CONCEPTUAL EXAMPLE 17–9 **Inserting a dielectric at constant V.** An airfilled capacitor consisting of two parallel plates separated by a distance d is connected to a battery of voltage V and acquires a charge Q. While it is still connected to the battery, a slab of dielectric material with $K = 3$ is inserted between the plates of the capacitor. Will Q increase, decrease, or stay the same?

RESPONSE Since the capacitor remains connected to the battery, the voltage stays constant and equal to the battery voltage V. The capacitance C increases when the dielectric material is inserted because K in Eq. 17–9 has increased. From the relation $Q = CV$, if V stays constant, but C increases, Q must increase as well. As the dielectric is inserted, more charge will be pulled from the battery and deposited onto the plates of the capacitor as its capacitance increases.

EXERCISE D If the dielectric in Example 17–9 fills the space between the plates, by what factor does (*a*) the capacitance change, (*b*) the charge on each plate change?

CONCEPTUAL EXAMPLE 17–10 **Inserting a dielectric into an isolated capacitor.** Suppose the airfilled capacitor of Example 17–9 is charged (to Q) and then disconnected from the battery. Next a dielectric is inserted between the plates. Will Q, C, or V change?

RESPONSE The charge Q remains the same—the capacitor is isolated, so there is nowhere for the charge to go. The capacitance increases as a result of inserting the dielectric (Eq. 17–9). The voltage across the capacitor also changes—it *decreases* because, by Eq. 17–7, $Q = CV$, so $V = Q/C$; if Q stays constant and C increases (it is in the denominator), then V decreases.

TABLE 17–3 Dielectric constants (at 20°C)

Material	Dielectric constant K	Dielectric strength (V/m)
Vacuum	1.0000	
Air (1 atm)	1.0006	3×10^6
Paraffin	2.2	10×10^6
Polystyrene	2.6	24×10^6
Vinyl (plastic)	2–4	50×10^6
Paper	3.7	15×10^6
Quartz	4.3	8×10^6
Oil	4	12×10^6
Glass, Pyrex	5	14×10^6
Rubber, neoprene	6.7	12×10^6
Porcelain	6–8	5×10^6
Mica	7	150×10^6
Water (liquid)	80	
Strontium titanate	300	8×10^6

* Molecular Description of Dielectrics

Let us examine, from the molecular point of view, why the capacitance of a capacitor should be larger when a dielectric is between the plates. A capacitor whose plates are separated by an air gap has a charge $+Q$ on one plate and $-Q$ on the other (Fig. 17–16a). Assume it is isolated (not connected to a battery) so charge cannot flow to or from the plates. The potential difference between the plates, V_0, is given by Eq. 17–7:

$$Q = C_0 V_0,$$

where the subscripts refer to air between the plates. Now we insert a dielectric between the plates (Fig. 17–16b). Because of the electric field between the capacitor plates, the dielectric molecules will tend to become oriented as shown in Fig. 17–16b. If the dielectric molecules are *polar*, the positive end is attracted to the negative plate and vice versa. Even if the dielectric molecules are not polar, electrons within them will tend to move slightly toward the positive capacitor plate, so the effect is the same. The net effect of the aligned dipoles is a net negative charge on the outer edge of the dielectric facing the positive plate, and a net positive charge on the opposite side, as shown in Fig. 17–16c.

Some of the electric field lines, then, do not pass through the dielectric but instead end on charges induced on the surface of the dielectric as shown in Fig. 17–16c. Hence the electric field within the dielectric is less than in air. That is, the electric field between the capacitor plates, assumed filled by the dielectric, has been reduced by some factor K. The voltage across the capacitor is reduced by the same factor K because $V = Ed$ (Eq. 17–4) and hence, by Eq. 17–7, $Q = CV$, the capacitance C must increase by that same factor K to keep Q constant.

FIGURE 17–16 Molecular view of the effects of a dielectric.