SOLUTION The time constant for this circuit is given by

$$\tau = RC = (120\,\Omega)(35 \times 10^{-6}\,\text{F}) = 4.2 \times 10^{-3}\,\text{s}.$$

After a time t the voltage across the capacitor will be

$$V_C = V_0\left(e^{-t/RC}\right).$$

We want to know the time t for which $V_C = 0.10V_0$. We substitute into the above equation

$$0.10V_0 = V_0 e^{-t/RC}$$

so

$$e^{-t/RC} = 0.10.$$

The inverse operation to the exponential e is the natural log, ln. Thus

$$\ln\left(e^{-t/RC}\right) = -\frac{t}{RC} = \ln 0.10 = -2.3.$$

Solving for t, we find the elapsed time is

$$t = 2.3(RC) = (2.3)\left(4.2 \times 10^{-3}\,\text{s}\right) = 9.7 \times 10^{-3}\,\text{s}$$

or 9.7 ms.

NOTE We can find the time for any specified voltage across a capacitor by using $t = RC\ln(V_0/V_C)$.

EXERCISE E For the same 35-μF capacitor as in Example 19–12, what value of resistance R would produce a voltage reduction to 10% of V_0 in exactly 1.0 s?

CONCEPTUAL EXAMPLE 19–13 **Bulb in *RC* circuit.** In the circuit of Fig. 19–22, the capacitor is originally uncharged. Describe the behavior of the lightbulb from the instant switch S is closed until a long time later.

RESPONSE When the switch is first closed, the current in the circuit is high and the lightbulb burns brightly. As the capacitor charges, the voltage across the capacitor increases and the current is reduced, causing the lightbulb to dim. As the potential difference across the capacitor approaches the same voltage as the battery, the current decreases toward zero and the lightbulb goes out.

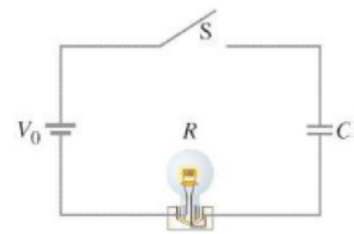

FIGURE 19–22 Example 19–13.

* Medical and Other Applications of *RC* Circuits

The charging and discharging in an RC circuit can be used to produce voltage pulses at a regular frequency. The charge on the capacitor increases to a particular voltage, and then discharges. A simple way of initiating the discharge of the capacitor is by the use of a gas-filled tube which has an electrical breakdown when the voltage across it reaches a certain value V_0. After the discharge is finished, the tube no longer conducts current and the recharging process repeats itself, starting at a lower voltage V_0'. Figure 19–23 shows a possible circuit, and the "sawtooth" voltage it produces.

PHYSICS APPLIED
Sawtooth voltage: blinking flashers

A simple blinker light can be an application of a sawtooth oscillator circuit. Here the emf is supplied by a battery; the neon bulb flashes on at a rate of perhaps 1 cycle per second. The main component of such a "flasher unit" is a moderately large capacitor.

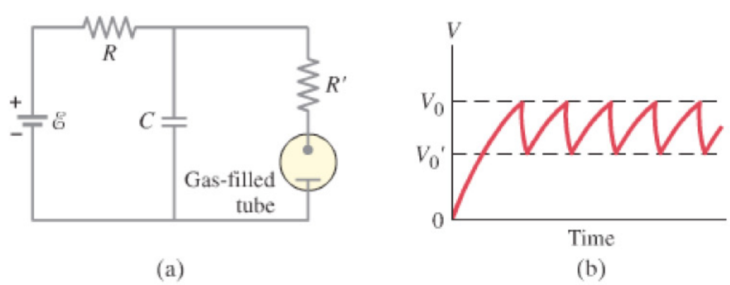

FIGURE 19–23 (a) An RC circuit, coupled with a gas-filled tube as a switch, can produce a repeating "sawtooth" voltage, as shown in (b).