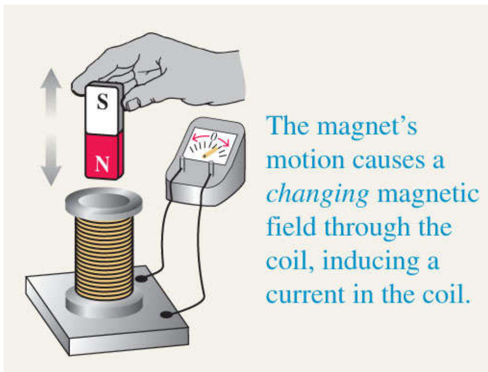
University Physics, 13/e

Young/Freedman

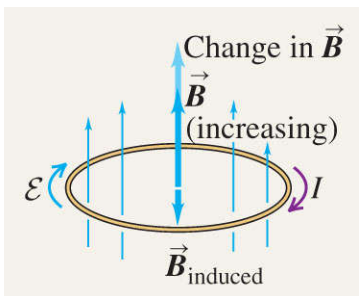
Chapter 29 Summary

1. **Faraday's law:** Faraday's law states that the induced emf in a closed loop equals the negative of the time rate of change of magnetic flux through the loop. This relationship is valid whether the flux change is caused by a changing magnetic field, motion of the loop, or both. (See Examples 29.1–29.6.)

$$\varepsilon = -\frac{d\Phi_B}{dt} \qquad (29.3)$$



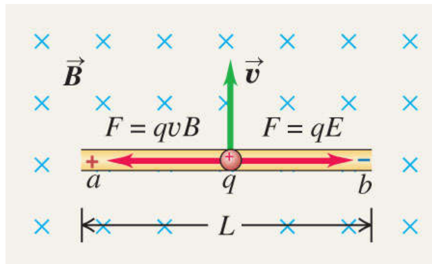
2. **Lenz's law:** Lenz's law states that an induced current or emf always tends to oppose or cancel out the change that caused it. Lenz's law can be derived from Faraday's law and is often easier to use. (See Examples 29.7 and 29.8.)



3. **Motional emf:** If a conductor moves in a magnetic field, a motional emf is induced. (See Examples 29.9 and 29.10.)

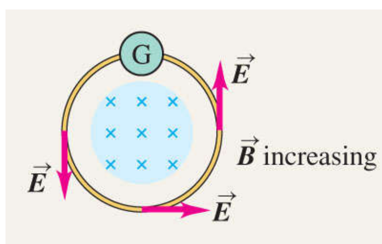
$$\mathcal{E} = vBL \quad \text{(conductor with length } L \text{ moves in uniform } \vec{B} \text{ field, } \vec{L} \text{ and } \vec{v} \text{ both perpendicular to } \vec{B} \text{ and to each other)} \tag{29.6}$$

$$\mathcal{E} = \oint (\vec{v} \times \vec{B}) \cdot d\vec{l} \quad \text{(all or part of a closed loop moves in a } \vec{B} \text{ field)} \tag{29.7}$$



4. **Induced electric fields:** When an emf is induced by a changing magnetic flux through a stationary conductor, there is an induced electric field $\vec{E}$ of nonelectrostatic origin. This field is nonconservative and cannot be associated with a potential. (See Example 29.11.)

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt} \tag{29.10}$$



5. **Displacement current and Maxwell's equations:** A time varying electric field generates a displacement current i_D, which acts as a source of magnetic field in exactly the same way as conduction current. The relationships between electric and magnetic fields and their sources can be stated compactly in four equations, called Maxwell's equations. Together they form a complete basis for the relationship of $\vec{E}$ and $\vec{B}$ fields to their sources.

$$i_D = \epsilon \frac{d\Phi_E}{dt} \quad \text{(displacement current)} \tag{29.14}$$

$$\oint \boldsymbol{E} \cdot d\boldsymbol{A} = \frac{Q_{encl}}{\epsilon_0} \quad \text{(Gauss's law for } \boldsymbol{E} \text{ fields)} \tag{29.18}$$

$$\oint \vec{B} \cdot d\vec{A} = 0 \quad \text{(Gauss's law for } \vec{B} \text{ fields)} \tag{29.19}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left(i_C + \epsilon_0 \frac{d\Phi_E}{dt} \right)_{\text{encl}} \quad \text{(Ampere's law including displacement current)} \tag{29.20}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt} \quad \text{(Faraday's law)} \tag{29.21}$$