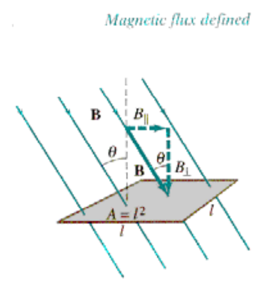
4 – Magnetism

Faraday's Law of Induction



- Quantitative investigation by Faraday yielded
- Magnitude of $\mathscr{E}$ depends on time
- The more rapid change in Magnetic Field, the higher the $\mathscr{E}$
- magnetic flux – fluctuation in B; Φ_B
- $\mathscr{E}$ NOT simply proportional to chaning B, BUT rather changing B through a loop of area A

Faraday's Law of Induction

- $\Phi_B = B \perp A = BA\cos\theta$
- $B \perp$ is the component B perpendicular to *the face of the coil*
- θ is the angle between B and a line drawn $\perp$ the face of the coil
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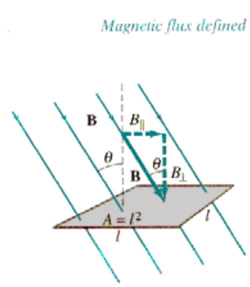
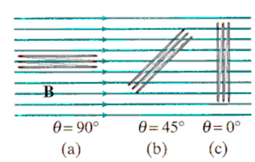


Faraday's Law of Induction

FIGURE 21–4 Magnetic flux Φ_B is proportional to the number of lines of **B** that pass through the loop.

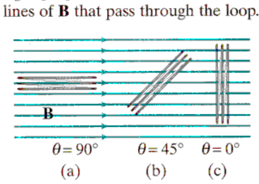


- Given a square coil of side ℓ
  - $A = \ell^2$
- When the face of the coil is parallel to B, $\theta = 90°$ and Φ_B = ZERO
- When B is perpendicular to coil
  - $\theta = 0°$ and $\Phi_B = BA$
  - When $\theta = 0°$, Φ_B is at a MAXIMUM
- Φ_B is proportional to total # of lines passing through coil so when $\theta = 90°$, no lines pass through the coil therefore the flux is ZERO

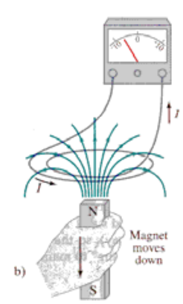
Faraday's Law of Induction

- $\Phi_B = T\bullet m^2$ = Weber = 1 Wb = 1 $T\bullet m^2$
- If the flux through N loops of wire changes by an amount $\Delta\Phi_B$ during a time Δt, the average emf during this time is
- $$\mathscr{E} = -N\frac{\Phi_B}{\Delta t}$$
- **Lenz's law**--The negative sign shows direction. An induced emf ALWAYS gives rise to a current whose B *opposes* the original change in flux.

FIGURE 21–4 Magnetic flux Φ_B is proportional to the number of lines of **B** that pass through the loop.

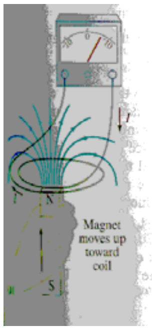


Lenz's Law



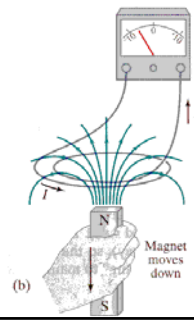
- Move a magnet thru a coil and an emf results therefore a current is produced
- The current produces its own magnetic field

Lenz's Law



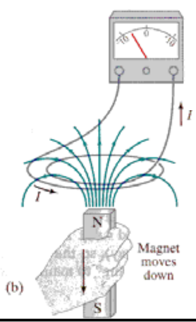
- In a) the distance between the coil and the magnet decreases therefore B and flux through coil increases
- The magnetic field points up while the magnetic field of the induced current points down; opposite to each other!

Lenz's Law



- Lenz's Law tells us that the current moves as shown in b) [move the magnet down and the current reverses and travels up as indicated by the needle moving to the other side of zero]
- "The flux is decreases so the induced current produces and upward magnetic field that is "trying" to keep equilibrium

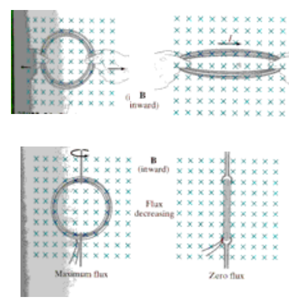
Lenz's Law



- If Lenz's Law was NOT true: Induced emf produces Φ_B in the same direction and current would "grow" to infinity with a power of P=I²R and violate the first law of thermodynamics!
- Therefore Lenz's Law is consistent with the first law of thermodynamics

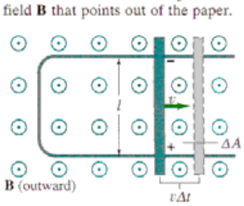
Lenz's Law

- ℰ is induced whenever there is a change in flux
  - $\Phi_B = BA\cos\theta$
- ℰ is induced in THREE ways:
  - ΔB
  - Δ A of loop in field
  - Δ loops orientation with respect to field



ℰ in a Moving Conductor

FIGURE 21–9 A conducting rod is moved to the right on a U-shaped conductor in a uniform magnetic field **B** that points out of the paper.



- Assume a uniform B is ⊥ to area bounded by the U - shaped conductor and the movable rod resting on it.
- The rod moves at a speed **v** travels a distance
  - Δx = v Δ t in a time Δ t
- Area of loop increases
  - Δ A = ℓΔ x = ℓvΔt
- $E = \frac{\Delta\Phi_B}{\Delta t} = \frac{B\Delta A}{\Delta t} = \frac{B\ell v\Delta t}{\Delta t} = B\ell$

ℰ in a Moving Conductor

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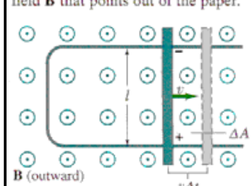

- This works ONLY if B, ℓ, v are mutually perpendicular.
- $E = \frac{\Delta\Phi_B}{\Delta t} = \frac{B\Delta A}{\Delta t} = \frac{B\ell v\Delta t}{\Delta t} = B\ell v$
- IF not mutually perpendicular, simply use the perpendicular components (sin, cos)

ΔB Produces ℰ

- Electrons in a moving conductor feel a force therefore there is an electric field in a conductor
- $\mathcal{E} = \frac{F}{q} = \frac{qvB}{q} = vB$
- Move conductor or move magnetic field–you get an emf either way.