

Physics with Synno – Electrical Energy – Lesson 2

EP.3 Lenz's Law

Video: Lenz's law in 2 minutes or less – watch 1st
Lenz's Law with Copper Pipe – watch 2nd
Lenz's Law_ Spinning Neodymium Disk Magnet – watch 3rd
Lenz's Law – watch 4th

Lenz's law helps us work out the direction of the induced current and states that the induced current is in a direction that opposes the change producing it.

i.e. The induced current produces a magnetic field opposing the one producing the current.

Example:

Consider a conductor of length 0.10 m and resistance 0.20 Ω pushed on a rail at a speed of 1.0 ms^{-1} . If it is placed at right angles to a magnetic field of 2.0 T and connected to an external resistance of 1.0 Ω , calculate:

- the magnitude of the EMF produced
- the current through and the potential difference across the external load

Solution

a)
$$\begin{aligned} \text{EMF} &= -BLv \\ &= -2.0 \times 0.10 \times 1.0 \\ &= -0.20 \text{ V} \\ \text{Magnitude is } &0.20 \text{ V} \end{aligned}$$

b)
$$\begin{aligned} &\text{From Ohm's law} \\ V &= I R_{\text{total}} \\ 0.2 &= I \times 1.2 \\ I &= 0.17 \text{ A} \end{aligned}$$

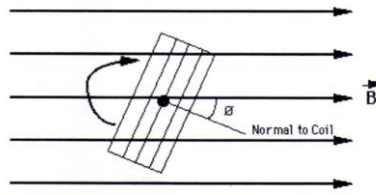
$$\begin{aligned} &\text{Voltage across external} \\ V &= I R \\ &= 0.17 \times 1.0 \\ &= 0.17 \text{ V} \end{aligned}$$

Note: EMF stands for Electromotive force and is measured in Volts.

EP.3.1 Electricity Generation

Video: Generating electricity with coil & magnet

We already know that if a coil of wire is in a magnetic field whose strength is constant, but we change the area of the coil an EMF will also be produced (from Faraday's Law of induction). This can be easily done if the coil is rotating.

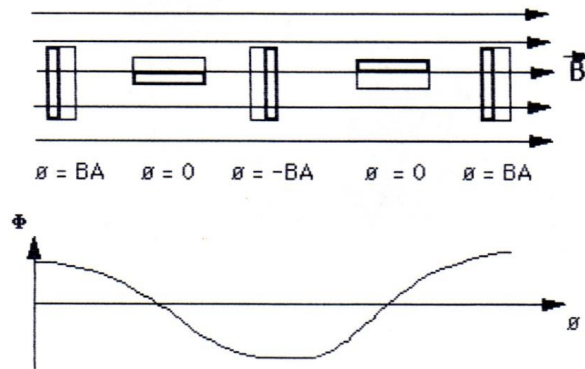


The magnetic flux is given by:

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

where ϕ is the angle between the normal to the coil and the magnetic field.

If we consider four different positions of the coil then the flux will vary as shown below:



From Faraday's Law the EMF induced in N coils is:

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

Thus an alternating EMF is produced.

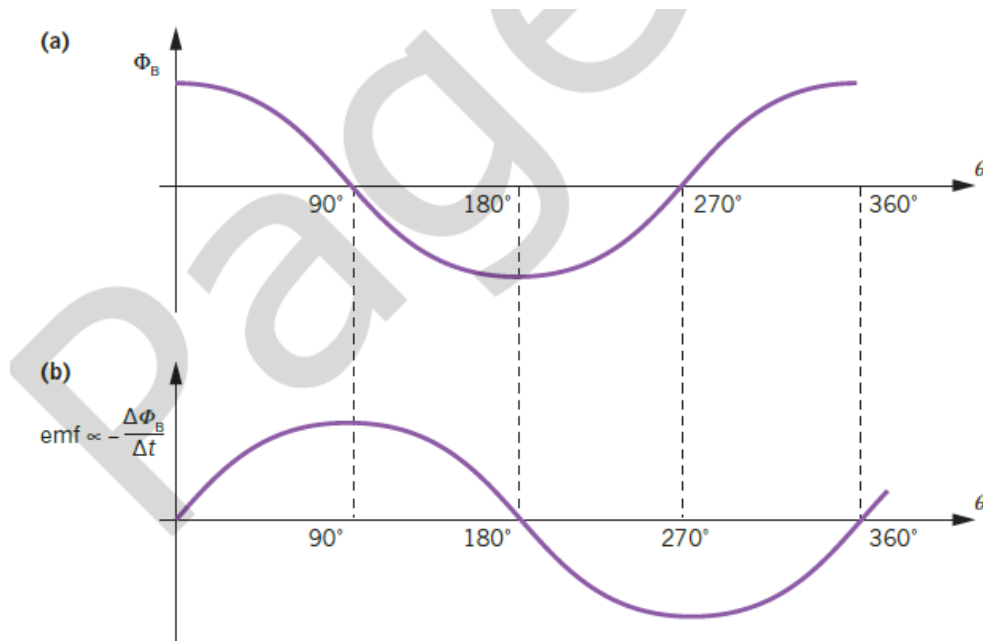
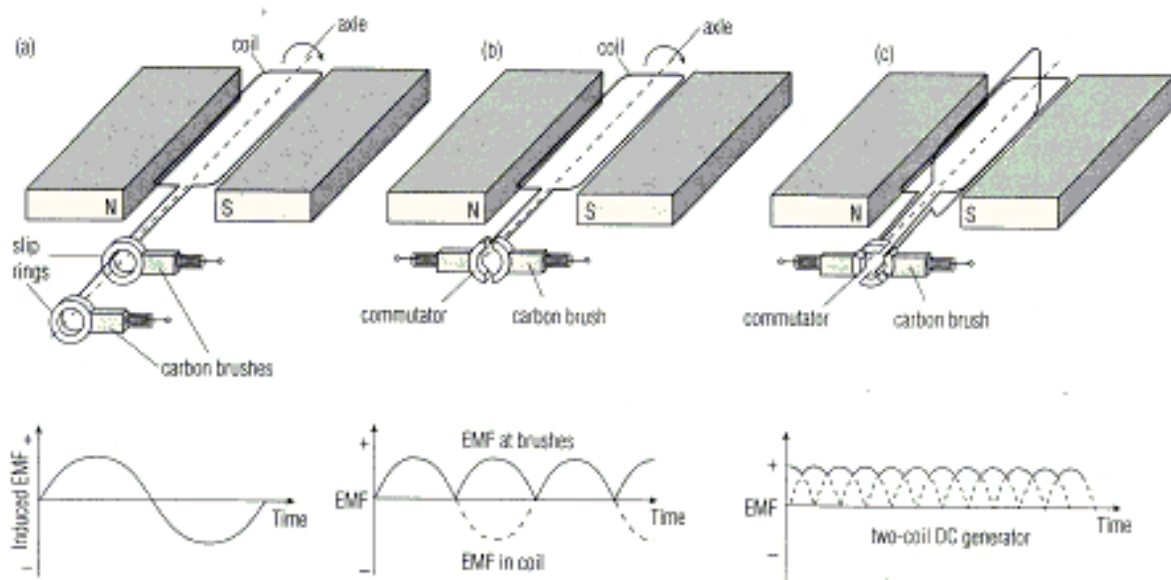


FIGURE 4.3.10 (a) The flux, Φ_B , through the loop of Figure 4.3.9 as a function of the angle between the field and the normal to the plane of the area, θ . (b) The rate of change of flux and hence emf through the loop as a function of the angle between the field and the normal to the plane of the loop, θ . The loop is rotating at a constant speed.

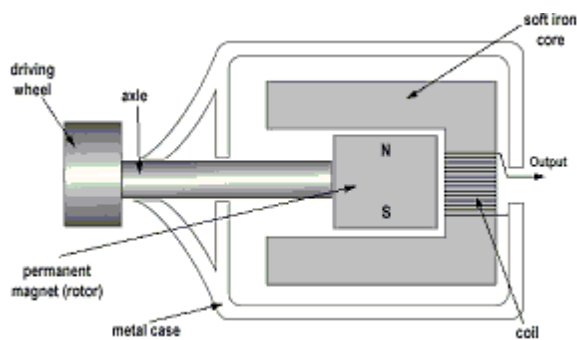
Examples of Generators: AC Generators (Alternators)

An AC generator has a rotating coil in a magnetic field, or a rotating magnetic field positioned inside a coil. Instead of a commutator, slip rings are used to keep contact with the brushes and the direction of the induced emf changes every half cycle and an AC output is produced.

Slip rings are used, where one end of the loop is always attached to the same ring, so that the output varies sinusoidally, i.e. AC output. If a split ring commutator is used the output is DC.



Examples of Generators: Dynamos



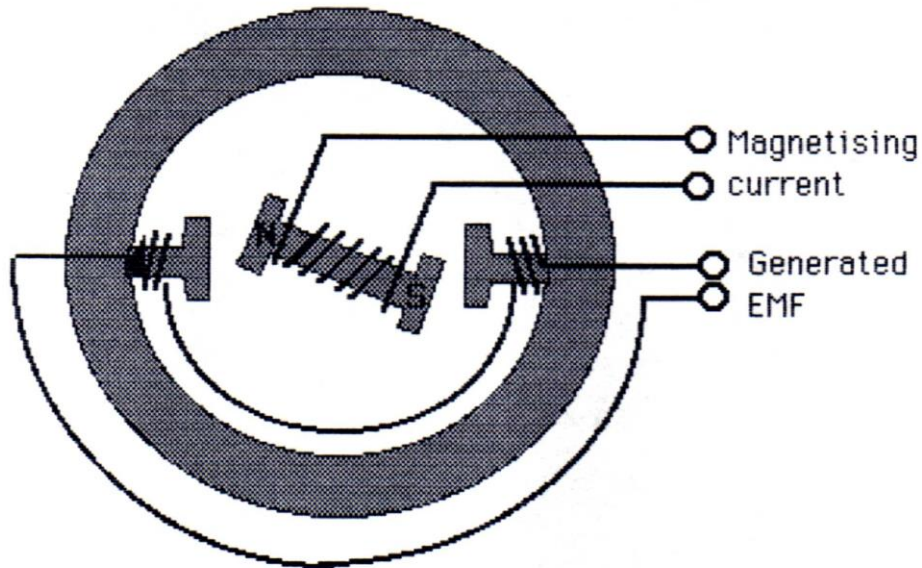
When a simple electric motor is set up so that the magnetic field is present, but the coil is not connected to a source of emf, a current can be generated in the coil by rotating it mechanically.

The direction of the current depends upon the direction of rotation of the coil. The current is direct if a split ring commutator is used for connecting the coil to the meter. The size of the current depends upon the rate of rotation of the coil. The

rotation of the coil induces an emf (ξ) in the coil, giving rise to an induced current through the circuit.

EP.3.2 Generation for the Home

The Power companies produce electricity by rotating a magnet inside a wire coil.



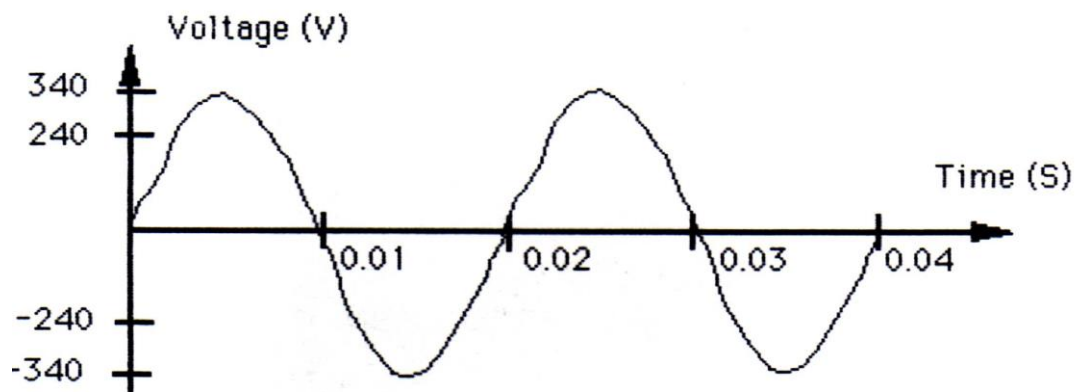
Such a set up produces a current which alternates. An alternating current has two main advantages over DC (direct current) power.

1. Less power lost in transmission
2. Its voltage is easily altered using a transformer.

E.5.4.2 Alternating Current

Alternating current is where the direction of flow of the current continually changes. The number of times the direction changes every second is called frequency. The frequency is governed by the speed of rotation of the generator. In Australia the standard frequency is 50 Hz.

A graph of our domestic power supply, 240 V, 50 Hz AC; varies as follows:



Note: The peak voltage is 340 volts, but the electricity is given the value that corresponds to the power transfer of a 240 V DC battery. This is also known as the root mean square (RMS) value and is calculated as follows:

$$V_{RMS} = \frac{1}{\sqrt{2}} V_{Peak}$$

The **Root Mean Square (RMS)** voltage is the square root of the mean of the square of the potential difference. This complicated value is used because it gives the value of the DC potential difference that has the same heating effect as the alternating potential.

To convert:

RMS to Peak	$\times \sqrt{2}$	Peak to RMS	$\div \sqrt{2}$
Peak to Peak-Peak	$\times 2$	Peak-Peak to Peak	$\div 2$
RMS to Peak-Peak	$\times 2\sqrt{2}$	Peak-Peak to RMS	$\div 2\sqrt{2}$

NOTE:

When doing calculations involving power always use the RMS values, unless otherwise stated.

Example

A 60 W light bulb supplied with 240 V AC uses 60 J every second, but the instantaneous power varies from 0 to 120 W, 100 times every second. Justify this statement.

Solution

The minimum power is obviously zero at the two points in every cycle when the voltage, and therefore the current, is zero. The quoted 60 W is the RMS power. It is obtained as the product of the RMS voltage and RMS current. The RMS voltage is 240 V and so the RMS current is given by:

$$\begin{aligned}
 I_{\text{RMS}} &= P/V_{\text{RMS}} \\
 &= 60 \div 240 \\
 &= 0.25 \text{ A}
 \end{aligned}$$

The peak power is given by:

$$\begin{aligned}
 P_{\text{p}} &= I_{\text{p}}V_{\text{p}} \\
 &= \sqrt{2} I_{\text{RMS}} \times \sqrt{2} V_{\text{RMS}} \\
 &= 2 I_{\text{RMS}} V_{\text{RMS}} \\
 &= 2 \times 0.25 \times 240 \\
 &= 120 \text{ W}
 \end{aligned}$$

Text Questions: Text Page 130 Ex 4.3 All Questions