FIGURE 22–7 Electric and magnetic field strengths in an electromagnetic wave. $\vec{E}$ and $\vec{B}$ are at right angles to each other. The entire pattern moves in a direction perpendicular to both $\vec{E}$ and $\vec{B}$.

If the source voltage varies sinusoidally, then the electric and magnetic field strengths in the radiation field will also vary sinusoidally. The sinusoidal character of the waves is shown in Fig. 22–7, which displays the field *strengths* as a function of position along the direction of wave travel. Notice that $\vec{B}$ and $\vec{E}$ are perpendicular to each other and to the direction of wave travel.

We call these waves electromagnetic (EM) waves. They are *transverse* waves because the amplitude is perpendicular to the direction of wave travel. However, EM waves are always waves of *fields*, not of matter (like waves on water or a rope). Because they are fields, EM waves can propagate in empty space.

As we have seen, EM waves are produced by electric charges that are oscillating, and hence are undergoing acceleration. In fact, we can say in general that

accelerating electric charges give rise to electromagnetic waves.

EM waves are produced by accelerating electric charges

Maxwell derived a formula for the speed of EM waves:

$$v = c = \frac{E}{B},\qquad (22\text{–}2)$$

where c is the special symbol for the speed of electromagnetic waves in empty space, and E and B are the magnitudes of electric and magnetic fields at the same point in space. More specifically, it was easily shown also that

c is symbol for speed of light

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}.\qquad (22\text{–}3)$$

Speed of EM waves

When Maxwell put in the values for ϵ_0 and μ_0, he found

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = \frac{1}{\sqrt{(8.85 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2})(4\pi \times 10^{-7}\,\mathrm{N \cdot s^2/C^2})}}$$
$$= 3.00 \times 10^8\,\mathrm{m/s},$$

which is equal to the measured speed of light in vacuum.

22–3 Light as an Electromagnetic Wave and the Electromagnetic Spectrum

Maxwell's prediction that EM waves should exist was startling. Equally remarkable was the speed at which EM waves were predicted to travel—$3.00 \times 10^8\,\mathrm{m/s}$, the same as the measured speed of light.

Light had been shown some 60 years before Maxwell's work to behave like a wave (we'll discuss this in Chapter 24). But nobody knew what kind of wave it was. What is it that is oscillating in a light wave? Maxwell, on the basis of the calculated speed of EM waves, argued that light must be an electromagnetic wave. This idea soon came to be generally accepted by scientists, but not fully until after EM waves were experimentally detected. EM waves were first generated and detected experimentally by Heinrich Hertz (1857–1894) in 1887, eight years after Maxwell's death. Hertz used a spark-gap apparatus in which charge was made to rush back and forth for a short time, generating waves whose