* Additional Example—Calculating Charge and Voltage

EXAMPLE 19–11 **Charge and voltage on capacitors.** Determine the charge on each capacitor in Fig. 19–19a of Example 19–10, and the voltage across each, assuming $C = 3.0\,\mu F$ and the battery voltage is $V = 4.0\,V$.

APPROACH We have to work "backward" through Example 19–10. That is, we find the charge Q that leaves the battery, using the equivalent capacitance. Then we find the charge on each separate capacitor and the voltage across each. Each step uses Eq. 17–7, $Q = CV$.

SOLUTION The 4.0-V battery "thinks" it is connected to a capacitance $C_{eq} = \frac{2}{3}C = \frac{2}{3}(3.0\,\mu F) = 2.0\,\mu F$. Therefore the charge Q that leaves the battery, by Eq. 17–7, is

$$Q = CV = (2.0\,\mu F)(4.0\,V) = 8.0\,\mu C.$$

From Fig. 19–19a, this charge arrives at the negative plate of C_1, so $Q_1 = 8.0\,\mu C$. The charge Q that leaves the positive plate is split evenly between C_2 and C_3 (symmetry: $C_2 = C_3$) and is $Q_2 = Q_3 = \frac{1}{2}Q = 4.0\,\mu C$. Also, the voltages across C_2 and C_3 have to be the same. The voltage across each capacitor is obtained using $V = Q/C$. So

$$V_1 = Q_1/C_1 = (8.0\,\mu C)/(3.0\,\mu F) = 2.7\,V$$
$$V_2 = Q_2/C_2 = (4.0\,\mu C)/(3.0\,\mu F) = 1.3\,V$$
$$V_3 = Q_3/C_3 = (4.0\,\mu C)/(3.0\,\mu F) = 1.3\,V.$$

19–6 *RC* Circuits—Resistor and Capacitor in Series

RC circuits

Capacitors and resistors are often found together in a circuit. Such ***RC* circuits** are used to control a car's windshield wipers and the timing of traffic lights; they are used in camera flashes, in heart pacemakers, and many other electronic devices. In *RC* circuits, we are not so interested in the final "steady state" voltage and charge on the capacitor, but rather in how these variables change in time. A simple example is shown in Fig. 19–20a. We now analyze this *RC* circuit.

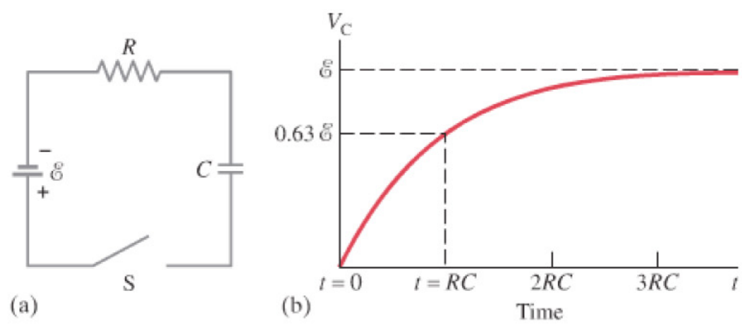

FIGURE 19–20 For the *RC* circuit shown in (a), the voltage across the capacitor increases with time, as shown in (b), after the switch S is closed.

Charging the capacitor

When the switch S is closed, current immediately begins to flow through the circuit. Electrons will flow out from the negative terminal of the battery, through the resistor R, and accumulate on the upper plate of the capacitor. And electrons will flow into the positive terminal of the battery, leaving a positive charge on the other plate of the capacitor. As charge accumulates on the capacitor, the potential difference across it increases $(V = Q/C)$, and the current is reduced until eventually the voltage across the capacitor equals the emf of the battery, $\mathscr{E}$. There is then no potential difference across the resistor, and no further current flow. The potential difference across the capacitor, which is proportional to the charge on the capacitor ($V_C = Q/C$, Eq. 17–7), thus increases in time, as shown in Fig. 19–20b. The actual shape of this curve is a type of exponential. It is given by the formula†

$$V_C = \mathscr{E}\left(1 - e^{-t/RC}\right),$$

where we use the subscript C to remind us that V_C is the voltage across the capacitor and is given here as a function of time t. [The constant e, known as the base for natural logarithms, has the value $e = 2.718\cdots$. Do not confuse this e with e for the charge on the electron.]

CAUTION
Don't confuse e for exponential with e for electron charge

†The derivation uses calculus.