Magnetic field units: The tesla and the gauss

The SI unit for magnetic field B is the **tesla** (T). From Eq. 20–1 or 20–2, it is clear that $1\,\text{T} = 1\,\text{N/A}\cdot\text{m}$. An older name for the tesla is the "weber per meter squared" $(1\,\text{Wb/m}^2 = 1\,\text{T})$. Another unit sometimes used to specify magnetic field is a cgs unit, the **gauss** (G): $1\,\text{G} = 10^{-4}\,\text{T}$. A field given in gauss should always be changed to teslas before using with other SI units. To get a "feel" for these units, we note that the magnetic field of the Earth at its surface is about $\frac{1}{2}$ G or 0.5×10^{-4} T. On the other hand, strong electromagnets can produce fields on the order of 2 T and superconducting magnets can produce over 10 T.

EXAMPLE 20–1 **Magnetic force on a current-carrying wire.** A wire carrying a 30-A current has a length $l = 12\,\text{cm}$ between the pole faces of a magnet at an angle $\theta = 60°$ (Fig. 20–12). The magnetic field is approximately uniform at 0.90 T. We ignore the field beyond the pole pieces. What is the magnitude of the force on the wire?

APPROACH We use Eq. 20–1 to find the force F on the 12-cm length of wire within the uniform field B.

SOLUTION Using Eq. 20–1 with $l = 12\,\text{cm}$, $I = 30\,\text{A}$, $B = 0.90\,\text{T}$, and $\theta = 60°$ gives

$$F = IlB\sin\theta$$
$$= (30\,\text{A})(0.12\,\text{m})(0.90\,\text{T})(0.866) = 2.8\,\text{N}.$$

EXERCISE C A straight power line carries 30 A and is perpendicular to the Earth's magnetic field of 0.50×10^{-4} T. What magnitude force is exerted on 100 m of this power line?

On a diagram, when we want to represent an electric current or a magnetic field that is pointing out of the page (toward us) or into the page, we use ⊙ or ×, respectively. The ⊙ is meant to resemble the tip of an arrow pointing directly toward the reader, whereas the × or ⊗ resembles the tail of an arrow going away. (See Fig. 20–13.)

EXAMPLE 20–2 **Measuring a magnetic field.** A rectangular loop of wire hangs vertically as shown in Fig. 20–13. A magnetic field $\vec{\mathbf{B}}$ is directed horizontally, perpendicular to the wire, and points out of the page at all points as represented by the symbol ⊙. The magnetic field $\vec{\mathbf{B}}$ is very nearly uniform along the horizontal portion of wire ab (length $l = 10.0\,\text{cm}$) which is near the center of the gap of a large magnet producing the field. The top portion of the wire loop is free of the field. The loop hangs from a balance which measures a downward force (in addition to the gravitational force) of $F = 3.48 \times 10^{-2}\,\text{N}$ when the wire carries a current $I = 0.245\,\text{A}$. What is the magnitude of the magnetic field B?

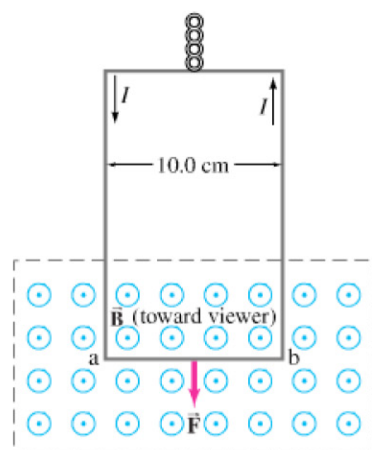

FIGURE 20–13 Measuring a magnetic field $\vec{\mathbf{B}}$. Example 20–2.

APPROACH Three straight sections of the wire loop are in the magnetic field: a horizontal section and two vertical sections. We apply Eq. 20–1 to each section and use the right-hand rule.

SOLUTION The magnetic force on the left vertical section of wire points to the left; the force on the vertical section on the right points to the right. These two forces are equal and in opposite directions and so add up to zero. Hence, the net magnetic force on the loop is that on the horizontal section ab, whose length is $l = 0.100\,\text{m}$. The angle θ between $\vec{\mathbf{B}}$ and the wire is $\theta = 90°$, so $\sin\theta = 1$. Thus Eq. 20–1 gives

$$B = \frac{F}{Il} = \frac{3.48 \times 10^{-2}\,\text{N}}{(0.245\,\text{A})(0.100\,\text{m})} = 1.42\,\text{T}.$$

NOTE This technique can be a precise means of determining magnetic field strength.