Electro Magnetic Induction

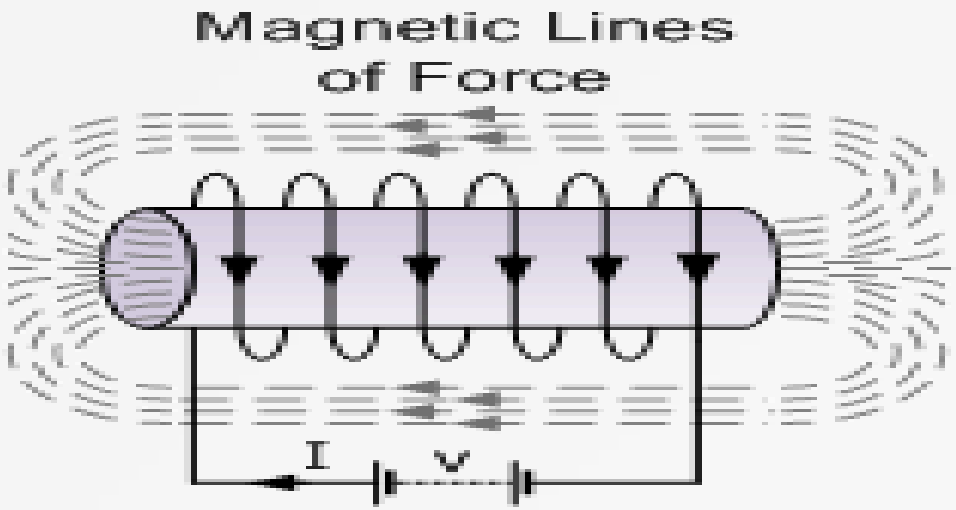
(NEP Semester II - Chapter 5)

Dr. Debojyoti Halder
Department of Physics,
R. B. C. Evening College, Naihati

Introduction

- Electromagnetic or magnetic induction is the production of an electromotive force (emf) across an electrical conductor in a **changing magnetic field.**

- Electromagnetic induction has found many applications, including electrical components such as inductors and transformers, and devices such as electric motors and generators.

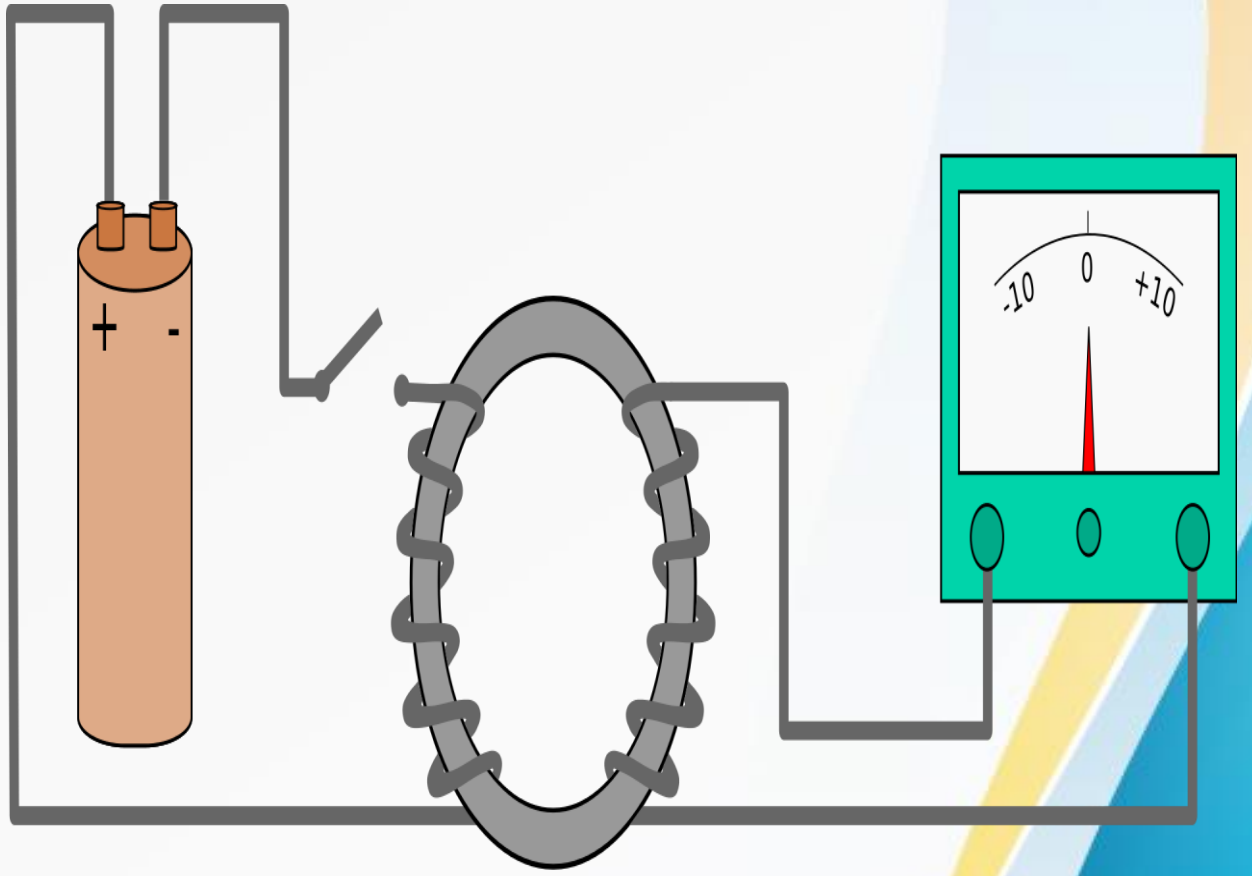


- Electromagnetic Induction is the process of using magnetic fields to produce voltage, and in a complete circuit, a current.

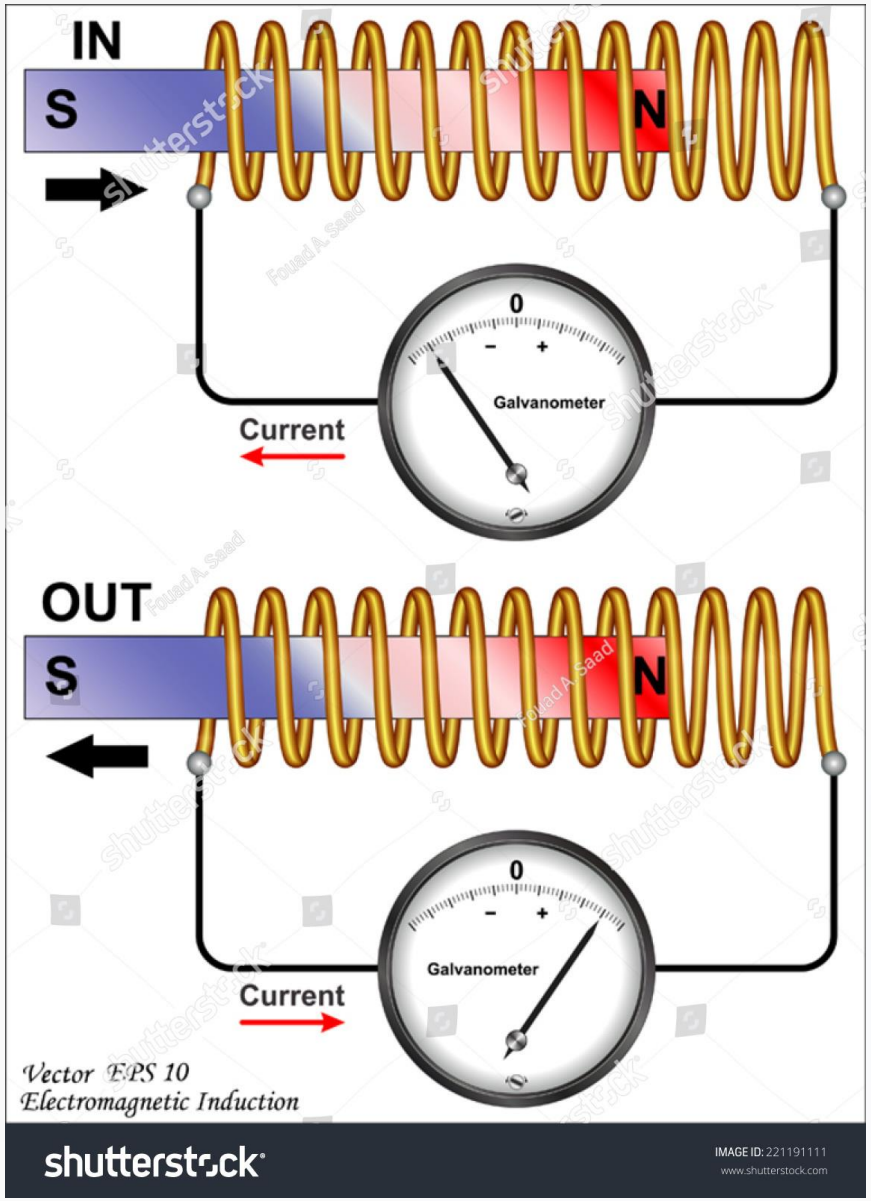
Michael Faraday first discovered it, using some of the works of Hans Christian Oersted. His work started at first using different combinations of wires and magnetic strengths and currents, but it wasn't until he tried moving the wires that he got any success

Electromagnetic Induction

- Almost 200 years ago, Faraday looked for evidence that a magnetic field would induce an electric current with this apparatus



- He found no evidence when the magnet was steady, but did see a current induced when the magnet moves up and down .

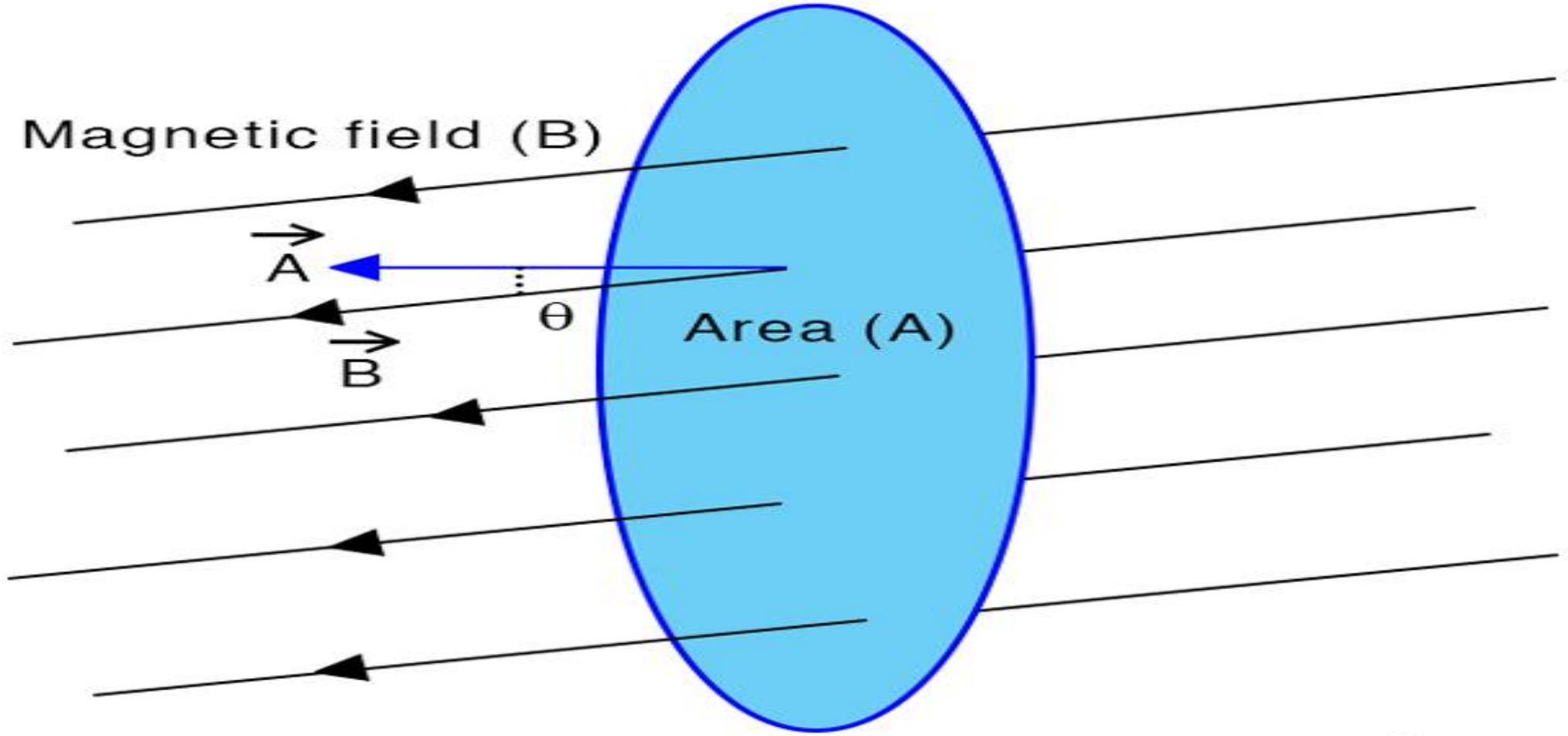


Magnetic Flux:

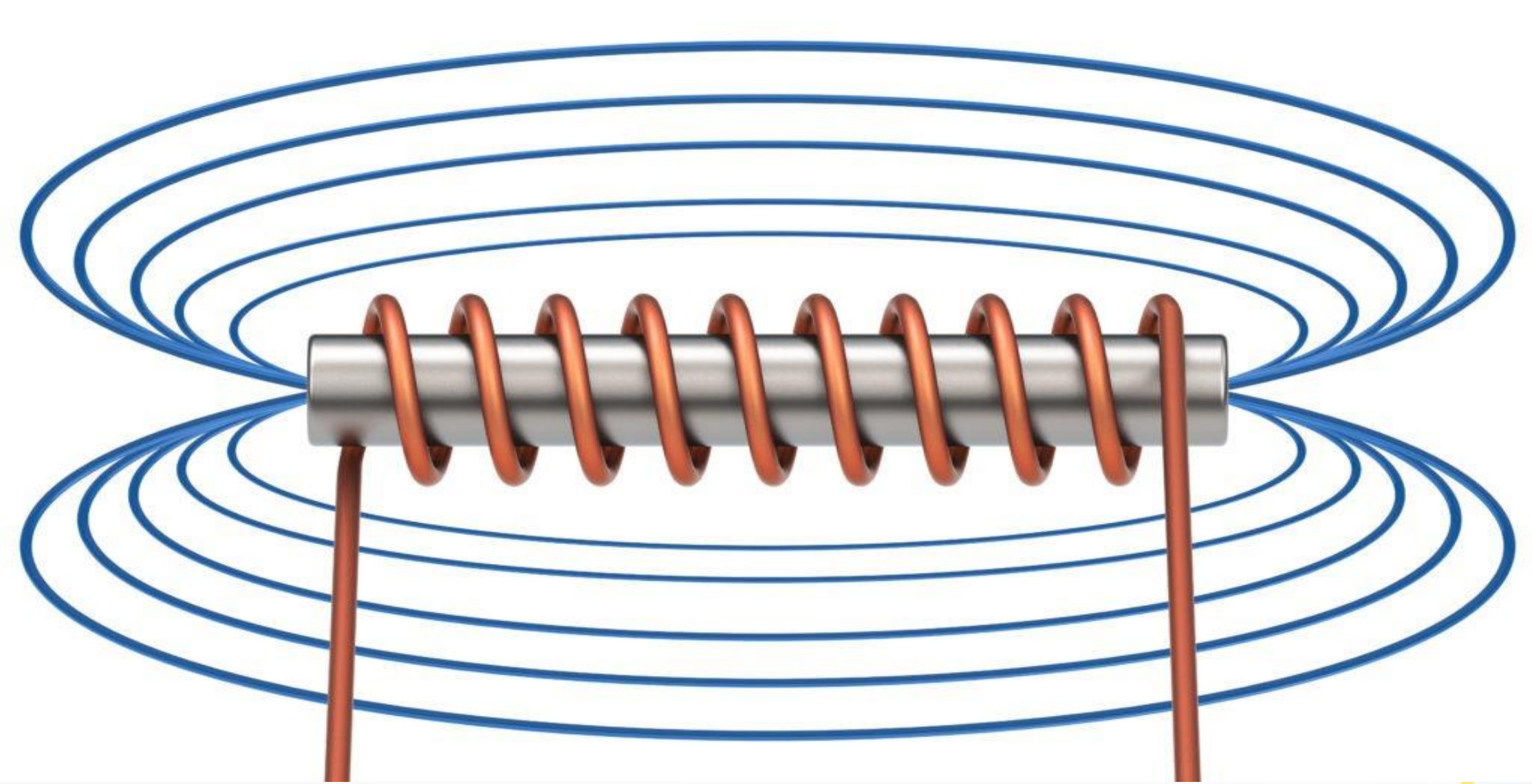
- Magnetic flux is the quantity of magnetic field that penetrates an area at right angles to it.
- Flux is a general term associated with a field that is bound by a certain area
- So Magnetic Flux is any area that has a Magnetic Field passing through it.
- We generally define an area vector as one that is perpendicular to the surface of the material.
- Therefore, you can see in the figure that the area vector and the Magnetic Field vector are parallel.
- This produces a dot product between the 2 variables that then define flux.

Magnetic Flux Equation

$$\text{Flux} = \phi = BA\cos\theta$$



Electro magnetic field



Electromagnetic Induction Faraday's Law

- Faraday's law of electromagnetic induction, also known as Faraday's law, is the basic law of electromagnetism which helps us predict how a magnetic field would interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction.

- Michael Faraday proposed the laws of electromagnetic induction in the year 1831. Faraday's law or the law of electromagnetic induction is the observation or results of the experiments conducted by Faraday. He performed three main experiments (LAWS) to discover the phenomenon of electromagnetic induction.

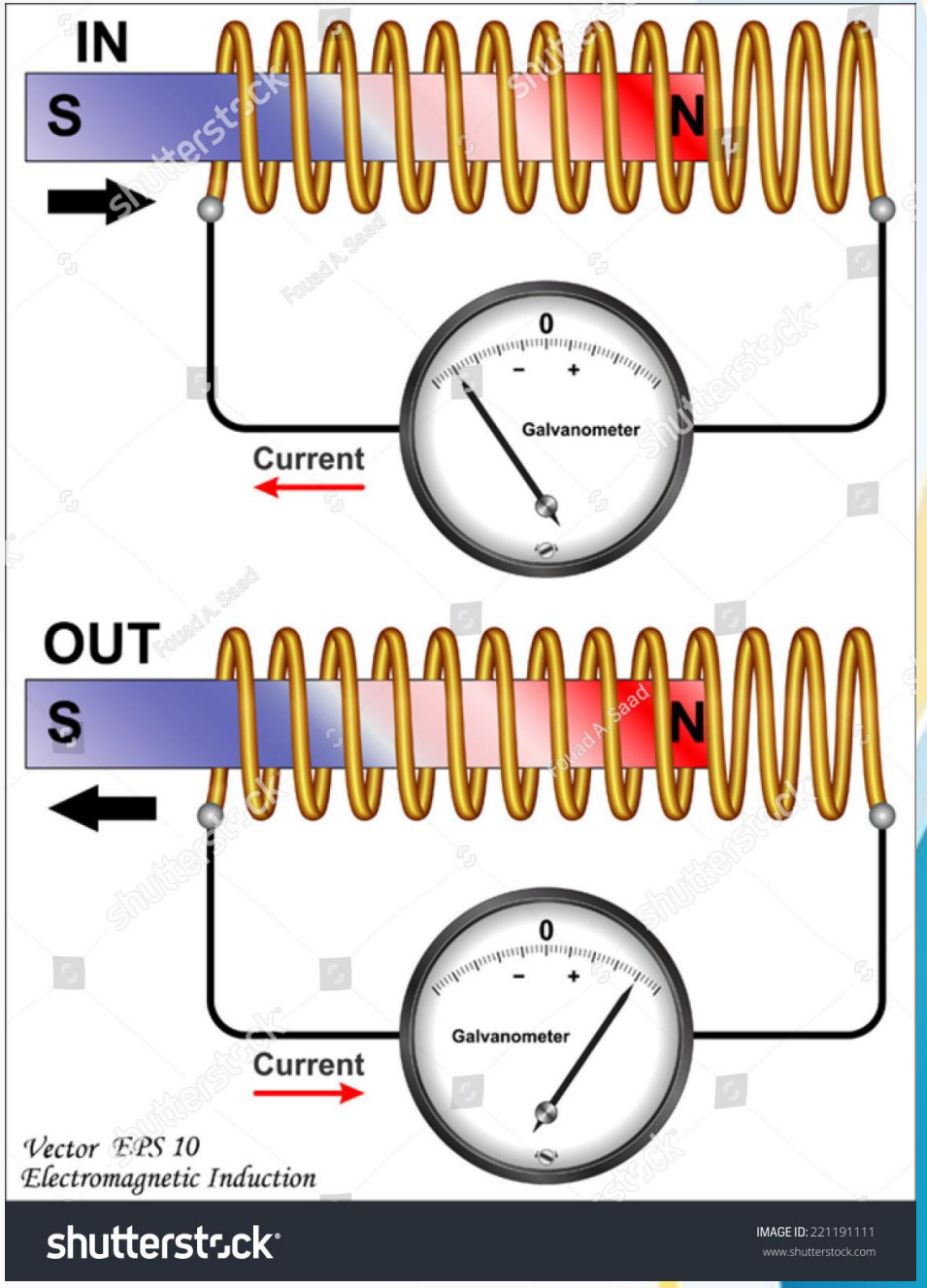
- Faraday’s Law of Electromagnetic Induction
    - Faraday’s First Law of Electromagnetic Induction
    - Faraday’s Second Law of Electromagnetic Induction
- Lenz’s Law
- Faraday’s Law Derivation

Faraday’s First Law of Electromagnetic Induction

- The first law describes the induction of emf in a conductor
- Whenever a conductor is placed in a varying magnetic field, an electromotive force is induced. If the conductor circuit is closed, a current is induced, which is called induced current

Ways to change the magnetic field intensity in a closed loop

- By rotating the coil relative to the magnet.
- By moving the coil into or out of the magnetic field.
- By changing the area of a coil placed in the magnetic field.
- By moving a magnet towards or away from the coil.



Faraday's Second Law of Electromagnetic Induction

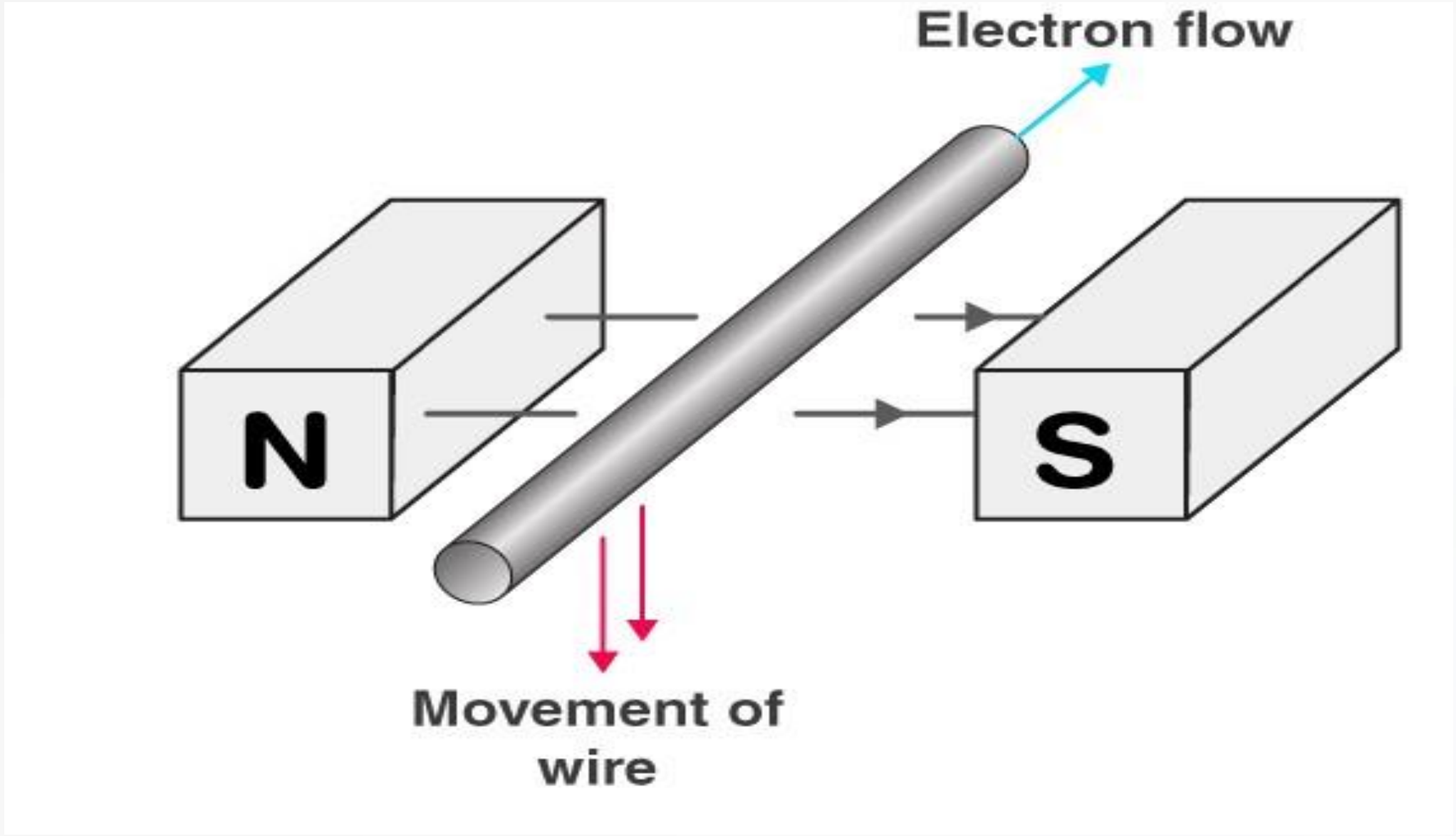
- The induced emf in a coil is equal to the rate of change of flux linkage

- The flux linkage is the product of the number of turns in the coil and the flux associated with the coil. The formula of Faraday's law is given below

$$\mathcal{E} = -N\frac{\Delta\Phi}{\Delta t}$$

Lenz’s Law

- The direction of the emf and thus the current is given by Lenz’s law.
- Use this to find the direction of the current.
- If you are looking down on the loop from above, is the current flowing clockwise or counter clockwise?
- It is the most convenient method to determine the direction of the induced current.


Electron flow
N
S
Movement of wire

- The induced electromotive force with different polarities induces a current whose magnetic field opposes the change in magnetic flux through the loop in order to ensure that the original flux is maintained through the loop when current flows in it

- Lenz's Law is part of Faraday's Law and can help you determine the direction of the current provided you know HOW the flux is changing

Application

- Eddy current balances
- Metal detectors
- Eddy current dynamometers
- Braking systems on train
- AC generators
- Card readers
- Microphones

Electromagnetic Induction Useful Applications

- AC Generators use Faraday's law to produce rotation and thus convert electrical and magnetic energy into rotational kinetic energy.

- This idea can be used to run all kinds of motors. Since the current in the coil is AC, it is turning on and off thus creating a CHANGING magnetic field of its own. Its own magnetic field interferes with the shown magnetic field to produce rotation.

- the magnitude of the induced emf in the conductor is equal to the rate of change of magnetic flux linked to the conductor

- electromagnetic induction, the EMF induced in the conductor is equal to the rate of change of flux linkage

Eddy Current

- Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor according to Faraday’s law of induction. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field.

- Induced electromotive force is produced in the coil when there is a change in the magnetic flux linked with that coil. Eddy currents are named so because the current looks like eddies or whirlpools. When a conductor is placed in the changing magnetic field, the induced current in the conductor is termed as Eddy current