# ECE343 Spring 2025

## Objective 7.1:

## Biot Savart



# SCHEDULE

| Lesson | Topics | Reading | Notes |
|---|---|---|---|
| 24 | BVP (Capacitor, Coax), Electric Potential | 5.16 | LO 5.3 |
| 25 | Electric Boundary Conditions | 5.18-5.22 | LO 5.4 |
| 26 | BC's/Capacitance | 5.23-5.24 | |
| 27 | Electrostatic Lab | Lab packet | |
| **Chapter 6: Steady Current & Conductivity** | | | |
| 28 | Current density, Conductivity, Resistance | Ch. 6 | |
| **Chapter 7: Magnetostatics** | | | |
| 29 | Magnetic Fields, Gauss' Law for Magnetism | 7.1-7.3 | LO 7.1-7.2 **GR 2** |
| 30 | Ampere's Law | 7.4-7.5, 7.9 | LO 7.3 |
| 31 | Ampere's Law Applied | 7.6-7.8 | LO 7.3 |
| 32 | Magnetic Boundary Conditions | 7.10-7.14 | LO 7.4 |
| 33 | Magnetostatics Lab | Lab packet | |
| **Chapter 8: Time-Varying Fields** | | | |
| 34 | Faraday's Law, Displacement Current, Maxwell Eqns | 8.3, 8.8, 8.9 | LO 8.1 |
| 35 | Faraday's Law, Displacement Current, Maxwell Eqns | 8.3, 8.8, 8.9 | LO 8.2-8.3 |
| **Chapter 9: Plane Waves in Lossless Media** | | | |
| 36 | Maxwell's Equations in lossless, source-free region | 9.1-9.2 | LO 9.1 |
| 37 | Maxwell's Equations in lossless, source-free region | 9.1-9.2 | LO 9.1 |
| 38 | Uniform Plane Waves & Polarization | 9.4-9.6 | LO 9.2-9.3 |
| 39 | Normal Incidence | Vol 2, 5.6-5.7 | LO 9.4-9.5 |
| 40 | Oblique Incidence | Vol 2, 5.6-5.7 | LO 9.5 |
| 41 | Oblique Incidence | Vol 2, 5.6-5.7 | LO 9.5 |
| 42 | Incidence Lab | TBD | LO 9.5 |

# Ch 7 Learning Objectives

7.1 I can use the Biot-Savart law to simple magnetostatic systems to find the magnetic field at an observation point.

7.2 I can articulate the meaning of both the integral form and point form of Gauss' Law for magnetism.

7.3 I can use Ampere's Law to calculate the magnetic field at an observation point for simple magnetostatic systems.

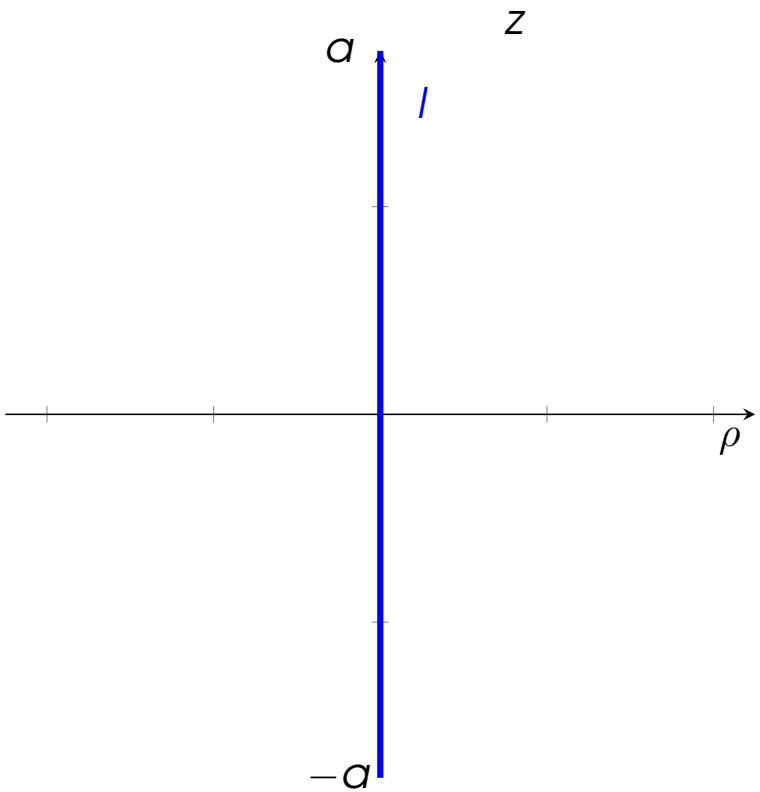
7.4 I can apply the magnetic field boundary conditions to calculate magnetic fields on both sides of a material boundary.

# Similarities to Electrostatics

| **Electrostatics** | **Magnetostatics** |
|---|---|
| $\vec{E}$ (V/m) | $\vec{H}$ (A/m) |
| $\vec{D}$ (C/m$^2$) | $\vec{B}$ (Wb/m$^2$) |
| $\vec{D} = \varepsilon \vec{E}$ | $\vec{B} = \mu \vec{H}$ |
| $\vec{E} = \int \frac{dQ}{4\pi\varepsilon \lvert R \rvert^3} \vec{R}$ | $\vec{H} = \int \frac{I d\vec{\ell} \times \vec{R}}{4\pi \lvert R \rvert^3}$ |
| $\iint \vec{E} \cdot d\vec{S} = \frac{Q_{\text{encls}}}{\varepsilon}$ | $\iint \vec{B} \cdot d\vec{S} = 0$ |

# Biot-Savart: Line Charge

Find $\vec{H}$ at a distance $b$ from the LC.




1. Draw a picture
2. Biot-Savart: $\vec{H} = \int \frac{I d\vec{\ell} \times \vec{R}}{4\pi |R|^3}$
3. $\vec{R} = \hat{\boldsymbol{\rho}} b - \hat{\mathbf{z}} z$

   $|R| = \sqrt{b^2 + z^2}$
4. $d\vec{\ell} = \hat{\mathbf{z}} dz$
5. $d\vec{\ell} \times \vec{R} =$

$$\begin{bmatrix} \hat{\rho} & \hat{\phi} & \hat{\mathbf{z}} \\ 0 & 0 & dz \end{bmatrix}$$

# Biot Savart: Line Charge

6 Integrate!

for "infinite" wire $\Longrightarrow$ $a >> b$

$$\vec{H} = \int_{-a}^{a} \frac{I\left(\hat{\phi} b dz\right)}{4\pi\left(b^2+z^2\right)^{3/2}}$$

$$= \hat{\phi}\frac{Ib}{4\pi}\left[\frac{z}{b^2\left(b^2+z^2\right)^{1/2}}\right]\Bigg|_{-a}^{a}$$

$$= \hat{\phi}\frac{Ib}{4\pi}\left[\frac{a}{b^2\left(b^2+a^2\right)^{1/2}} - \frac{-a}{b^2\left(b^2+(-a)^2\right)^{1/2}}\right]$$

$$= \hat{\phi}\frac{Ia}{2\pi b\left(b^2+a^2\right)^{1/2}} \longrightarrow \text{"finite" wire}$$

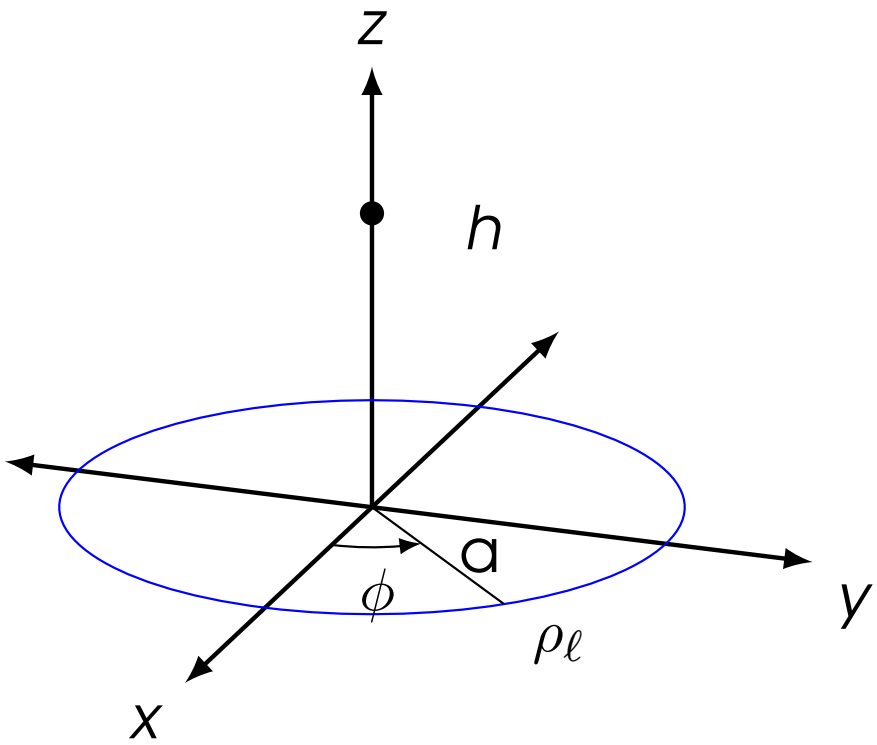
$$\vec{H} = \hat{\phi}\lim_{a>>b}\frac{Ia}{2\pi b\left(b^2+a^2\right)^{1/2}}$$

$$= \hat{\phi}\frac{I}{2\pi b\left(a^2\right)^{1/2}}$$

$$= \hat{\phi}\frac{I}{2\pi b}$$

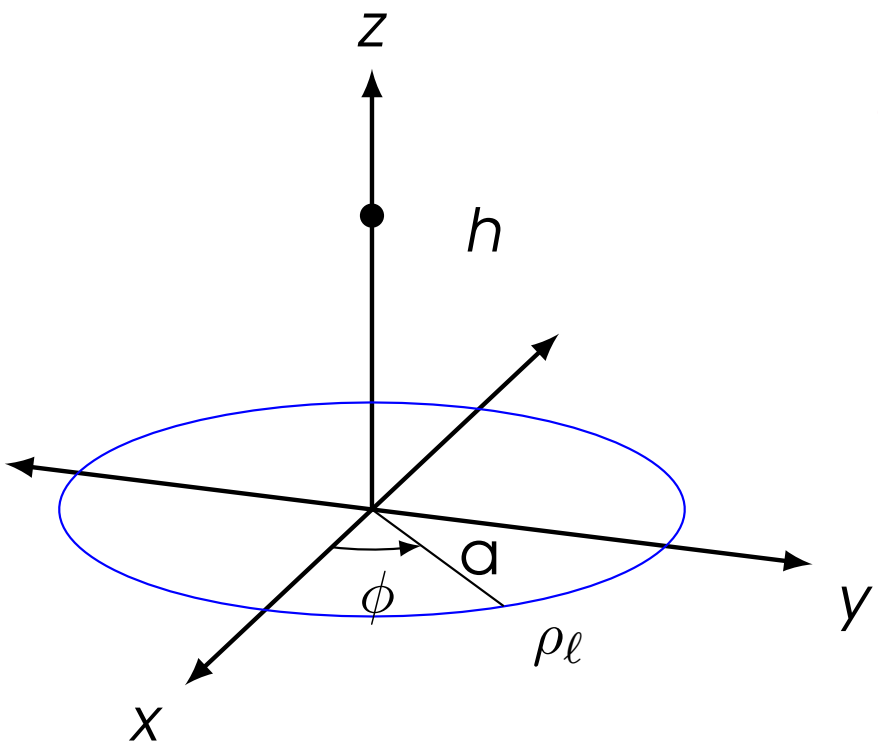
# Biot-Savart: Wire Loop

Find $\vec{H}$ at $z = h$.




1. Draw a picture
2. Biot-Savart: $\vec{H} = \int \frac{I d\vec{\ell} \times \vec{R}}{4\pi |R|^3}$
3. $\vec{R} = -\hat{\boldsymbol{\rho}} a - \hat{\mathbf{z}} h$
4. $|R| = \sqrt{a^2 + h^2}$
5. $d\vec{\ell} = \hat{\phi} \rho d\phi = \hat{\phi} a d\phi$
6. $d\vec{\ell} \times \vec{R} =$

# Biot-Savart: Wire Loop




(6) Integrate!

$$\vec{H} = \frac{I}{4\pi}\int_0^{2\pi} \frac{\hat{\boldsymbol{\rho}} h a d\phi + \hat{\mathbf{z}} a^2 d\phi}{\left(a^2+h^2\right)^{3/2}}$$

$$= \frac{I}{4\pi}\left[\hat{\boldsymbol{\rho}} 0 + \int_0^{2\pi} \frac{\hat{\mathbf{z}} a^2 d\phi}{\left(a^2+h^2\right)^{3/2}}\right]$$

$$= \hat{\mathbf{z}} \frac{I a^2 2\pi}{4\pi\left(a^2+h^2\right)^{3/2}}$$

$$= \hat{\mathbf{z}} \frac{I a^2}{2\left(a^2+h^2\right)^{1/2}}$$