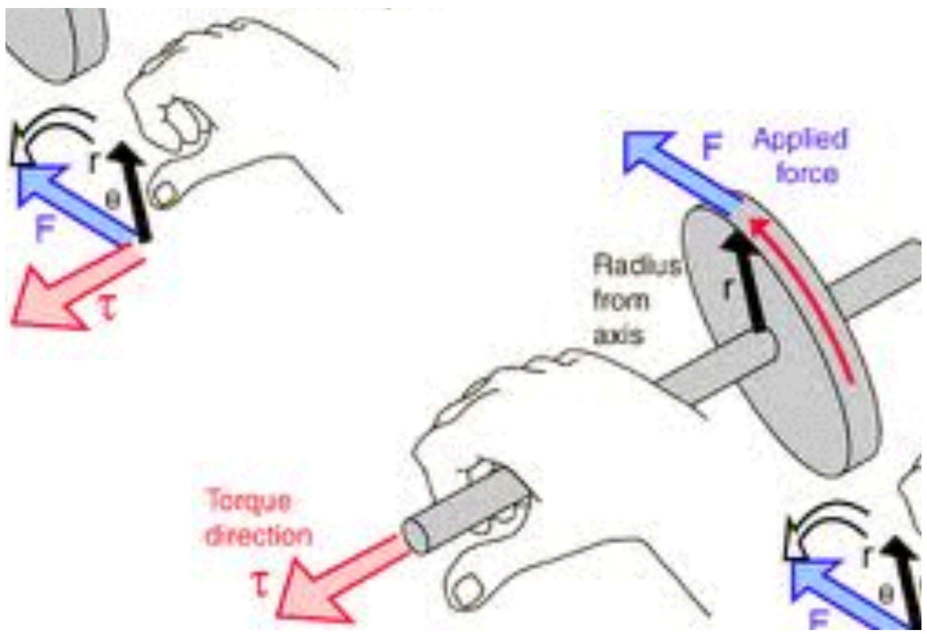
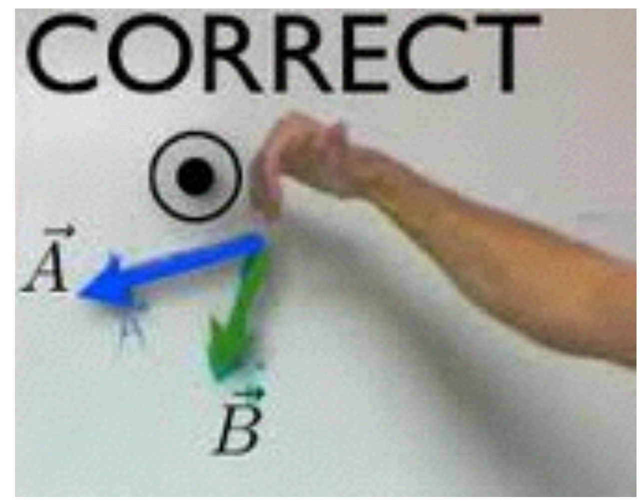
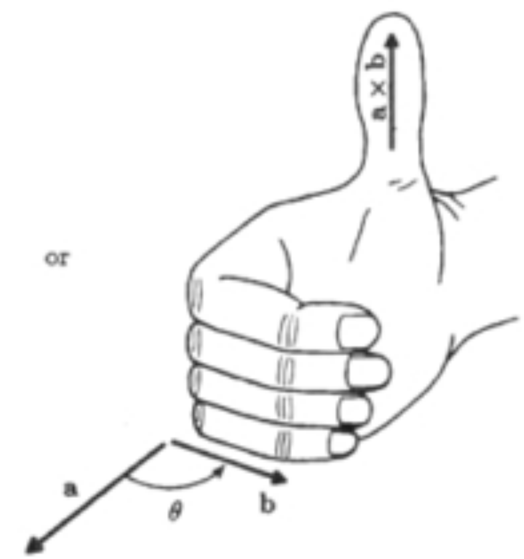
Ampère Law

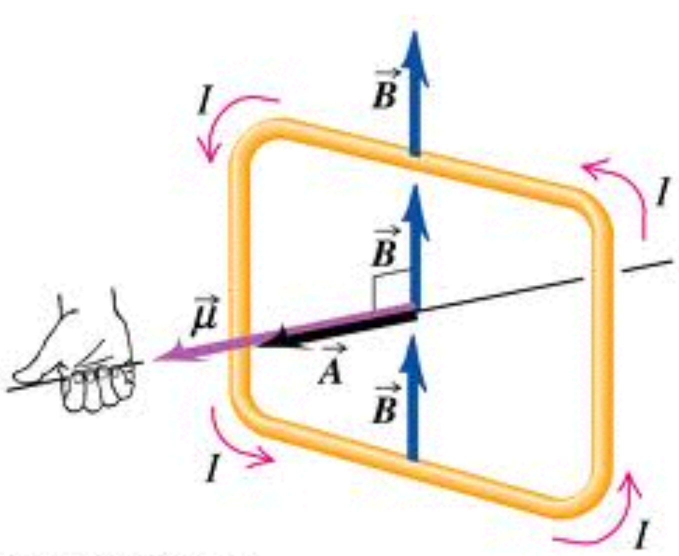
Lecture 20

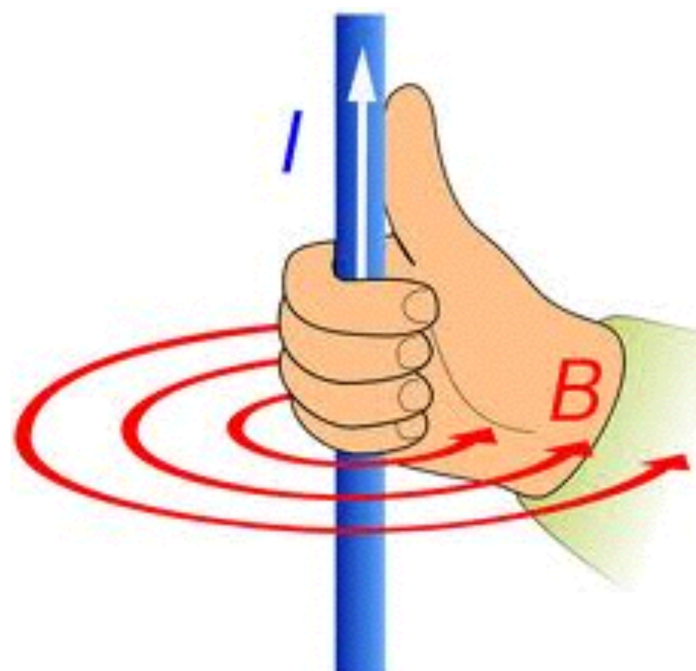
Review: Right Hand Rules

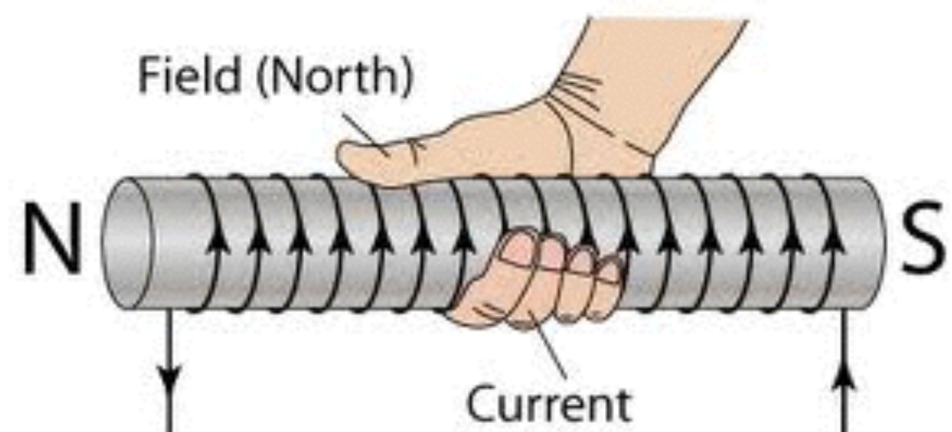












Review: Fundamental law(s) of Electrostatics

- **Coulomb Law**: (Solution to DE) E field generated by charge

$$\vec{E} = \frac{kq}{r^2}\hat{r} \qquad\qquad d\vec{E} = \frac{dq}{4\pi\epsilon_0}\frac{\hat{r}}{r^2}$$

or

Gauss Law: (DE) Relationship between charge of E field

Integral Equation:

$$\oint_{\mathcal{M}} d^2A\ \hat{n}\cdot\vec{E} = Q_{\text{inside}}/\epsilon_0$$

Differential Equation (DE):

$$\vec{\nabla}\cdot\vec{E} = \rho/\epsilon_0$$

Review: Fundamental law(s) of B field generation

Biot-Savart Law: (Solution to DE) B generated by current:

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

or

Ampère Law: (DE) Relationship between current and B field

Integral Equation:

$$\oint d\vec{\ell} \cdot \vec{B} = \mu_0 \, I_{\text{inside}}$$

Differential Equation (DE):

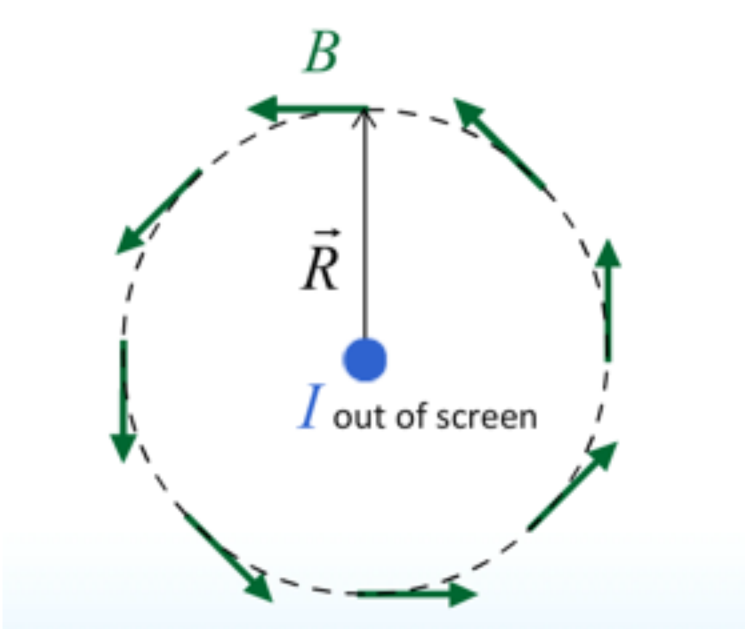
$$\vec{\nabla} \times \vec{B} = \mu_0 \, \vec{j}$$

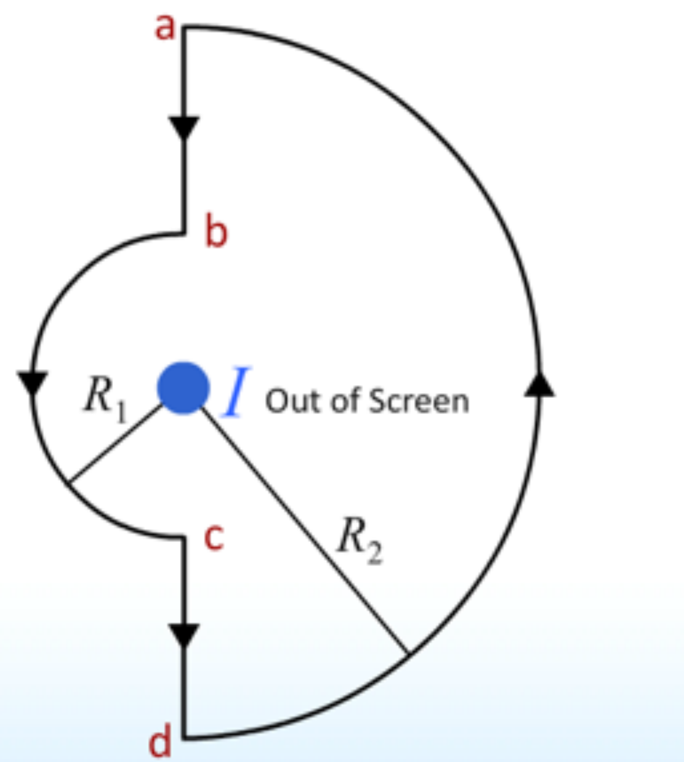
Ampère Law

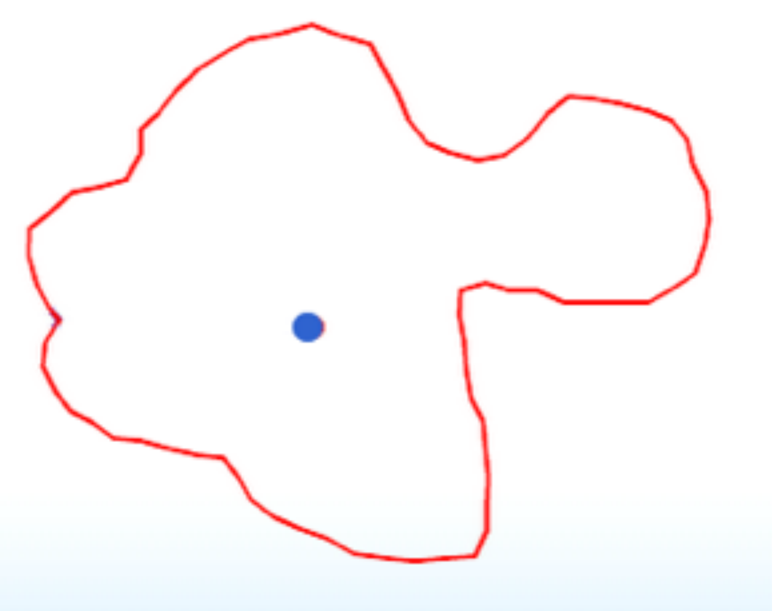
- New physical law (same physics as Biot-Savart)

- Line integral over a closed loop:

$$\oint \vec{d\ell} \cdot \vec{B} = \mu_0 \, I_{\text{inside}}$$

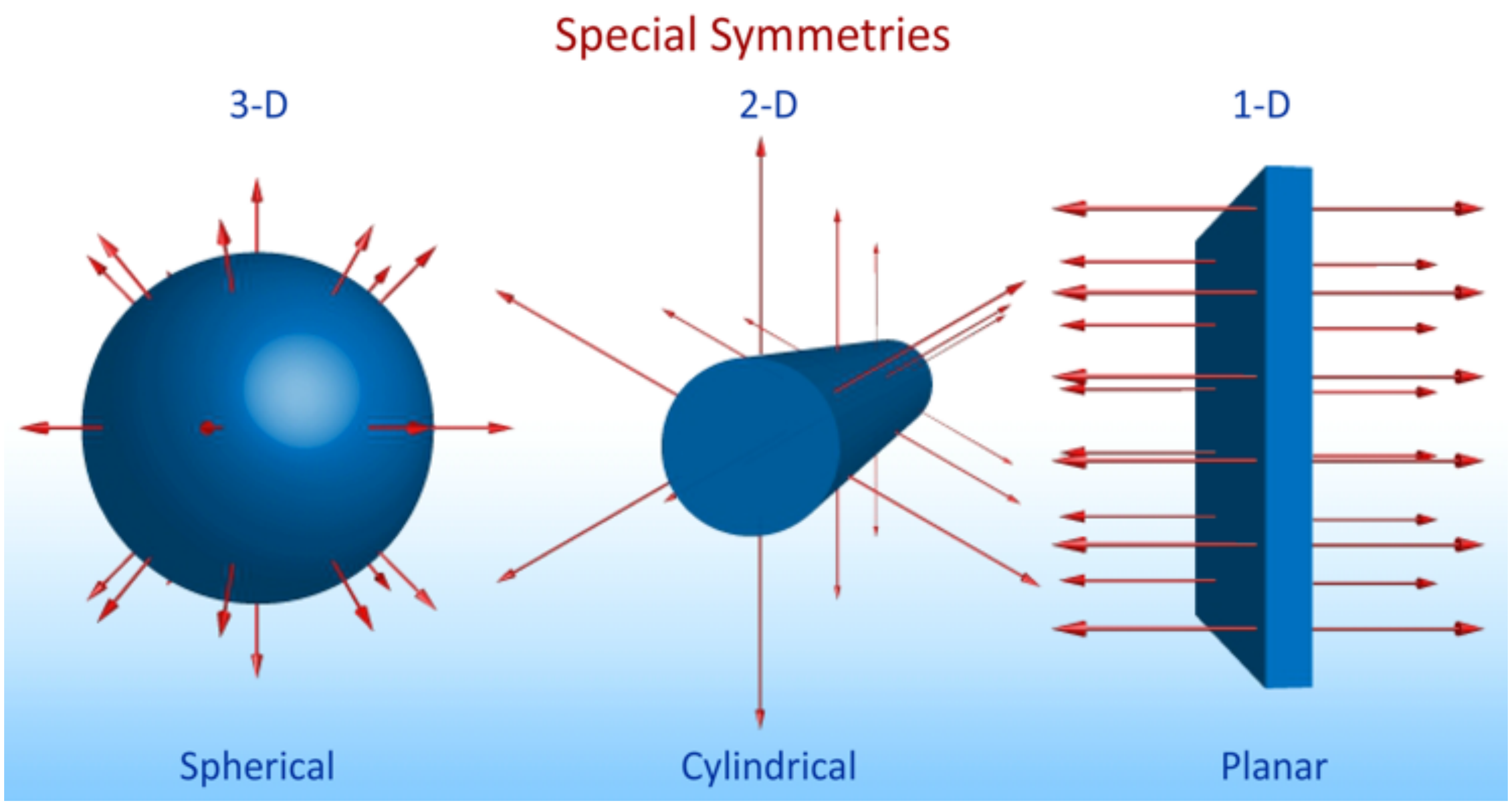






Review: Gauss Law and computing E

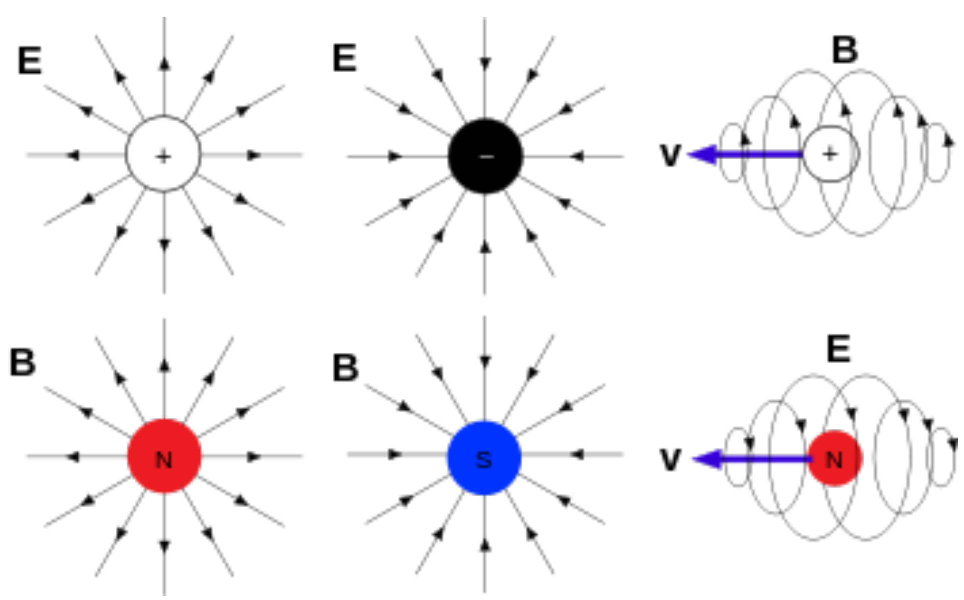
$$\oint d^2A\ \hat{n} \cdot \vec{E} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$



By the way: Gauss Law for B

- No magnetic monopoles (except on 2/14 )

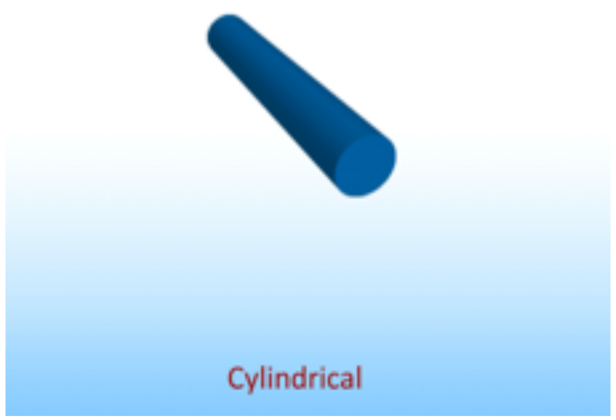
$$\oint d^2A\ \hat{n} \cdot \vec{B} = \frac{Q^M_{\mathrm{enclosed}}}{\epsilon^M_0} = 0$$

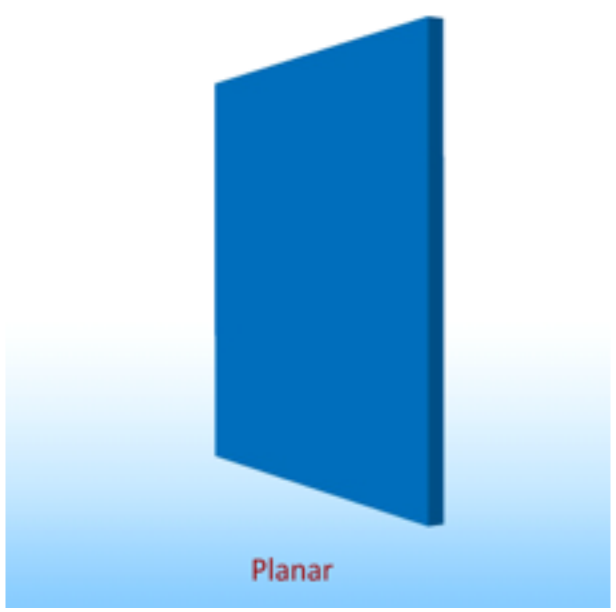


New: Ampère Law and computing B

$$\oint \vec{d\ell} \cdot \vec{B} = \mu_0 \, I_{\text{inside}}$$

1. Identify **symmetry** (only 2 options)
2. Draw B field/field lines
3. Choose a Ampère Loop
4. Compute B





Ampère Law: Infinite Wire (1)

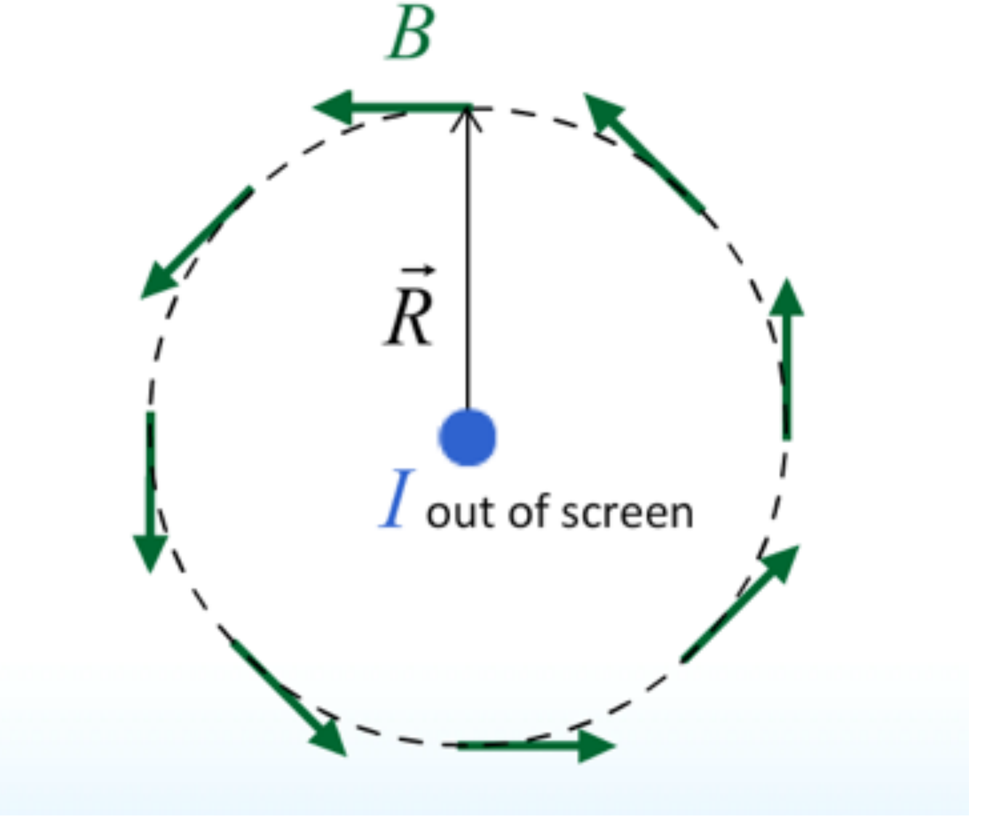
(Overhead)

1. Identify **symmetry**

2. Draw B field/field lines

3. Choose a Ampère Loop

4. Compute B

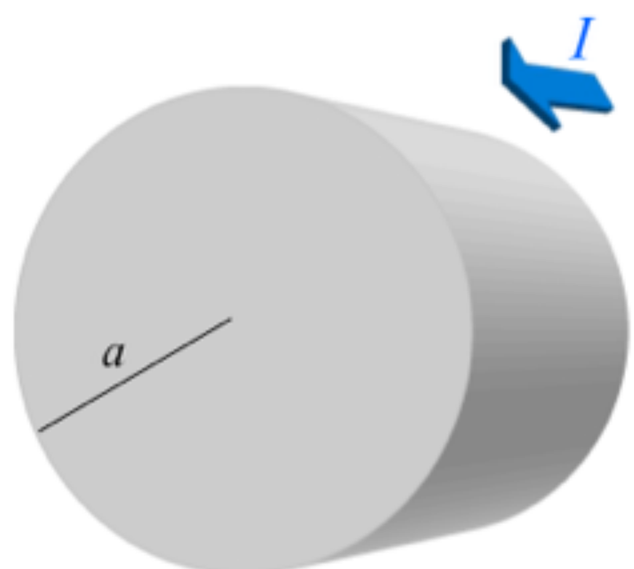


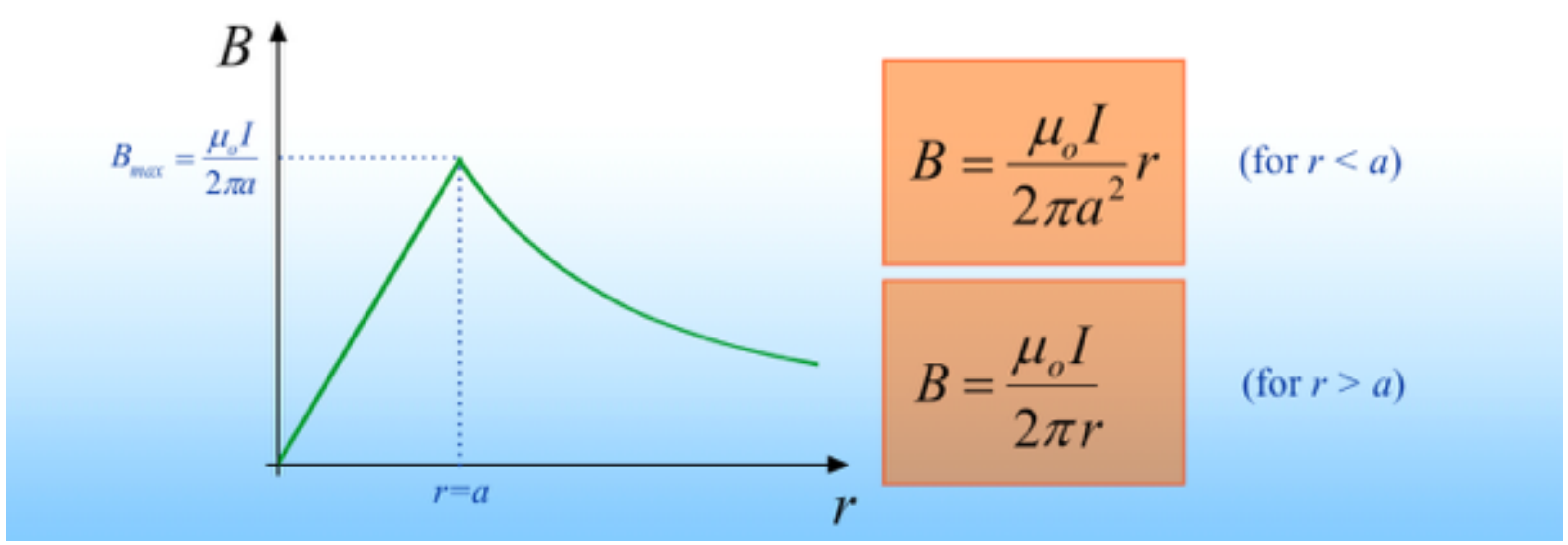
$$B = \frac{\mu_0 I}{2\pi R}$$

Ampère Law: Infinite Wire (2)

(Overhead)

- Why is n const?
- Why must wire be infinite?





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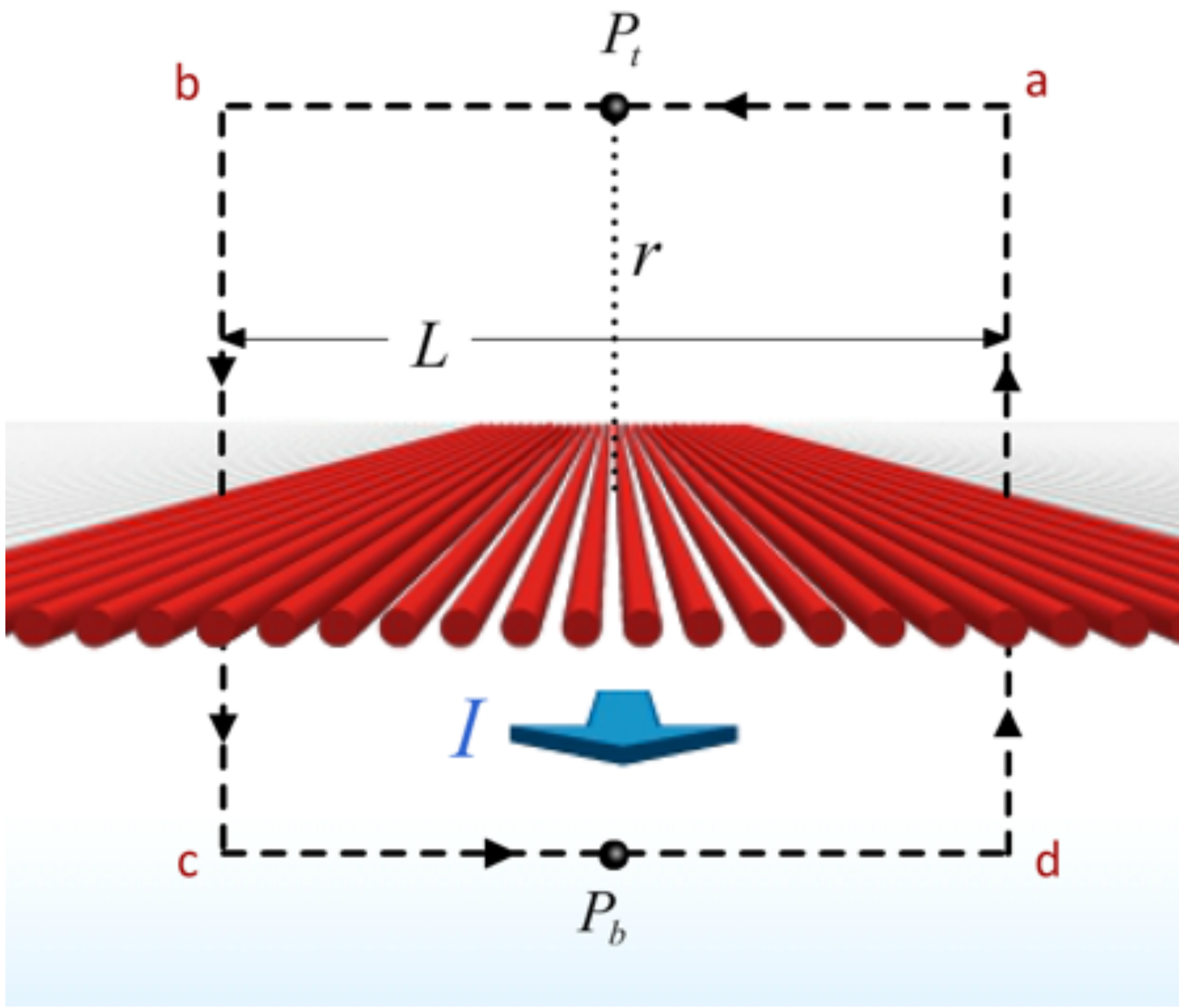
Ampère Law: Infinite Sheet

(Overhead)

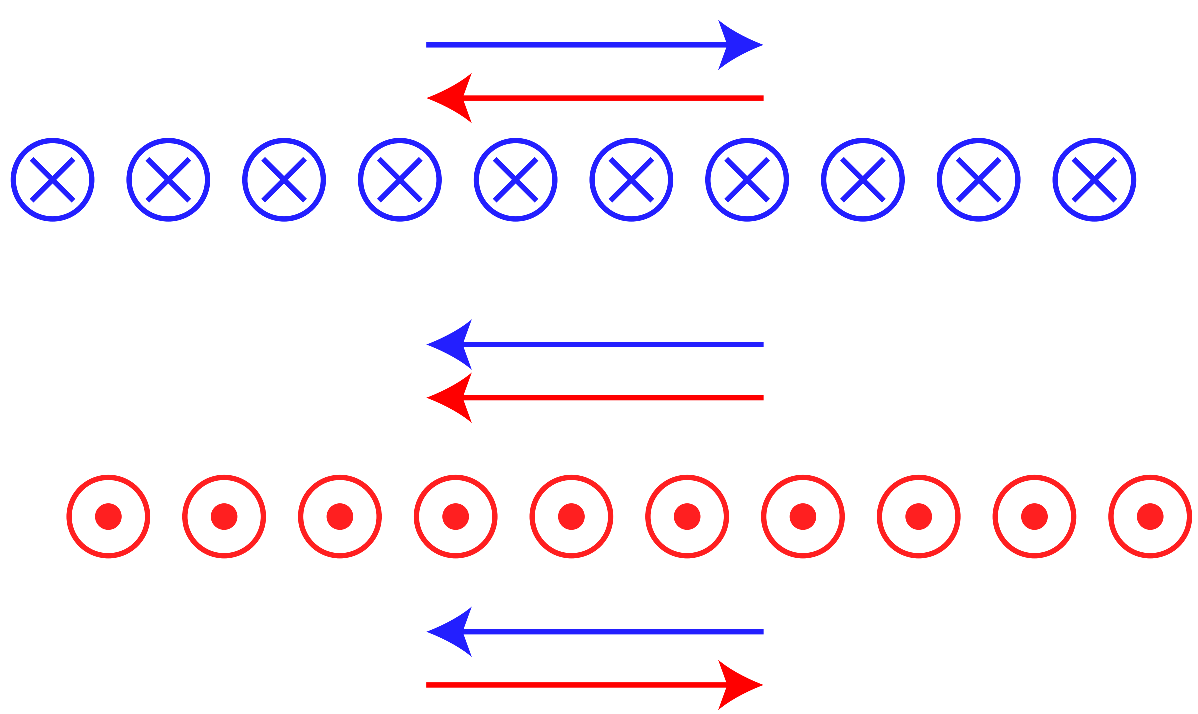
1. Identify **symmetry**
2. Draw B field/field lines
3. Choose a Ampère Loop
4. Compute B



$$B = \frac{1}{2}\mu_0 n I$$

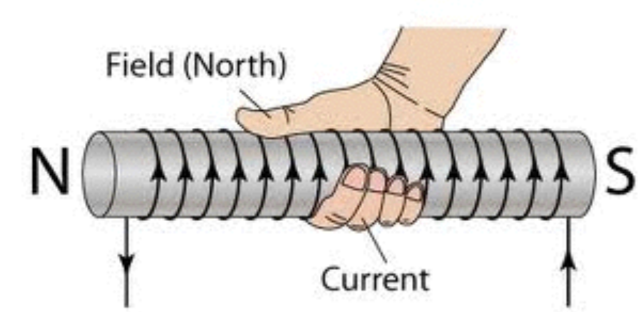
B field for an ∞ solenoid

- Intuitive picture: ~ 2 infinite sheets



- Field is ~ zero outside

$$B = \mu_0 n I$$



Electrodynamics & the Maxwell Equations

- Gauss Law (E): $$\oint_{\mathcal{M}} d^2A\ \hat{n}\cdot\vec{E} = Q_{\mathrm{inside}}/\epsilon_0$$
- Gauss Law (B): $$\oint_{\mathcal{M}} d^2A\ \hat{n}\cdot\vec{B} = 0$$
- Ampère Law: $$\oint_{\partial\mathcal{M}} \vec{d\ell}\cdot\vec{B} = \mu_0 I + \mu_0\epsilon_0 \frac{d}{dt}\int_{\mathcal{M}} d^2A\,\hat{n}\cdot\vec{E}$$
- Faraday Law: $$\oint_{\partial\mathcal{M}} \vec{d\ell}\cdot\vec{E} = -\frac{d}{dt}\int_{\mathcal{M}} d^2A\,\hat{n}\cdot\vec{B}$$