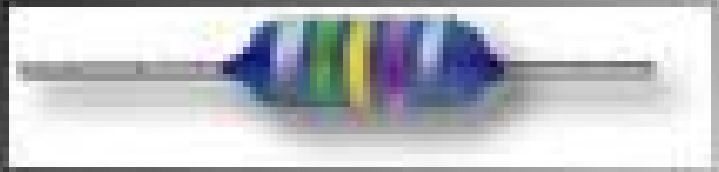
INDUCTORS



Objective 3a. Identify inductor principles

Inductor-Component designed to store electrical energy in the form of an electromagnetic field.

Inductors will oppose changes in current, both in direction and amplitude.

The amount of energy it can store is called inductance, which is measured in henries (H or h).

Purposes

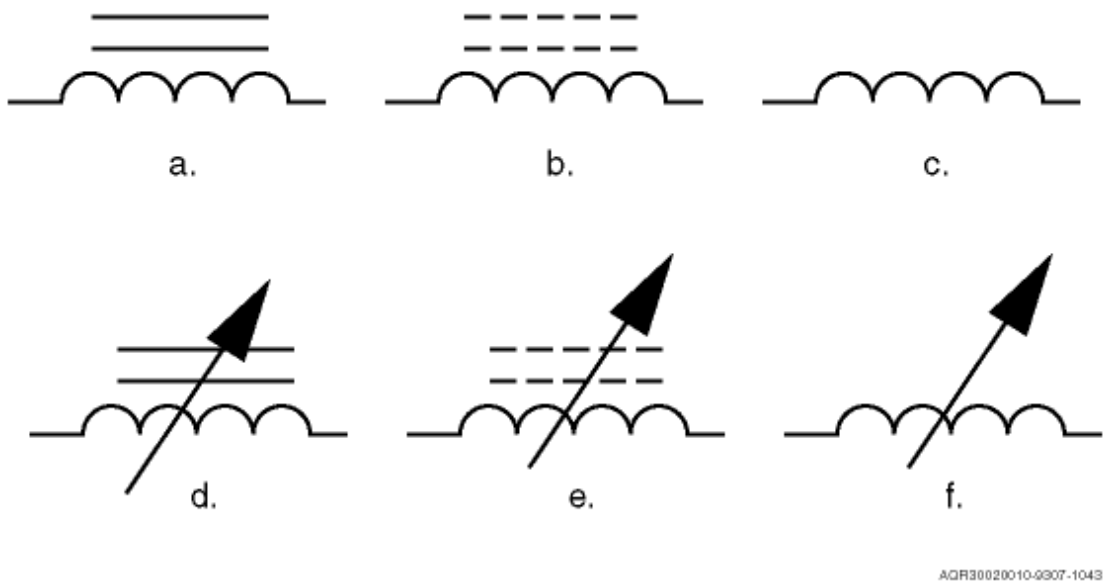
- **Opposes AC (High frequencies)**
- **Passes DC (Low frequencies)**

  - **Used in**
    - **Wave Shaping devices**
    - **Frequency Filters**
    - **Current Regulator**

Basic construction of inductors is a wire wrapped around a core material.

Inductors are labeled in circuits with the letter L

Schematic symbols



Frequency and the power requirements will determine which type inductor we will use.

Air core inductors are used at high frequencies (RF).

Iron core inductors are used at low frequencies (AF/Power).

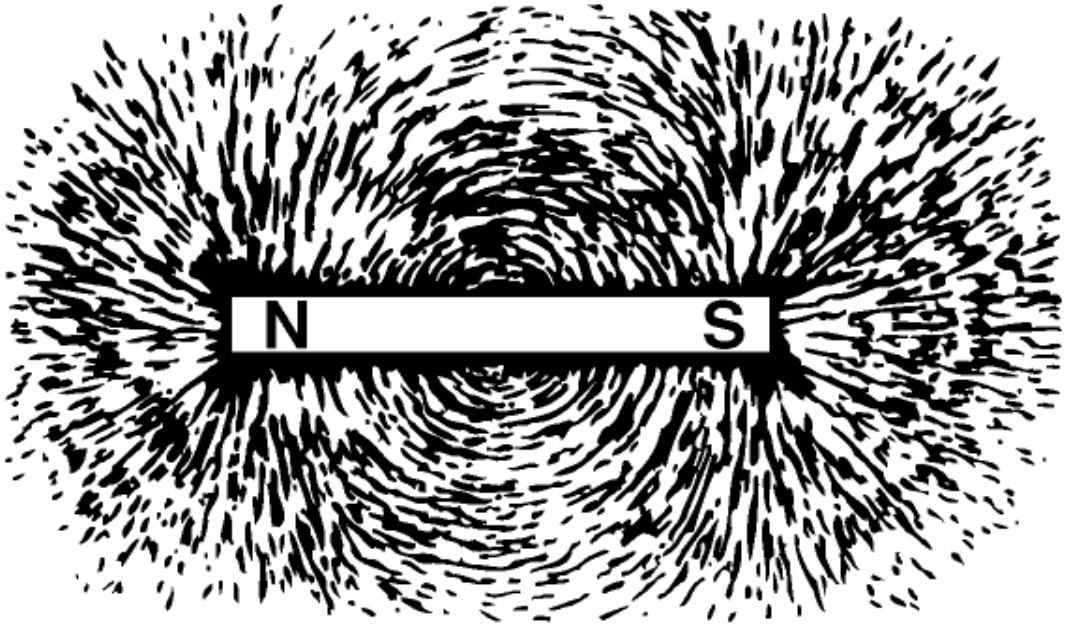
Magnets are objects that have the property of attracting iron and steel and which point north when allowed to swing freely.

- Natural Magnets-As found in nature
- Artificial Magnets-Man-made
  - Permanent- Retains its magnetism after the magnetizing force is removed
  - Temporary- Loses its magnetism after the magnetizing force is removed

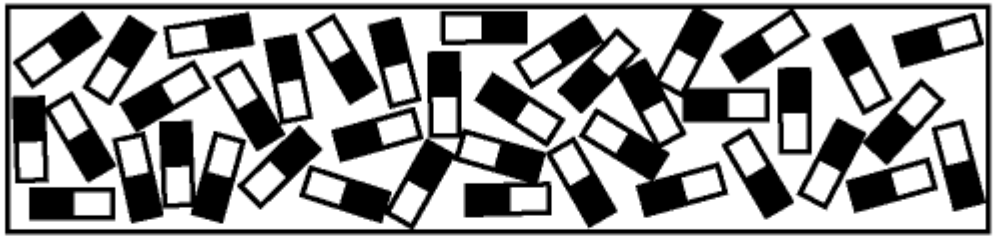
The ability of a material to remain magnetized after the magnetizing force is removed is called retentivity.

Poles

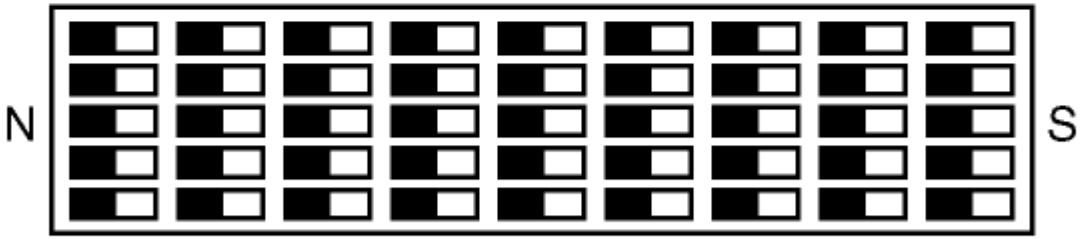
- If a bar magnet is placed on a flat surface and sprinkled with iron filings it will show the poles.
- Attraction- Unlike poles attract
- Repulsion- Like poles repel



Molecular theory of Magnetism



A. UNMAGNETIZED



B. MAGNETIZED

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In drawing A all the molecules are in a haphazard arrangement.

In drawing B all the molecules are arranged in neat orderly rows evenly spaced.

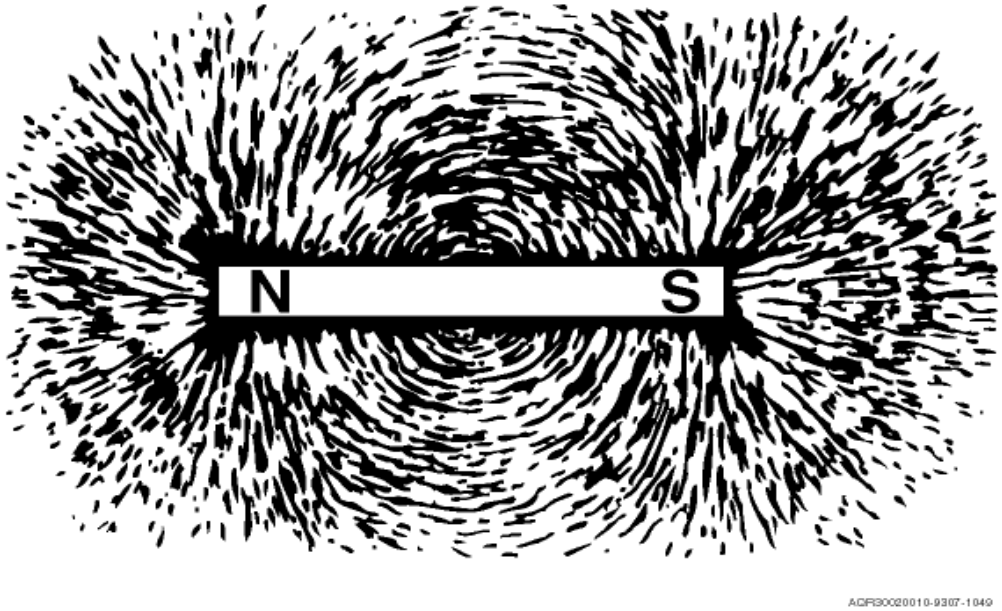
When the power is removed from an electromagnet the material will retain a small amount of magnetism this is called **Residual Magnetism**.

All electromagnets will have this property.
Although steel will retain it longer than a soft iron.

This is due to the fact that steels molecules are more tightly bound than those of soft iron.

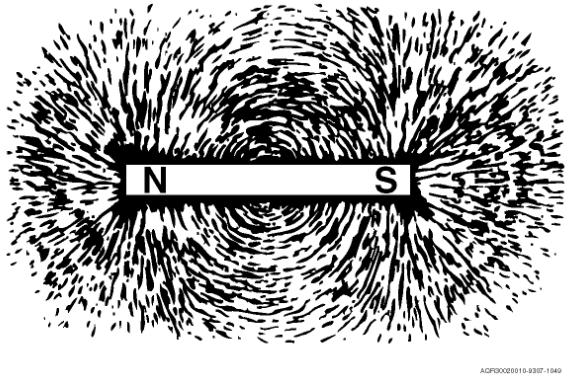
Magnetic Fields

Remember when we sprinkled the iron fillings on the magnet to show the poles. They also showed us the **MAGNETIC LINES OF FORCE.**



Magnetic Flux
Field Intensity
Flux Density
Reluctance
Permeability

Magnetic Flux



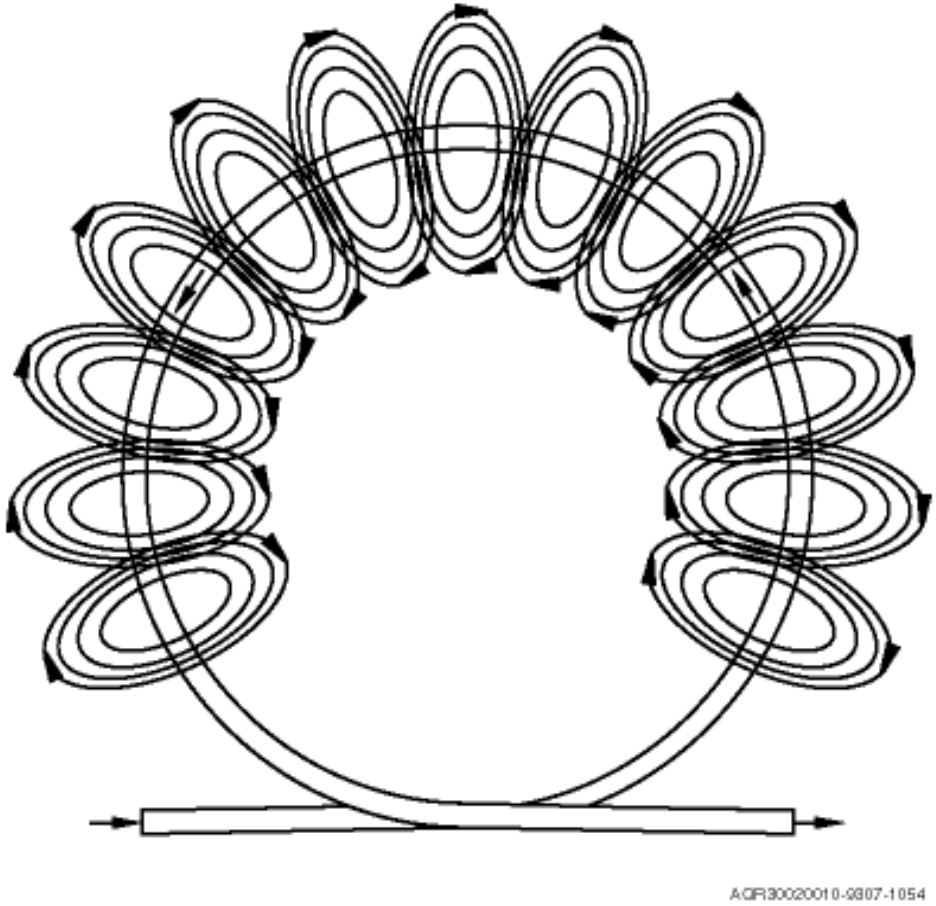
- **4 Basic characteristics**
  - 1. They always form complete loops. They travel from north to south outside the magnet.
  - 2. They never cross each other.
  - 3. They expand and contract like rubber bands as a force is exerted upon them and return to their original state when the force is removed.
  - 4. They will pass more easily through a magnetic material than a nonmagnetic material. No material can completely prevent their passage.

Principles of electromagnetism

We are now going to apply a voltage source to a wire and create an electromagnetic. By applying the voltage source to the conductor we have current flow through the conductor and the current flow is creating a magnetic field about the conductor.

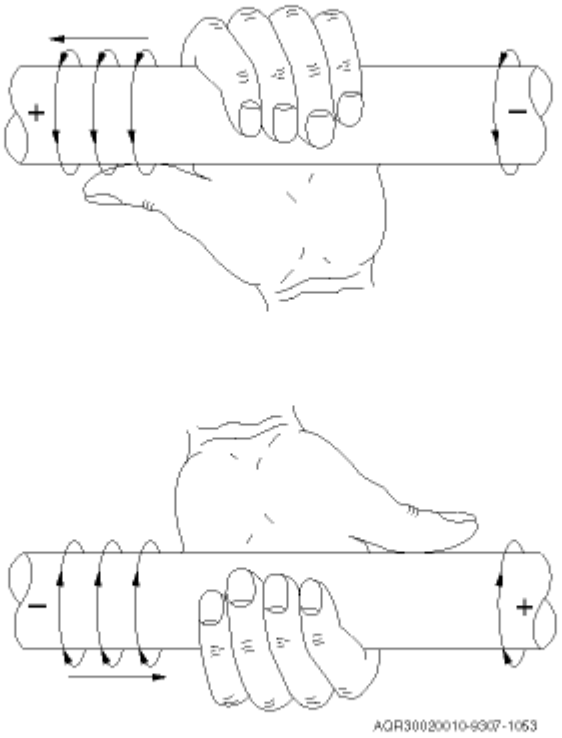
This magnetic field travels in a circular pattern about the conductor depending upon the direction of current flow.

By taking that conductor and forming a loop you should notice the magnetic lines are becoming more concentrated in the center of the loop.



This brings us to a method to determine the direction of the magnetic lines around a conductor called the **Left Hand Rule For Conductors**.

Left Hand Rule For Conductors

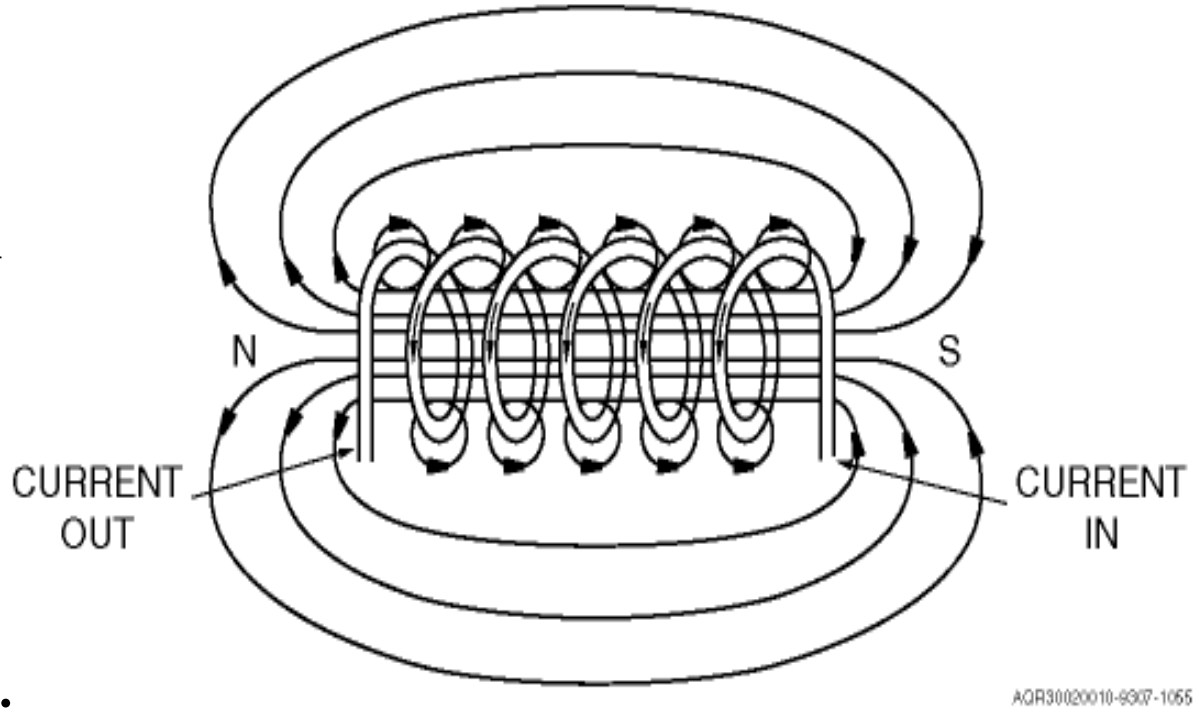


The rule states that if you wrap your left hand about a conductor with your thumb in the direction of current flow your fingers will follow the magnetic lines of force.

If we take that conductor and place many loops into it we have formed a coil or an artificial magnetic.

To determine the polarity of the coil we will use the Left Hand Rule for Coils.

Grasp the coil so your fingers point in the direction of current flow and your thumb will point toward the north end of the coil.



Electromagnets

There are a couple of ways to change the strength of an electromagnet.

- Increasing the amount of current through the coil, but only to the point of saturation (this is the point in which lines of flux is maximum), current and magnetic fields are directly proportional.
- Inserting a core material into the coil (this causes the magnetic lines of force to greatly increase).

Principles of Electromagnetic Induction

Electromagnetic Induction – The creation of an electromotive force and current within a conductor by varying the magnetic field affecting the conductor.

There are three conditions necessary for induction:

1. A Conductor (Coil)
2. A Magnetic Field
3. Relative Motion (Expanding or Collapsing field)

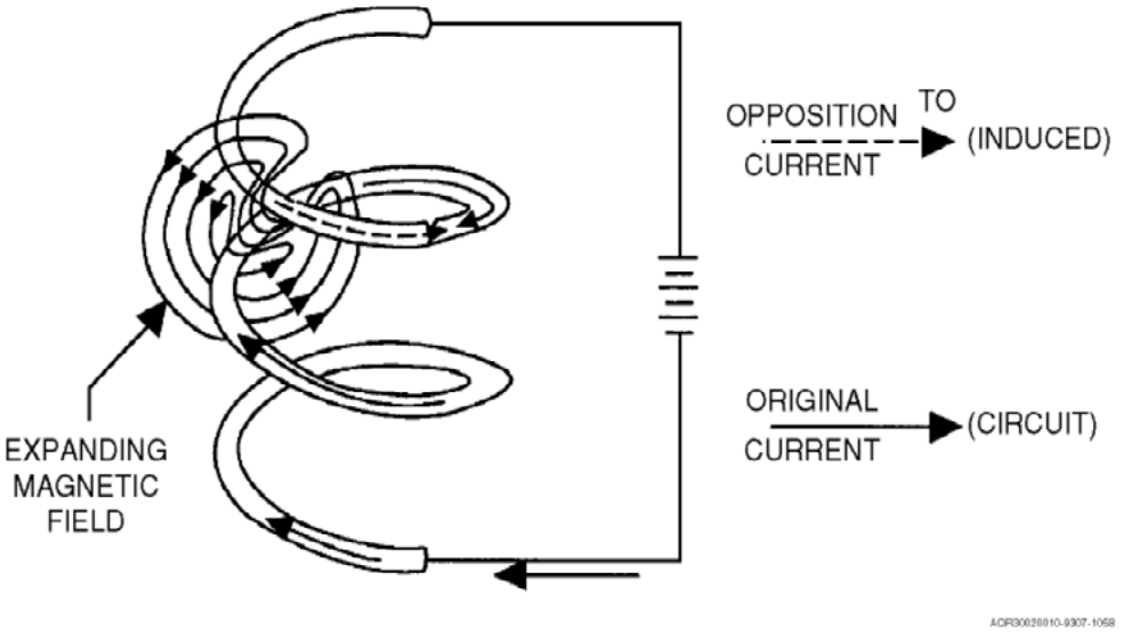
Principles of Electromagnetic Induction

If a conductor is passed through (relative motion) a magnetic field, current will be induced into the conductor. Or if an expanding or collapsing magnetic field (relative motion) cuts across a conductor, current will also be induced.

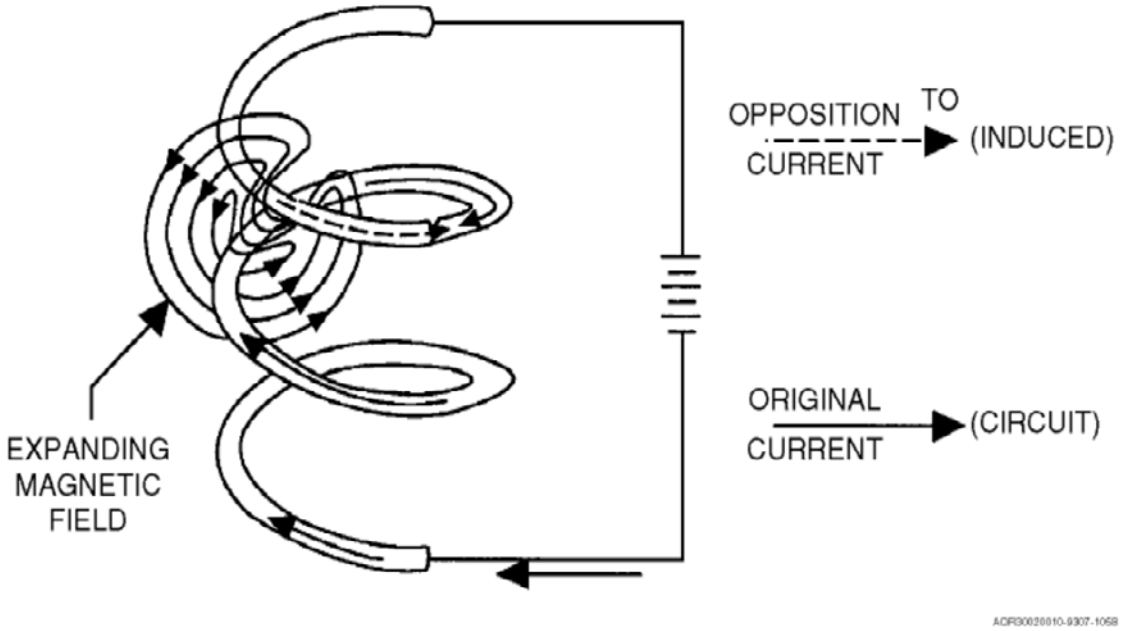
In DC if the current levels change the amount of induction changes.

SELF-INDUCTION

Starts when an expanding magnetic field of one winding cuts the adjacent winding of the coi and induces a current in the opposite direction this current is known as CEMF



CEMF



Counter Electromotive Force (CEMF) –

The current that opposes the original current.

Inductance

- Inductance is the physical property of a circuit that opposes any change in current flow.
- Symbol for inductance is the letter L
- Unit of measurement for Inductance is henry
- Symbol for henry is the letter h or H

Factors Affecting Inductance

$$L = \frac{N^2 A \mu}{\ell}$$

L = Inductance

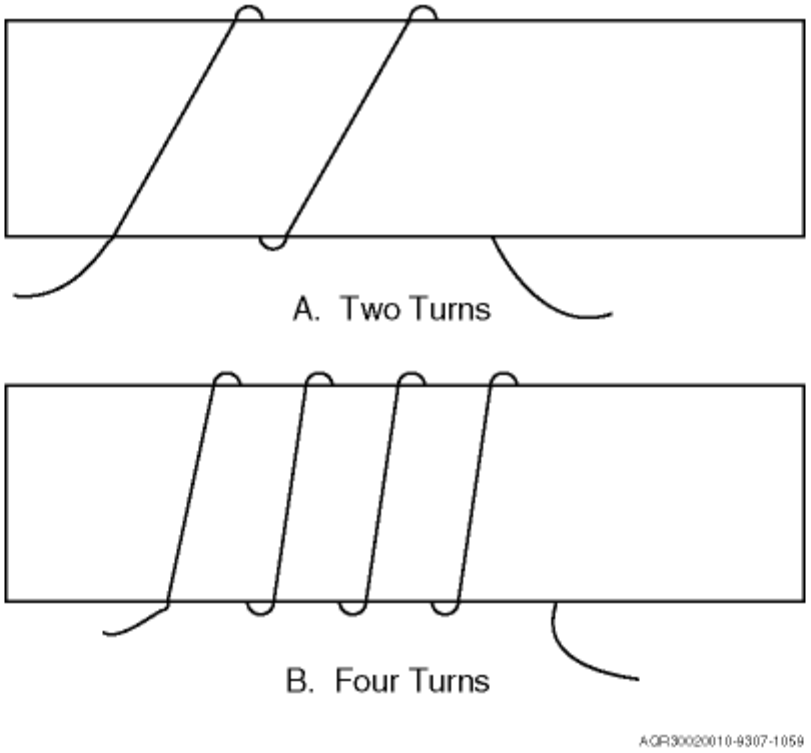
N = Number of turns

A = Cross section area of the core (Diameter)

μ = Permeability of core material (Less opposition to lines of flux)

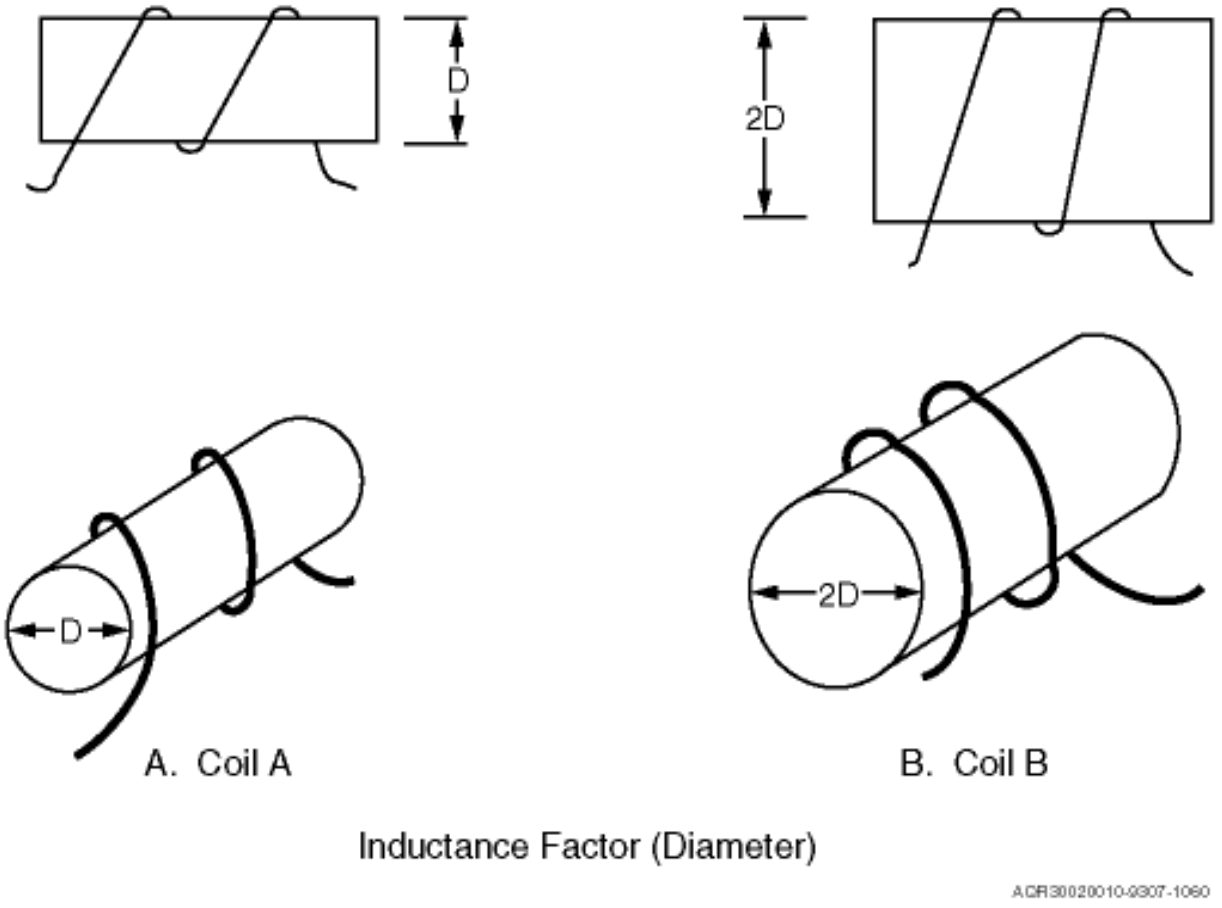
ℓ = Length of the coil

Number of turns



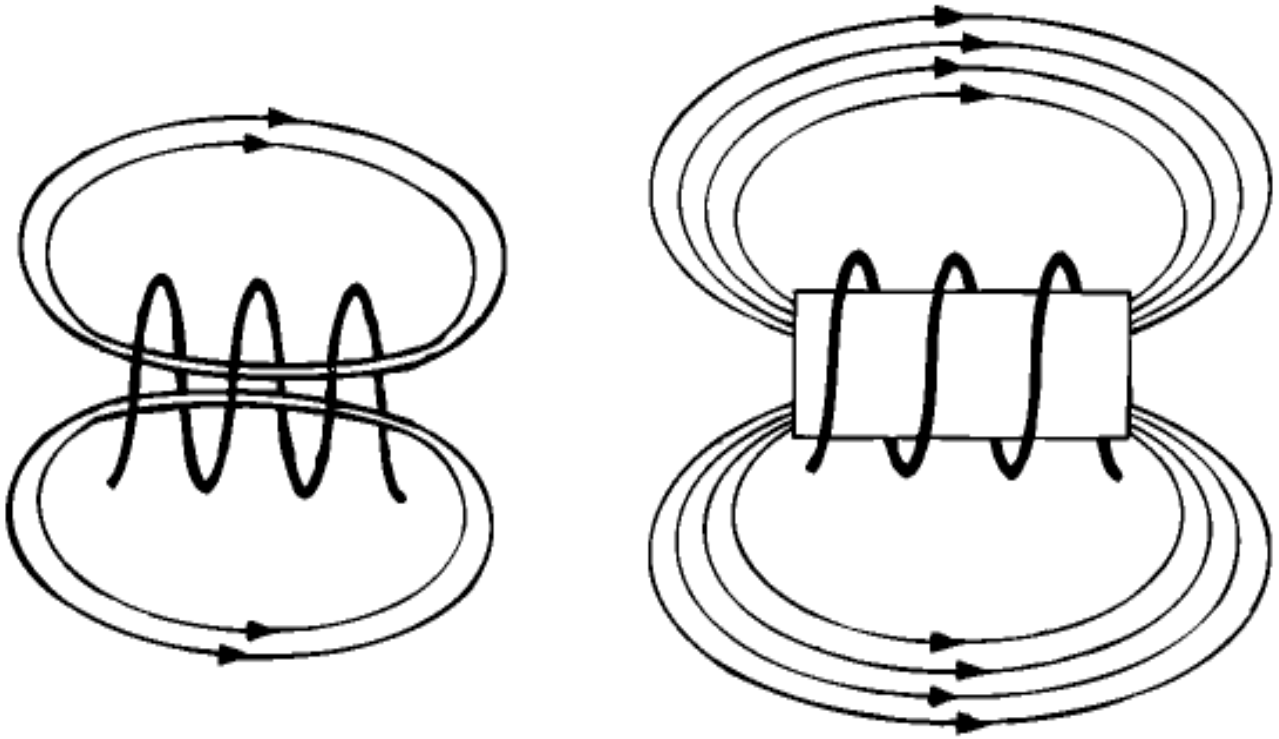
Increasing the number of turns increases inductance causes an increase in inductance.

Cross Sectional Area



Increasing the cross sectional area inductance causes an increase in inductance.

Permeability of core material



A. Air Core B. Soft Iron Core

Inductance Factor (Core Material)

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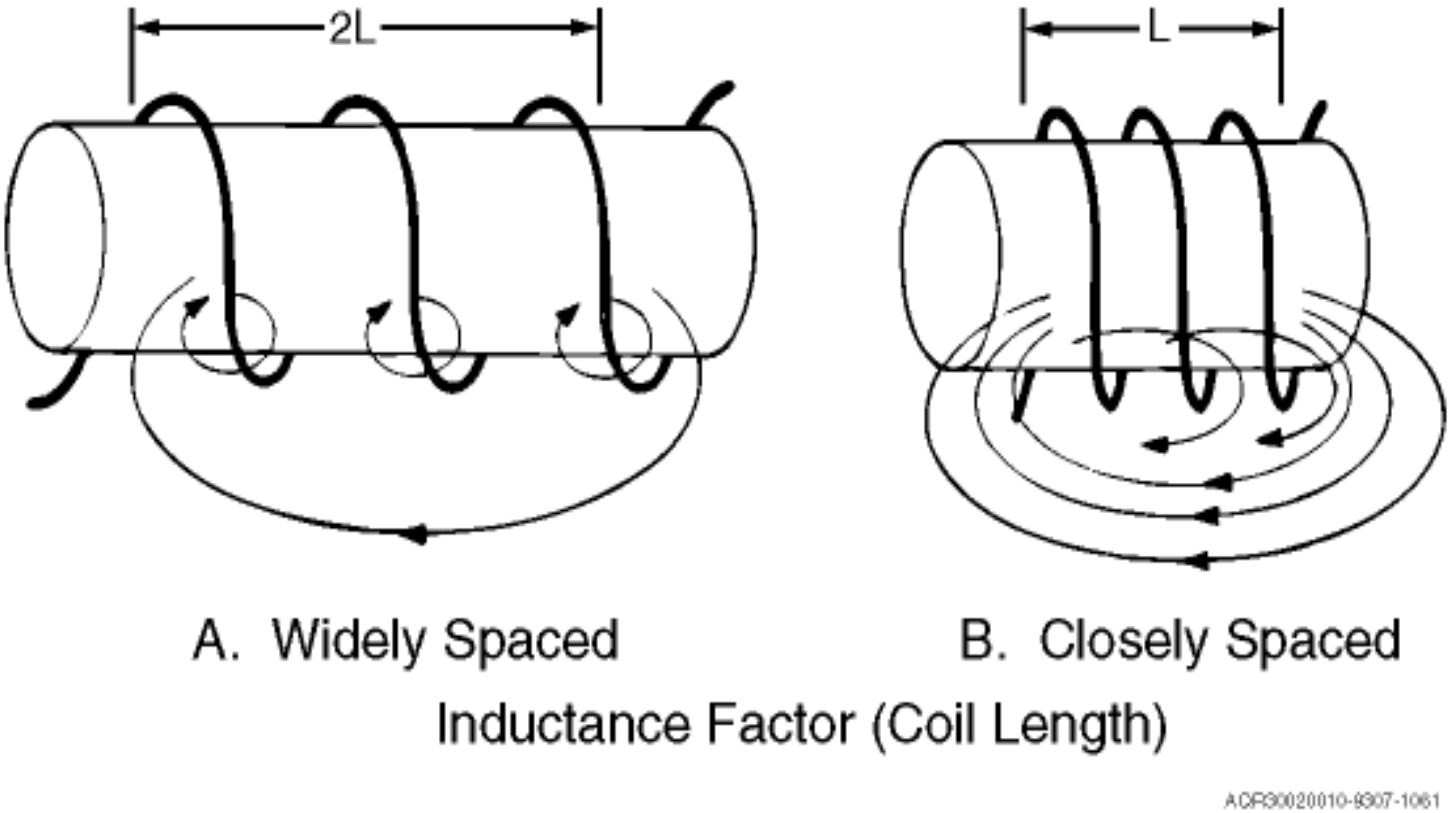
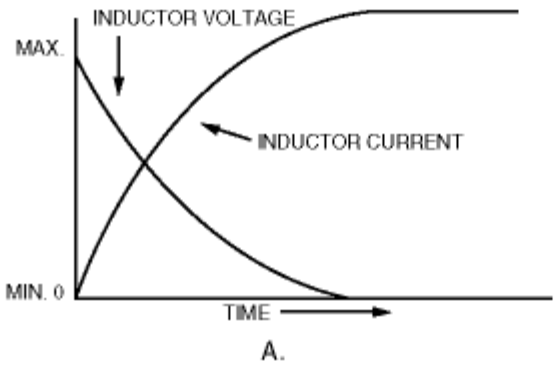
Increasing the permeability increases the number of lines of force this causes an increase in inductance.

Length of coil



As the length of the coil increases flux linkage decreases their by decreasing inductance.

DC Operation



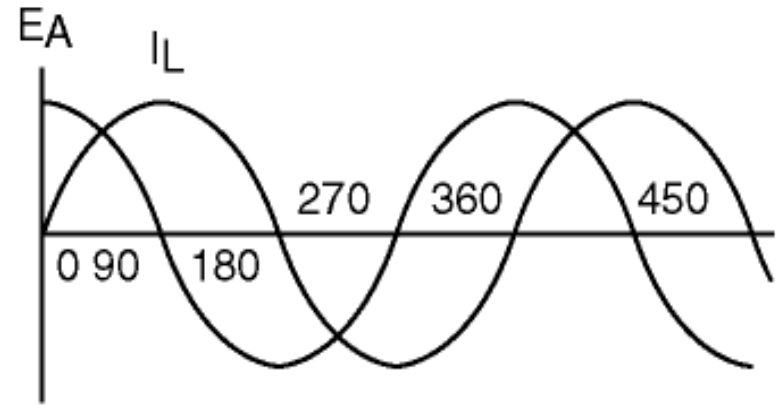
ELI 90º

When DC is first applied to the inductor, current is being opposed. At the first instant the voltage across the inductor is maximum and the current flow through the inductor is minimum.

As time progress the current increases through the inductor to maximum and the voltage across the inductor falls to zero.

AC Operation

ELI 90°



Just as we discussed with DC the Voltage is leading the current. We do have to remember that with AC we have a constantly changing current level with it periodically changing direction.

Inductive reactance (XL) and the factors affecting inductive reactance

The opposition to an AC Current flow offered by the inductance of the circuit is called **INDUCTIVE REACTANCE**

- **Symbol for Inductive Reactance = X_L**
- **Unit of measurement = Ohms**
- **Symbol for unit of measurement = Ω**

Inductive reactance (X_L) and the factors affecting inductive reactance

- **<u>Two</u> factors affect X_L**
  - **Frequency = f**
  - **Inductance = L**
- **XL = 2 πfL**
  - **By the formula we can see L & f are directly related to XL**

Effects of frequency and inductance on circuit operation

Since the unit of measurement of X_L is Ohms, it can replace resistance in all of the Ohm's law formulas.

$I = E / X_L$ $E = I * X_L$

Remember the formula for inductive reactance

$$X_L = 2 \pi f L$$

Effects of frequency on circuit operation

- Increasing Frequency
  - L ⟷ X_L ↑ I_T ↓ EA ⟷
- Decreasing Frequency
  - L ⟷ X_L ↓ I_T ↑ EA ⟷

Effects of inductance on circuit operation

- Increasing Inductance
  - F ⟷ X_L ↑ I_T ↓ EA ⟷
- Decreasing Inductance
  - F ⟷ X_L ↓ I_T ↑ EA ⟷

Summary of Changes

Increase		EA	F	L	X_L	I_T
Frequency						
Inductance **OF ONE INDUCTOR**						
Decrease		EA	F	L	X_L	I_T
Frequency						
Inductance **OF ONE INDUCTOR**						

Objective 3b

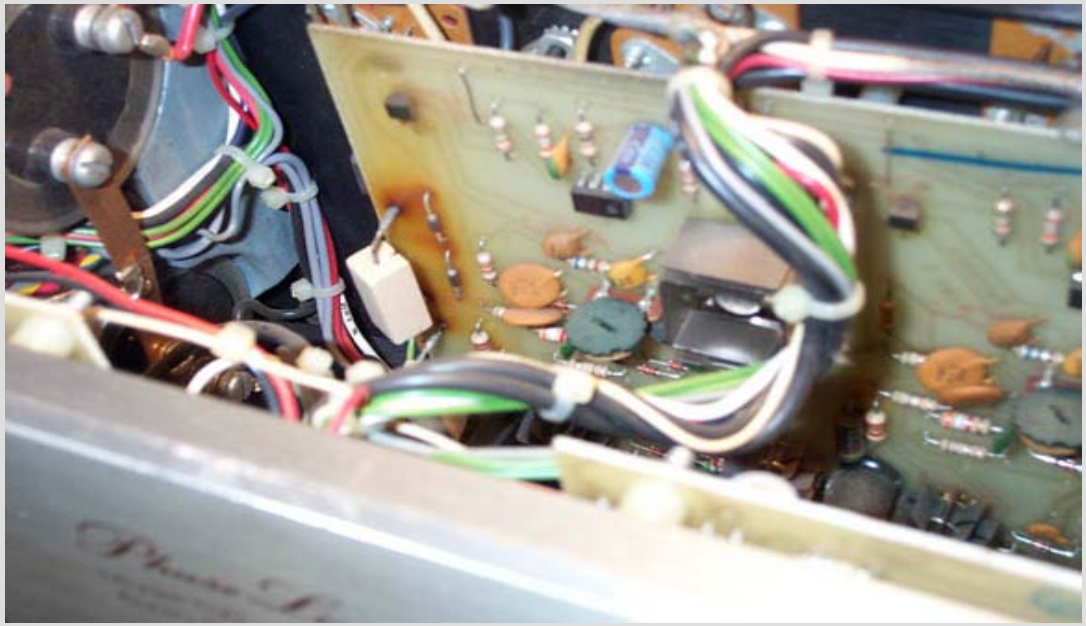
Use test equipment and a trainer to troubleshoot an inductive circuit IAW the PC checklist.

We are going to look at three types of malfunctions.

- **OPEN**
  - There is no continuity between the two leads
- **SHORT**
  - Current can flow from one lead to next lead without going through the coil.
- **PARTIAL SHORT**
  - Current flows from one lead to next lead but only going through part of the coil.

Visual Inspection

With this check we are looking for the obvious things like missing or broken components



- Voltage Checks
  - If the component is **open** the voltage across the open component will measure EA and the remaining components will measure zero volts.
  - If the component is **shorted** the voltage across the shorted component will measure zero volts and the remaining components will have voltage on them.
  - If the component is **partial shorted** the voltage across the partial shorted component will measure lower than normal voltage and the remaining components will have a higher than normal voltage on them.

- Resistance Checks
  - POWER OFF (Out of Circuit)
  - Use the lowest Ohm's range (ohms * 1)
    - **Open** – Component will measure (∞Ω) or O.L.
    - **Shorted -** Component will measure zero Ω
    - **Partial Short -** Component will measure lower resistance than normal
  - If you suspect a partial shorted inductor substitute the inductor out with a good one.

	I	E	R
OPEN	None	Ea	∞
SHORT	Maximum	Zero	Zero
METER	Series	Parallel	Parallel
POWER	On	On	Off