* 21–9 Inductance

* Mutual Inductance

If two coils of wire are near one another, as in Fig. 21–31, a changing current in one will induce an emf in the other. We apply Faraday's law to coil 2: the emf $\mathscr{E}_2$ induced in coil 2 is proportional to the rate of change of flux passing through it. A changing flux in coil 2 is produced by a changing current in coil 1. So $\mathscr{E}_2$ is proportional to the rate of change of the current in coil 1:

Mutual inductance

$$\mathscr{E}_2 = -M \frac{\Delta I_1}{\Delta t}, \tag{21–8a}$$

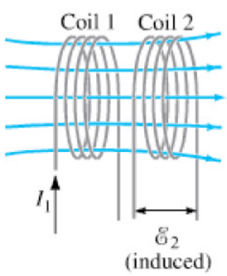


FIGURE 21–31 A changing current in one coil will induce a current in the second coil.

where we assume the time interval Δt is very small, and the constant of proportionality, M, is called the **mutual inductance**. (The minus sign is because of Lenz's law.) Mutual inductance has units of $\mathrm{V \cdot s/A} = \Omega \cdot \mathrm{s}$, which is called the **henry** (H), after Joseph Henry: $1\ \mathrm{H} = 1\ \Omega \cdot \mathrm{s}$.

The mutual inductance M is a "constant" in that it does not depend on I_1; M depends on "geometric" factors such as the size, shape, number of turns, and relative positions of the two coils, and also on whether iron (or other ferromagnetic material) is present. For example, the farther apart the two coils are in Fig. 21–31, the fewer lines of flux can pass through coil 2, so M will be less. If we consider the inverse situation—a changing current in coil 2 inducing an emf in coil 1—the proportionality constant, M, turns out to have the same value,

$$\mathscr{E}_1 = -M \frac{\Delta I_2}{\Delta t}. \tag{21–8b}$$

PHYSICS APPLIED

Pacemaker

A transformer is an example of mutual inductance in which the coupling is maximized so that nearly all flux lines pass through both coils. Mutual inductance has other uses as well, including some types of *pacemakers* used to maintain blood flow in heart patients (Section 19–6). Power in an external coil is transmitted via mutual inductance to a second coil in the pacemaker at the heart. This type has the advantage over battery-powered pacemakers in that surgery is not needed to replace a battery when it wears out.

* Self-Inductance

The concept of inductance applies also to an isolated single coil. When a changing current passes through a coil or solenoid, a changing magnetic flux is produced inside the coil, and this in turn induces an emf. This induced emf opposes the change in flux (Lenz's law); it is much like the back emf generated in a motor. (For example, if the current through the coil is increasing, the increasing magnetic flux induces an emf that opposes the original current and tends to retard its increase.) The induced emf $\mathscr{E}$ is proportional to the rate of change in current (and is in the direction opposed to the change):

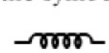
Self-inductance (induced emf for an inductor)

$$\mathscr{E} = -L \frac{\Delta I}{\Delta t}. \tag{21–9}$$

The constant of proportionality L is called the **self-inductance**, or simply the **inductance** of the coil. It, too, is measured in henrys. The magnitude of L depends on the size and shape of the coil and on the presence of an iron core.

Inductors

An ac circuit (Section 18–7) always contains some inductance, but often it is quite small unless the circuit contains a coil of many loops or turns. A coil that has significant self-inductance L is called an **inductor**. It is shown on circuit diagrams by the symbol

. [inductor symbol]