In this unit, you will explore the properties of static magnetic fields coming from sources that are steady currents. You will use many of the same ideas as for static electric fields coming from static charge densities (so there is a chance to revisit/review this content), but all of the formulas literally have an extra "twist" coming from cross products and the right-hand-rule. The geometries you will encounter are more subtle and beautiful. Keep the following analogies in mind:

$$\text{charge density } \rho \longleftrightarrow \text{current density } \vec{J} \tag{1}$$

$$\frac{1}{4\pi\epsilon_0} \longleftrightarrow \frac{\mu_o}{4\pi} \tag{2}$$

$$\text{electrostatic potential } V \longleftrightarrow \text{magnetic vector potential } \vec{A} \tag{3}$$

$$\text{electric field } \vec{E} \longleftrightarrow \text{magnetic field } \vec{B} \tag{4}$$

$$\text{Gauss's Law} \longleftrightarrow \text{Ampere's Law} \tag{5}$$

$$\text{Maxwell } \vec{\nabla} \cdot \vec{E} = \tfrac{1}{\epsilon_0}\rho \longleftrightarrow \text{Maxwell } \vec{\nabla} \cdot \vec{B} = 0 \tag{6}$$

$$\text{Maxwell } \vec{\nabla} \times \vec{E} = 0 \longleftrightarrow \text{Maxwell } \vec{\nabla} \times \vec{B} = \mu_0 \vec{J} \tag{7}$$

Key Activities/Problems

- Total Current, Square Cross-Section
- Ampère's Law in Symmetric Situations
- Magnetic Field and Current

At the end of this unit, you should be able to:

- Find an integral expression for the magnetic vector potential and magnetic field from a steady current.
- Predict the magnitude and direction of the magnetic field around steady currents with some symmetry.
- Find the magnetic field from the magnetic vector potential in rectangular, cylindrical, and spherical coordinates.
- Recognize when you have sufficiently high symmetry to use Ampère's Law in integral form to find the magnetic field around steady currents and then be able to calculate this field.
- Make clear, correct symmetry arguments about the direction and functional dependence of the magnetic field around steady currents with sufficiently high symmetry.
- Explain when Stokes' theorem is valid and when Ampère's law (in both integral and differential form) is valid.
- Use Ampère's law in differential form to go back and forth between magnetostatic fields and the currents that create them.