CONCEPTUAL EXAMPLE 21–13 **Direction of emf in inductor.** Current passes through the coil in Fig. 21–32 from left to right as shown. (*a*) If the current is increasing with time, in which direction is the induced emf? (*b*) If the current is decreasing in time, what then is the direction of the induced emf?

RESPONSE (*a*) From Lenz's law we know that the induced emf must oppose the change in magnetic flux. If the current is increasing, so is the magnetic flux. The induced emf acts to oppose the increasing flux, which means it acts like a source of emf that opposes the outside source of emf driving the current. So the induced emf in the coil acts to oppose I in Fig. 21–32a. In other words, the inductor might be thought of as a battery with a positive terminal at point A (tending to block the current entering at A), and negative at point B.
(*b*) If the current is decreasing, then by Lenz's law the induced emf acts to bolster the flux—like a source of emf reinforcing the external emf. The induced emf acts to increase I in Fig. 21–32b, so in this situation you can think of the induced emf as a battery with its negative terminal at point A to attract more (+) current to move to the right.

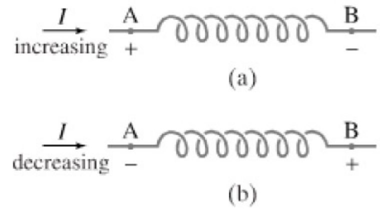

FIGURE 21–32 Example 21–13. The + and − signs refer to the induced emf due to the changing current, as if points A and B were the terminals of a battery (and the coiled loops were the insides of the battery).

EXAMPLE 21–14 **Solenoid inductance.** (*a*) Determine a formula for the self-inductance L of a tightly wrapped solenoid (a long coil) of length l and cross-sectional area A, that contains N turns (or loops) of wire. (*b*) Calculate the value of L if $N = 100$, $l = 5.0\,\text{cm}$, $A = 0.30\,\text{cm}^2$ and the solenoid is air filled.

APPROACH The induced emf in a coil can be determined either from Faraday's law $\left(\mathscr{E} = -N\,\Delta\Phi_B/\Delta t\right)$ or the self-inductance $\left(\mathscr{E} = -L\;\Delta I/\Delta t\right)$. If we equate these two expressions, we can solve for the inductance L since we know how to calculate the flux Φ_B for a solenoid using Eq. 20–8.

SOLUTION (*a*) We equate Faraday's law (Eq. 21–2b) and Eq. 21–9 for the inductance:

$$\mathscr{E} = -N\frac{\Delta\Phi_B}{\Delta t} = -L\frac{\Delta I}{\Delta t},$$

and solve for L:

$$L = N\frac{\Delta\Phi_B}{\Delta I}.$$

We know $\Phi_B = BA$ (Eq. 21–1), and Eq. 20–8 gives us the magnetic field B for a solenoid, $B = \mu_0 NI/l$, so the magnetic flux inside the solenoid is

Calculating self-inductance of a coil

$$\Phi_B = \frac{\mu_0 NIA}{l}.$$

Any change in current, ΔI, causes a change in flux

$$\Delta\Phi_B = \frac{\mu_0 N\,\Delta I\,A}{l}.$$

We put this into our equation above for L:

$$L = N\frac{\Delta\Phi_B}{\Delta I} = \frac{\mu_0 N^2 A}{l}.$$

(*b*) Using $\mu_0 = 4\pi \times 10^{-7}\,\text{T}\cdot\text{m/A}$, and putting in values given,

$$L = \frac{\left(4\pi \times 10^{-7}\,\text{T}\cdot\text{m/A}\right)(100)^2\left(3.0 \times 10^{-5}\,\text{m}^2\right)}{\left(5.0 \times 10^{-2}\,\text{m}\right)} = 7.5\,\mu\text{H}.$$