18: Electromagnetism

Key Physics Terms

- **Charge**: A fundamental intrinsic property of matter that gives rise to the attractions and repulsions between electrons and protons.
- **Electron**: A small, light negative particle in the shell of an atom.
- **Current**: Electrical charge flowing past a given point per unit of time.
- **Magnetic Field Lines**: Lines showing the shape and extent of a magnetic field around a permanent magnet or a moving charged object.
- **Magnetic Flux**: A measurement of the number of magnetic field lines passing through a particular area or surface.
- **Faraday's Law**: The voltage induced is directly proportional to the number of loops and the change in the magnetic flux. It is inversely proportional to the time that it takes for the change to occur.
- **Electromotive Force, EMF**: A voltage that gives rise to a current flow. This voltage can be induced or created by a changing magnetic field.
- **Induced current**: The flow of charge in a conductor due to the changing magnetic flux near that conductor.
- **Lenz's Law**: The induced emf always gives rise to a current whose magnetic flux opposes the original change in magnetic flux. Thus, the induced current tries to maintain the level of magnetic flux.
- **Generator**: A machine that produces electricity by a rotating coil of wire immersed in a stationary magnetic field. This rotating motion could be obtained from a variety of sources.
- **Right Hand Rule**: The fingers extend or curl in the direction of the magnetic field. The outstretched thumb points in the direction of conventional current.

Variables Used

- I = current
- Φ_B = magnetic flux
- $\Delta\Phi$ = change in magnetic flux over a period of time
- A = area of surface or loop through which flux flows
- B = Magnetic field strength
- θ = angle between a normal to the surface, and the B field
- ε = induced electromotive force, emf
- N = number of coils of conductor
- Δt = change in time through which B field changes
- v = velocity of a conductor moving in a B field
- L = length of conductor in B field
- V = voltage
- R = resistance

Key Formulas and Constants

- $\Phi_B = BA\cos\theta$
- $A_{circle} = \pi r^2$
- $\varepsilon = -N\Delta\Phi/\Delta t$
- $\varepsilon = BLv$
- $v = d/t$
- $V = I/R$

Typical Key Metric Units

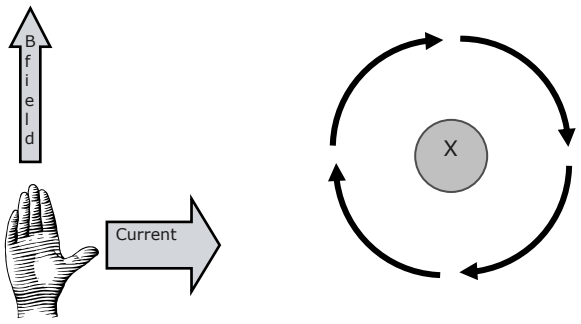
- Current: Amperes, Amp, A
- Magnetic field: Tesla, T
- Magnetic flux: Tm^2, Weber, Wb
- Area: meters squared, m^2
- Length: meters, m
- EMF: volts, V
- Angle: degrees
- Distance or radius: meters, m
- Velocity: meters per second, m/s
- Time: seconds, s
- Resistance, ohms, Ω

Electromagnetism Problem Solving Tips

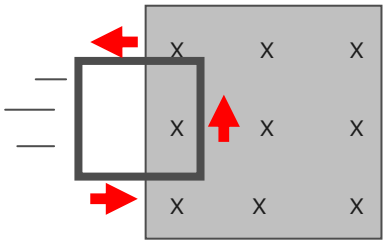
These tips will make it easier to solve any physics problems.

- Thoroughly read the entire problem.
- Draw a diagram if needed.
- Identify all given information.
- Identify the quantity to be found.
- Select appropriate formula(s) that incorporate what you know and what you want to find.
- Be sure to consider the direction of the B field and flux when deciding upon a current direction.
- Convert units if needed.
- Do any mathematical calculations carefully.

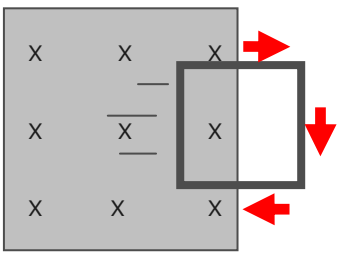
Right Hand Rule Diagrams



Examples of Lenz's Law



Here the conducting loop begins to pass into the magnetic field that goes into the page. An induced emf and current are created. The current flows counterclockwise so that the newly created B field is out of the page so that it opposes the change in the original B field.



Here, as the loop leaves the field, a current flows in the opposite direction because the B field is now decreasing as the loop leaves. The current flows clockwise creating a B field that is into the page, so as to maintain the diminishing flux.

If the loop were continuously immersed in the same constant magnetic field flux, no current would flow since there would be no change in the magnetic field flux. All of these changes can also be quantitatively described by Faraday's law.

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

How to Use This Cheat Sheet: These are the keys related this topic. Try to read through it carefully twice then recite it out on a blank sheet of paper. Review it again before the exams.