13.9: Electromagnetic Induction (Summary)

Key Terms

back emf	emf generated by a running motor, because it consists of a coil turning in a magnetic field; it opposes the voltage powering the motor
eddy current	current loop in a conductor caused by motional emf
electric generator	device for converting mechanical work into electric energy; it induces an emf by rotating a coil in a magnetic field
Faraday's law	induced emf is created in a closed loop due to a change in magnetic flux through the loop
induced electric field	created based on the changing magnetic flux with time
induced emf	short-lived voltage generated by a conductor or coil moving in a magnetic field
Lenz's law	direction of an induced emf opposes the change in magnetic flux that produced it; this is the negative sign in Faraday's law
magnetic damping	drag produced by eddy currents
magnetic flux	measurement of the amount of magnetic field lines through a given area
motionally induced emf	voltage produced by the movement of a conducting wire in a magnetic field
peak emf	maximum emf produced by a generator

Key Equations

Magnetic flux	$\Phi_m = \int_S \vec{B} \cdot \hat{n} dA$
Faraday's law	$\varepsilon = -N \frac{d\Phi_m}{dt}$
Motionally induced emf	$\varepsilon = Blv$
Motional emf around a circuit	$\varepsilon = \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_m}{dt}$
Emf produced by an electric generator	$\varepsilon = NBA\omega sin(\omega t)$

Summary

13.2 Faraday's Law

- The magnetic flux through an enclosed area is defined as the amount of field lines cutting through a surface area A defined by the unit area vector.
- The units for magnetic flux are webers, where $1Wb = 1T \cdot m^2$.
- The induced emf in a closed loop due to a change in magnetic flux through the loop is known as Faraday's law. If there is no change in magnetic flux, no induced emf is created.

13.3 Lenz's Law

- We can use Lenz's law to determine the directions of induced magnetic fields, currents, and emfs.
- The direction of an induced emf always opposes the change in magnetic flux that causes the emf, a result known as Lenz's law.

13.4 Motional Emf

- The relationship between an induced emf εε in a wire moving at a constant speed **v** through a magnetic field **B** is given by $\varepsilon = Blv$.
- An induced emf from Faraday's law is created from a motional emf that opposes the change in flux.

13.5 Induced Electric Fields

- A changing magnetic flux induces an electric field.
- Both the changing magnetic flux and the induced electric field are related to the induced emf from Faraday's law.

13.6 Eddy Currents

- Current loops induced in moving conductors are called eddy currents. They can create significant drag, called magnetic damping.
- Manipulation of eddy currents has resulted in applications such as metal detectors, braking in trains or roller coasters, and induction cooktops.

13.7 Electric Generators and Back Emf

- An electric generator rotates a coil in a magnetic field, inducing an emf given as a function of time by $\varepsilon = NBA\omega sin(\omega t)$ where **A** is the area of an **N**-turn coil rotated at a constant angular velocity ω in a uniform magnetic field $\vec{B}$.
- The peak emf of a generator is $\varepsilon_0 = NBA\omega$.
- Any rotating coil produces an induced emf. In motors, this is called back emf because it opposes the emf input to the motor.

13.8 Applications of Electromagnetic Induction

- Hard drives utilize magnetic induction to read/write information.
- Other applications of magnetic induction can be found in graphics tablets, electric and hybrid vehicles, and in transcranial magnetic stimulation.
