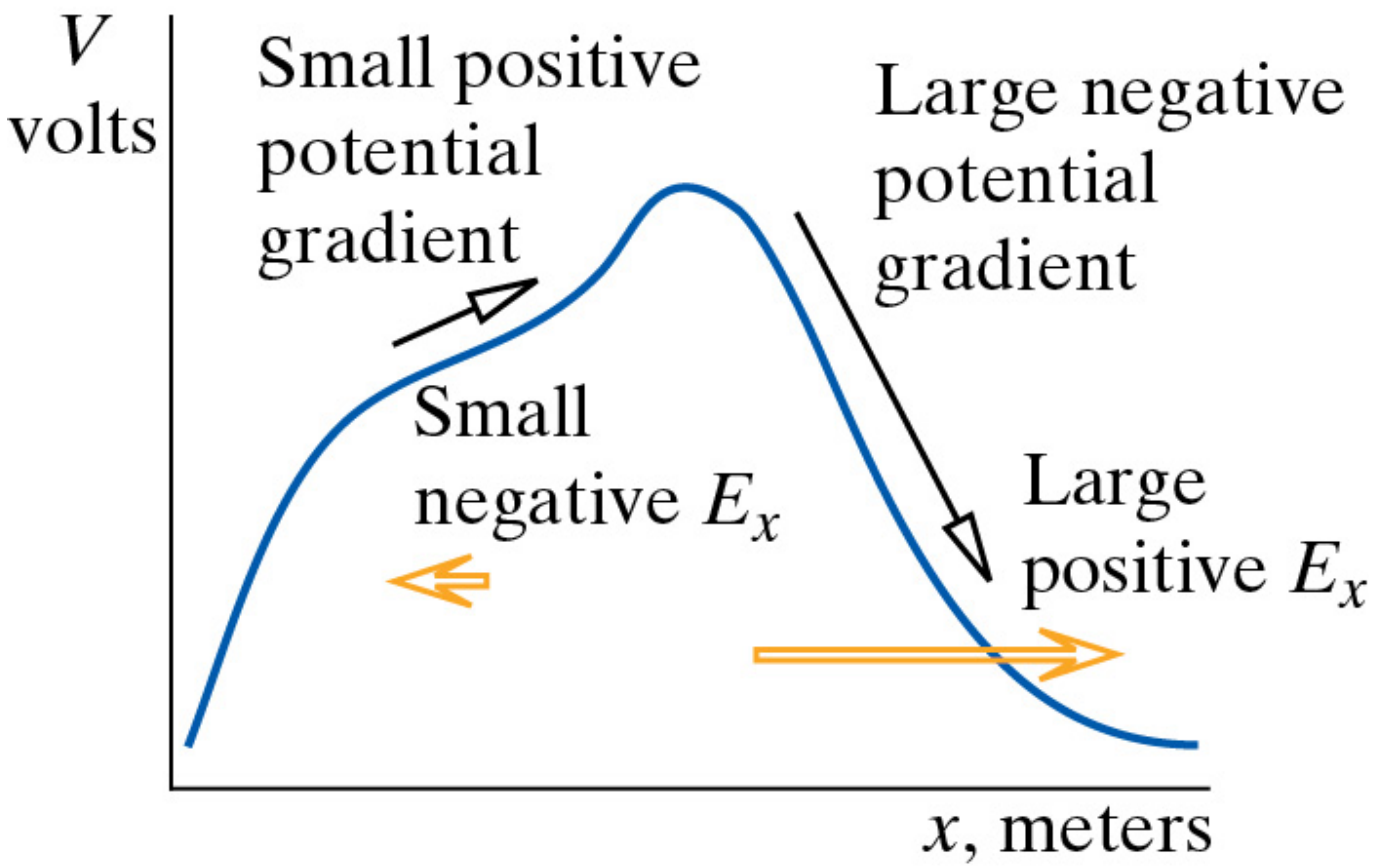
Most important concepts

- Definition of electric potential difference

$$\Delta V = V_f - V_i = -\vec{E} \cdot \Delta \vec{l} \text{ (constant } \vec{E}\text{)}$$

$$\Delta V = -\sum_i^f \vec{E} \cdot \Delta \vec{l} \rightarrow -\int_i^f \vec{E} \cdot \Delta \vec{l} \text{ (varying } \vec{E}\text{)}$$

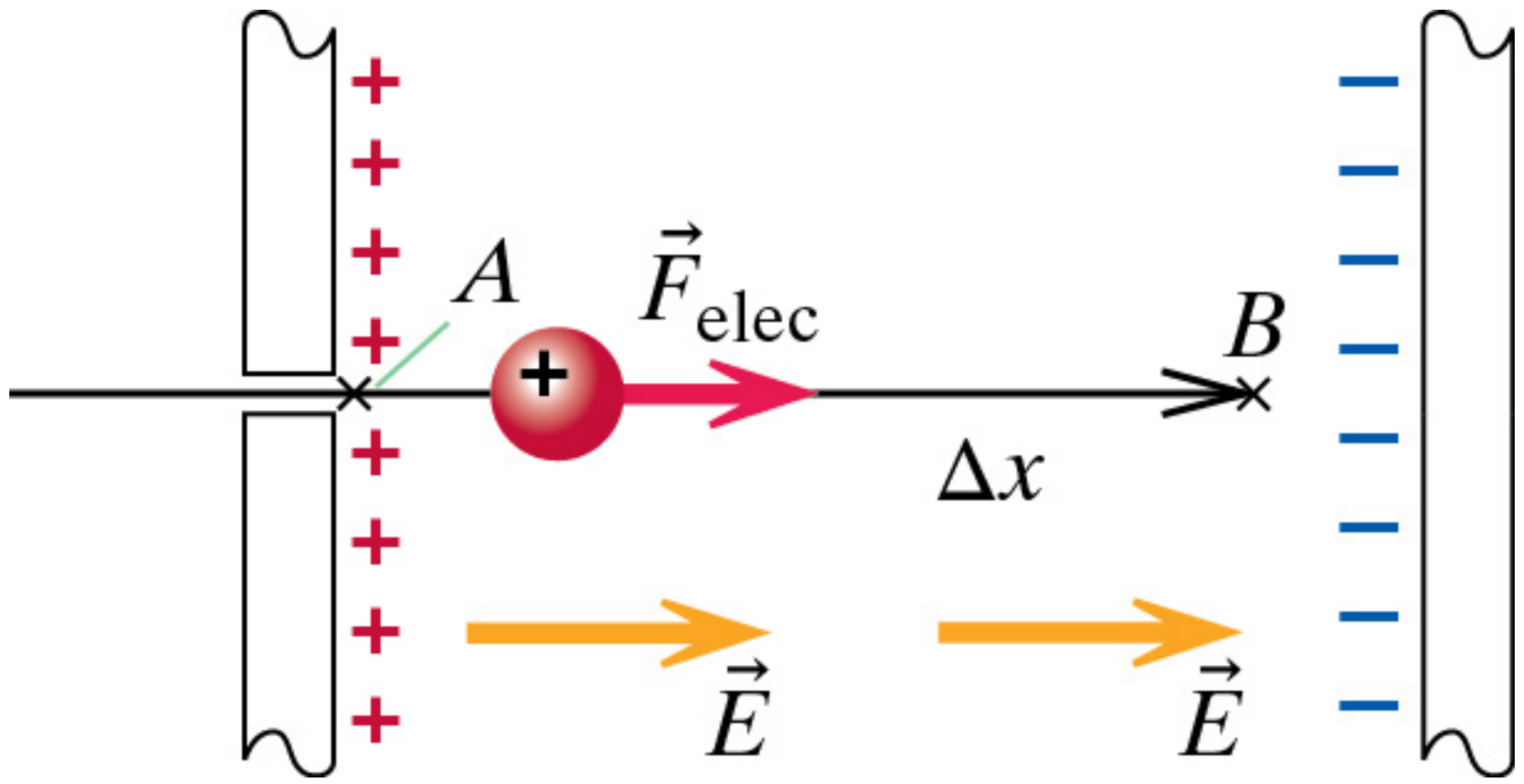


CHAPTER 16

Most important concepts

- Relationship between electric potential and potential energy

$$\Delta U = q\Delta V$$



CHAPTER 16

You should also know:

- Electric potential difference of a point charge:

$$\Delta V = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$$

Relative to ∞:

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

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CHAPTER 17

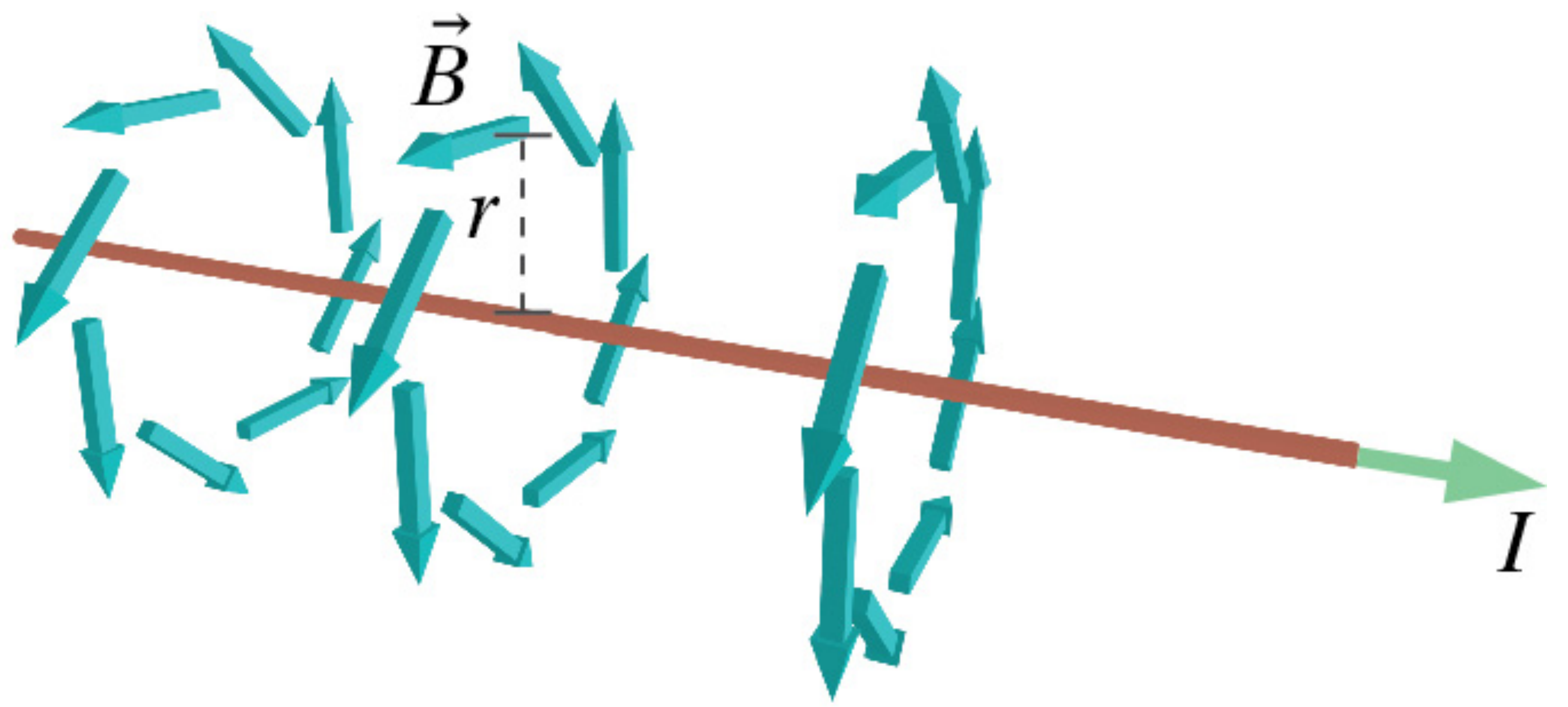
Most important concepts

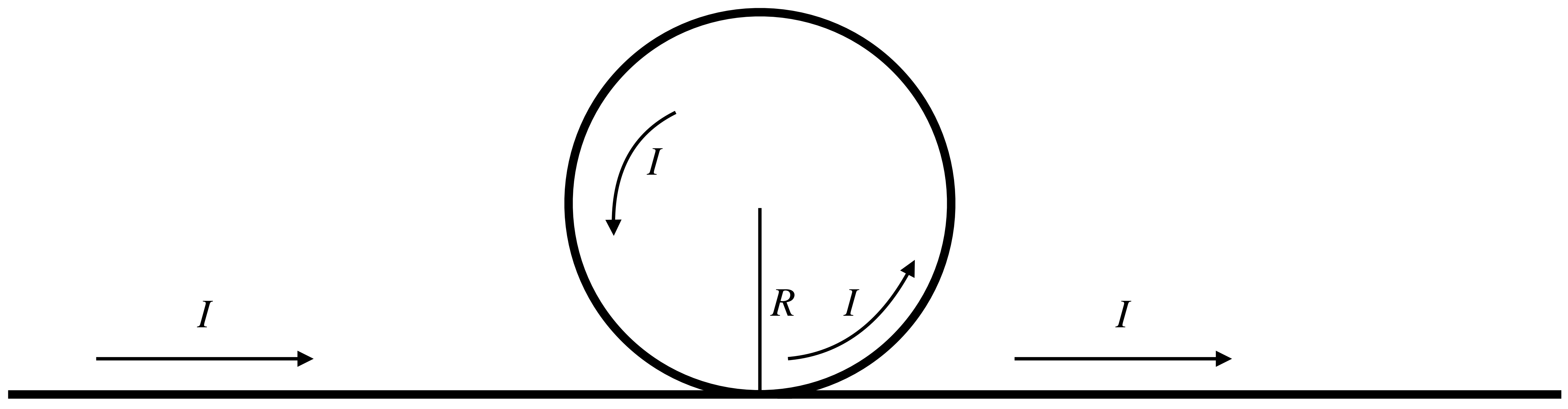
- Magnetic field of a current (Biot-Savart law)

$$\Delta \vec{B} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{l}\times\hat{r}}{r^2}$$

$$\left|\vec{B}_{\text{long wire}}\right| \approx \frac{\mu_0}{4\pi}\frac{2I}{r}$$

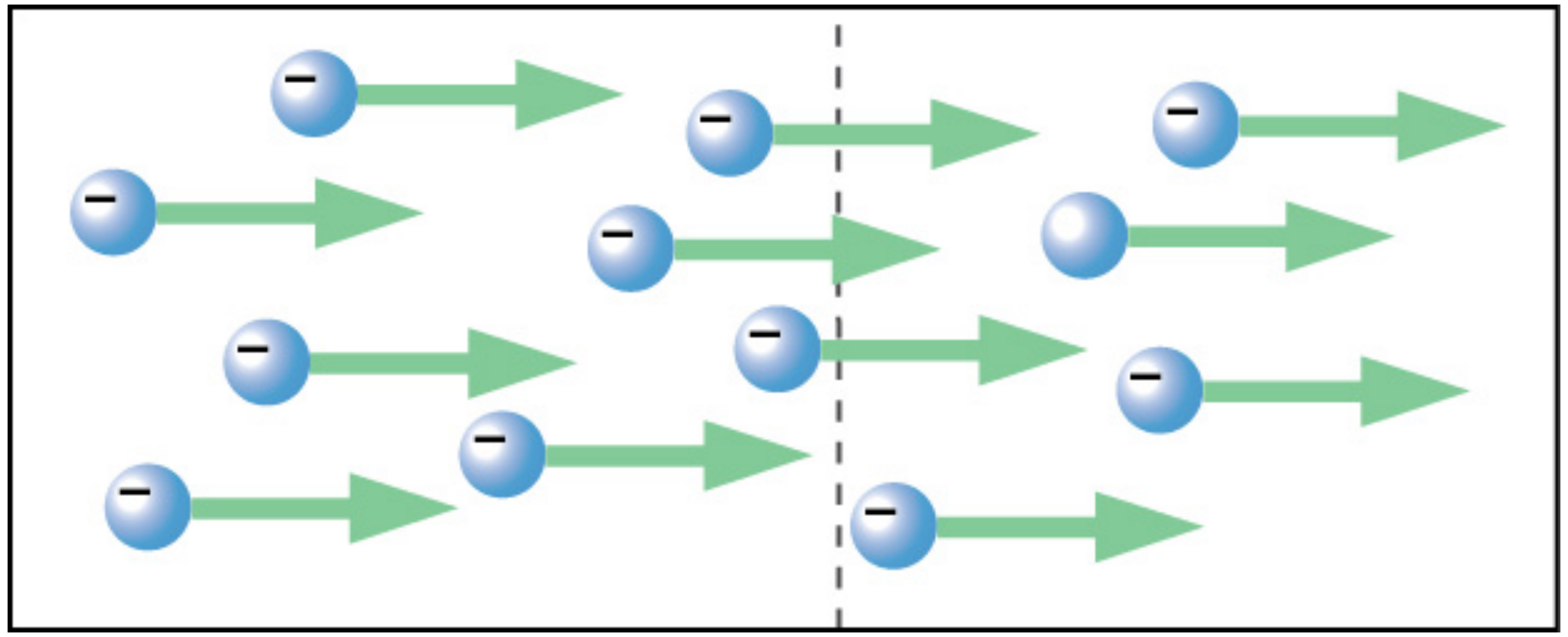
$$\left|\vec{B}_{\text{loop}}\right| = \frac{\mu_0}{4\pi}\frac{2\pi R^2 I}{\left(z^2+R^2\right)^{\frac{3}{2}}}$$



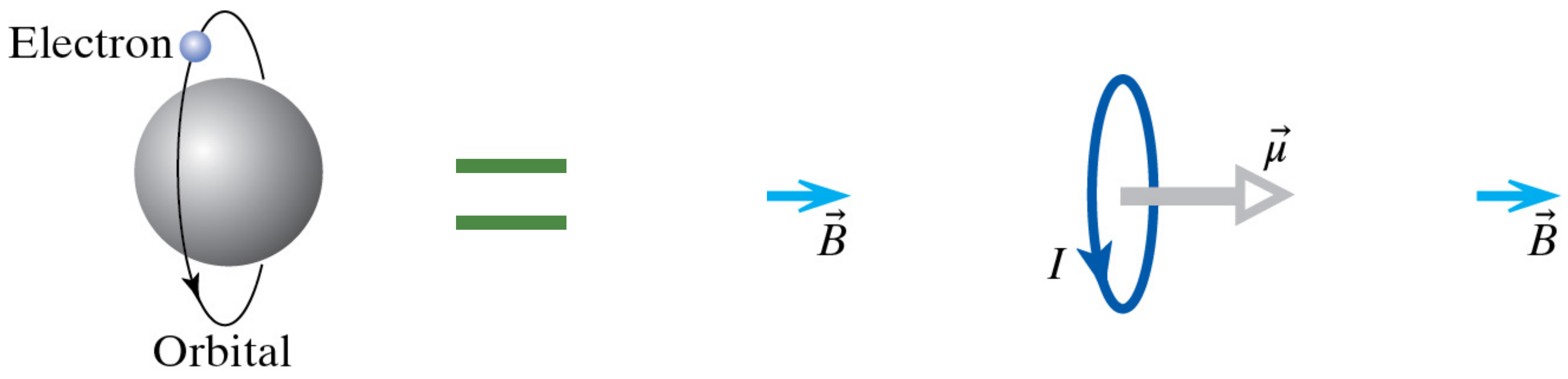


Most important concepts

- Current
  - Electron current $i = nA\bar{v}$ (electrons per unit time)
  - Conventional current $I = \left|q\right| i$ (charge per unit time)

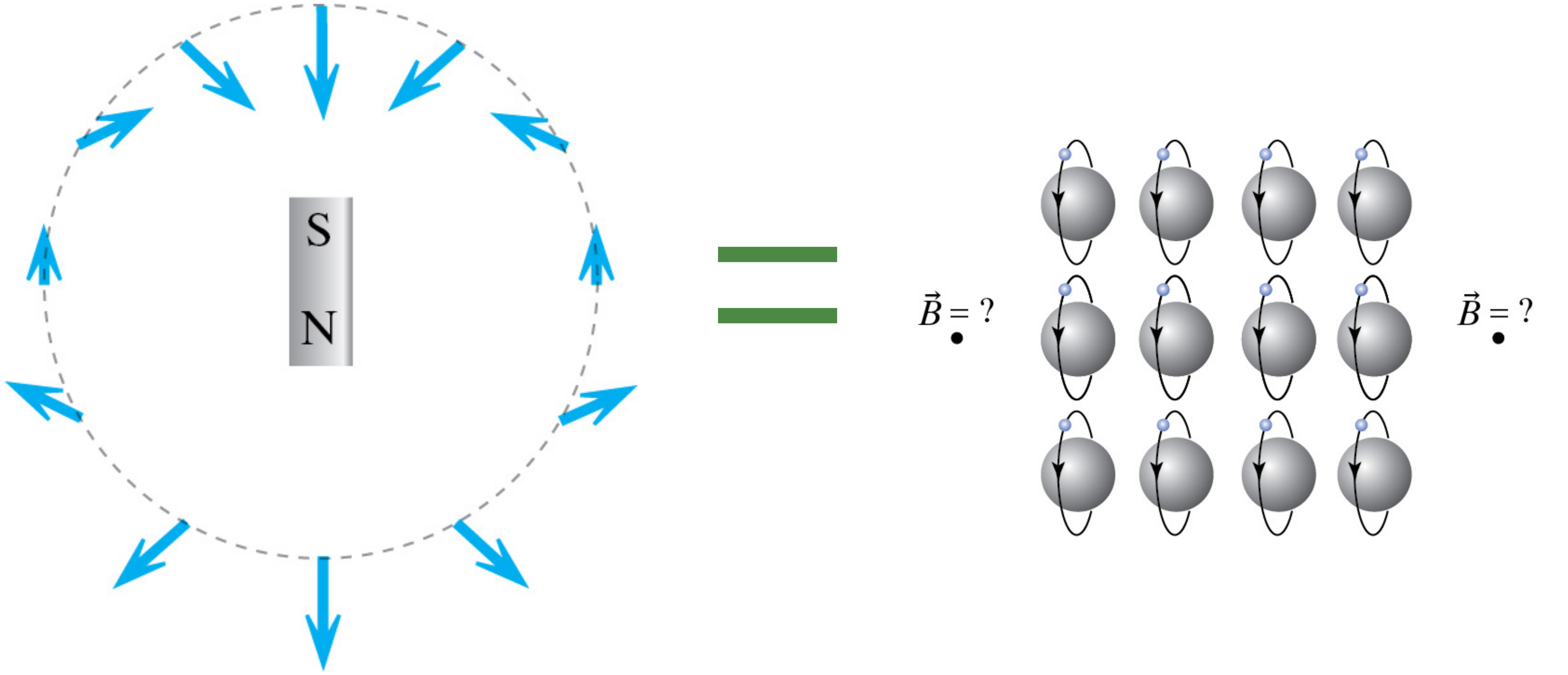


CHAPTER 17



You should also know:

- Magnetic dipoles, permanent magnets



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CHAPTER 18

Most important concepts:

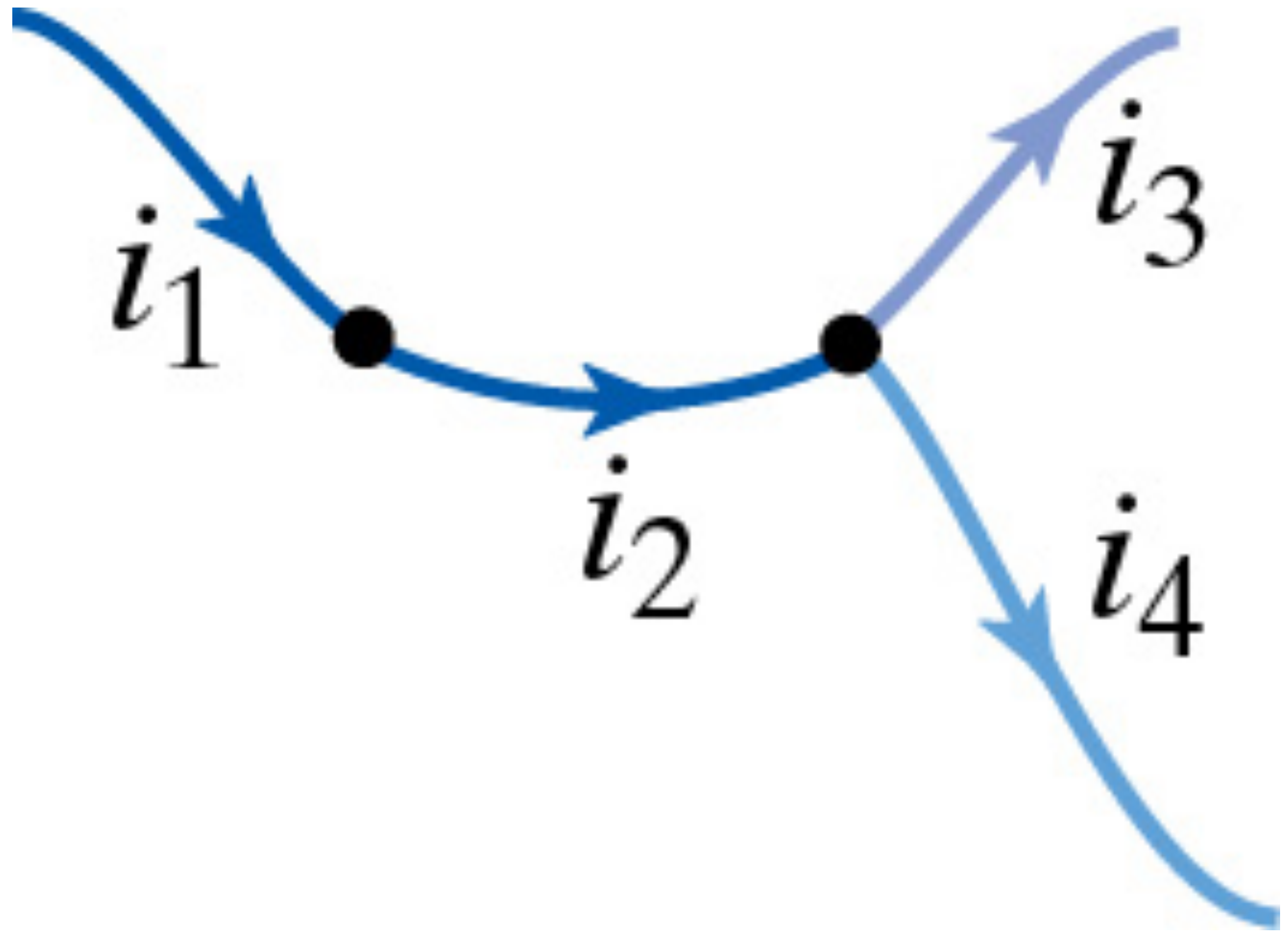
- Node rule

$$\sum i_{\text{in}} = \sum i_{\text{out}}$$

- Loop rule

Along any **closed** path in a circuit:

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



ANALYZING CIRCUITS

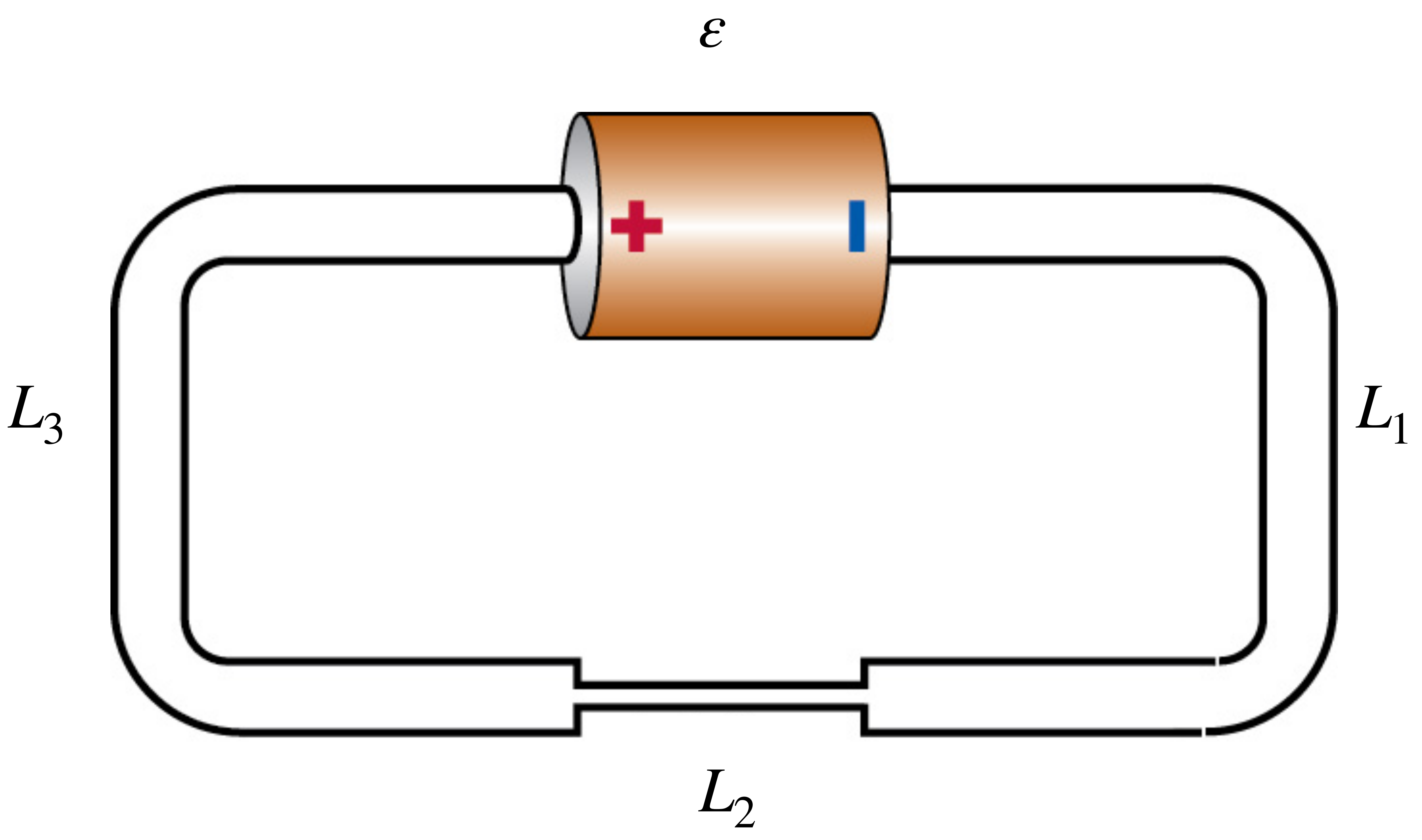
Start with fundamental principles and write down set of equations

1. Node rule $i_{\text{in}} = i_{\text{out}}$
2. Loop rule $\sum_{\text{loop}} \Delta V = 0$

Now solve system of equations for quantities you want.

Remember:

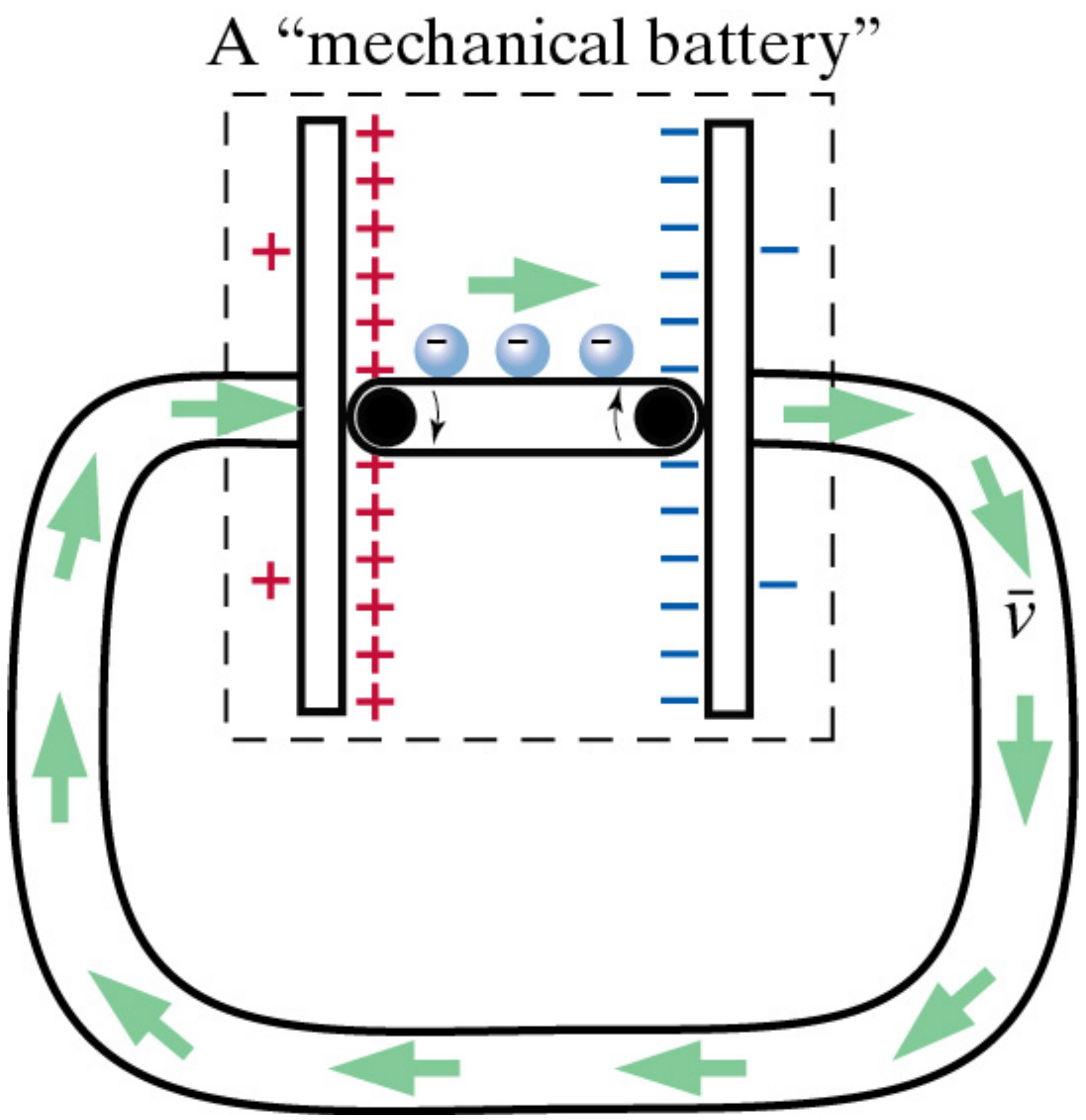
- $i = nA\overline{v}$
- $\overline{v} = uE$



CHAPTER 18

You should also know:

- The function of a battery
- What makes the electric field in a circuit?
- Why does a light come on right away?



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CHAPTER 19

Most important concepts:

- Use the node rule and loop rule to analyze circuits with resistors
- Ohm's law: $I = \dfrac{\Delta V}{R}$
    - $R = \dfrac{L}{\sigma A}$

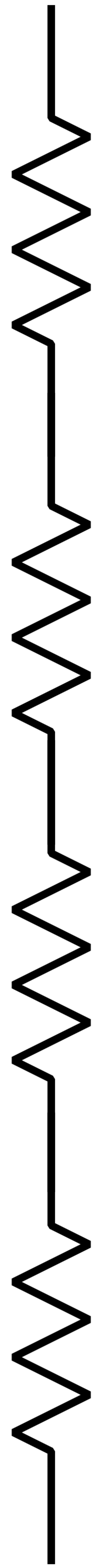
CIRCUIT ELEMENTS CONNECTED IN SERIES

$$I_1 = I_2 = I_3 = \ldots = I_n = I$$

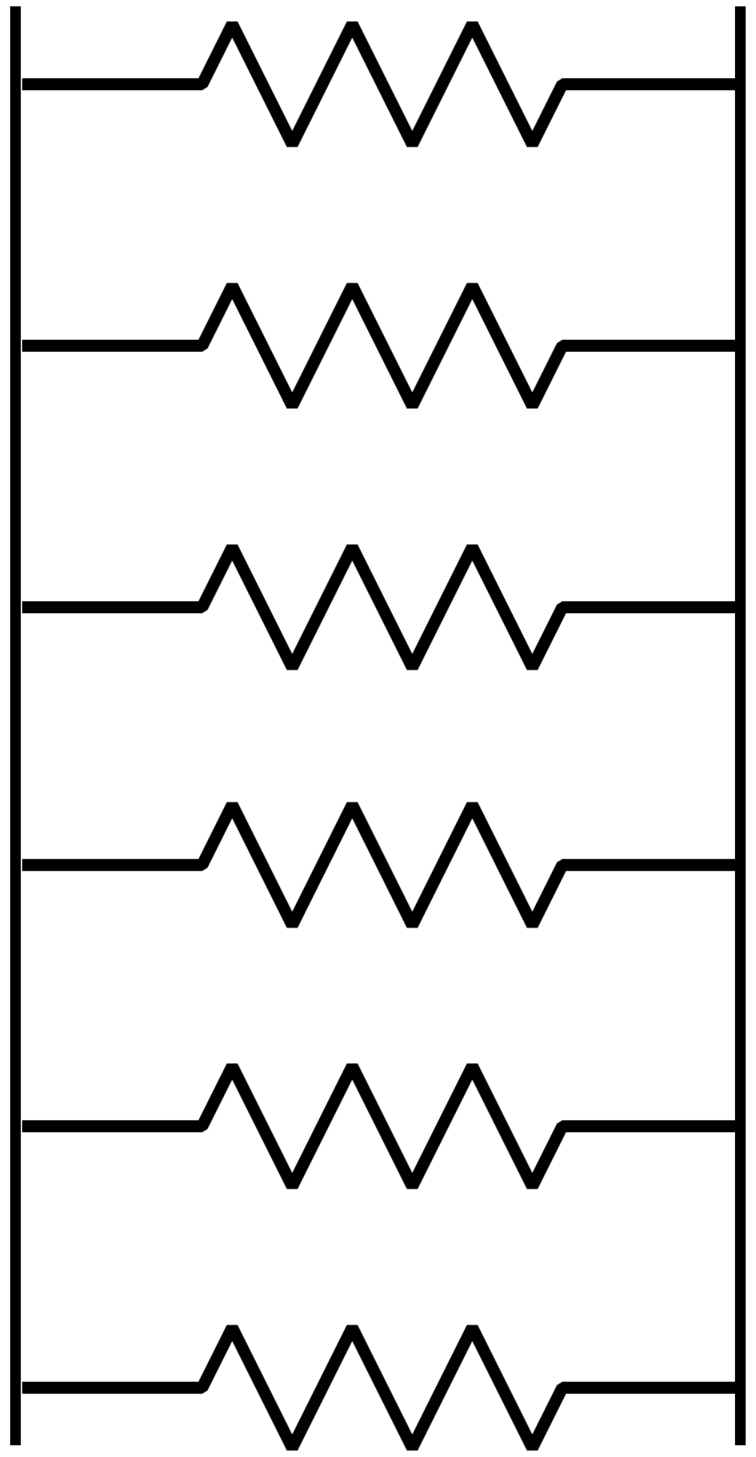
$$\Delta V = \Delta V_1 + \Delta V_2 + \Delta V_3 + \ldots + \Delta V_n$$

$$I = \frac{\Delta V}{R_1 + R_2 + R_3 + \ldots + R_n} = \frac{\Delta V}{R_{\mathrm{eqiv}}}$$

$$R_{\mathrm{equiv}} = R_1 + R_2 + R_3 + \ldots + R_n$$



CIRCUIT ELEMENTS CONNECTED IN PARALLEL



$$I = I_1 + I_2 + I_3 + \ldots + I_n$$

$$\Delta V = \Delta V_1 = \Delta V_2 = \Delta V_3 = \ldots = \Delta V_n$$

$$I = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n} \right) \varepsilon = \frac{\varepsilon}{R_{\text{equiv}}}$$

$$\frac{1}{R_{\text{equiv}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

CHAPTER 19

You should also know:

- Power dissipated across a resistor: $P = I\Delta V = I^2R$
- Internal resistance
- Ammeters and voltmeters
    - How to connect in circuit, what kind of resistor to use

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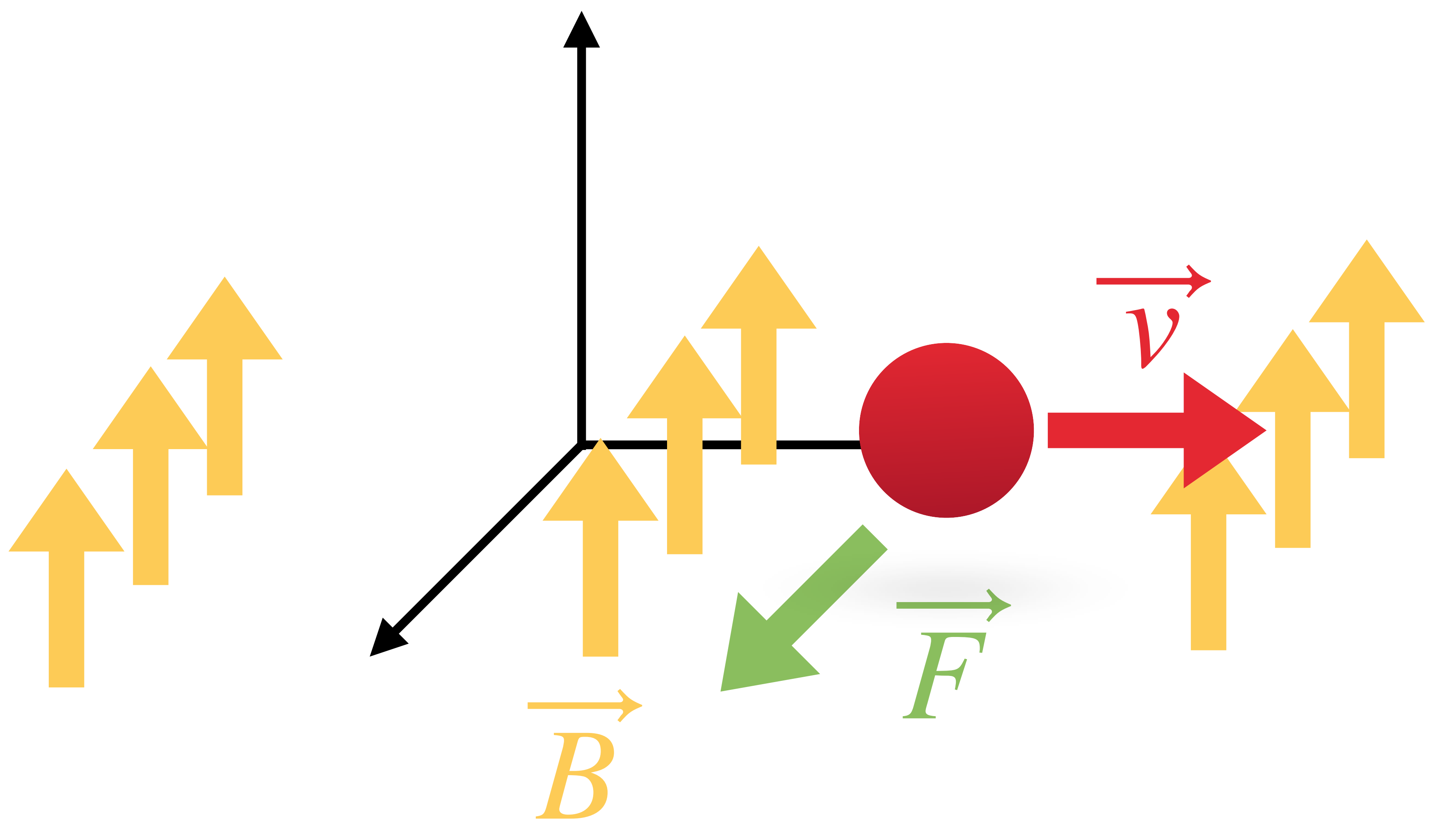
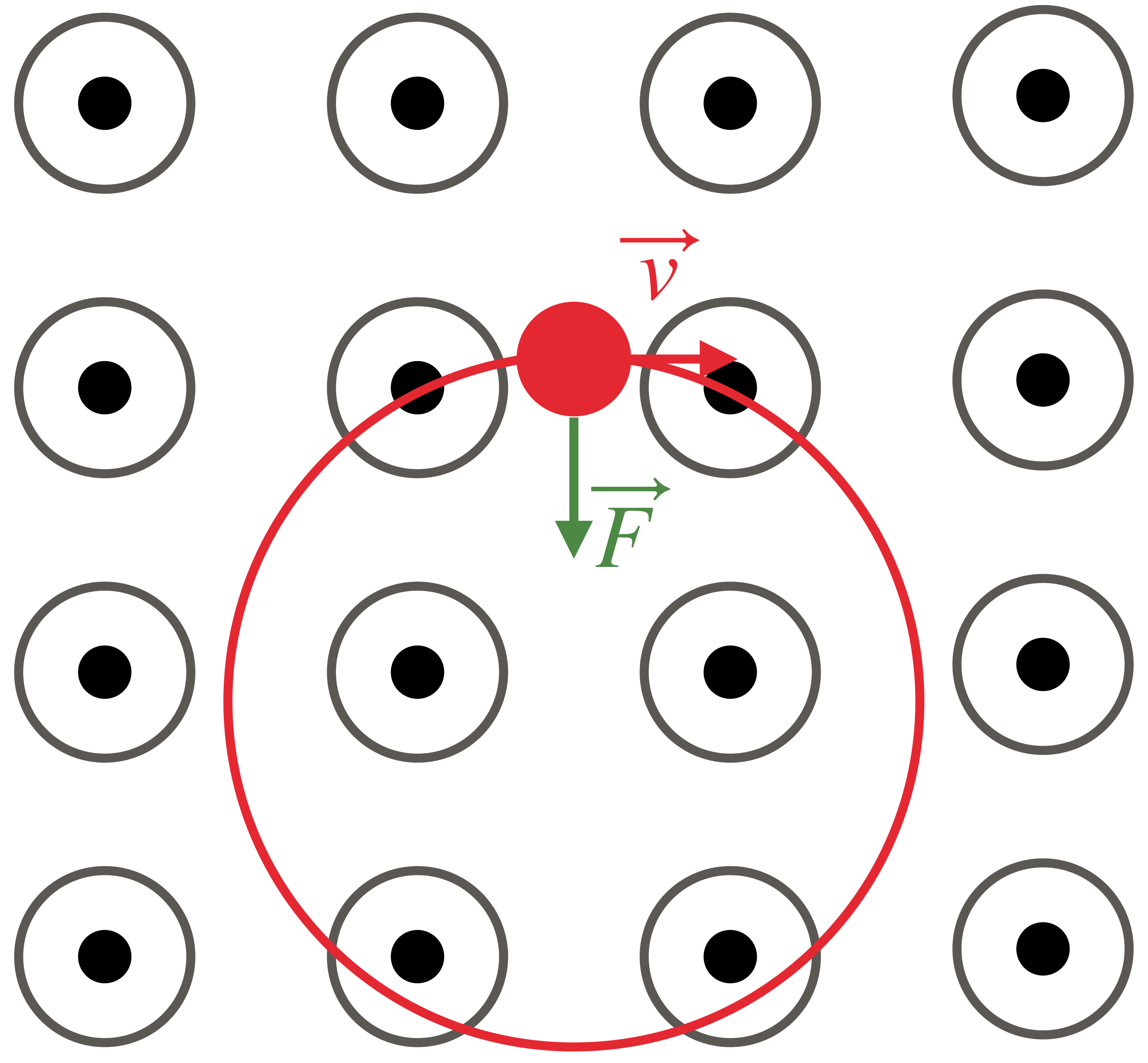
Most important concepts:

- The **Lorentz** force: $\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$
  - Magnetic force only deflects, does not change $\left|\vec{v}\right|$
  - Magnetic force does not do work

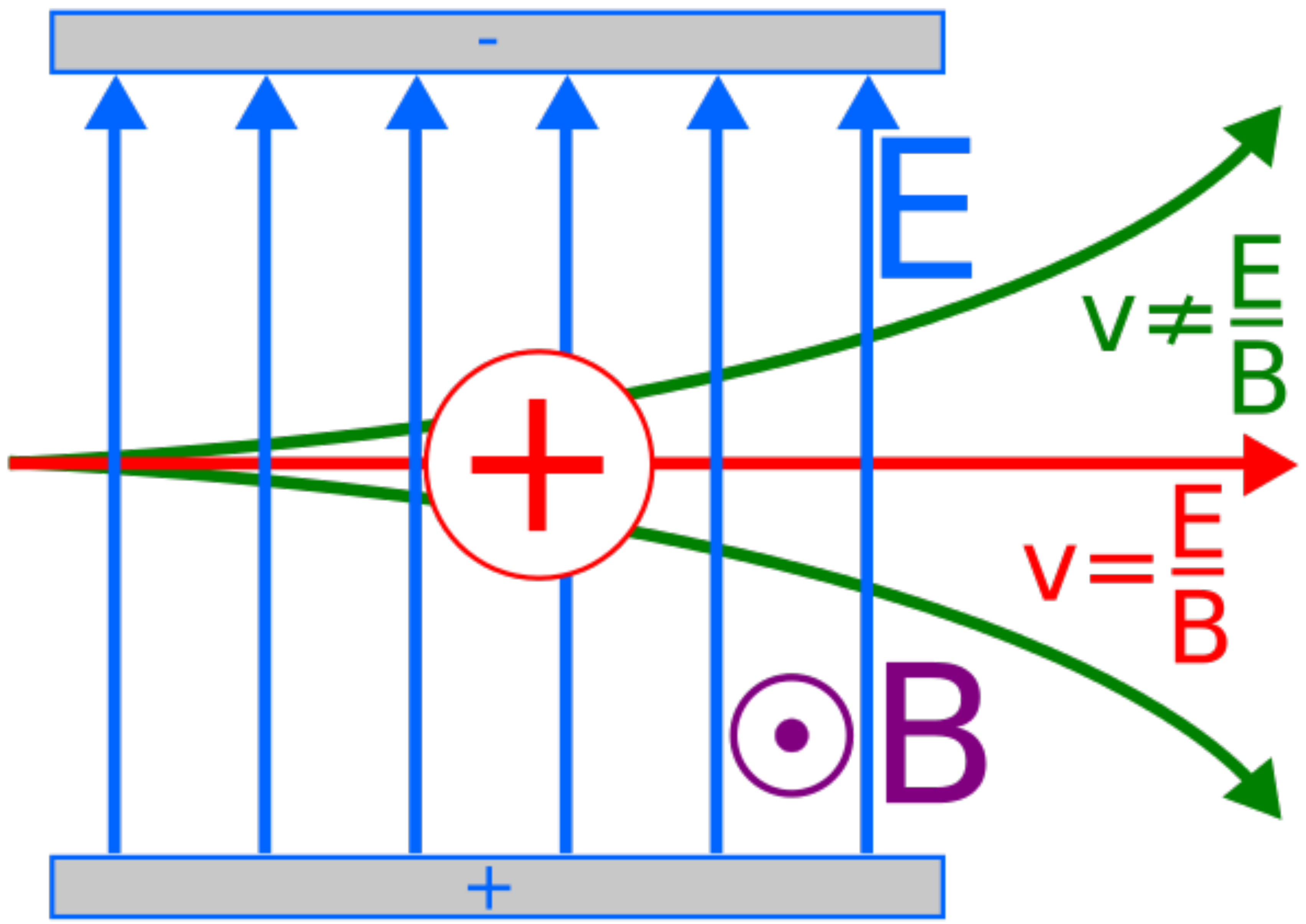




CHAPTER 20

Most important concepts:

- Combining electric and magnetic forces
  - Velocity selector

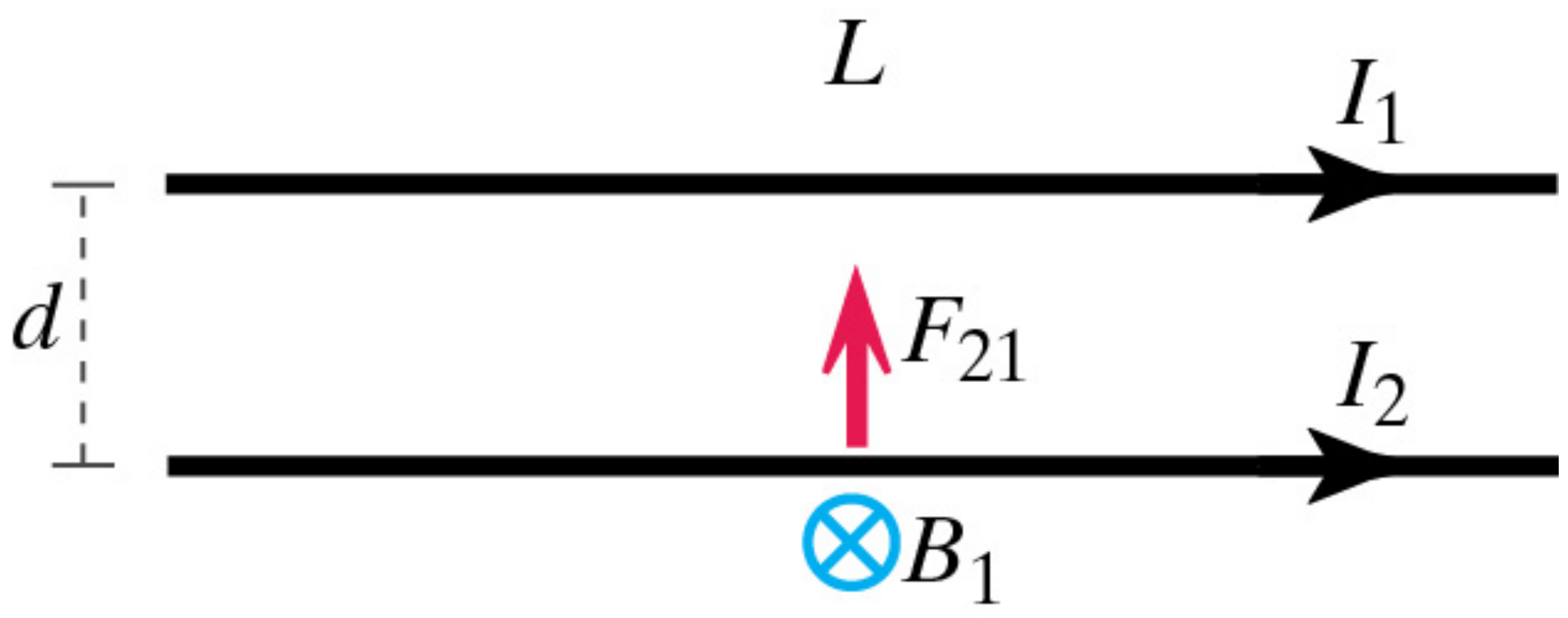


CHAPTER 20

Most important concepts:

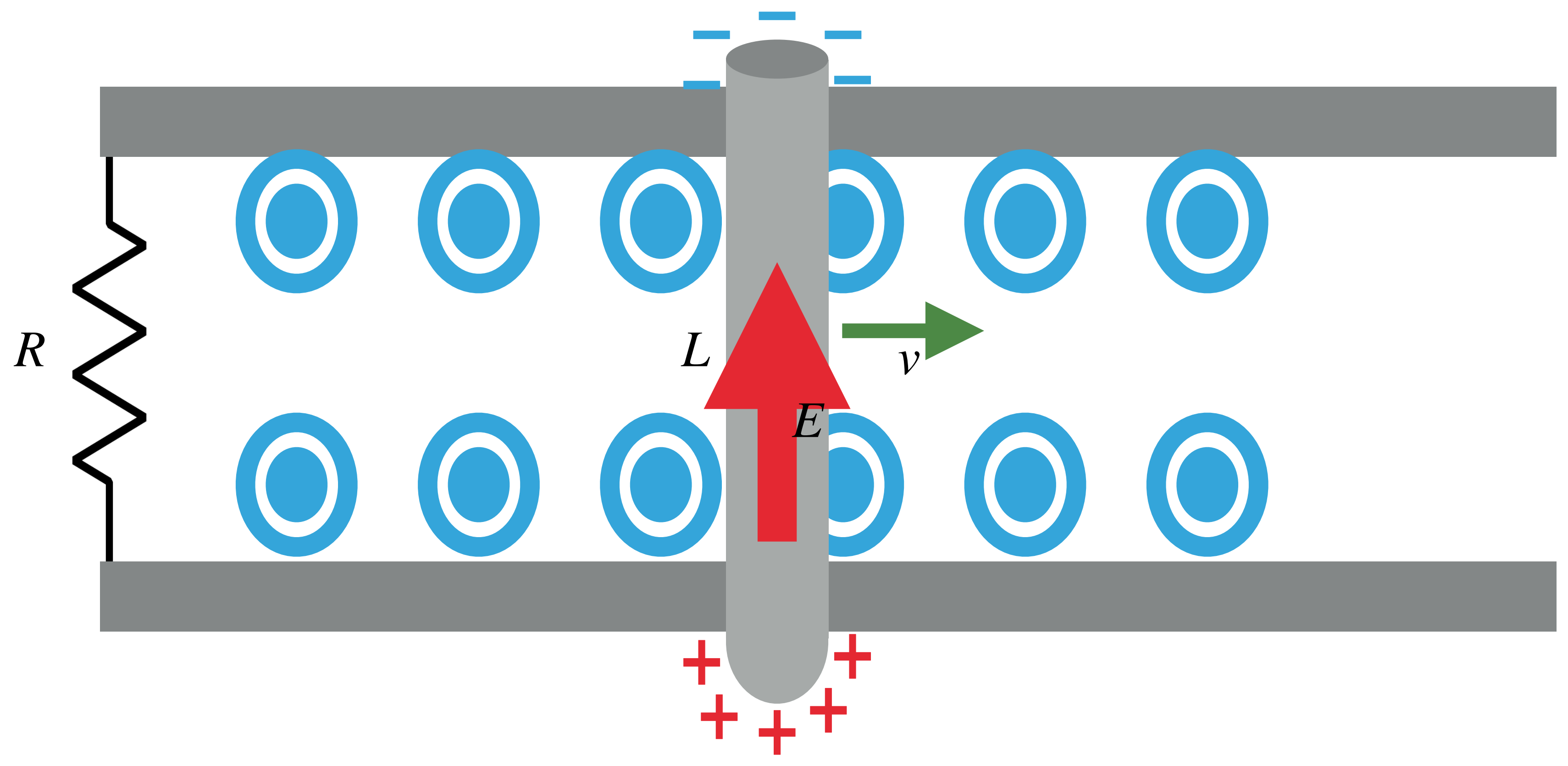
- Force on a current-carrying wire:

$$\Delta \vec{F} = I \Delta \vec{l} \times \vec{B}$$



Most important concepts:

- Motional EMF
  - Calculate induced emf and current
  - Can use Lorentz force OR Faraday's Law



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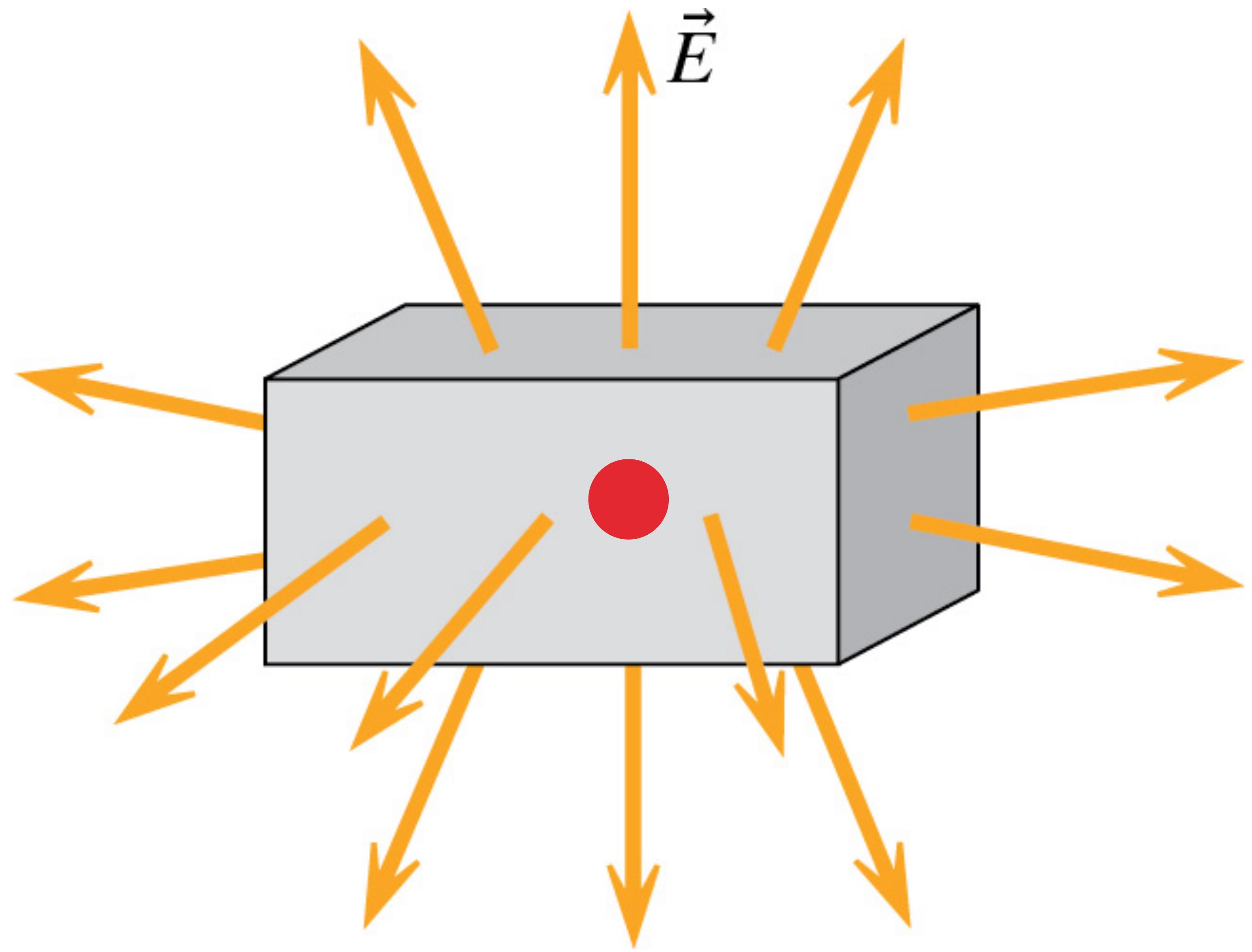
Most important concepts:

- Gauss's Law

$$\oint_S \overrightarrow{E} \cdot \hat{n} dA = \frac{q_{\text{in}}}{\epsilon_0}$$

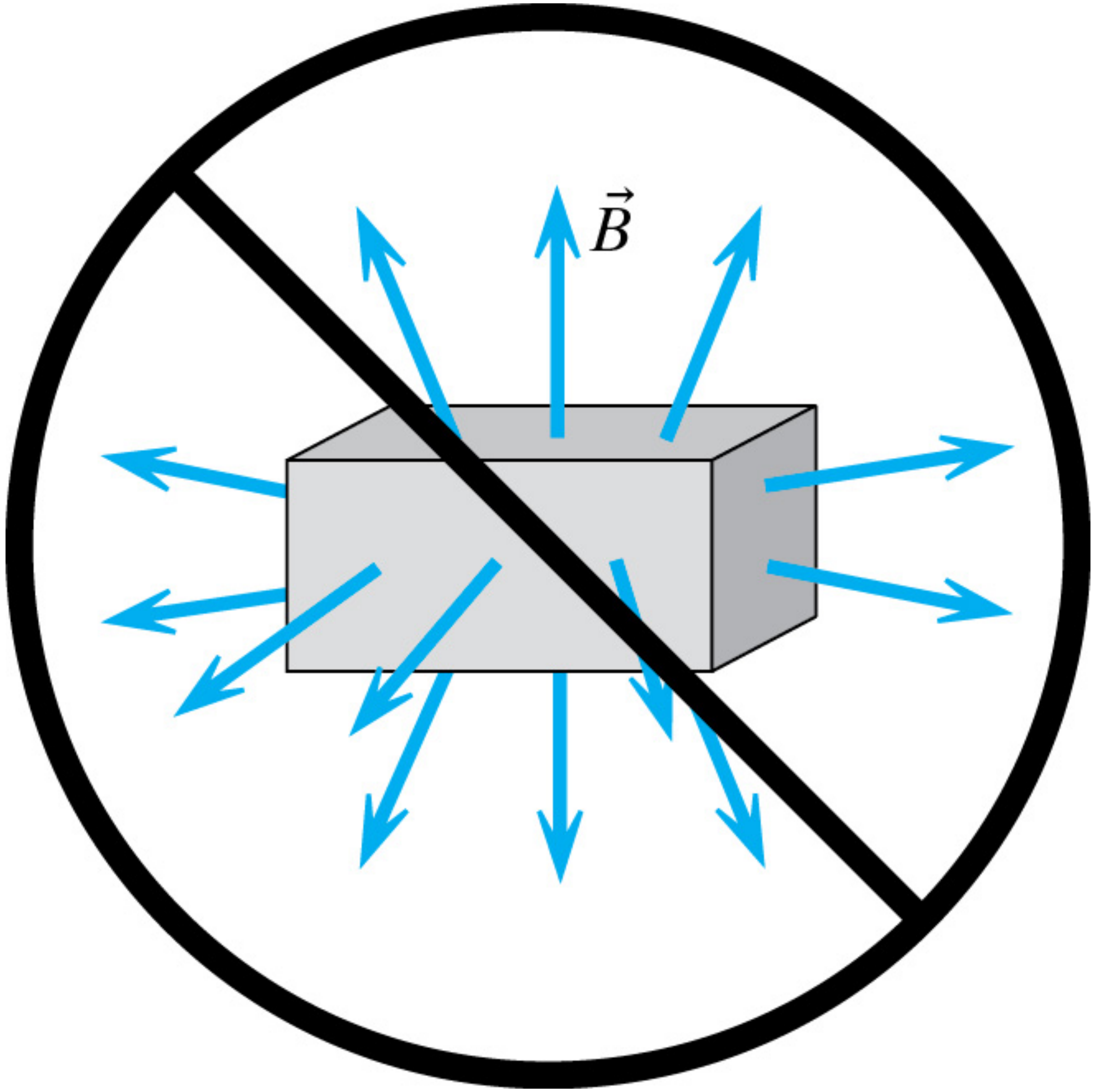


CHAPTER 21

Most important concepts:

- Gauss's Law for Magnetic fields

$$\phi_{\text{mag}} = \oint \overrightarrow{B} \cdot \hat{n} dA = 0$$

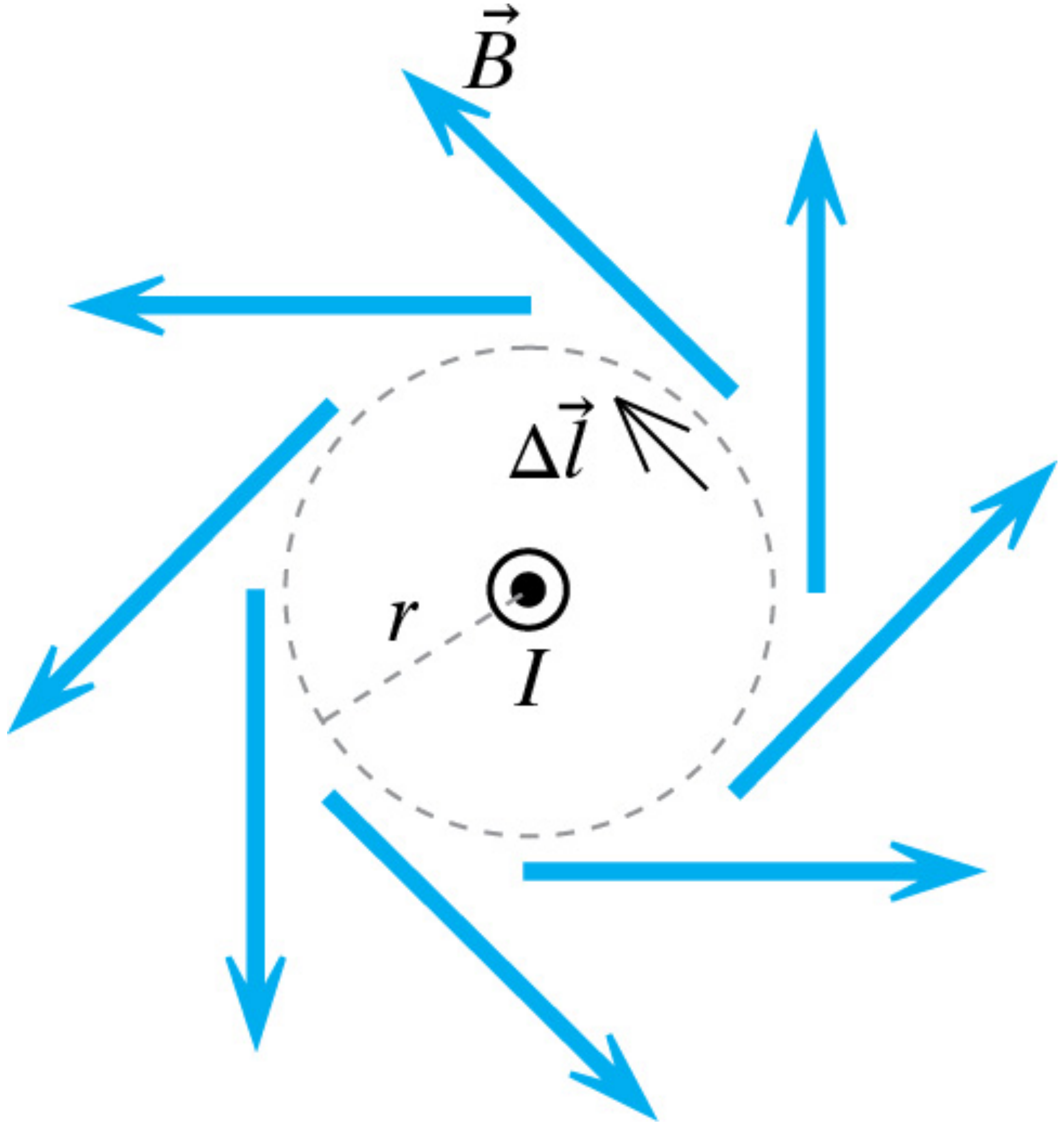


CHAPTER 21

Most important concepts:

- Ampere's Law

$$\oint \overrightarrow{B} \cdot d\vec{l} = \mu_0 I_{\text{inside}}$$



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CHAPTER 22

Most important concepts:

- Faraday's Law
  - Changing magnetic field creates a "curly" electric field

$$\varepsilon = -\frac{d\phi_{\text{mag}}}{dt}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot \hat{n} dA$$

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CHAPTER 23

Most important concepts:

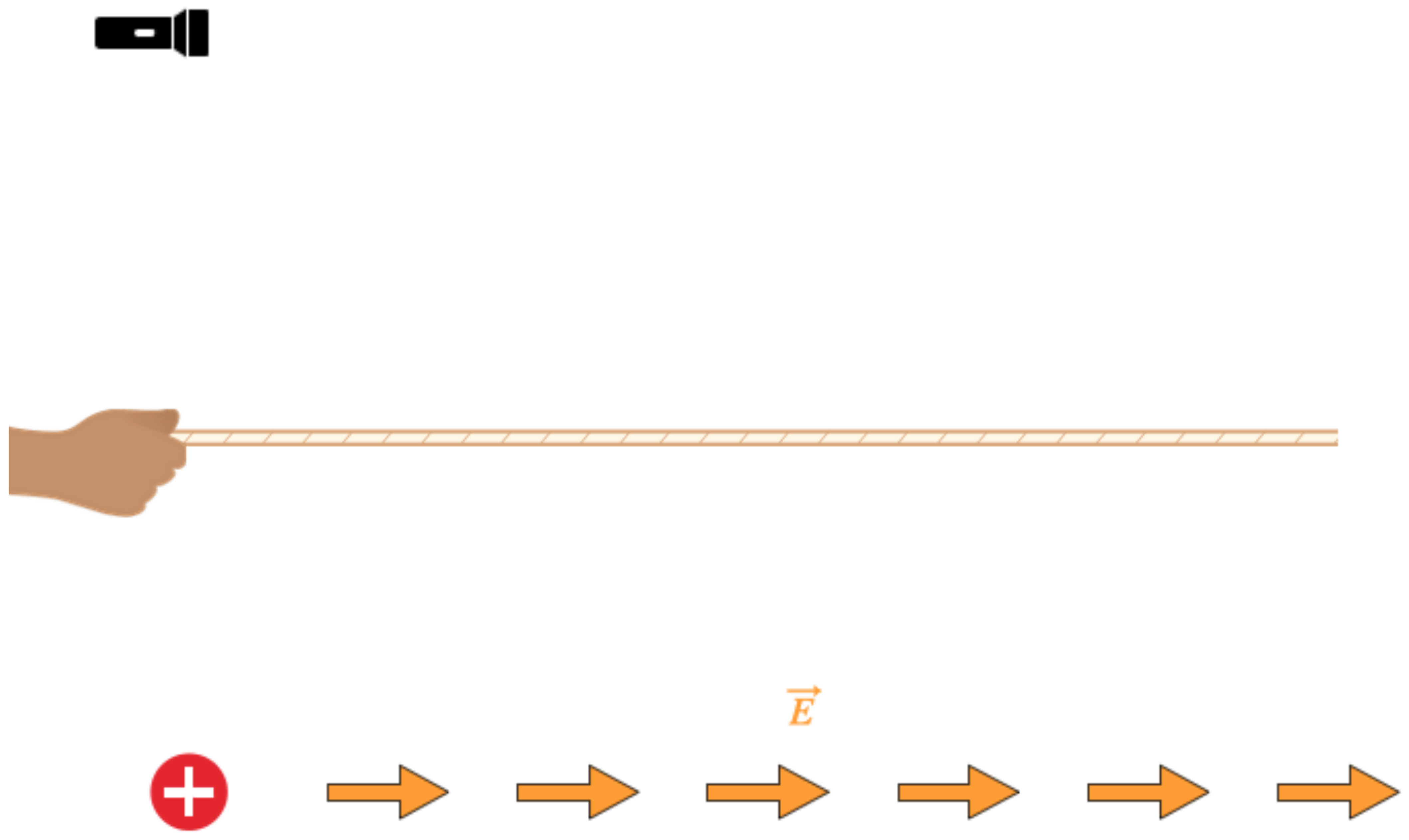
- Ampere-Maxwell law
    - Changing electric field creates a magnetic field

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(\sum I_{\text{inside}} + \epsilon_0 \frac{d}{dt} \int \vec{E} \cdot \hat{n} dA \right)$$

CHAPTER 23

Most important concepts:

- Electromagnetic radiation
    - Light consists of propagating disturbances in the electric and magnetic fields
    - Maxwell's equations dictate the speed of light
    - EM radiation is produced by accelerating charges



CHAPTER 23

Most important concepts:

- How the fields are produced:

Electric field

  - Electric charge (Coulomb's Law)
  - Changing magnetic field (Faraday's Law)

CHAPTER 23

Most important concepts:

- How the fields are produced:

Magnetic field

- Electric current (Biot-Savart Law)
- Changing electric field (Ampere-Maxwell Law)