If the secondary coil contains more loops than the primary coil $(N_S > N_P)$, we have a **step-up transformer**. The secondary voltage is greater than the primary voltage. For example, if the secondary coil has twice as many turns as the primary coil, then the secondary voltage will be twice that of the primary voltage. If N_S is less than N_P, we have a **step-down transformer**.

Although ac voltage can be increased (or decreased) with a transformer, we don't get something for nothing. Energy conservation tells us that the power output can be no greater than the power input. A well-designed transformer can be greater than 99% efficient, so little energy is lost to heat. The power output thus essentially equals the power input. Since power $P = IV$ (Eq. 18–5), we have

$$I_P V_P = I_S V_S,$$

or

Transformer equation II

$$\frac{I_S}{I_P} = \frac{N_P}{N_S}. \tag{21–7}$$

EXAMPLE 21–11 Portable radio transformer. A transformer for home use of a portable radio reduces 120-V ac to 9.0-V ac. (Such a device also contains diodes to change the 9.0-V ac to dc, to be like its 9.0-V battery.) The secondary coil contains 30 turns and the radio draws 400 mA. Calculate (*a*) the number of turns in the primary coil, (*b*) the current in the primary, and (*c*) the power transformed.

APPROACH We assume the transformer is ideal, with no flux loss, so we can use Eq. 21–6 and then Eq. 21–7.

SOLUTION (*a*) This is a step-down transformer, and from Eq. 21–6 we have

$$N_P = N_S \frac{V_P}{V_S} = \frac{(30)(120\text{ V})}{(9.0\text{ V})} = 400 \text{ turns.}$$

(*b*) From Eq. 21–7,

$$I_P = I_S \frac{N_S}{N_P} = (0.40\text{ A})\left(\frac{30}{400}\right) = 0.030\text{ A}.$$

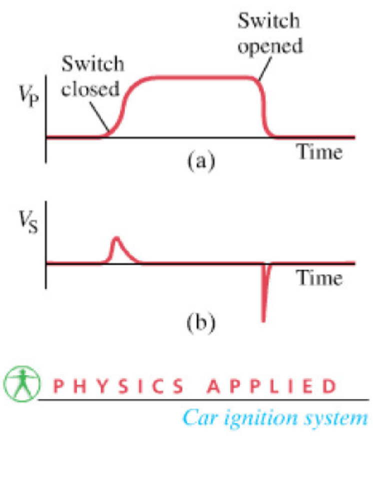
(*c*) The power transformed is

$$P = I_S V_S = (0.40\text{ A})(9.0\text{ V}) = 3.6\text{ W}.$$

NOTE The power in the primary coil, $P = (0.030\text{ A})(120\text{ V}) = 3.6\text{ W}$, is the same as the power in the secondary coil. There is 100% efficiency in power transfer for our ideal transformer.

EXERCISE D How many turns would you want in the secondary coil of the transformer in Example 21–11 $(N_P = 400 \text{ turns})$ if it were to reduce the voltage from 120-V ac to 3.0-V ac?

FIGURE 21–24 A dc voltage turned on and off as shown in (a) produces voltage pulses in the secondary (b). Voltage scales in (a) and (b) are not the same.



PHYSICS APPLIED

Car ignition system

A transformer operates only on ac. A dc current in the primary coil does not produce a changing flux and therefore induces no emf in the secondary. However, if a dc voltage is applied to the primary through a switch, at the instant the switch is opened or closed there will be an induced current in the secondary. For example, if the dc is turned on and off as shown in Fig. 21–24a, the voltage induced in the secondary is as shown in Fig. 21–24b. Notice that the secondary voltage drops to zero when the dc voltage is steady. This is basically how, in the **ignition system** of an automobile, the high voltage is created to produce the spark across the gap of a spark plug that ignites the gas-air mixture. The transformer is referred to simply as an "ignition coil," and transforms the 12 V of the battery (when switched off in the primary) into a spike of as much as 30 kV in the secondary.