ELECTROMAGNETIC INDUCTION

TOPIC 11.1

Lesson Objectives:

- Describe the production of an induced emf by a changing magnetic flux and within a uniform magnetic field
- Solve problems involving magnetic flux, magnetic flux linkage and Faraday's law
- Explain Lenz's law through the conservation of energy

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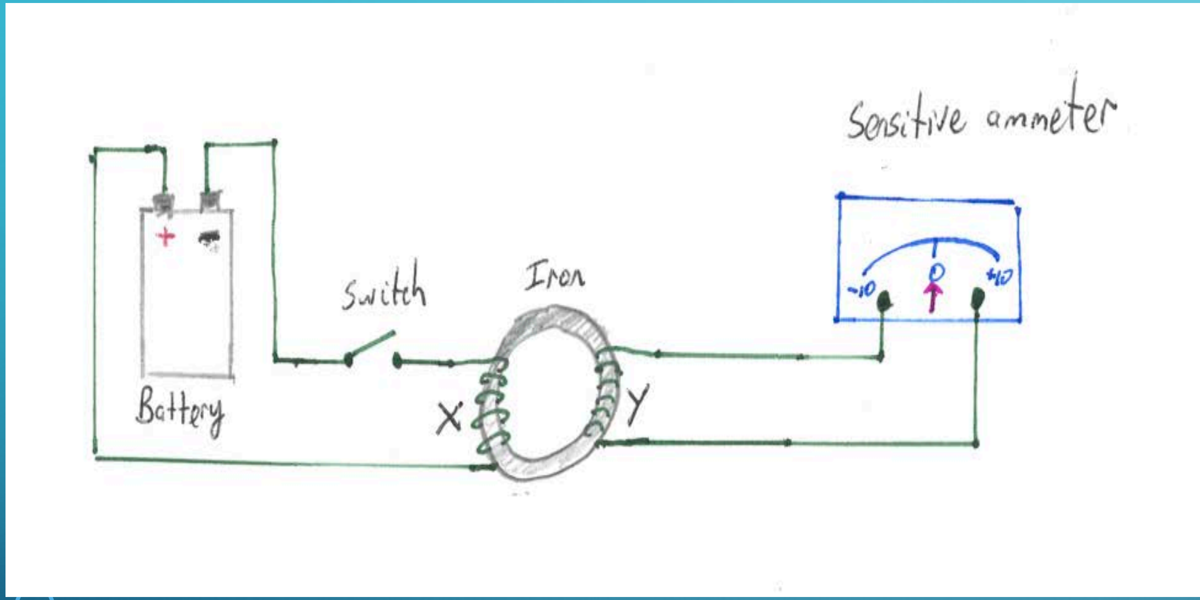
FARADAY'S LAW



- Observe small pulse of current in coil Y only when the current in coil X was switched on or off:

  Current in coil X varies thus producing a changing magnetic field which induces a potential difference (emf) in coil Y.

- Switch is continuously turned on/off:

  Current in coil X is constant which produces a constant (non-zero or zero) magnetic field

- Faraday concluded:

  Induced emf is produced by a

  <u>changing</u> magnetic field

MAGNETIC FLUX

- Before we look in detail at Faraday's law we must first look at 2 concepts, magnetic flux and magnetic flux linkage.

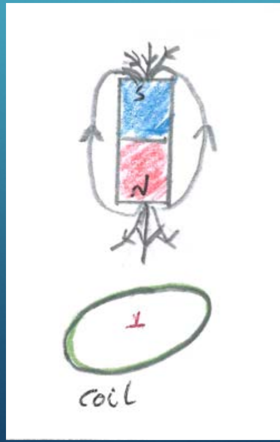
$$\text{magnetic flux} = \text{magnetic flux density} \times \text{area of coil} \times \cos\theta$$

$$\phi = \mathbf{B\ A\ \cos}\ \theta$$

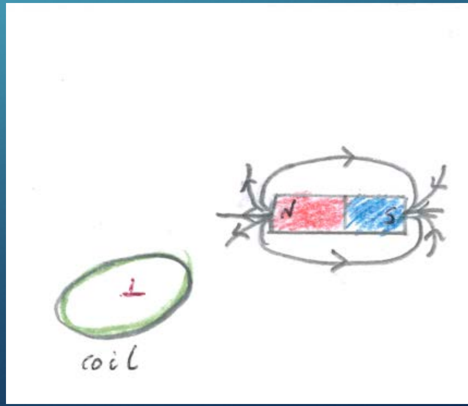
[Unit Webers (Wb); 1 Wb = 1 T m^2]

- θ is the angle between the magnetic field lines and the normal to the surface of a coil:

Max effect



Min effect



MAGNETIC FLUX LINKAGE

- Magnetic flux linkage = number of turns in a coil × magnetic flux

$$= N\,\phi = \mathbf{N\,B\,A\,cos}\,\boldsymbol{\theta}$$

- This leads us to Faraday's law of electromagnetic induction:

the induced emf is proportional to

the rate of change of magnetic flux linkage

- For a coil/conductor with N turns

$$\boldsymbol{\varepsilon} = -\boldsymbol{N}\frac{\boldsymbol{\Delta\phi}}{\boldsymbol{\Delta t}}.$$

A CLOSER LOOK AT FARADAY'S LAW

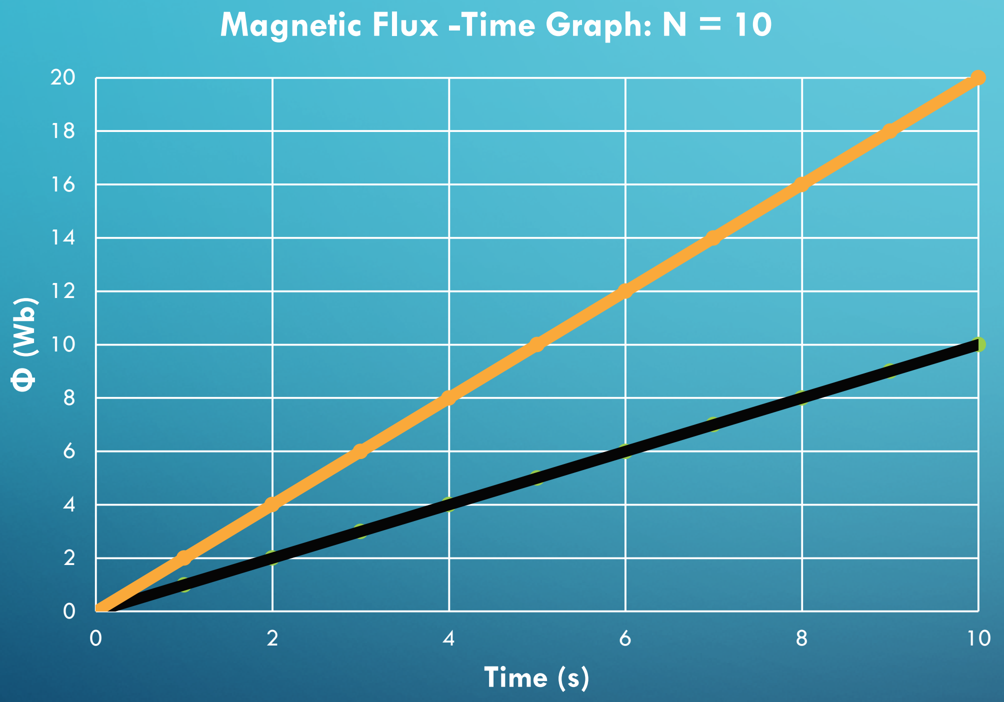
- Meaning of rate of change?

  How a quantity changes with respect to time

- For example, acceleration is the rate of change of velocity, or in this case emf is proportional to the rate of change of $N\,\phi = N\,B\,A\cos\theta$

- What can change? B, A, or θ.

EXAMPLES



- Calculate the magnitude of the induced emf for both cases:

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

N =

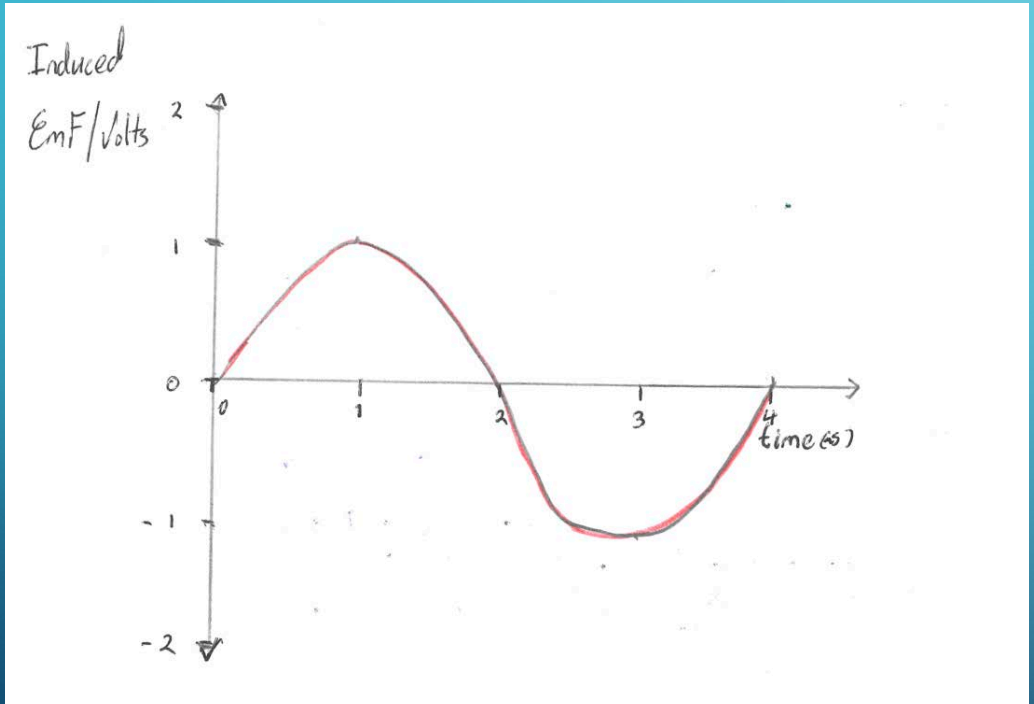
$\frac{\Delta\phi}{\Delta t}$ =

$\frac{\Delta\phi}{\Delta t}$ =

ε =

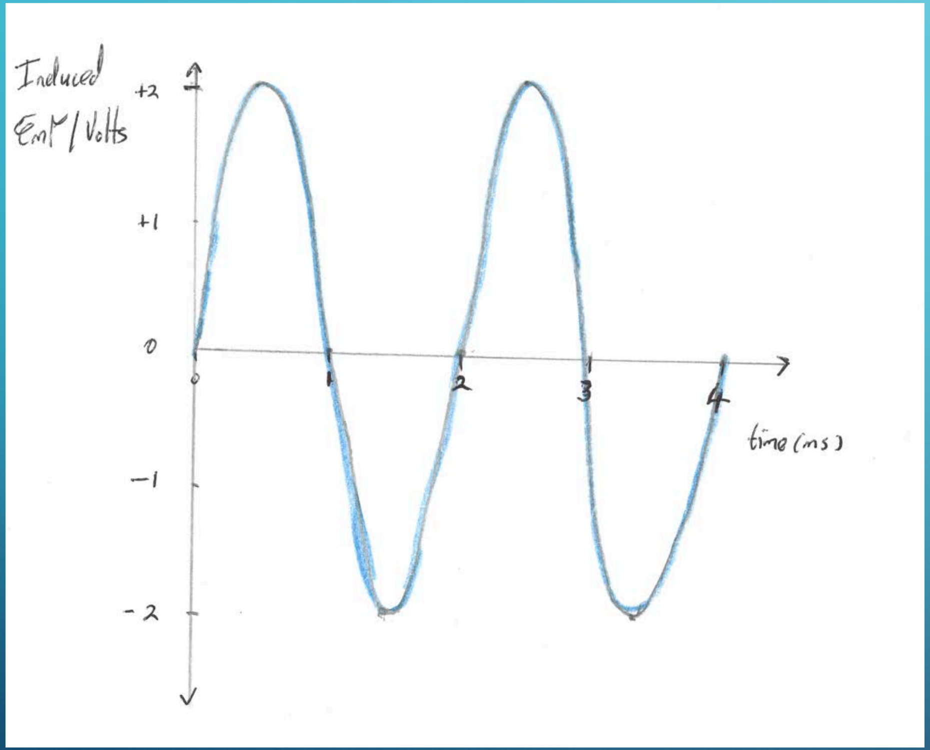
ε =

ANOTHER EXAMPLE WITH A GENERATOR



Speed of rotation	Peak Voltage (V)	Period (ms)	Frequency (Hz)
v			

DOUBLE THE ROTATIONAL SPEED …

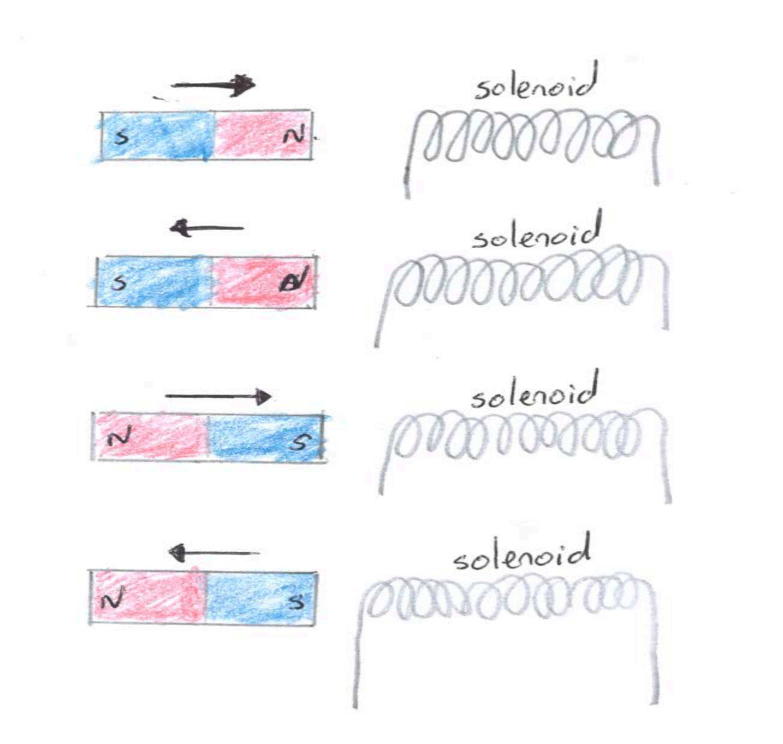


Speed of rotation	Peak Voltage (V)	Period (ms)	Frequency (Hz)
$2v$			

LENZ'S LAW

<< DEMONSTRATION >>

Lenz's law states the direction of the induced emf is such as to tend to oppose the change producing it.



- Lenz's law is equivalent to the law of conservation of energy
- Which end of the solenoid behaves like a North or South magnetic pole?

ONLINE LINKS & SIMULATIONS

Faraday's Law

https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html

Generator

https://phet.colorado.edu/en/simulation/legacy/generator

Lenz's Law

https://www.youtube.com/watch?v=N7tIi71-AjA