Table 30–2

THREE ELECTRIC VECTORS

Name	Symbol	Associated with	Boundary Condition
Electric field strength	**E**	All charges	Tangential component continuous
Electric displacement	**D**	Free charges only	Normal component continuous
Polarization (electric dipole moment per unit volume)	**P**	Polarization charges only	Vanishes in a vacuum

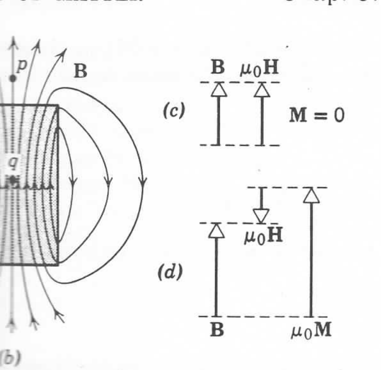
Defining equation for **E**	$\mathbf{F} = q\mathbf{E}$	Eq. 27–2
General relation among the three vectors	$\mathbf{D} = \epsilon_0\mathbf{E} + \mathbf{P}$	Eq. 30–21
Gauss's law when dielectric media are present	$\oint \mathbf{D}\cdot d\mathbf{S} = q$ (q = free charge only)	Eq. 30–24
Empirical relations for certain dielectric materials *	$\mathbf{D} = \kappa\epsilon_0\mathbf{E}$ $\mathbf{P} = (\kappa - 1)\epsilon_0\mathbf{E}$	Eq. 30–22 Eq. 30–23

* Generally true, with κ independent of **E**, except for certain materials called *ferroelectrics*; see footnote on page 758.

30–7 Energy Storage in an Electric Field

In Section 29–6 we saw that all charge configurations have a certain *electric potential energy* U, equal to the work W (which may be positive or negative) that must be done to assemble them from their individual components, originally assumed to be infinitely far apart and at rest. This potential energy reminds us of the potential energy stored in a compressed spring or the gravitational potential energy stored in, say, the earth-moon system.

For a simple example, work must be done to separate two equal and opposite charges. This energy is stored in the system and can be recovered if the charges are allowed to come together again. Similarly, a charged capacitor has stored in it an electrical potential energy U equal to the work W required to charge it. This energy can be recovered if the capacitor is allowed to discharge. We can visualize the work of charging by imagining



ines of **B** for a permanent magnet. the boundary. The closed dashed Ampère's law may be applied. The d for (c) a particular outside point p

dipoles present to be aligned, the in Eq. 37–26 leads to

uum). (37–31)

um must be described by $\kappa_m = 1$. anishes if we put κ_m equal to unity. ter than unity. For diamagnetic shows that this requires **M** and **H** th in Section 37-4. tween **B** and **H** is far from linear, proves to be a function not only f the magnetic and thermal history

s the permanent magnet, for which the magnet even though there is no f **B** and **H** associated with such a ous loops, the boundary condition lines enter and leave the magnet. iated with the *total* current, both und any loop such as that shown iated with a hypothetical magne- e magnet at its surface; actual or gure 37–22*b* shows that **H** reverses -27) is associated with true currents p such as that shown by the dashed

alled *ferroelectrics*, for which the rela- it hysteresis, and from which quasi- ed. However, most commonly useful ly useful magnetic materials are non-

The reversal of **H** at the boundary makes this possible. Note that **M** and **H** point in opposite directions within the magnet. Table 37–1 summarizes the properties of the three vectors **B**, **H**, and **M**.

Table 37–1

THREE MAGNETIC VECTORS

Name	Symbol	Associated with	Boundary Condition
Magnetic induction	**B**	All currents	Normal component continuous
Magnetic field strength	**H**	True currents only	Tangential component continuous †
Magnetization (magnetic dipole moment per unit volume)	**M**	Magnetization currents only	Vanishes in a vacuum

Defining equations for **B**	$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ or $= i\mathbf{l} \times \mathbf{B}$	Eq. 33–3*a* Eq. 33–6*a*
General relation among the three vectors	$\mathbf{B} = \mu_0\mathbf{H} + \mu_0\mathbf{M}$	Eq. 37–26
Ampère's law when magnetic materials are present	$\oint \mathbf{H}\cdot d\mathbf{l} = i$ (i = true current only)	Eq. 37–27
Empirical relations for certain magnetic materials *	$\mathbf{B} = \kappa_m\mu_0\mathbf{H}$ $\mathbf{M} = (\kappa_m - 1)\mathbf{H}$	Eq. 37–29 Eq. 37–30

* For paramagnetic and diamagnetic materials only, if κ_m is to be independent of **H**.
† Assuming no true currents exist at the boundary.

▶ **Example 6.** In the Rowland ring the (true) current i_0 in the windings is 2.0 amp and the number of turns per unit length (n) in the toroid is 10 turns/cm. B, measured by the technique of Section 37–5, is 1.0 weber/meter². Calculate (*a*) H, (*b*) M, and (*c*) the magnetizing current $i_{M,0}$ both when the core is in place and when it is removed. (*d*) For these particular operating conditions, what is κ_m?

(*a*) H is independent of the core material and may be found from Eq. 37–28:

$$H = ni$$

$$= (10 \text{ turns/cm})(2.0 \text{ amp})$$

$$= 2.0 \times 10^3 \text{ amp/meter}.$$