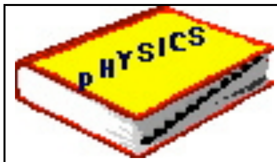


Text References

5^{th} Ed. Giancolli Pg. 588-96

ELECTROMAGNETISM
MAGNETIC FORCE AND FIELDS

Objectives:
- state the rules of magnetic interaction
- determine the direction of magnetic field lines
- use the right hand rule to solve problems
- solve problems involving current carrying wires and moving charges in magnetic fields

A magnet has two poles, a north pole and a south pole. Surrounding a magnet is a magnetic field (analogous to a gravitational field, or electric field). The direction of the magnetic field at any given point is defined as ____. Because of this definition, the magnetic field lines always point from the______________ toward the _________________ of a magnet. The magnetic field **B** is a **vector** quantity.

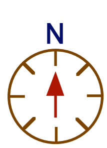
Permanent Magnetics (Nickel, Cobalt, Iron etc)

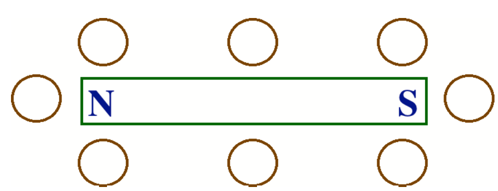
Hands-on Lab: Magnetic Field Lines.

Obtain some iron filings, a bar magnet, and a piece of acetate from your teacher. Place the acetate over the bar magnet and sprinkle the iron filings over the acetate. Draw your results below. Remove the acetate and iron filings. Place a compass at various positions around the bar magnet and draw your results below.

1. Draw the magnetic field lines surrounding a bar magnet.

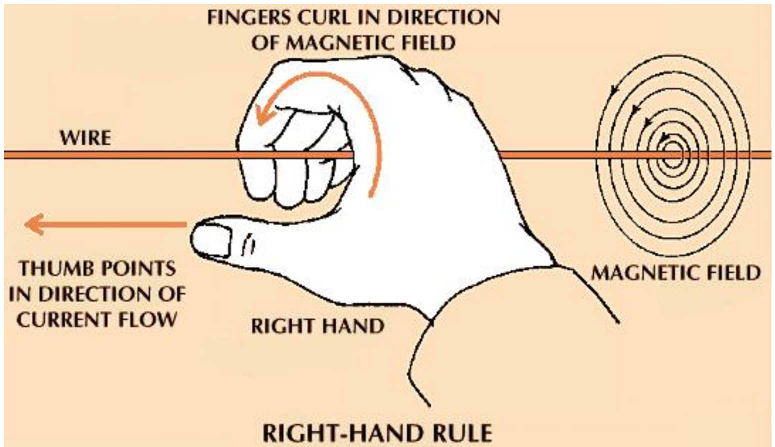
2. Using the notation below, draw in the compass needle directions around the bar magnet.

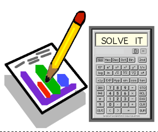




Electromagnetism

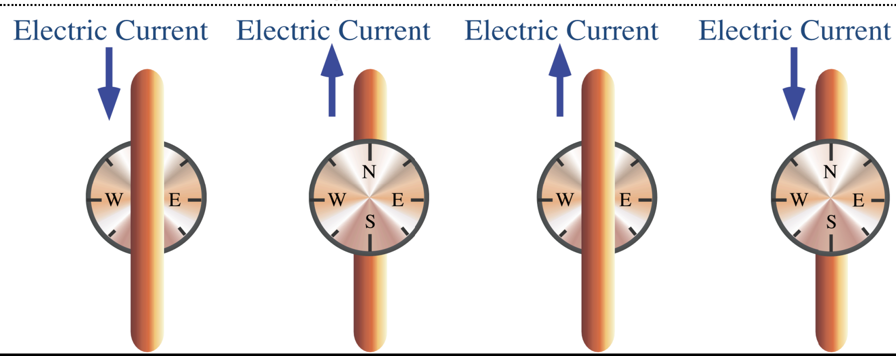
Electric currents produce magnetic fields. The direction of the magnetic field lines is indicated by ___________. The direction of the magnetic field depends on the direction of conventional current, and is found by using the **Right Hand Rule**.





Sample Problem: Using the Right Hand Rule

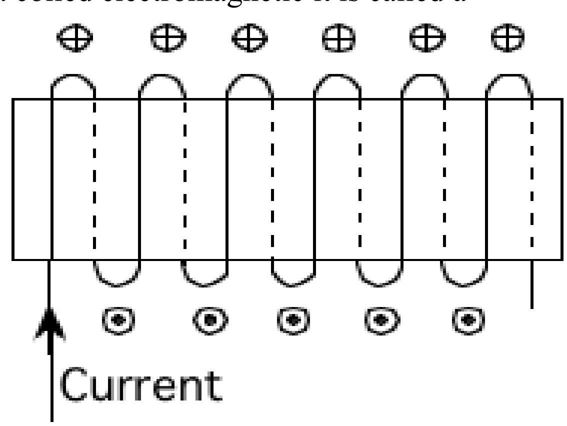
Use the right hand rule to determine the directions for the needle of a compass placed near a wire as shown in each diagram.

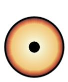


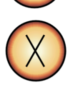
Even a single loop of wire produces a magnetic field. By having several loops, we can produce a solenoid. The magnetic field of a solenoid is the sum of the magnetic fields from each loop.
When a wire is wrapped around a cylindrical form to produce a coiled electromagnetic it is called a _______________ .

The strength of the magnetic field can be increased by:

- increasing the numbers of turns (windings)
- increasing current flowing through the wire



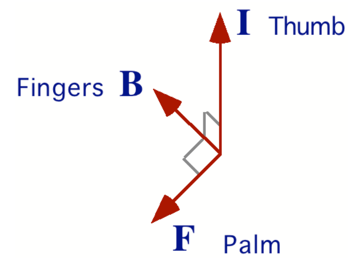
 current flowing <u>out of</u> the page

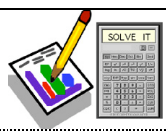
 current flowing <u>into</u> the page

Magnetic Force

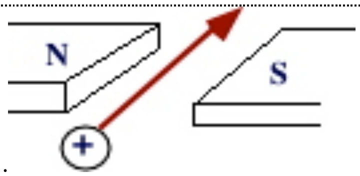
A magnet exerts a force on a current carrying wire. The magnetic field also exerts a force on moving charged particles such as free electrons. It is found that the direction of the magnetic force is always perpendicular to the direction of the current-carrying wire and also perpendicular to the direction of the magnetic field.

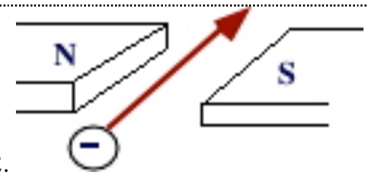
To determine the direction of the magnetic force, point your __________ in the direction of conventional current flow. Point your ___________ in the direction of the magnetic field lines, and your ____________ will face (push) in the direction of the force acting on the object (particle, wire, etc.)





Practice Problems: Moving Charged particles in a Magnetic Field
Using the information above, show the direction of the force on each of the charged particles. (up, down, left, right) Hint: look in your textbook for examples!

1. 

2. 

The force is: ______________________________

The force is: ______________________________

Force on a Charge:

The equation below gives the magnitude of the force acting on a moving charge in a magnetic field.

$F = qvB \sin\theta$ where:

F:

q:

v:

B:

θ:

Force on a Wire:

The equation below gives the magnitude of the force acting on a current carrying wire in a magnetic field.

$F = BIL \sin\theta$ where:

F:

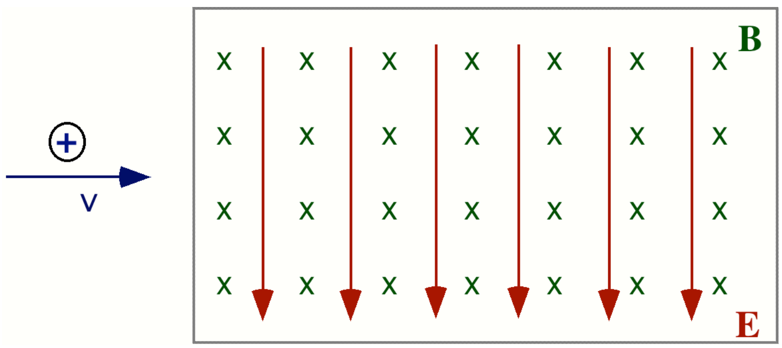
I:

L:

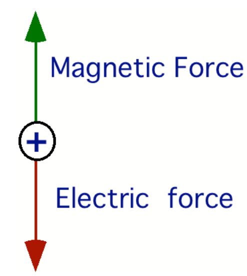
B:

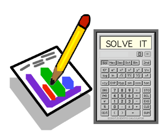
θ:

From your study of Electrostatics, you know that when a charged particle enters an electric field, an electric force, **F** = q**E,** is exerted on the particle. If we place a magnetic field perpendicular to an electric field in such a way that the forces oppose each other, the configuration acts as a velocity selector.



$$F_B = F_E$$
$$qvB = qE$$
$$v = \frac{E}{B}$$





Practice Problems: Charged particle in Crossed E & B fields

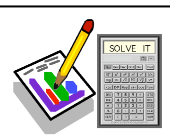
A magnetic field is perpendicular to an electric field.

a) What velocity does an electron need to have in order to travel straight through the crossed E and B fields, given that E = 1.0 x 10^5 N/C and B = 0.40 T?

b) What electric field is needed to balance the effects of an electron traveling with velocity 3.0 x 10^5 m/s through a magnetic field 0.5 T in strength?

c) What magnetic field is needed to balance the effects of an electron traveling with velocity 8.0 x 10^5 m/s through an electric field of 4.0 x 10^5 N/C?

a)	b)	c)
v = 2.5 x 10^5 m/s	E = 1.5 x 10^5 N/C	B = 0.5 T



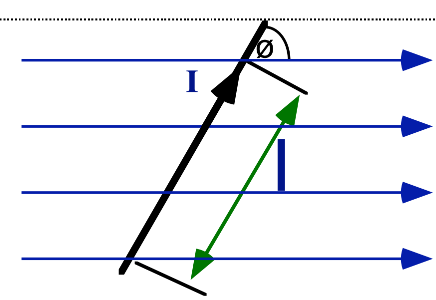
Practice Problem: Current carrying wire in a magnetic field.

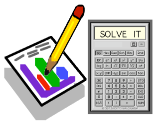
Solve the problem below. Hint: look in your textbook for examples!

A 12 cm length of wire carrying a 30 A current is positioned between the pole faces of a magnet at an angle of ø = 60˚ as shown below. The magnetic field is approximately uniform at 0.90 T. What is the magnitude of the force on the wire? (Ignore the field beyond the pole ends).

Solution:F = ILBsinø

F = 2.8 N



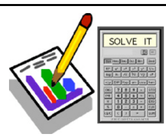


Practice Problem: Magnetic Force on charged particles

An electron travels with a speed of 2.60×10^6 m/s in a magnetic field of 0.30 T. What is the magnitude of the force exerted on the electron?

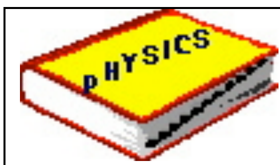
Hint: look in your text book for examples!

$F = 1.25 \times 10^{-13}$ N



Problem Set #1: Magnetic Force and Field

3rd Ed. Giancolli Pg. **532-36**	4th Ed. Giancolli Pg. **582-87**	5th Ed. Giancolli Pg. **614-20**
Questions # 2, 7, 15, 16, 23	Questions # 2, 7, 12, 13, 20	Questions # 2, 6, 9
Problems # 1-9 odd, 53, 56	Problems # 1, 3, 5, 7, 10, 58, 61	Problems # 3, 5, 6, 7, 9, 13, 17, 58



Text References

3rd Ed. Giancolli Pg. 505-37
4th Ed. Giancolli Pg. 558-76
5th Ed. Giancolli Pg. 596-611

ELECTROMAGNETISM
SOLENOIDS AND AMPERE'S LAW

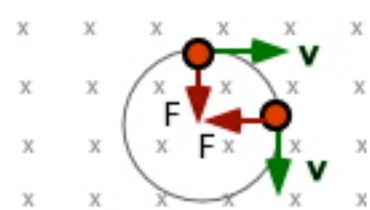
Objectives:
- solve problems involving circular motion with charges in magnetic fields
- solve problems involving solenoids, parallel wires, and Ampere's Law

If a charged particle enters a strong magnetic field, the curvature of its path may be quite severe, producing a circular path. As you have verified on the previous page, we can determine the radius of the curvature by equating Newton's Second Law to the magnetic force.

$$F_B = ma_c$$

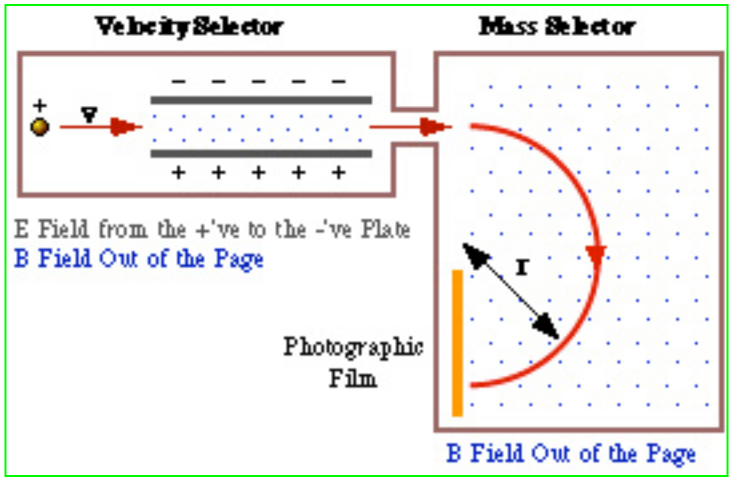
$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$



Mass Spectrograph:

The mass spectrograph is a device for making accurate measurements of the masses of atoms. Charged particles are accelerated into a region that has both an electric and a magnetic field; the fields are arranged so that the magnetic force and electric force are directly opposed.



In the region labeled 'Velocity Selector', the electric force pushes the positively charged particle _____________ while the magnetic field pushes the particle _____________ .

Applying equations gives:

$$F_E = F_B$$

$$qE = qvB$$

$$v = \frac{E}{B}$$

In the region labeled 'Mass Selector', the magnetic force causes the positively charged particle to move in a circular path. Applying equations gives:

$$F_B = F_c$$

$$qvB' = \frac{mv^2}{r}$$

Combining the two sets of equations gives:

$$q\frac{E}{B}B' = \frac{mv^2}{r}$$

$$m = \frac{qBB'r}{E}$$

All quantities on the right may be measured, and thus **m** can be determined.

Ampere's Law: (Strength of Magnetic Field)

Experimentally, it was found that the strength of the magnetic field around a current carrying wire is directly proportional to the current and inversely proportional to the distance from the wire. Ampere suggested that summing the component of B parallel to length $\Delta\ell$ around a current carrying wire would be equal to a constant times the current $\sum B_{//}\Delta\ell = \mu_o I$.

$$B \propto \frac{I}{r}$$

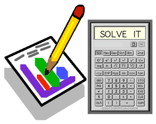
Using a circular path around a wire, this relationship for the magnetic field strength around a single wire becomes:

$$B = \frac{\mu_o I}{2\pi r}$$

If we apply Ampere's Law to a loop of wires (as in a solenoid) the equation becomes:

$$B = \frac{\mu_o NI}{\ell}$$

The equations below give the magnitude of the magnetic field for a solenoid. Define the variables involved in these equations in the space below.



Sample Problem: Magnetic force between two parallel wires
Using the equations for the force exerted on a current carrying wire in a magnetic field and the magnetic field around a current carrying wire, derive an equation for the force between two current carrying wires.

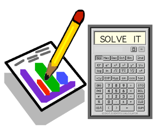
Solution:

Wire #1 produces a magnetic field according to $B_1 = \frac{\mu_o I_1}{2\pi r}$.

Wire #2 (in the magnetic field produced by wire #1) has a force exerted on it according to $F_2 = B_1 I_2 L$.

Substituting B_1 into the force equation gives:

$$F_2 = \frac{\mu_o(\_\_\_\_)}{(\_\_\_\_\_)} I_2 L$$



Practice Problems: Ampere’s Law, Solenoids, and Parallel Wires
Solve the problems below, clearly showing all your work. Remember that these will be samples for you to study from later. Correct answers are shown on the right of each problem. Hint: look in your textbook for example problems...

1. A vertical wire in the wall of a building carries a dc current of 25 A upward. What is the magnetic field at a point 10 cm north of this wire?

$$B = \frac{\mu_o I}{2\pi r}$$

$B = 5.0 \times 10^{-5}$ T

2. A thin, 10-cm long solenoid has a total of 400 turns of wire and carries a current of 2.0 A. Calculate the field inside the solenoid, near the center.

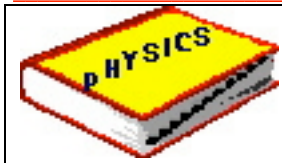
$$B = \frac{\mu_o N I}{\ell}$$

$B = 1.0 \times 10^{-2}$ T

3. Two wires of a 2.0 m long appliance cord are 3.0 mm apart and carry 8.0 A dc. Calculate the force between these wires.

$$F = \frac{\mu_o I_1 I_2 L}{2\pi r}$$

$F = 8.5 \times 10^{-3}$ N



Text References

3rd Ed. Giancolli Pg. 538-50
4th Ed. Giancolli Pg. 589-602
5th Ed. Giancolli Pg. 622-36

ELECTROMAGNETISM
INDUCTION

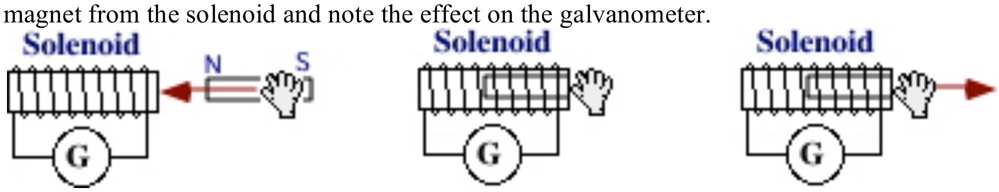
Objectives: • solve problems involving emf, magnetic flux, Faraday's Law, and Lenz's Law

In this section you will examine a third relationship, namely that changing magnetic fields produce an electric current. The hands-on demonstration below will prove this relationship.

Hands-on Lab: Faraday’s Law.

Connect a galvanometer to a solenoid as shown below. Obtain a bar magnet that has recently been magnetized. Note: if your bar magnets are weak, you can stack two on top of each other with like poles together to increase the magnetic field strength.

Move one pole of a bar magnet into the centre of the solenoid and leave it there. Note what happens to the galvanometer. Remove the bar magnet from the solenoid and note the effect on the galvanometer.

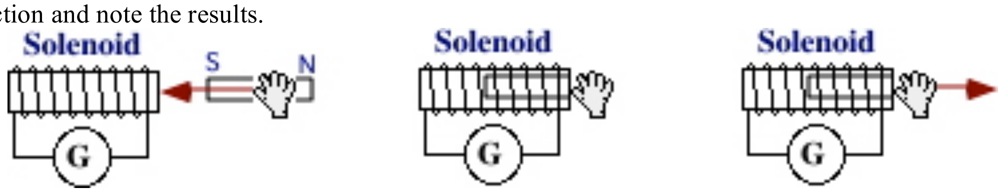


Results

Predict what will happen if you use the other pole of the magnet.

Prediction

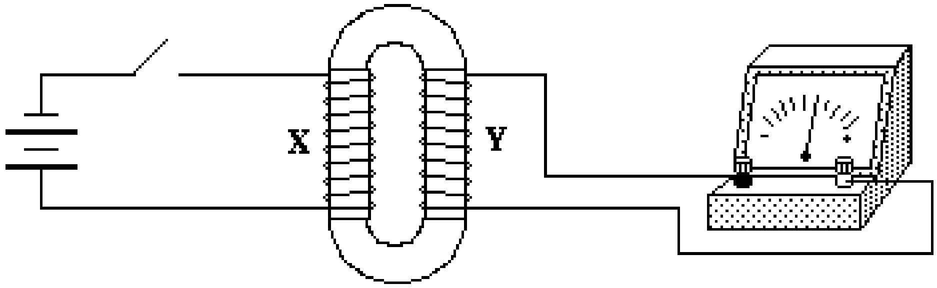
Test your prediction and note the results.



Results

What can you say about the relationship between magnetic fields and current?

Using the diagram below summarize Faraday's experiment. What did he observe?



Magnetic flux: Φ is the number of magnetic field lines perpendicular to a unit area and has units of Tesla•meter^2 or Weber(Wb).

$$\Phi = BA\cos\theta$$

where:

Φ:

B:

A:

ø:

We can change magnetic flux in two ways. State these ways below.

Faraday's Law of Induction: relates the change of flux with the number of coils of wire to the emf that is induced.

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

where:

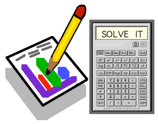
ε:

$\Delta\Phi$:

Δt :

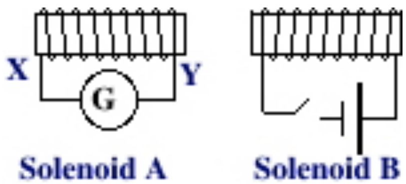
N:

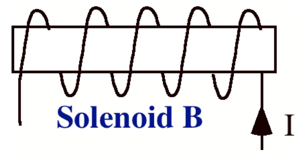
The minus sign in the equation above, indicates the direction that the induced emf acts. This direction was determined experimentally and is known as **Lenz's Law**. State Lenz's law below.



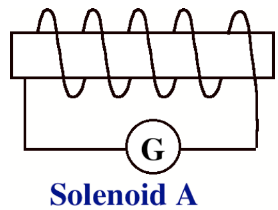
Practice Problem: Changing Magnetic Flux & Emf

This question uses the right hand rule and concepts presented above. Examine the diagram below carefully.

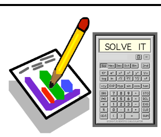




1. Use the right hand rule and draw the magnetic field produced by solenoid B when the switch is closed.
2. The induced current in solenoid A will produce a magnetic field that opposes that in solenoid B. Draw this magnetic field in solenoid A.
3. Use the right rule and determine the direction of the induced current in solenoid A. Note the direction of the windings.



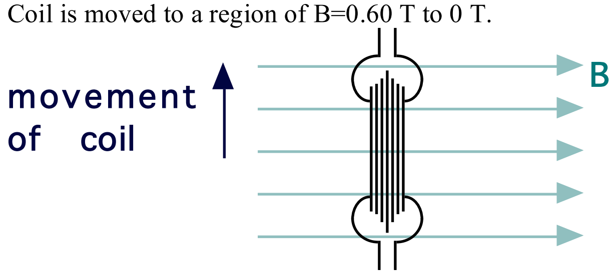
4. Label the north and south ends of each solenoid.



Practice Problems: Changing Magnetic Flux & Emf

Determine if the situations below will produce a change in the magnetic flux and if so, give the value of $\Delta\Phi$ and the emf induced. The coil consists of 7 loops, each with area of 0.55 m^2. The magnetic field strength is 0.60 T. The time for each change is 0.10 s.

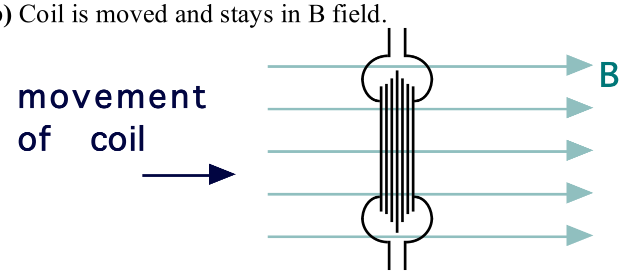
a) Coil is moved to a region of B=0.60 T to 0 T.



$\Delta\Phi$ = -0.33 Wb

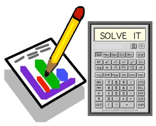
ε = 23.1 V

b) Coil is moved and stays in B field.



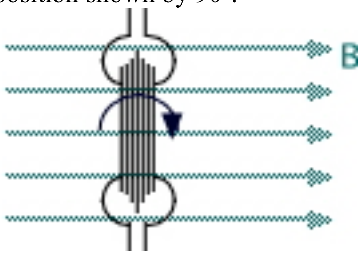
$\Delta\Phi$ = 0 Wb

ε = 0 V



Practice Problems: Changing Magnetic Flux & Emf (Continued)
Determine if the situations below will produce a change in the magnetic flux and if so, give the value of $\Delta\Phi$ and the emf induced. The coil consists of 7 loops, each with area of 0.55 m^2. The magnetic field strength is 0.60 T. The time for each change is 0.10 s.

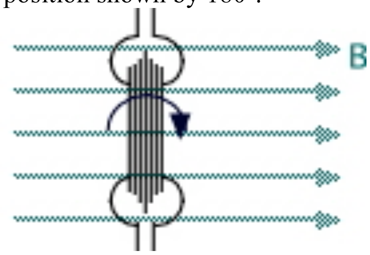
c) Coil is rotated from position shown by 90°.



$\Delta\Phi$ = -0.33 Wb

$\mathcal{E}$ = 23.1 V

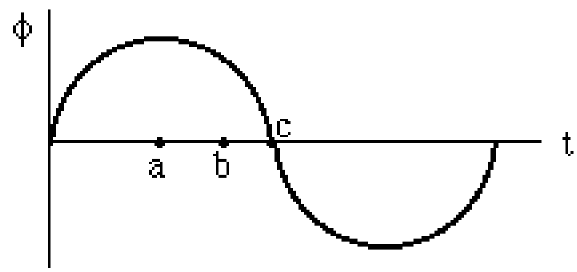
d) Coil is rotated from position shown by 180°.



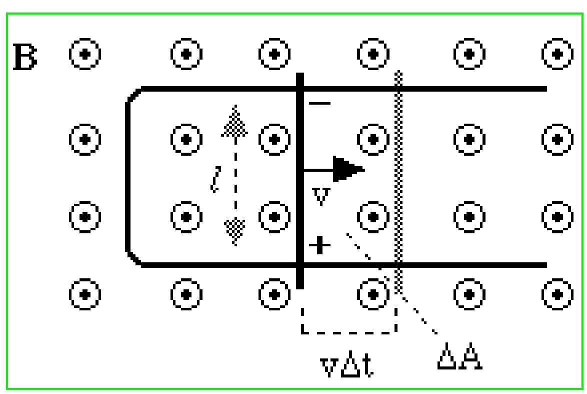
$\Delta\Phi$ = 0 Wb

$\mathcal{E}$ = 0 V

e) If a coil is rotated in a magnetic field, and the flux is plotted against time, where, on the graph, will the greatest change of flux occur?



Emf induced in a moving conductor:



If a rod is made to move in a magnetic field (see diagram), it will travel a distance vΔt. Therefore, the area of the loop is increased by $\Delta A = \ell v \Delta t$.

By Faraday's Law, there is an induced emf $\mathcal{E}$, given by:

$$\mathcal{E} = \frac{\Delta\Phi}{\Delta t} = \frac{B\Delta A}{\Delta t} = \frac{B\ell v\Delta t}{\Delta t} = B\ell v$$

If B, ℓ and v are not perpendicular to each other, then we use only the components that are perpendicular.

Define each term in the equation in the space below.

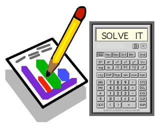
$\mathcal{E} = B\ell v$ where:

$\mathcal{E}$:

B:

ℓ:

v:

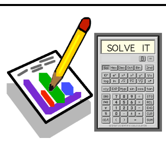


Sample Problem: Induced Emf in a moving conductor

An airplane travelling at 278 m/s upward at an angle of 30° to the horizontal is in a region where earth's magnetic field is 5.0×10^{-5} T upward. What is the potential difference induced between the wing tips that are 80 m apart?

Solution: We must use the perpendicular component of the velocity to the B field.

$\mathcal{E} = 0.96$ V

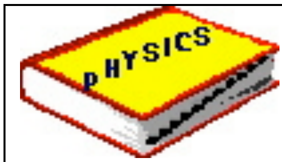


Problem Set #3: Magnetic Flux and Induced Emf

3rd Ed. Giancolli Pg. 565
Questions # 3, 5, 17
Problems #3, 4, 7-9, 80

4th Ed. Giancolli Pg. 618
Questions #3, 5, 15
Problems #3, 4, 7-9, 12, 86

5th Ed. Giancolli Pg. 652
Questions #3, 5, 16
Problems #3, 4, 7-9, 12, 14-16, 88, 90



Text References

3^{rd} Ed. Giancolli Pg. 538-50
4^{th} Ed. Giancolli Pg. 589-602
5^{th} Ed. Giancolli Pg. 622-36

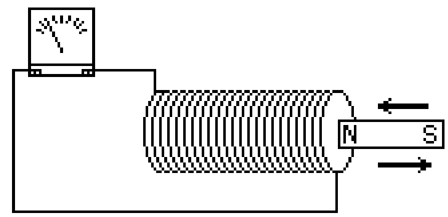
ELECTROMAGNETISM
BACK EMF and TRANSFORMERS

Objectives: • solve problems involving back emf and transformers

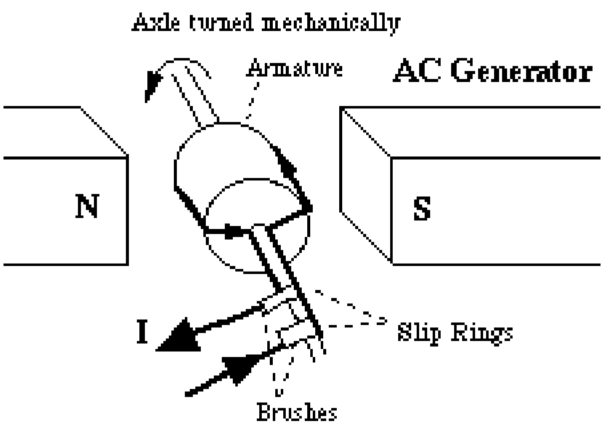
Generators:

The most important result of Faraday's discovery is the generator.

A generator transforms ____________________ energy into ____________________ energy, while a motor transforms ________________ energy into __________________ energy.



Simple Generator



Describe how a generator uses induction to produce an electric current.

Back Emf:

As the armature of a motor turns, an emf is generated. This induced emf acts to oppose the motion (Lenz's law) and is called back emf. The greater the speed of the motor the greater the back emf.

$$V_b = V_a - IR$$

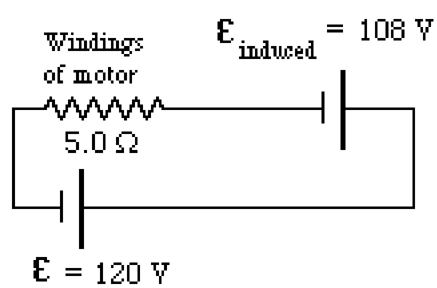
where:

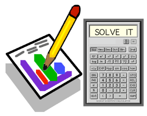
V_b:

V_a:

I:

R:





Sample Problem: Back Emf

The armature windings of a dc motor have a resistance of 5.0 Ω. The motor is connected to a 120 V line and when the motor reaches full speed against its normal load, the counter emf is 108 V. Calculate: **a)** the current into the motor when it is just starting up, and **b)** the current when the motor reaches full speed

a) when the motor is starting up, there is no back emf.

I = 24 A

b) when the motor is at full speed, the current will be reduced due to the back emf:

I = 2.4 A

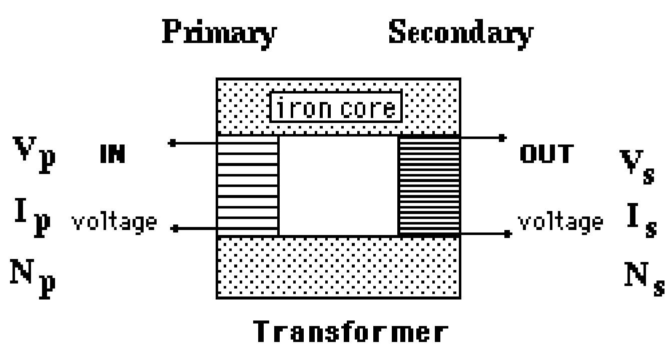
Define **back (counter) emf** and explain its significance for DC motors:

Transformers:

A transformer is a device for and is based on ___________________________ law. A transformer only works with _______ current.

$V_s = N_s \frac{\Delta\Phi}{\Delta t}$ and $V_p = N_p \frac{\Delta\Phi}{\Delta t}$

So $\boxed{\frac{V_s}{V_p} = \frac{N_s}{N_p}}$ **(transformer equation)**



Now the law of conservation of energy states that the power must be the same in both sections so:

$P_s = P_p$ which gives $V_sI_s = V_pI_p$ So $\boxed{\frac{V_s}{V_p} = \frac{I_p}{I_s}}$

Sample Problem: Transformer

A transformer for a transistor radio reduces 120 V ac to 9.0 V ac. The secondary contains 30 turns and the radio draws 400 mA. Calculate:

a) the number of turns in the primary
b) the current in the primary
c) the power transformed

a) $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

$N_p = 400$ turns

b) $\frac{V_s}{V_p} = \frac{I_p}{I_s}$

$I_p = 0.030$ A

c) $P = V_pI_p$

$P = 3.6$ W

Explain how a transformer works.

Some devices which use transformers are:

Problem Set #4: Back Emf & Transformers

3rd Ed. Giancolli Pg. **565**
Questions # 9, 11, 19
Problems #19, 23-29 odd

4th Ed. Giancolli Pg. 618
Questions #8, 17
Problems #23, 29, 31, 33, 35, 91

5th Ed. Giancolli Pg. 653
Questions #9, 10, 18
Problems #25, 31, 33, 35, 37, 94

