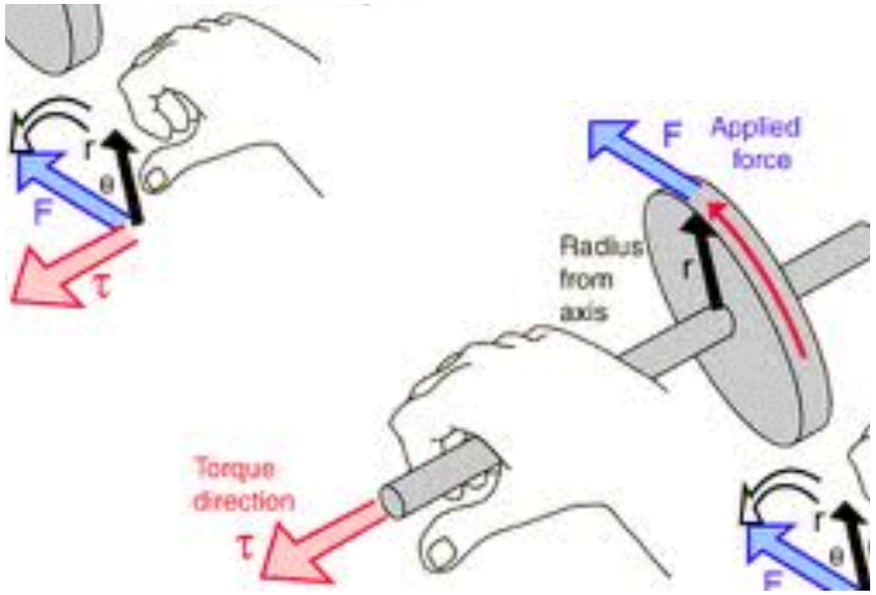
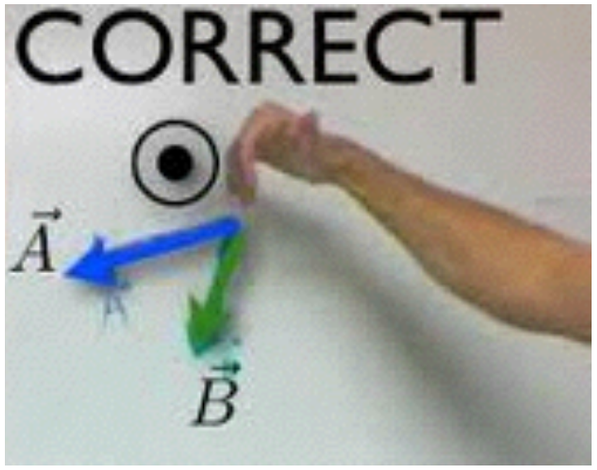
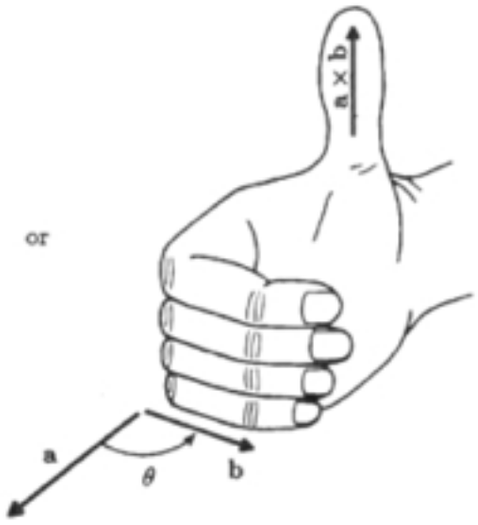
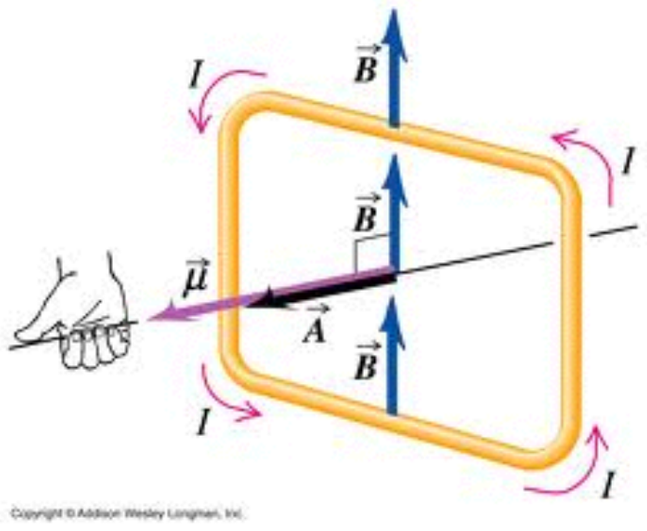
Exams: Pick up from Susan Miller

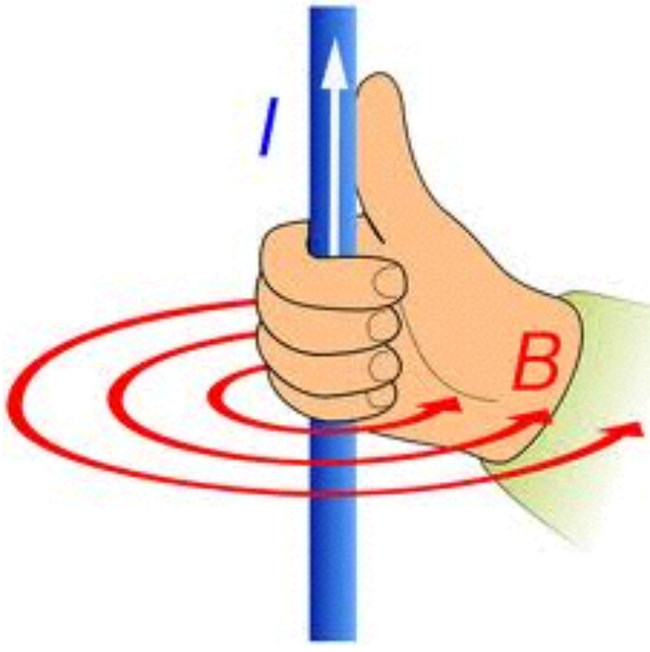
Review: Right Hand Rules

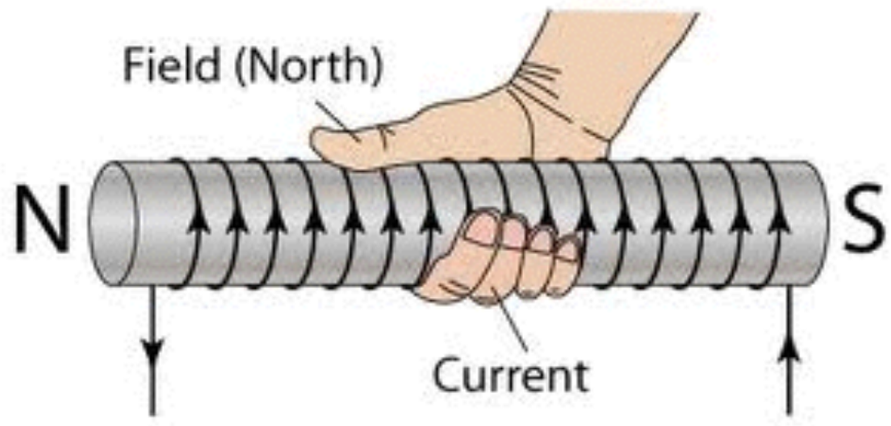










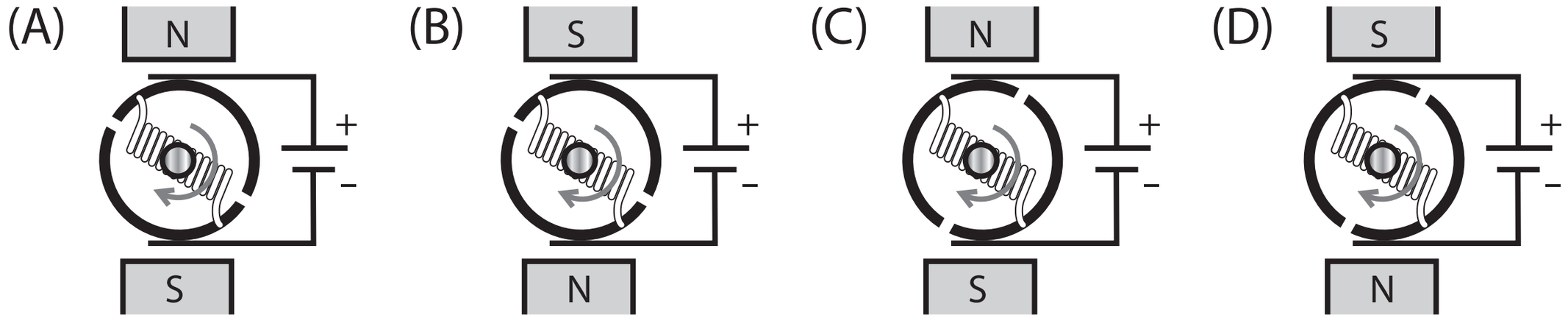


B field generated by current

Lecture 19

Demo: Electric motor

- Commutator:



From last time: Unification

- **Electricity** and **Magnetism** were **unified** into a single theory!

- Current **generates** B and B **applies forces** on currents.

- Lorentz Force Law (J.J. Thomson ++):

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

- Ampère Law (w/o Maxwell correction):

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

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):

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

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):

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

By the way… units

- Units of magnetic field:

$$\vec{F} = q\vec{v} \times \vec{B} \qquad\qquad [B] = \mathrm{T} = \frac{\mathrm{N} \cdot \mathrm{s}}{\mathrm{C} \cdot \mathrm{m}}$$

- 1 Tesla is a HUGE magnetic field

- Earth's magnetic field ~40 μT.

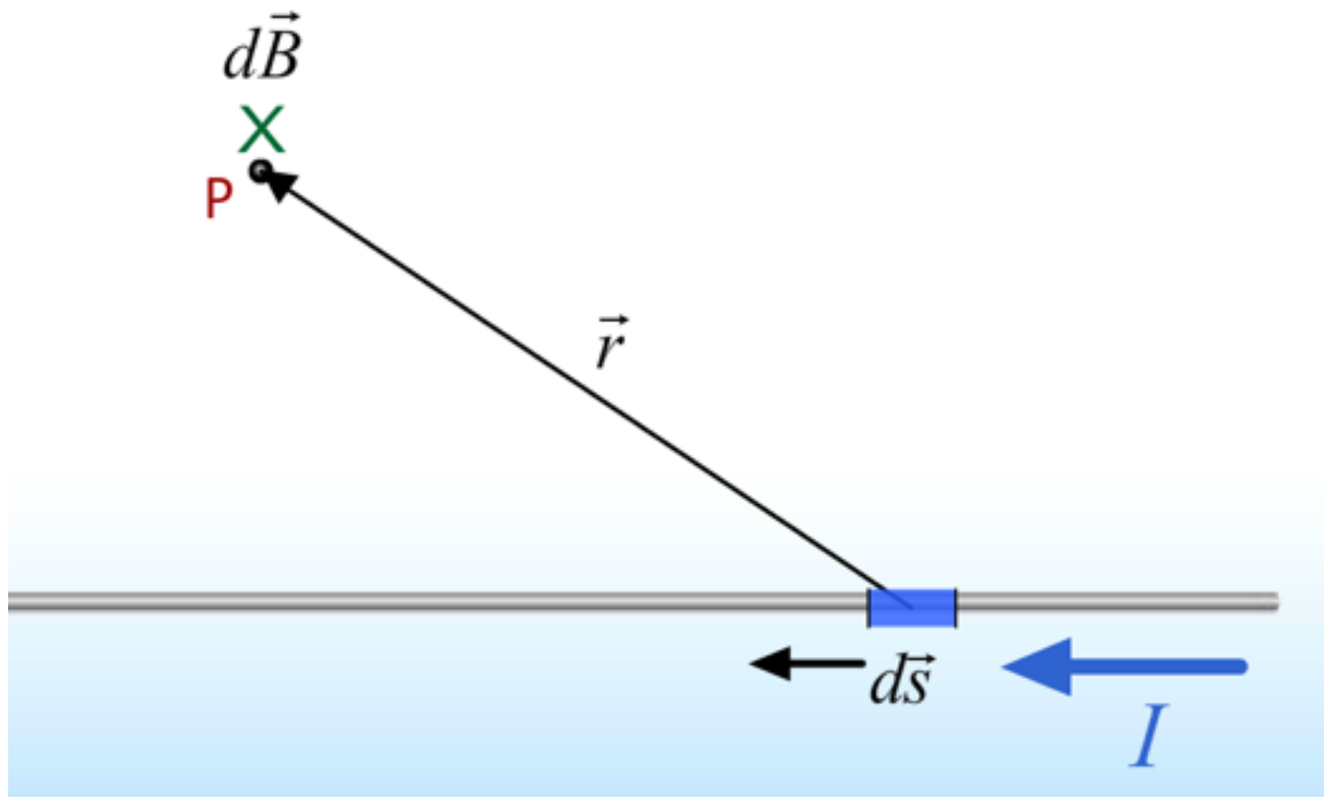
- Magnetic constant = Vacuum permeability

$$\mu_0 = 4\pi \times 10^{-7} \ \frac{\mathrm{T} \cdot \mathrm{m}}{\mathrm{A}}$$

Biot-Savart: Infinite Wire

- Infinite wire calculation:

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



- (Overhead)
- Result:

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

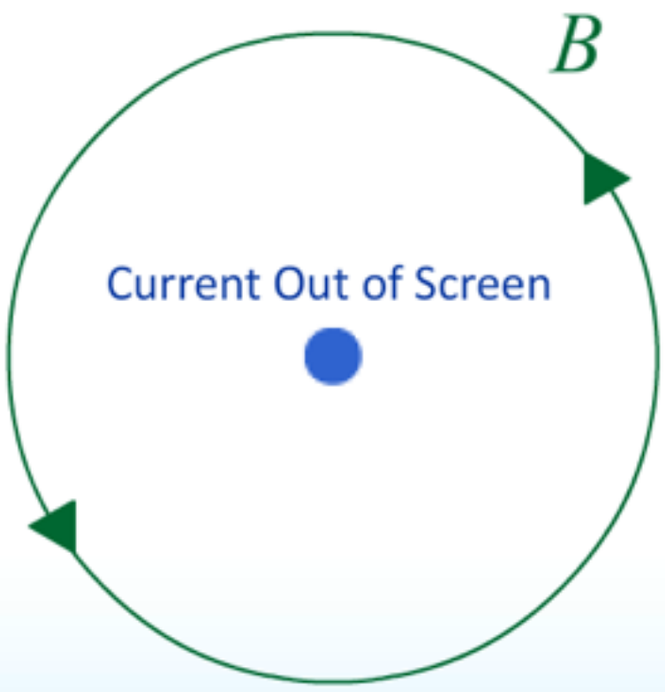
$$E = \frac{\lambda}{2\pi\epsilon_0 R}$$

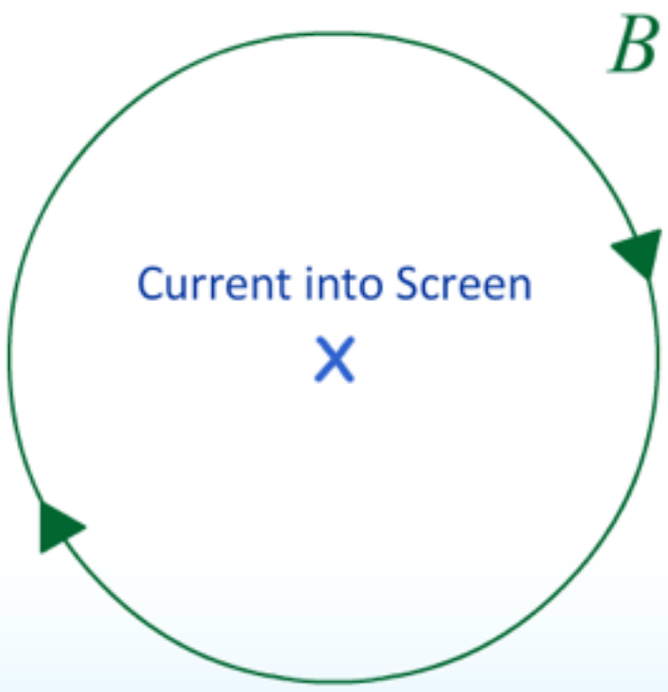
Biot-Savart Law

- Infinite wire calculation:

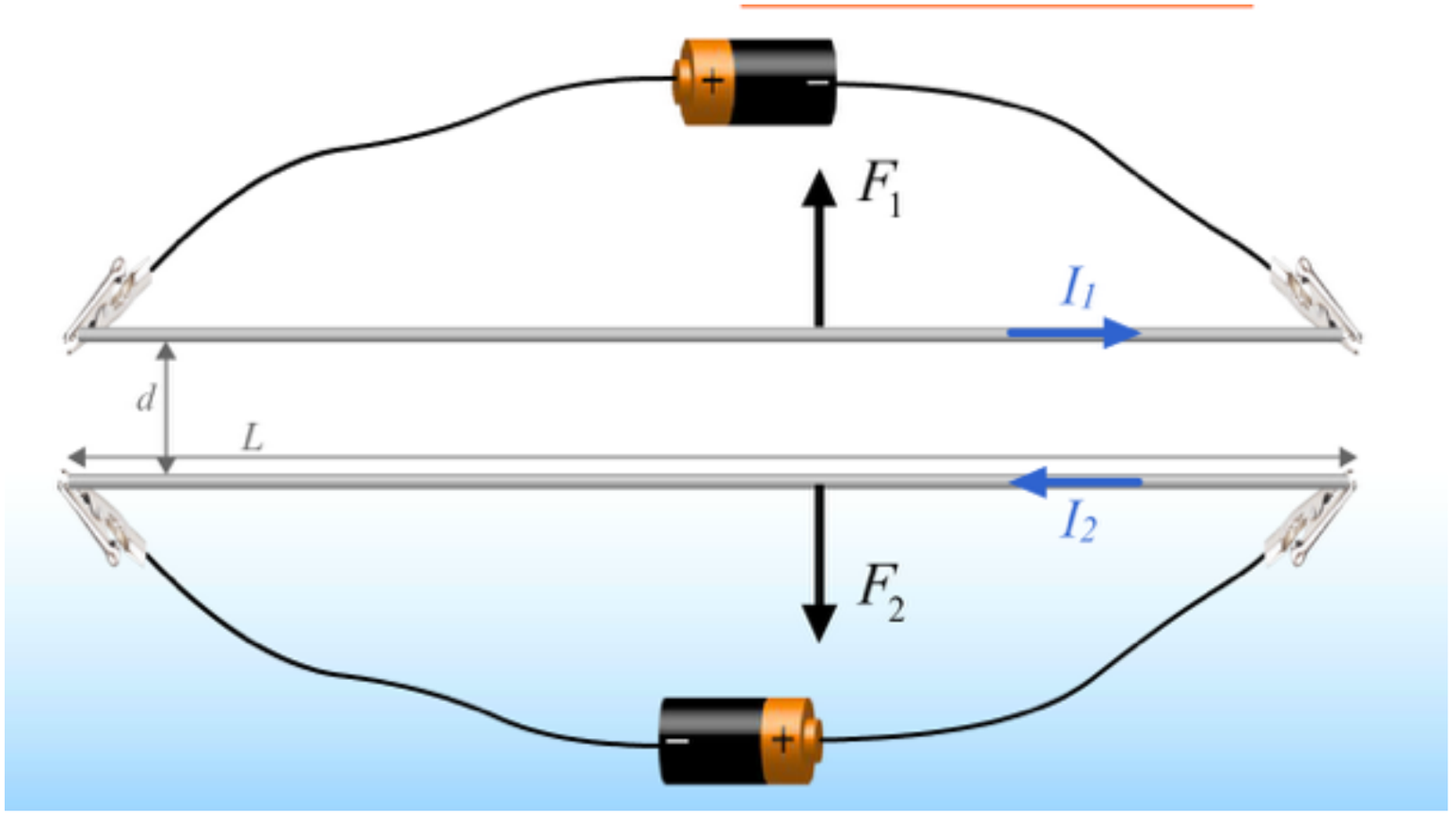
$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{\ell} \times \hat{r}}{r^2}$$

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





Demo: Pinch wires



$$F = \frac{\mu_0 L I^2}{2\pi d}$$

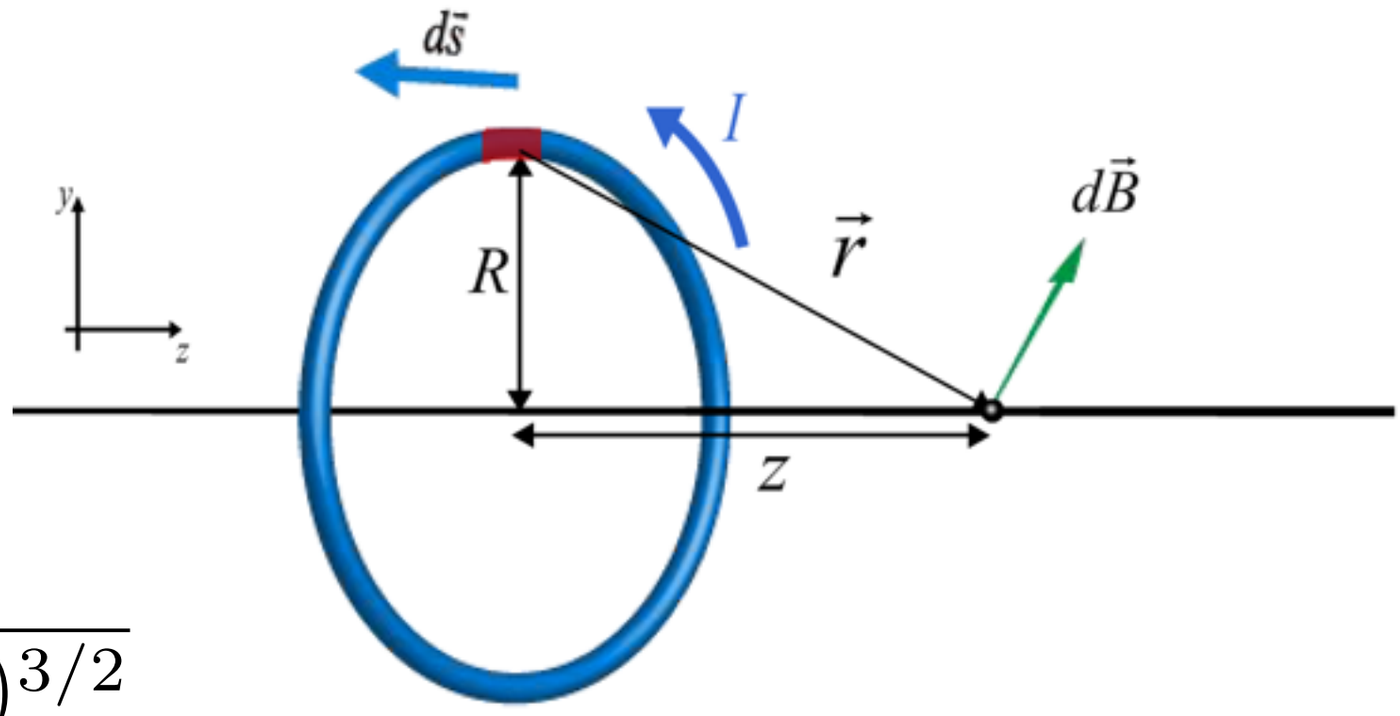
Overhead

Biot-Savart: Loop

- Infinite wire calculation:

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

- (Overhead)



- Result:

$$B = \frac{\mu_0 I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}}$$