

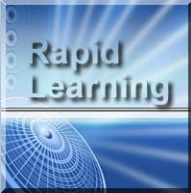
 **Rapid Learning Center**
Chemistry :: Biology :: Physics :: Math 

Rapid Learning Center Presents ...

Teach Yourself
College Physics in 24 Hours




1/44 <http://www.RapidLearningCenter.com> 

 **Electromagnetism**

Physics Rapid Learning Series

Wayne Huang, Ph.D.
Keith Duda, M.Ed.
Peddi Prasad, Ph.D.
Gary Zhou, Ph.D.
Michelle Wedemeyer, Ph.D.
Sarah Hedges, Ph.D.

Rapid Learning Center
www.RapidLearningCenter.com/
© Rapid Learning Inc. All rights reserved. 



Learning Objectives

By completing this tutorial, you will:

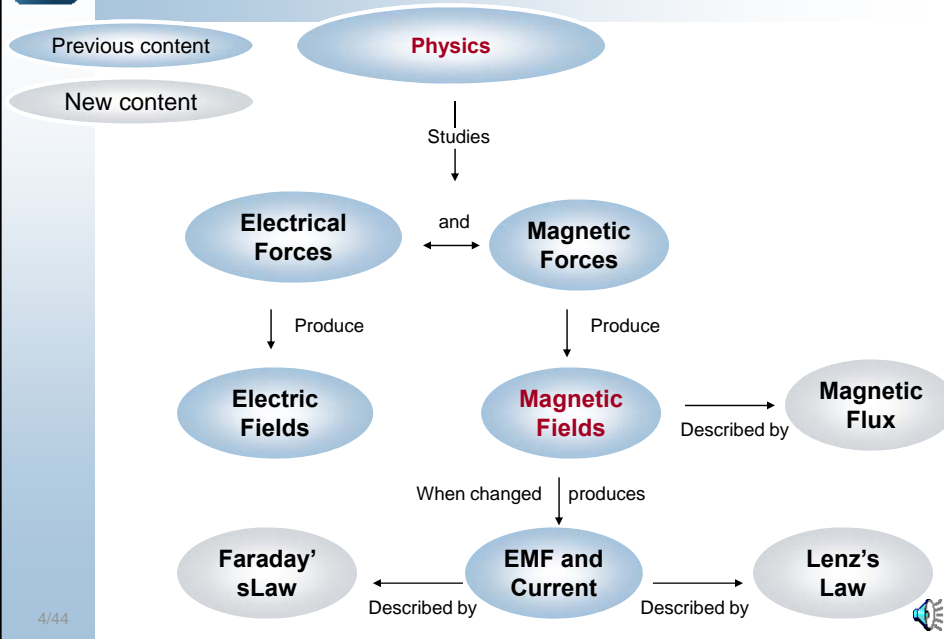



- Describe the idea of magnetic flux.
- Understand concepts and problems involving Faraday's law of magnetic induction.
- Use Lenz's law to describe the direction of current and magnetic flux.

3/44




Concept Map






Magnetic Flux



We can describe the amount or density of a magnetic field with the concept of magnetic flux.

5/44 

Magnetic Flux

The idea of flux can be described as the total number of lines passing through an area or coil. It can also be calculated.


$$\Phi_B = BA \cos\theta$$

Magnetic Flux, T m²

Magnetic Field, T

Area of surface, m²

Angle between field and a normal line on the surface area


6/44 

> Flux Observations

If the B field is greater, the flux is greater.

If the B field is perpendicular to the area, the flux is a maximum.

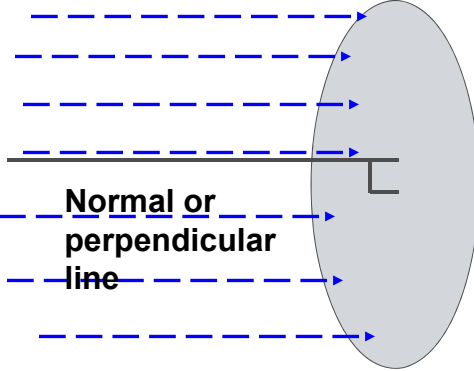
If the area is larger, the flux is larger.



7/44

> Angle Description

The angle θ refers to the angle between the B field, and a line drawn perpendicular to the surface/area.



Here the angle is 0° ,
 $\cos 0 = 1$

8/44

Flux Units

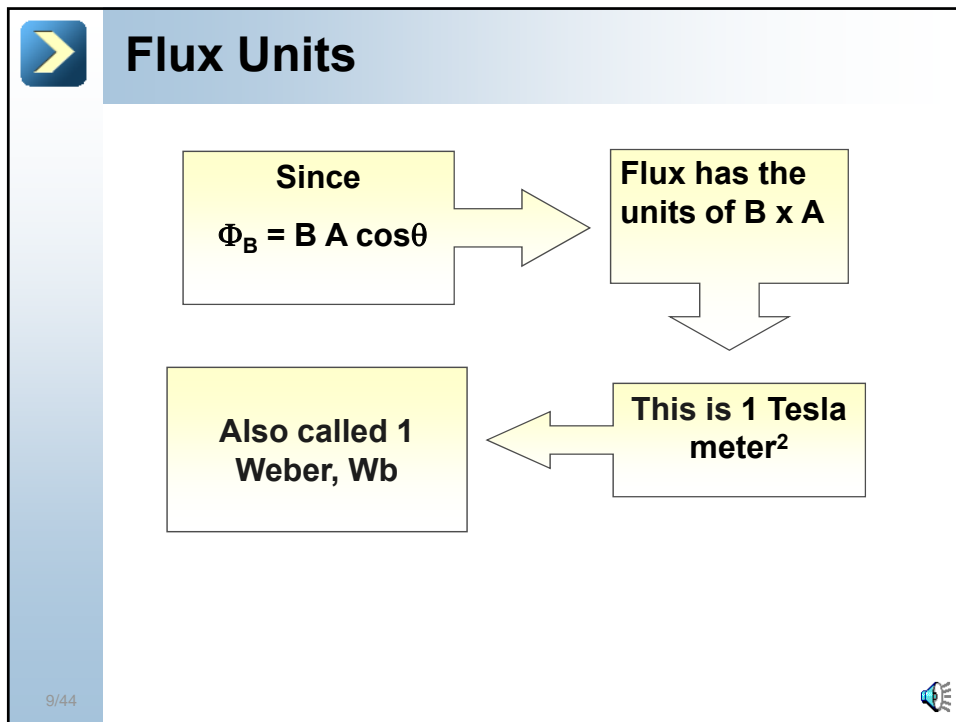
Since $\Phi_B = B A \cos\theta$

Flux has the units of $B \times A$

This is 1 Tesla meter²

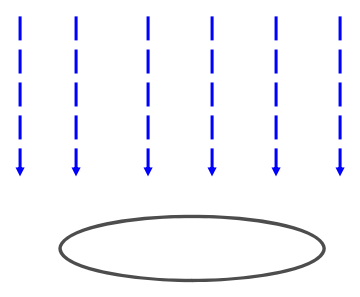
Also called 1 Weber, Wb

9/44

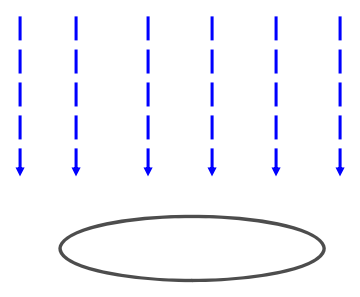


Hula Hoop Analogy

To simulate the idea of magnetic flux through a surface, consider a hula hoop in the rain.



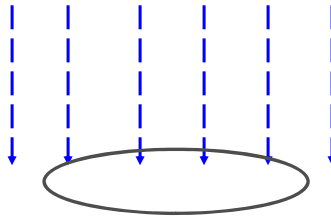
10/44





Angle Variation

It should seem obvious that a change in the angle of the surface compared to the field lines will change the flux through the surface.



Greatest flux

Less flux

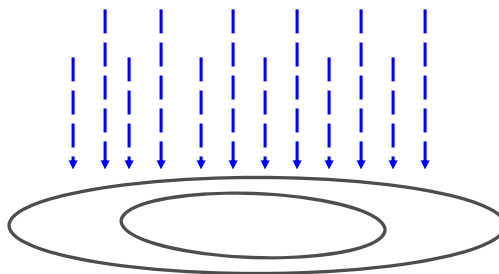
Least flux

11/44



Field and Area Variation

You can increase the flux through the hoop other ways too.



**A larger
surface area**

**A stronger
B field**

12/44





Magnetic Flux Example

Imagine that you have a hula hoop of radius .7m immersed in the magnetic field of the Earth, $5 \times 10^{-5} \text{ T}$. A normal line from the hoop is facing 30° away from North pole of the Earth. What is the flux through the hoop?

$$\Phi_B = BA \cos \theta$$

$$\Phi_B = (5 \times 10^{-5} \text{ T})(1.5 \text{ m}^2) \cos 30^\circ$$

$$\Phi_B = 6.5 \times 10^{-5} \text{ Tm}^2$$

$$\Phi_B = 6.5 \times 10^{-5} \text{ Wb}$$

Find the area of the circular hoop.

$$A = \pi r^2$$

$$A = 3.14 (.7 \text{ m})^2$$

$$A = 1.5 \text{ m}^2$$

13/44



Faraday's Law



Faraday's law describes the relationship between magnetism and electric current.


14/44




➤ Magnetic Induction

If current in a wire can produce a magnetic field, could a magnetic field produce a current?

Yes!



Joseph Henry (US) and Michael Faraday (England) both discovered such a phenomenon.

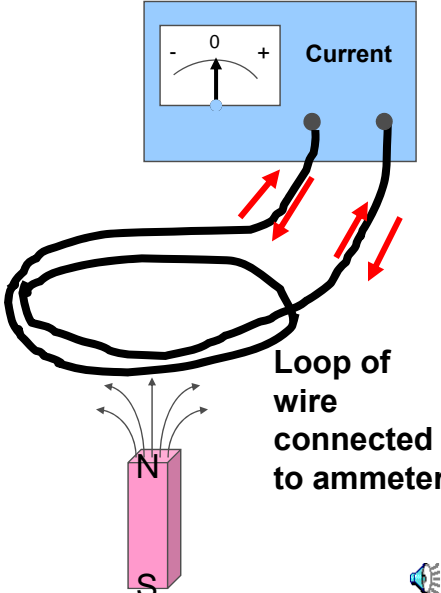
Michael Faraday 

15/44

➤ Induced Current

Just as electricity needs to be moving to create a B field, the B field must be moving, or changing, to create a current.

Notice how the current is created, and how it varies.



Loop of wire connected to ammeter

16/44



Induced Current Observations

When the magnetic field **changes**, a current **flows**.

When the magnetic field is **constant**, **zero** current flows.

Induced emf, electromotive force, is produced by a changing B field.

17/44



Faraday's Law of Induction

The greater the change in flux in a wire loop, the greater the induced current.

Less time equates to a greater current too.

Adding more loops will also increase the current.

18/44



Faraday's Law Equation

Induced emf, V


Change in Magnetic Flux, Wb

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

Number of coils

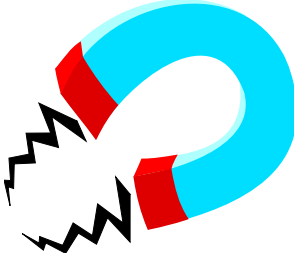
Change in time, s

19/44




Example Faraday's Law Problem

A coil of wire consists of 20 turns, each of which has an area of $1.5 \times 10^{-3} \text{ m}^2$. A B field is perpendicular to the surface. At $t = 0$ seconds, the B field is .05 T. At $t = .1$ seconds, the B field is .06 T. Find the average induced *emf* in the coil.



20/44





Solution

First, we must combine our definition of magnetic flux and Faraday's law:

$$\epsilon = -N \frac{\Delta\Phi}{\Delta t} \quad \Phi_B = BA \cos\theta$$

$$\epsilon = -N \frac{\Delta BA \cos\theta}{\Delta t}$$

Since the field is perpendicular to the loop, $\cos 0^\circ = 1$

21/44



Solution Continued

$$\epsilon = -N \frac{\Delta BA}{\Delta t}$$

Change in magnetic field
.06T-.05T

$$\epsilon = -20 \frac{(.01\text{T})1.5 \times 10^{-3} \text{m}^2}{.1\text{s}}$$

$$\epsilon = -.003\text{V}$$

If the units for Teslas are substituted in, you see that you do end up with a unit of Volts...

22/44





Lenz's Law

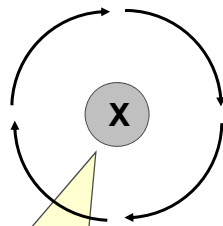
Lenz's law describes the direction of the current produced by a changing magnetic field.

23/44



Right Hand Rule Review Question

The wire shown below carries conventional current into the plane of the page/screen. How will the B field point in the vicinity of the wire?



By the RHR, the thumb points in the direction of current. This is into the page here.

Thus, the fingers curl in the direction of the B field.

24/44

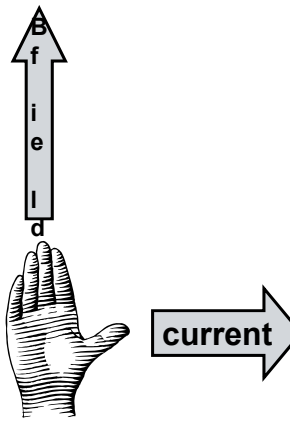


Applying RHR

In cases where a current is created, the RHR can be used to find the direction of that current.

Point the fingers of the right hand in the direction to maintain the magnetic field flux (opposing any change).

The thumb now shows the direction of the induced current!



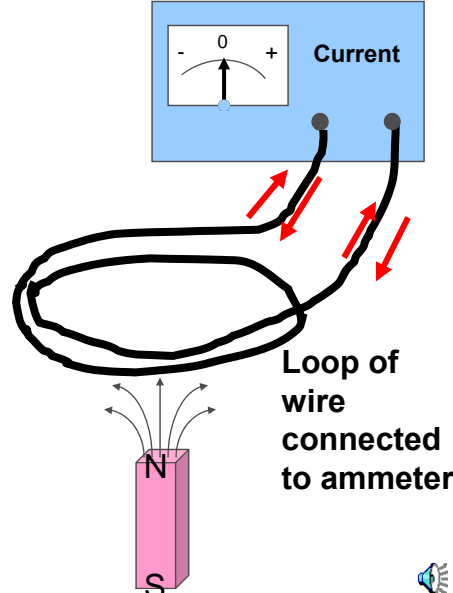
25/44

Lenz's Law

An induced emf always gives rise to a current whose magnetic field opposes the original change in flux.

The right hand rule is used in these situations.

Loop of wire connected to ammeter

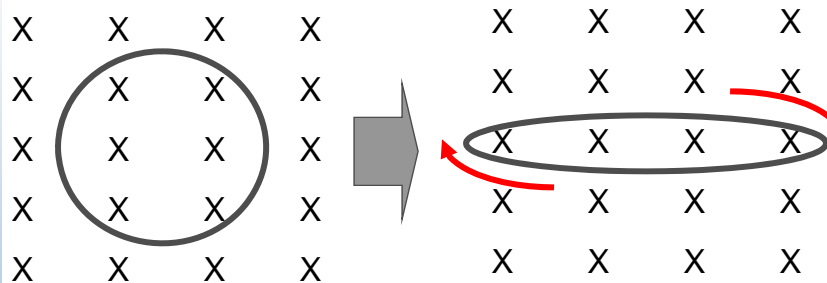


26/44



Change in Flux

Notice how the area is lessened when the hoop is stretched.



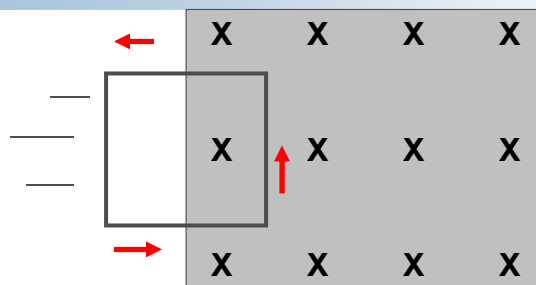
Since the flux is reduced, the current flows in the direction that produces a B field that helps maintain the original flux.

27/44

The induced current attempts to keep the status quo. 



Hoop Entering a B Field



The gray area represents a magnetic field. When the loop enters into the field, will a current be produced? Which way?

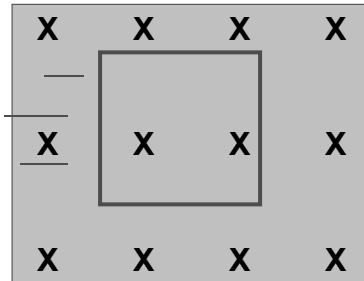
Counter clockwise so that the currents seems to oppose the increase in flux from the field.

28/44





Continued Motion



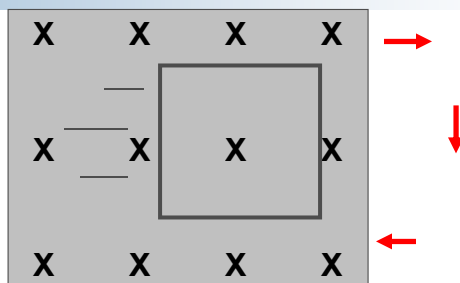
While the loop is totally immersed in the field, describe the current flowing.

Because there is no change in flux, **NO** current flows.

29/44



Hoop Leaving the B Field



The gray area represents a magnetic field. When the loop leaves the field, will a current be produced? Which way?

Clockwise so that the currents seems to oppose the decrease in flux from the field.

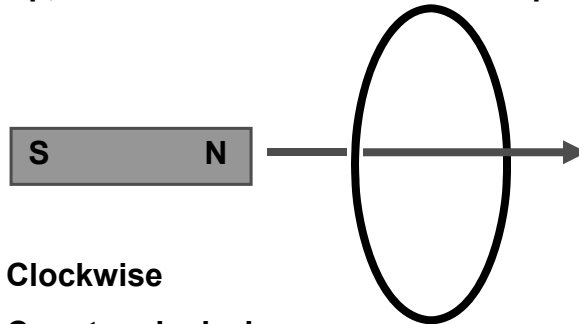
30/44





Moving Magnet

If the magnet is inserted all the way through the loop, how will current flow in the loop?



- A. Clockwise
- B. Counter clockwise
- C. Clockwise then counterclockwise
- D. Counterclockwise then clockwise
- E. No current flows at all

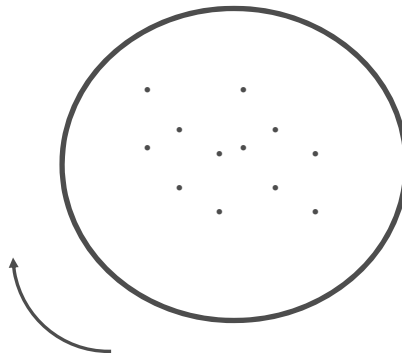


31/44



Additional Question

If you were looking at a loop of wire, and the magnetic field coming through there IS *increased*, would any current flow? Which way?



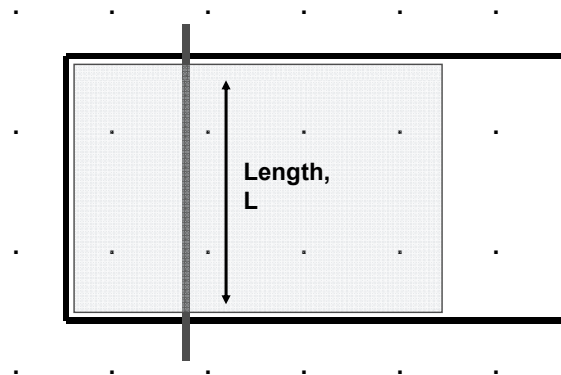
The current would flow to counter the increase in B field coming at you, clockwise.

32/44





Emf Induced in Moving Conductor



Imagine the conduction bar moving along the U shaped wire immersed in the B field. This increases the flux through the opening. Notice the larger area.

33/44



Combining Flux and Faraday's Formulas

Since:

$$\varepsilon = \Delta\Phi / \Delta t$$

and

$$\Delta\Phi = BA$$

then:

$$\varepsilon = B \Delta A / \Delta t$$

34/44





Deriving EMF in Moving Conductor

The changing area is equal to:

$$L v \Delta t$$

Equivalent to
the area of
the rectangle

substituting that as ΔA ,

$$\varepsilon = B L v \Delta t / \Delta t$$

The Δt
variables
cancel out.

$$\varepsilon = BLv$$

35/44



EMF in a Moving Conductor Formula

Induced
emf

Velocity,
m/s

$$\varepsilon = BLv$$

Magnetic
Field, T

Length of
conductor, m

36/44

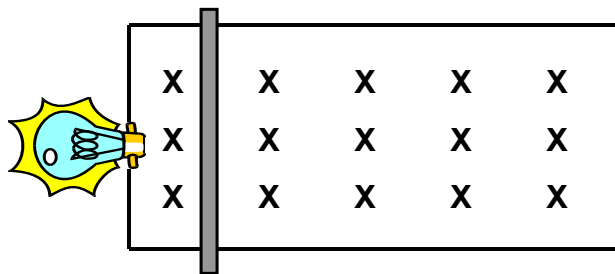




Induction Example Problem

As pictured, a 1.6 m long rod is moving at 5 m/s perpendicular to the .8 T B field. The rod and rails have negligible resistance, but the light bulb has a resistance of 96 Ω .

- Find the induced emf
- Find the induced current



37/44

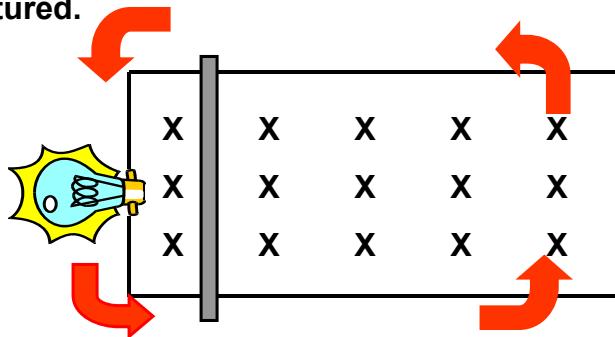


Induction Solution

$$\text{a) } \varepsilon = B l v = (.8 \text{ T}) 1.6\text{m} (5\text{m/s}) = 6.4 \text{ V}$$

$$\text{b) } V = IR \quad I = \frac{V}{R} = \frac{6.4\text{V}}{96\Omega} = .067\text{A}$$

The current will move counter clockwise as pictured.



38/44

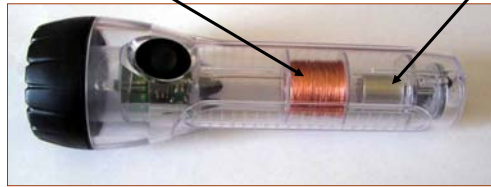




Application Example

You may have noticed a popular gadget that uses Faraday's law. Some flashlights use no batteries at all yet still produce light apparently by the magic of shaking them.

Instead you shake the light, moving a magnet through a coil of wire.



This supplies a current which charges a capacitor. This stores the charge for use in the bulb or LED to produce light when needed.

39/44



Generators

An electric motor takes current and translates it into mechanical motion. A generator takes motion and turns it into current.



40/44





Sources of Mechanical Motion



Generators can get their mechanical motion from many sources:

- **Steam**
- **Wind**
- **Water**
- **Humans, etc.**

41/44



Learning Summary

Lenz's law: the induced current flows in the direction that produces a B field that helps maintain the original flux.

Magnetic flux can be described as the number of field lines through an area.

EMF induced by a moving conductor:
 $\epsilon = BLv$

Magnetic flux:

$$\Phi_B = BA \cos \theta$$



Faraday's law of induction:

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

42/44






 **Rapid Learning Center** 
Chemistry :: Biology :: Physics :: Math

What's Next ...

Step 1: Concepts – Core Tutorial (Just Completed)
→ Step 2: Practice – Interactive Problem Drill
Step 3: Recap – Super Review Cheat Sheet

Go for it! 

44/44 <http://www.RapidLearningCenter.com>