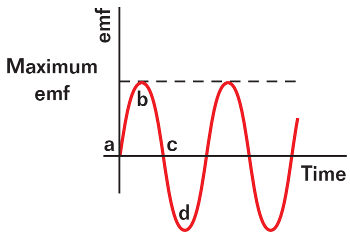

Figure 9
The change with time of the induced emf in a rotating loop is depicted by a sine wave. The letters on the plot correspond to the coil locations in **Figure 8.**

A graph of the change in emf versus time as the loop rotates is shown in **Figure 9.** Note the similarities between this graph and a sine curve. The four locations marked on the curve correspond to the orientation of the loop with respect to the magnetic field in **Figure 8.** At locations *a* and *c,* the emf is zero. These locations correspond to the instants when the plane of the loop is parallel to the direction of the magnetic field. At locations *b* and *d,* the emf is at its maximum and minimum, respectively. These locations correspond to the instants when the plane of the loop is perpendicular to the magnetic field.

The induced emf is the result of the steady change in the angle θ between the magnetic field lines and the normal to the loop. The following equation for the emf produced by a generator can be derived from Faraday's law of induction. The derivation is not shown here because it requires the use of calculus. In this equation, the angle of orientation, θ, has been replaced with the equivalent expression ωt, where ω is the angular frequency of rotation $(2\pi f)$.

$$\text{emf} = NAB\omega \sin \omega t$$

The equation describes the sinusoidal variation of emf with time, as graphed in **Figure 9.**

The maximum emf strength can be easily calculated for a sinusoidal function. The emf has a maximum value when the plane of a loop is parallel to a magnetic field; that is, when $\sin \omega t = 1$, which occurs when $\omega t = \theta = 90°$. In this case, the expression above reduces to the following:

$$\text{maximum emf} = NAB\omega$$

Note that the maximum emf is a function of four things: the number of loops, N; the area of the loop, A; the magnetic field strength, B; and the angular frequency of the rotation of the loop, ω.

ADVANCED TOPICS

See "Angular Kinematics" in **Appendix J: Advanced Topics** to learn more about angular frequency.

Alternating current changes direction at a constant frequency

Note in **Figure 9** that the emf alternates from positive to negative. As a result, the output current from the generator changes its direction at regular intervals. This variety of current is called **alternating current,** or, more commonly, *ac.*

alternating current

an electric current that changes direction at regular intervals

The rate at which the coil in an ac generator rotates determines the maximum generated emf. The frequency of the alternating current can differ from country to country. In the United States, Canada, and Central America, the frequency of rotation for commercial generators is 60 Hz. This means that the emf undergoes one full cycle of changing direction 60 times each second. In the United Kingdom, Europe, and most of Asia and Africa, 50 Hz is used. (Recall that $\omega = 2\pi f$, where f is the frequency in Hz.)

Resistors can be used in either alternating- or direct-current applications. A resistor resists the motion of charges regardless of whether they move in one continuous direction or shift direction periodically. Thus, if the definition for resistance holds for circuit elements in a dc circuit, it will also hold for the same circuit elements with alternating currents and emfs.

extension

Practice Problems

Visit go.hrw.com to find a sample and practice problems for induction in generators.

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