Very high capacitance

Such high capacitance capacitors can be made of "activated" carbon which has very high porosity, so that the surface area is very large; one-tenth of a gram of activated carbon can have a surface area of $100\ m^2$. Furthermore, the equal and opposite charges can exist in an electric "double layer" only about 10^{-9} m thick.

PHYSICS APPLIED

Computer keys

One type of computer keyboard operates by capacitance. As shown in Fig. 17–15, each key is connected to the upper plate of a capacitor. The upper plate moves down when the key is pressed, reducing the spacing between the capacitor plates, and increasing the capacitance (Eq. 17–8: smaller d, larger C). The *change* in capacitance becomes an electric signal that is detected by an electronic circuit.

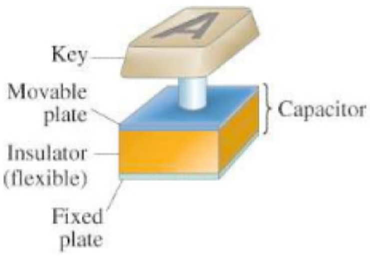

FIGURE 17–15 Key of a computer keyboard. Pressing the key reduces the capacitor spacing, thus increasing the capacitance which can be detected electronically.

EXERCISE C Two circular plates of radius 5.0 cm are separated by a 0.10-mm air gap. What is the magnitude of the charge on each plate when connected to a 12-V battery?

* Derivation of Capacitance for Parallel-Plate Capacitor

Equation 17–8 is readily derived using the result from Section 16–10 on Gauss's law, namely that the electric field between two parallel plates is given by Eq. 16–10:

$$E = \frac{Q/A}{\epsilon_0}.$$

We combine this with Eq. 17–4a magnitudes, $V = Ed$, to obtain

$$V = \left(\frac{Q}{A\epsilon_0}\right)d.$$

Then, from Eq. 17–7, the definition of capacitance,

$$C = \frac{Q}{V} = \frac{Q}{(Q/A\epsilon_0)d} = \epsilon_0 \frac{A}{d}$$

which is Eq. 17–8.

17–8 Dielectrics

In most capacitors there is an insulating sheet of material, such as paper or plastic, called a **dielectric** between the plates. This serves several purposes. First, dielectrics do not break down (allowing electric charge to flow) as readily as air, so higher voltages can be applied without charge passing across the gap. Furthermore, a dielectric allows the plates to be placed closer together without touching, thus allowing an increased capacitance because d is less in Eq. 17–8. Thirdly, it is found experimentally that if the dielectric fills the space between the two conductors, it increases the capacitance by a factor K, known as the **dielectric constant**. Thus, for a parallel-plate capacitor,

Dielectric constant

Parallel-plate capacitor with dielectric

$$C = K\epsilon_0 \frac{A}{d}. \qquad \textbf{(17–9)}$$

This can also be written

$$C = \epsilon \frac{A}{d},$$

where

$$\epsilon = K\epsilon_0$$

is called the **permittivity** of the material.

The values of the dielectric constant for various materials are given in Table 17–3. Also shown in Table 17–3 is the **dielectric strength**, the maximum electric field before breakdown (charge flow) occurs.