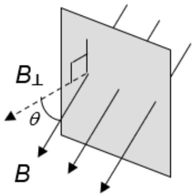
ELECTROMAGNETIC INDUCTION

Magnetic flux ϕ : Magnetic flux through a plane surface is the product of the flux density normal to the surface and the area of the surface.

$\phi = B_\perp A$; $[\phi]$ = weber Wb = T m^2
where
$B_\perp$ = component of B perpendicular to the surface plane,
A = area of the plane



Magnetic flux linkage $N\phi$: Magnetic flux linkage through a coil of N turns is the product of the number of turns N of the coil and the magnetic flux ϕ linking each turn.

$N\phi = N B_\perp A$

Magnetic flux density ***B*** is a **vector**;
Magnetic flux ϕ is a **scalar**.

Faraday's Law of Electromagnetic Induction states that the induced e.m.f. ε is directly proportional to the rate of change of magnetic flux linkage.

$$\varepsilon = -\frac{d(N\phi)}{dt}$$

-ve sign in the expression is due to Lenz's law

$$\varepsilon = -\frac{Nd\Phi}{dt} = -\frac{NAdB}{dt} = -\frac{NAkdI}{dt}$$

The ε vs t graph is thus the negative of of the gradient of ϕ vs t, B vs t, or I vs t graph (if N and A are constant).

For constant or average induced e.m.f.:
$|\varepsilon| = (\Delta N\phi) / (\Delta t)$

e.m.f. can be induced even when there is no induced current (eg. an isolated conductor not in a complete circuit).

Lenz's law states that the direction of the induced e.m.f. is such as to cause effects to oppose the change producing it.

Lenz's law is a statement of the **conservation of energy** where mechanical energy is converted to electrical energy.

Lenz's law allows the polarity of induced e.m.f. and direction of induced current to be determined.

3-step for closed loop

1) Direction of flux linkage? Change? Due to?

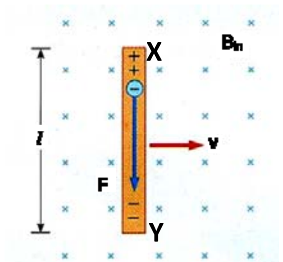
a. What is the direction of the magnetic flux linkage through the loop?
b. Magnetic flux linkage increasing or decreasing?
c. Cause of the change in magnetic flux linkage?
   - Flux density B increase/decrease?
   - Area A increase/decrease?
   - Angle θ of plane of loop to magnetic field changing?

2) Apply Faraday's Law → how magnetic flux linkage changes → e.m.f. induced.
If the loop is a closed circuit, the induced e.m.f. causes an induced current to flow.

3) Apply Lenz's Law to determine the direction of induced current -> The induced current flows in a (direction) so as to produce the (effect) to oppose the (change) in magnetic flux linkage.

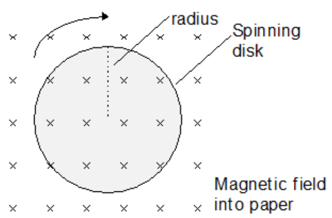
Examples of induced e.m.f.

1) Moving rod: $|\varepsilon| = B\ell v$

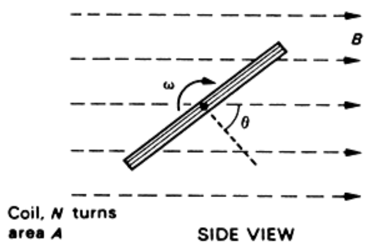


X has a HIGHER potential,
Y has a LOWER potential

2) Spinning disc: $|\varepsilon| = B\pi r^2 f$



3) Rotating coil: $|\varepsilon| = NBA\omega \sin(\omega t)$



Eddy (induced) currents, generated within thick/broad piece of conductor, dissipate energy and create magnetic fields that tend to oppose the changes in the magnetic field.