2.7: Magnetic Field Intensity

Magnetic field intensity $\mathbf{H}$ is an alternative description of the magnetic field in which the effect of material is factored out. For example, the magnetic flux density $\mathbf{B}$ (reminder: Section 2.5) due to a point charge q moving at velocity $\mathbf{v}$ can be written in terms of the *Biot-Savart Law*:

$$\mathbf{B} = \mu \frac{q\mathbf{v}}{4\pi R^2} \times \hat{\mathbf{R}} \tag{2.7.1}$$

where $\hat{\mathbf{R}}$ is the unit vector pointing from the charged particle to the field point $\mathbf{r}$, R is this distance, "$\times$" is the cross product, and μ is the permeability of the material. We can rewrite Equation 2.7.1 as:

$$\mathbf{B} \triangleq \mu\mathbf{H} \tag{2.7.2}$$

with:

$$\mathbf{H} = \frac{q\mathbf{v}}{4\pi R^2} \times \hat{\mathbf{R}} \tag{2.7.3}$$

so $\mathbf{H}$ in homogeneous media does not depend on μ.

Dimensional analysis of Equation 2.7.3 reveals that the units for $\mathbf{H}$ are amperes per meter (A/m). However, $\mathbf{H}$ does not represent surface current density, as the units might suggest. While it is certainly true that a distribution of current (A) over some linear cross-section (m) can be described as a current density having units of A/m, $\mathbf{H}$ is associated with the magnetic field and not a particular current distribution (the concept of *current density* is not essential to understand this section; however, a primer can be found in Section 6.2). Said differently, $\mathbf{H}$ can be viewed as a description of the magnetic field in terms of an equivalent (but not actual) current.

> The magnetic field intensity $\mathbf{H}$ (A/m), defined using Equation 2.7.2, is a description of the magnetic field independent from material properties.

It may appear that $\mathbf{H}$ is redundant information given $\mathbf{B}$ and μ, but this is true only in homogeneous media. The concept of magnetic field intensity becomes important – and decidedly not redundant – when we encounter boundaries between media having different permeabilities. As we shall see in Section 7.11, boundary conditions on $\mathbf{H}$ constrain the component of the magnetic field which is tangent to the boundary separating two otherwise-homogeneous regions. If one ignores the characteristics of the magnetic field represented by $\mathbf{H}$ and instead considers only $\mathbf{B}$, then only the perpendicular component of the magnetic field is constrained.

The concept of magnetic field intensity also turns out to be useful in a certain problems in which μ is not a constant, but rather is a function of magnetic field strength. In this case, the magnetic behavior of the material is said to be *nonlinear*. For more on this, see Section 7.16.