8-8 Maxwell's Equations

Electricity in a nutshell

The collection of the basic laws of electricity (Coulomb's law, Ampere's law, and Faraday's law) is known as Maxwell's equations. In Faraday's law $(\overline{E}_L \cdot L)_{\text{closed path}}$ is used in place of emf. As we have seen, it is the induced force on an electric charge which drives the electrons around a circuit. Since force on charge per unit charge is the definition of E, Faraday's law states that an induced electric field must always accompany a changing magnetic field. In this form Eq. 8–21 becomes

$(\overline{E}_L \cdot L)_{C.P.} = \frac{\Delta N_B}{\Delta t}$

$$(\overline{E}_L \cdot L)_{\text{closed path}} = \frac{1}{c}\frac{\Delta N_B}{\Delta t} \qquad (8\text{–}22)$$

Maxwell pondered whether the reverse might not also be true. Should not a changing electric field also produce a magnetic field? If this should be the case, then the equation

$(\overline{B}_L \cdot L)_{C.P.} = \mu_0 I$

$$(\overline{B}_L \cdot L)_{\text{closed path}} = \frac{4\pi I}{c} \qquad (8\text{–}23)$$

would require another term on the right-hand side of the form $1/c(\Delta N_E/\Delta t)$. Maxwell called this new term the displacement current. Maxwell thought of an example which shows that something must be wrong with Eq. 8–23 in its present form. This example and the reasoning that led Maxwell to his displacement current term is given in the Appendix to this chapter.

In summary, Maxwell's equations in noncalculus form are

$N_E = \frac{Q}{\varepsilon_0}$

$$N_E = 4\pi Q \qquad (8\text{–}24)$$

is the total number of lines leaving charge Q

$(\overline{B}_L \cdot L)_{C.P.} = \mu_0 I + \mu_0 \varepsilon_0 \frac{\Delta N_E}{\Delta t}$

$(\overline{E}_L \cdot L)_{C.P.} = -\frac{\Delta N_B}{\Delta t}$

$$(\overline{B}_L \cdot L)_{\text{closed path}} = \frac{1}{c}4\pi I + \frac{1}{c}\frac{\Delta N_E}{\Delta t} \qquad (8\text{–}25)$$

$$(\overline{E}_L \cdot L)_{\text{closed path}} = -\frac{1}{c}\frac{\Delta N_B}{\Delta t} \qquad (8\text{–}26)$$

where the quantities in the right-hand sides of the last two equations are those enclosed by the closed path. These equations must hold for all possible closed paths.