AMPERE'S CIRCUIT LAW

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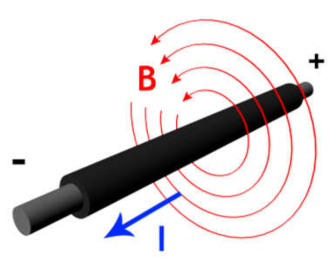
Ampere's Circuit Law

- Ampere's law is only useful for calculation in certain specific situations, involving highly symmetric currents.
- Only holds for constant fields. We will need to introduce another term when the electric field is changing with time.

$$\oint \vec{H} \cdot d\vec{l} = I_{enc}$$



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Applications of Ampere's Law

1. Identify region in which to calculate magnetic field.
2. Choose Amperian path using symmetry: magnetic field is zero or constant of the loop.
3. Calculate $\oint \vec{\mathrm{H}} \cdot d\vec{\mathrm{l}}$.
4. Calculate current enclosed by loop I_{enc}.
5. Apply Ampere's law to solve for magnetic field

$$\oint \vec{\mathrm{H}} \cdot d\vec{\mathrm{l}} = I_{\mathrm{enc}}$$

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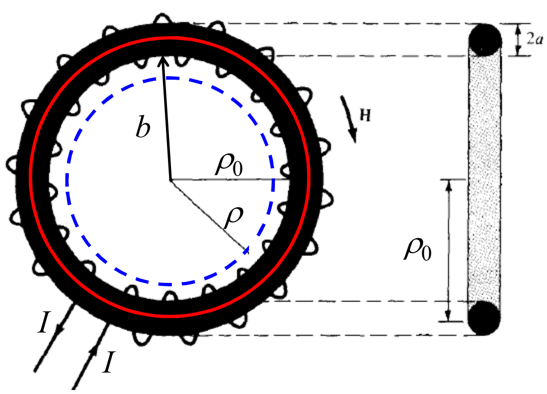
A Toroidal Coil

Determine H inside and outside the toroidal coil that has N turns.

Region 1: $\rho < b$

Draw Amperian path

Choose a concentric path with radius ρ less than b.



Apply Ampere's Law

$$\oint \vec{\mathrm{H}} \cdot d\vec{\mathrm{l}} = I_{\mathrm{enc}} = 0$$

$$H = 0$$

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A Toroidal Coil

Determine H inside and outside the toroid that has N turns.

Region 2: $b < \rho < b + 2a$

Draw Amperian path

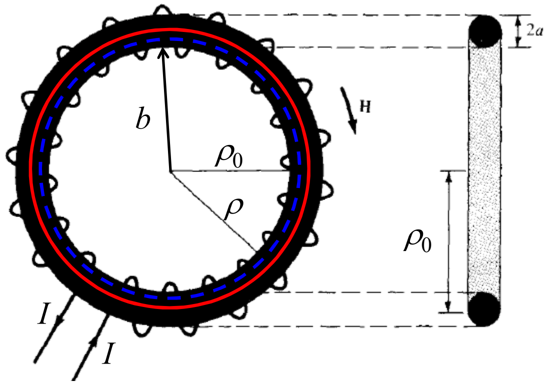
Choose a concentric path of radius $b < \rho < b + 2a$.

Apply Ampere's Law

$$\oint \vec{H} \cdot d\vec{l} = I_{enc}$$

$$H \cdot 2\pi\rho = NI$$

$$H = \frac{NI}{2\pi\rho} \rightarrow \vec{H} = -\frac{NI}{2\pi\rho}\hat{a}_\phi$$



A Toroidal Coil

Determine H inside and outside the toroid that has N turns.

Region 3: $\rho > b + 2a$

Draw Amperian path

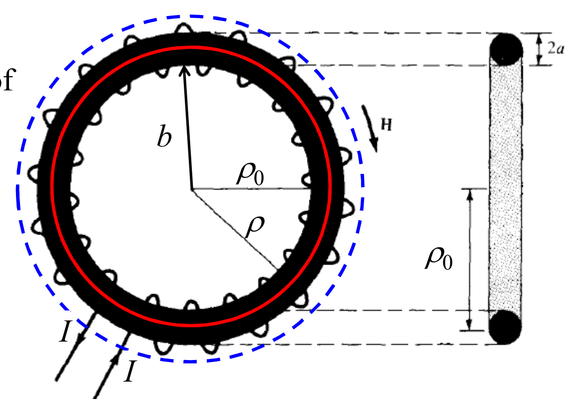
Choose a concentric path of radius $\rho > b + 2a$.

Apply Ampere's Law

$$\oint \vec{H} \cdot d\vec{l} = I_{enc}$$

$$H \cdot 2\pi\rho = NI - NI = 0$$

$$H = 0$$



Maxwell's Equation

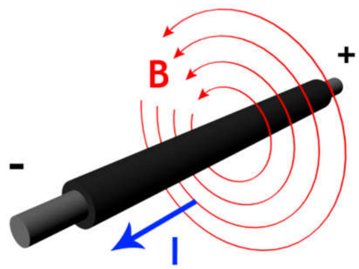
Ampere's law:

$$I_{\text{enc}} = \oint_L \vec{H} \cdot d\vec{l}$$

Using Stoke's theorem

$$I_{\text{enc}} = \int_S \left(\nabla \times \vec{H}\right) \cdot d\vec{S}$$

$$= \int_S \vec{J} \cdot d\vec{S}$$



$\nabla \times \vec{H} = \vec{J}$ → Third Maxwell's equation

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Magnetic Flux Density

$$\vec{B} = \mu_0 \vec{H}$$

μ_0: permeablitiy of free space

$\mu_0 = 4\pi \times 10^{-7}$ H/m

Magnetic flux through a surface S

$$\psi = \int_S \vec{B} \cdot d\vec{S}$$

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