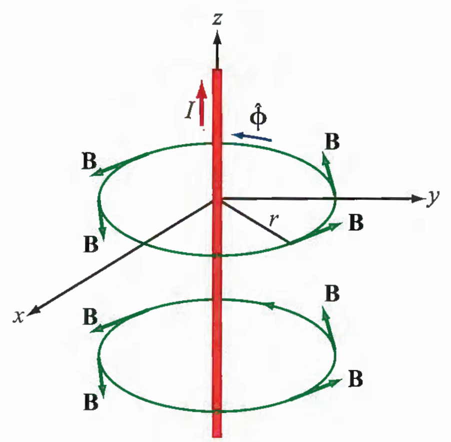

Figure 1-9: The magnetic field induced by a steady current flowing in the z-direction.

in honor of Nikola Tesla (1856–1943), a Croatian-American electrical engineer whose work on transformers made it possible to transport electricity over long wires without too much loss. The quantity μ_0 is called the ***magnetic permeability of free space*** [$\mu_0 = 4\pi \times 10^{-7}$ henry per meter (H/m)], and it is analogous to the electrical permittivity ε_0. In fact, as we will see in Chapter 2, the product of ε_0 and μ_0 specifies c, the ***velocity of light in free space***:

$$\boxed{c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \quad \text{(m/s)}. \qquad (1.14)}$$

We noted in Section 1-3.2 that when an electric charge q' is subjected to an electric field $\mathbf{E}$, it experiences an electric force $\mathbf{F}_e = q'\mathbf{E}$. Similarly, if a charge q' resides in the presence of a magnetic flux density $\mathbf{B}$, it will experience a ***magnetic force*** $\mathbf{F}_m$, but only if the charge is in motion and its velocity $\mathbf{u}$ is in a direction not parallel (or anti-parallel) to $\mathbf{B}$. In fact, as we will learn in more detail in Chapter 5, $\mathbf{F}_m$ points in a direction perpendicular to both $\mathbf{B}$ and $\mathbf{u}$.

To extend Eq. (1.13) to a medium other than free space, μ_0 should be replaced with μ, the ***magnetic permeability*** of the material in which $\mathbf{B}$ is being observed. The majority of natural materials are ***nonmagnetic***, meaning that they exhibit a magnetic permeability $\mu = \mu_0$. For ferromagnetic materials, such as iron and nickel, μ can be much larger than μ_0. The magnetic permeability μ accounts for ***magnetization*** properties of a material. In analogy with Eq. (1.11), μ of a particular material can be defined as

$$\mu = \mu_r \mu_0 \qquad \text{(H/m)}, \qquad (1.15)$$

where μ_r is a dimensionless quantity called the ***relative magnetic permeability*** of the material. The values of μ_r for commonly used ferromagnetic materials are given in Appendix B.

We stated earlier that $\mathbf{E}$ and $\mathbf{D}$ constitute one of two pairs of electromagnetic field quantities. The second pair is $\mathbf{B}$ and the ***magnetic field intensity*** $\mathbf{H}$, which are related to each other through μ:

$$\boxed{\mathbf{B} = \mu \mathbf{H}. \qquad (1.16)}$$

1-3.4 Static and Dynamic Fields

In EM, the time variable t, or more precisely if and how electric and magnetic quantities vary with time, is of crucial importance. Before we elaborate further on the significance of this statement, it will prove useful to define the following time-related adjectives unambiguously:

- ***static***—describes a quantity that does not change with time. The term ***dc*** (direct current) is often used as a synonym for static to describe not only currents, but other electromagnetic quantities as well.

- ***dynamic***—refers to a quantity that does vary with time, but conveys no specific information about the character of the variation.

- ***waveform***—refers to a plot of the magnitude profile of a quantity as a function of time.

- ***periodic***—a quantity is periodic if its waveform repeats itself at a regular interval, namely its period T. Examples include the sinusoid and the square wave. By application of the Fourier series analysis technique, any periodic waveform can be expressed as the sum of an infinite series of sinusoids.

- ***sinusoidal***—also called ***ac*** (alternating current), describes a quantity that varies sinusoidally (or cosinusoidally) with time.