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Electronic Components
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Induction
In 1824, Oersted discovered that current passing through a coil created a magnetic field capable of shifting a compass needle. Seven years later, Faraday and Henry discovered just the opposite. They noticed that a moving magnetic field would induce current in an electrical conductor. This process of generating electrical current in a conductor by placing the conductor in a changing magnetic field is called electromagnetic induction or just induction. It is called induction because the current is said to be induced in the conductor by the magnetic field.
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Faraday also noticed that the rate at which the magnetic field changed also had an effect on the amount of current or voltage that was induced. Faraday's Law for an uncoiled conductor states that the amount of induced voltage is proportional to the rate of change of flux lines cutting the conductor. Faraday's Law for a straight wire is shown below.

\[ V_L = \frac{d\phi}{dt} \]

Where:
\( V_L \) = the induced voltage in volts
\( \frac{d\phi}{dt} \) = the rate of change of magnetic flux in webers/second
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Induction is measured in unit of Henries (H) which reflects this dependence on the rate of change of the magnetic field. One henry is the amount of inductance that is required to generate one volt of induced voltage when the current is changing at the rate of one ampere per second. Note that current is used in the definition rather than magnetic field. This is because current can be used to generate the magnetic field and is easier to measure and control than magnetic flux.
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When induction occurs in an electrical circuit and affects the flow of electricity it is called inductance, $L$. Self-inductance, or simply inductance, is the property of a circuit whereby a change in current causes a change in voltage in the same circuit. When one circuit induces current flow in a second nearby circuit, it is known as mutual-inductance. The image to the right shows an example of mutual-inductance. When an AC current is flowing through a piece of wire in a circuit, an electromagnetic field is produced that is constantly growing and shrinking and changing direction due to the constantly changing current in the wire. This changing magnetic field will induce electrical current in another wire or circuit that is brought close to the wire in the primary circuit. The current in the second wire will also be AC and in fact will look very similar to the current flowing in the first wire.
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An electrical transformer uses inductance to change the voltage of electricity into a more useful level. In nondestructive testing, inductance is used to generate eddy currents in the test piece. It should be noted that since it is the changing magnetic field that is responsible for inductance, it is only present in AC circuits. High frequency AC will result in greater inductive reactance since the magnetic field is changing more rapidly. The property of self-inductance is a particular form of electromagnetic induction.

Self-inductance is defined as the induction of a voltage in a current-carrying wire when the current in the wire itself is changing. In the case of self-inductance, the magnetic field created by a changing current in the circuit itself induces a voltage in the same circuit. Therefore, the voltage is self-induced.
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The term inductor is used to describe a circuit element possessing the property of inductance and a coil of wire is a very common inductor. In circuit diagrams, a coil or wire is usually used to indicate an inductive component. Taking a closer look at a coil will help understand the reason that a voltage is induced in a wire carrying a changing current. The alternating current running through the coil creates a magnetic field in and around the coil that is increasing and decreasing as the current changes. The magnetic field forms concentric loops that surround the wire and join to form larger loops that surround the coil as shown in the image below. When the current increases in one loop the expanding magnetic field will cut across some or all of the neighboring loops of wire, inducing a voltage in these loops. This causes a voltage to be induced in the coil when the current is changing.
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In a circuit, it is much easier to measure current than it is to measure magnetic flux, so the following equation can be used to determine the induced voltage if the inductance and frequency of the current are known. This equation can also be reorganized to allow the inductance to be calculated when the amount of inducted voltage can be determined and the current frequency is known.

\[ V_L = L \frac{di}{dt} \]

Where:
- \( V_L \) = the induced voltage in volts
- \( L \) = the value of inductance in henries
- \( di/dt \) = the rate of change of current in amperes per second
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Lenz's Law
Soon after Faraday proposed his law of induction, Heinrich Lenz developed a rule for determining the direction of the induced current in a loop. Basically,

 LENZ'S LAW STATES THAT AN INDUCED CURRENT HAS A DIRECTION SUCH THAT ITS MAGNETIC FIELD OPPOSES THE CHANGE IN MAGNETIC FIELD THAT INDUCED THE CURRENT.

This means that the current induced in a conductor will oppose the change in current that is causing the flux to change. Lenz's law is important in understanding the property of inductive reactance, which is one of the properties measured in eddy current testing.
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Any current will create a magnetic field, so in fact every current-carrying wire in a circuit acts as an inductor! However, this type of “stray” inductance is typically negligible, just as we can usually ignore the stray resistance of our wires and only take into account the actual resistors. To store any appreciable amount of magnetic energy, one usually uses a coil of wire designed specifically to be an inductor. How much energy does an inductor store? The energy density is proportional to the square of the magnetic field strength, which is in turn proportional to the current flowing through the coiled wire, so the energy stored in the inductor must be proportional to $I^2$. We write $L/2$ for the constant of proportionality, giving

$$E_L = \frac{L}{2} I^2$$
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As in the definition of capacitance, we have a factor of $1/2$, which is purely a matter of definition. The quantity $L$ is called the *inductance* of the inductor, and we see that its units must be joules per ampere squared. This clumsy combination of units is more commonly abbreviated as the henry, $1$ henry = $1$ J/A$^2$. Rather than memorizing this definition, it makes more sense to derive it when needed from the definition of inductance. Many people know inductors simply as “coils,” or “chokes,” and will not understand you if you refer to an “inductor,” but they will still refer to $L$ as the “inductance.”
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Identical inductances in series

If two inductors are placed in series, any current that passes through the combined double inductor must pass through both its parts. Thus by the definition of inductance, the inductance is doubled as well. In general, inductances in series add, just like resistances.

\[ L = L_1 + L_2 \]
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