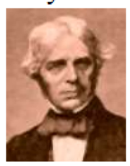
Lesson 5
Electromagnetic Induction

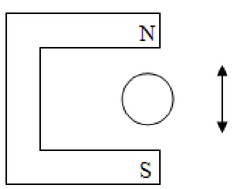
If current in a conductor can create a magnetic field (as discovered by Oersted) can a magnetic field create current? In 1831, Michael Faraday discovered an answer to this question.



Faraday's law of electromagnetic induction states that whenever the magnetic field in the region of a conductor changes relative to the conductor, then electric current is induced in the conductor.

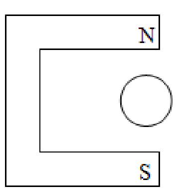
Consider:

i)



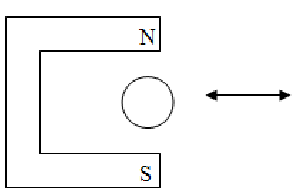
When the wire is moved up and down, no current is produced in the wire.

ii)



When the wire is moved into and out of the page, no current is produced in the wire.

iii)



When the wire is moved back and forth, a current is produced in the wire.

In order for current to be produced the wire must cut across the magnetic field lines of the permanent magnet. Relative to the wire the magnetic field must be changing. The current produced as a result of this relative motion is called an **induced current**. We could also hold the wire stationary and move the magnet, or we could change the size of the magnetic field around a stationary wire.

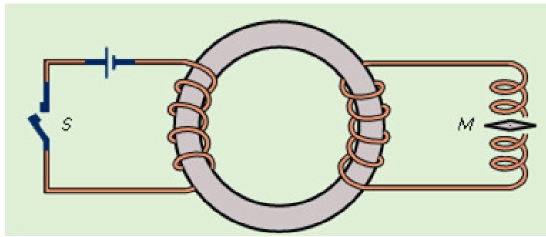
Simulation:
http://phet.colorado.edu/simulations/sims.php?sim=Faradays_Law#ideas

Faraday's Ring

Figure 1

Faraday found that when he passed an electric current through one coil, he induced an electric current in the other coil which flowed for a very brief period of time.

Primary circuit



Secondary circuit

Faraday observed:

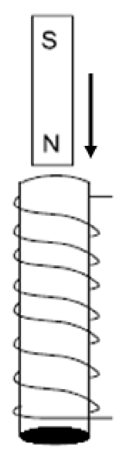
- At the instant the primary switch was opened or closed there was a current detected in the secondary circuit.
- When the switch is closed the magnetic field lines created around the primary circuit expand out and cut across the wires of the secondary circuit, thus inducing a current in one direction.
- When the field stops expanding the current is 0 in the secondary circuit.
- When the switch is opened, the magnetic field starts to collapse and current is again induced in the secondary circuit but in the opposite direction.
- Current is only induced in the secondary circuit at the opening and closing of the switch.
- To determine the direction of induced currents we use **Lenz's law.**

Lenz's Law:
Heinrich Lenz first explained the direction of the current induced by a changing magnetic field.

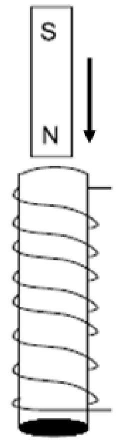
Consider the apparatus below:

According to Faraday, a current will be induced in the wire because the magnet is moving relative to the wire.

Lenz's Law:
For a current induced in a conductor by a changing magnetic field, the induced current is in such a direction that its own magnetic field opposes the change that produced it.



Example:
What is the direction of the induced current in the diagram shown?

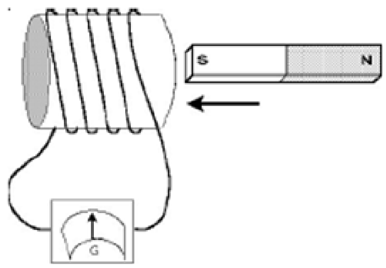


Solution:
The motion or change inducing the current is the downward direction of the magnet. To oppose this the top of the coil would have to be a N pole. Thus induced current would have to be in a clockwise direction when viewed from above.

If current were induced in a counterclockwise direction in this case, the law of conservation of energy would be violated. A ccw induced current would mean the top of the coil were a south pole which would attract the north pole of the magnet. This would increase its speed, leading to more induced current and so on. This would mean that electrical energy were being produced with no effort.

Note: Moving the magnet into and out of the coil continuously causes the induced current to change direction. A current that has electrons moving back and forth is called alternating current (AC).

Example:
What is the direction of the induced current?



Example:
In the diagram shown, what is the direction of induced current in the secondary circuit at the instant the switch is closed?

Induced current is affected by:

1. The relative speed between the magnetic field and the coil (more speed = more current).
2. The orientation of the magnetic field (determines direction of current).
3. The strength of the magnetic field (more strength = more current).
4. Time (faster time = more current)

CORE LAB 6 (p. 691)