Phys 132 2022

Lecture 27

Weds: Discussion / quiz Ex 155, 157, 160, 161
162, 163, 164

Thurs: Warm Up 10

Magnetic flux

We have observed that a time varying magnetic field can generate a current in a loop. We can quantify how the magnetic field changes via the magnetic flux through the loop. Then

For a uniform magnetic field and a plane loop, the flux is

$$\Phi_m = AB\cos\theta$$

where $A =$ area of loop

$B =$ magnitude of field (positive)

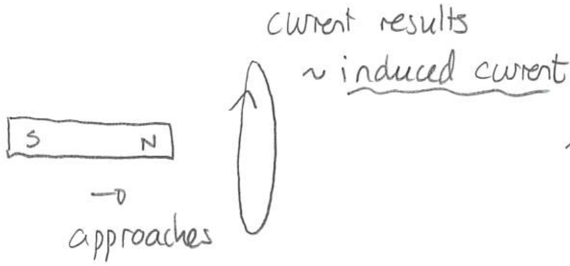
$\theta =$ angle between normal to the loop and field.

When the field through the loop changes as time passes then the flux will change with time

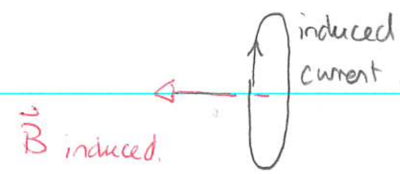
$$\underbrace{\text{smaller field} \Rightarrow \text{smaller } \Phi_m \qquad \text{larger field} \Rightarrow \text{larger } \Phi_m}_{\text{during process } \Phi_m \text{ changes with time.}}$$

Observations indicate that the changing field will produce a current - this is called an induced current.

Then:



~> The induced current produces another magnetic field, called the induced field.



Lenz's Law

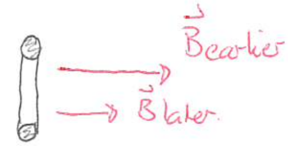
There is a law that describes the direction of the induced current. This is Lenz's Law:

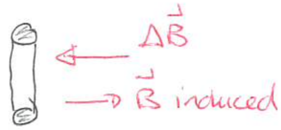
> There will be an induced current in a loop only if the magnetic flux through the loop changes with time. The direction of the induced current is such that the induced magnetic field that it produces opposes the change in the external magnetic flux

Quiz 1 30% → 90%

These can be analyzed via a side view through a cross section of the loop.

1) sketch external field / flux at an earlier instant
2) sketch " " " " a later "
3) determine change in field $\Delta\vec{B} = \vec{B}_{earlier} - \vec{B}_{later}$
4) then $\vec{B}_{induced}$ is opposite to $\Delta\vec{B}$
5) use r.h.rule to determine current that gives $\vec{B}$ induced.





Quiz 2 50% → 90%

Demo: Eddy current tube.

Quiz 3 80%

Demo: Shooting ring.

Faraday's Law

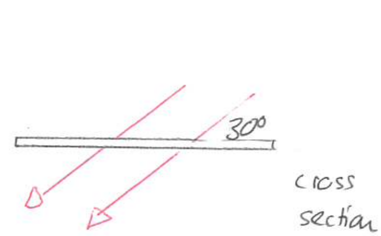
Lenz's law gives a rule that determines the direction of an induced current. We need a law that will give the magnitude of the induced current. The conceptual scheme will be

Flux through loop changes with time $\Phi_m(t)$ → Determine EMF, a type of potential difference around the loop → $\mathcal{E}$ → Current via Ohm's Law $I = \mathcal{E}/R$ where R = resistance of loop

The crucial piece is Faraday's Law

> If the flux through a loop changes with time then the induced EMF has magnitude
>
> $$\mathcal{E} = \left| \frac{d\Phi_m}{dt} \right|$$

Example: A plane loop with area A lies in a uniform magnetic field. The field initial has magnitude B_i and this decreases at a constant rate to B_f in time Δt.



a) Determine an expression for the magnitude of the induced EMF

b) Suppose that the loop is a circle with radius 0.15m and the field drops from 8.0×10^{-4}T to 3.0×10^{-4}T in 4.0μs. Determine the EMF.

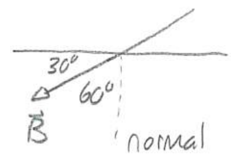
<u>Answer:</u> a) $\mathcal{E} = \left| \frac{d\Phi_m}{dt} \right|$

Since the field decreases at a constant rate.

$$\left| \frac{d\Phi_m}{dt} \right| = \left| \frac{\Delta\Phi_m}{\Delta t} \right|$$

Now $\Phi_m = AB\cos\theta$ and here $\theta = 60°$

$$\Phi_m = AB\cos 60°$$



$$\Rightarrow \Delta\Phi_m = \Delta(AB\cos 60°)$$

$$= A(\Delta B)\cos 60°$$

So

$$\mathcal{E} = \left| \frac{A\,\Delta B\cos 60°}{\Delta t} \right| = A\left| \frac{\Delta B}{\Delta t} \right| \cos 60° = A\left| \frac{B_f - B_i}{\Delta t} \right| \cos 60°$$

b) $A = \pi r^2 \Rightarrow \mathcal{E} = \pi r^2 \left| \frac{B_f - B_i}{\Delta t} \right| \cos 60°$

$$= \pi \times (0.15\,m)^2 \left| \frac{3.0\times10^{-4}T - 8.0\times10^{-4}T}{4.0\times10^{-6}s} \right| \cos 60°$$

$$= 4.4\ V$$

Quiz 4.