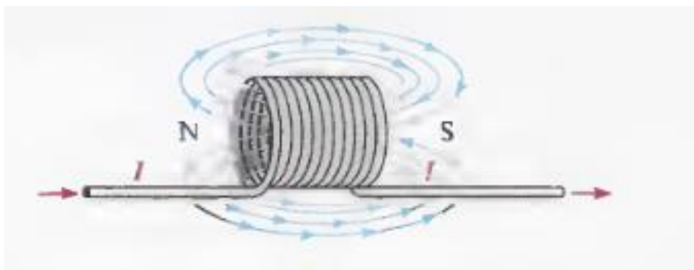
Applied Physics Lecture 6

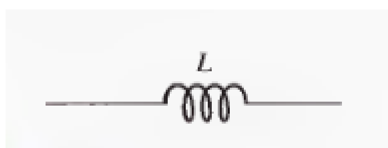
Inductor

A passive electrical component formed by a wire wound around a core and which exhibits a property of *inductance*.

When length of wire is formed into a *coil*, it becomes an inductor. The terms *coil* and *inductor* are used interchangeably. When current is passed through the coil, magnetic lines around each loop add up with the lines of adjacent loops and forms a strong magnetic field inside and outside the coil. The total electromagnetic field creates a North and South Pole.



Symbol



Inductance

It is a measure of coil's ability to establish an induced voltage as a result of change in its current, and that induced voltage is in a direction to oppose the change in current.

Induced voltage v_{ind} or emf is directly proportional to inductance L and time rate of change of current di/dt

$$v_{ind} = L(di/dt)$$

$$L = \frac{v_{ind}}{(di/dt)}$$

Unit of inductance is Henry (H)

Physical parameters

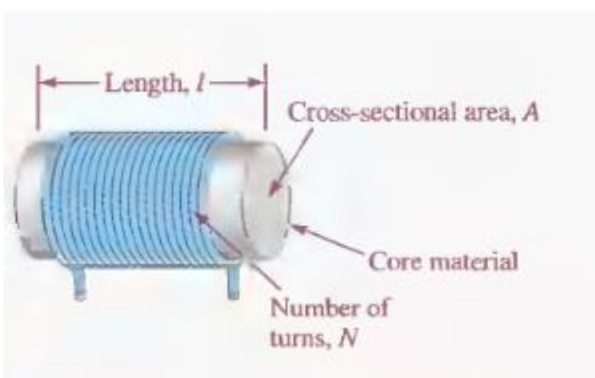
The value of inductance depends upon number of turns of wire, length and cross-sectional area of the core. L is inversely proportional to the length l of the wire and directly proportional to the cross sectional area A and square of number of turns N^2.

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

μ is permeability of the core material. It means how easily a magnetic field can be established.

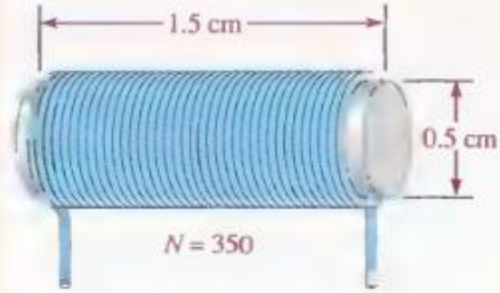
$$\mu = \mu_r \mu_o$$

$\mu_o = 4\pi \times 10^{-7}$ is the permeability of vacuum.



Determine the inductance of the coil in Figure [redacted] The permeability of the core is 0.25×10^{-3} H/m.

FIGURE [redacted]



First determine the length and area in meters.

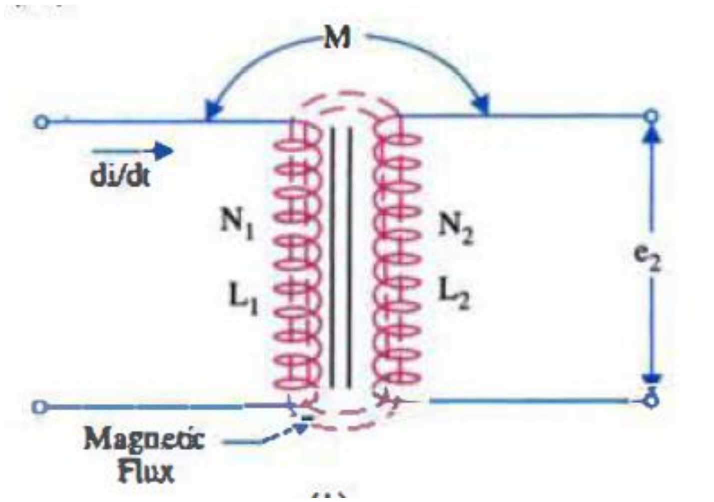
$$l = 1.5 \text{ cm} = 0.015 \text{ m}$$
$$A = \pi r^2 = \pi(0.25 \times 10^{-2} \text{ m})^2 = 1.96 \times 10^{-5} \text{ m}^2$$

The inductance of the coil is

$$L = \frac{N^2 \mu A}{l} = \frac{(350)^2(0.25 \times 10^{-3} \text{ H/m})(1.96 \times 10^{-5} \text{ m}^2)}{0.015 \text{ m}} = \mathbf{40 \text{ mH}}$$

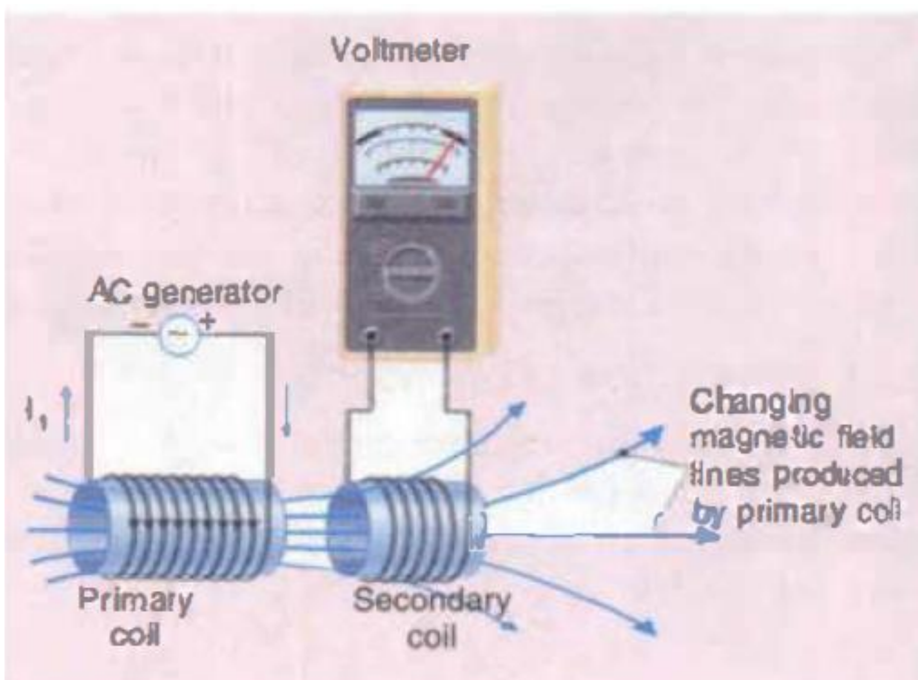
Mutual Inductance

When two coils are placed close to each other, a changing electromagnetic field produced by the current in one coil will cause an induced voltage in the second coil because of mutual inductance M between the coils.



$v_{ind} = M(di/dt)$

$M = \frac{N_1 N_2 A\mu}{l}$



Types of Inductors

An inductor is basically a coil of wire that surrounds a magnetic or non-magnetic material called the core.

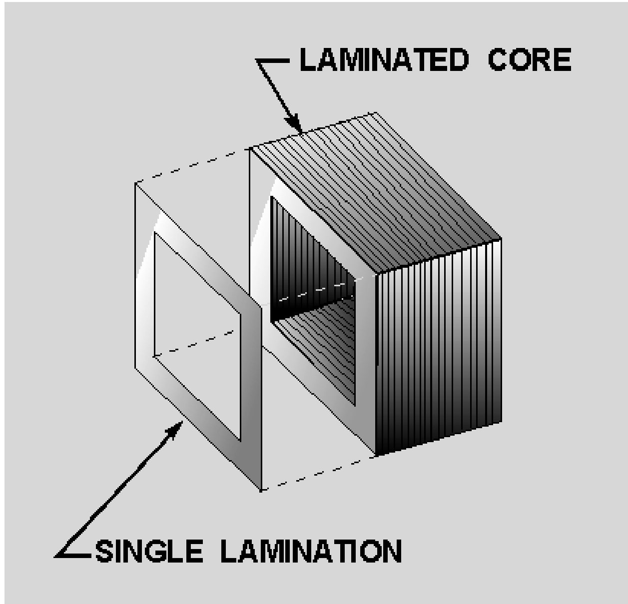
Air core Inductor

It has air inside the coil and has least inductance because air is non-magnetic. It has least inductance.

Iron core Inductor

Coil of wire is wound over an iron core which is a magnetic material so it produces strong magnetic fields and have large inductance. It increases inductance as μ_r. Iron core is laminated to avoid eddy current loss.

Eddy Current loss: The current produced in the core due to induced voltage is known as eddy current. This current is not useful as it produces power loss known as eddy current loss which increases the temperature of the magnetic material.

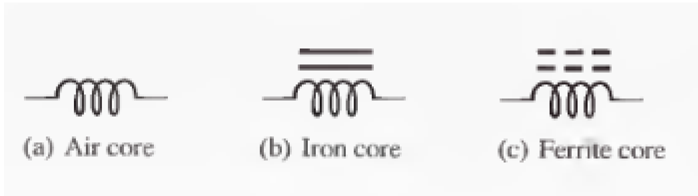


Ferrite core Inductor

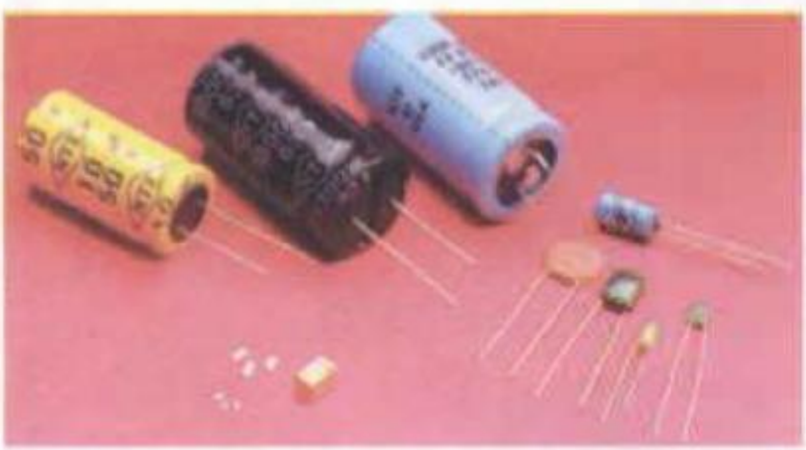
Ferrite is mixture of iron oxide and some metal like zinc, nickel etc. It's a ferromagnetic material and has minimum eddy current loss. They are used in high power systems.

Comparison

Air core has low inductance but there are no current losses. Laminated iron cores have larger inductance than air core coils. Ferrite cores have minimum current losses and have high inductance.

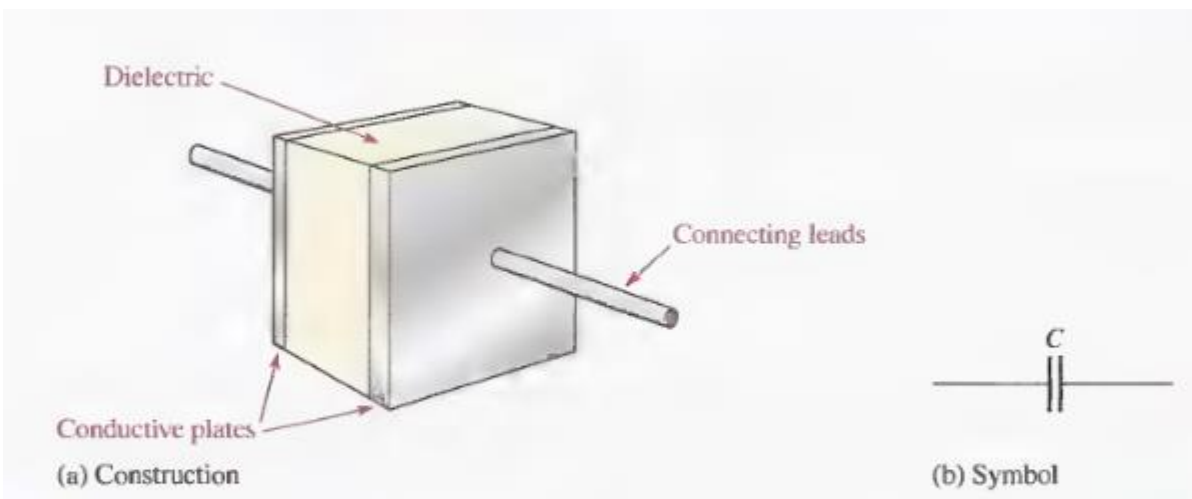


Capacitors



Capacitors.

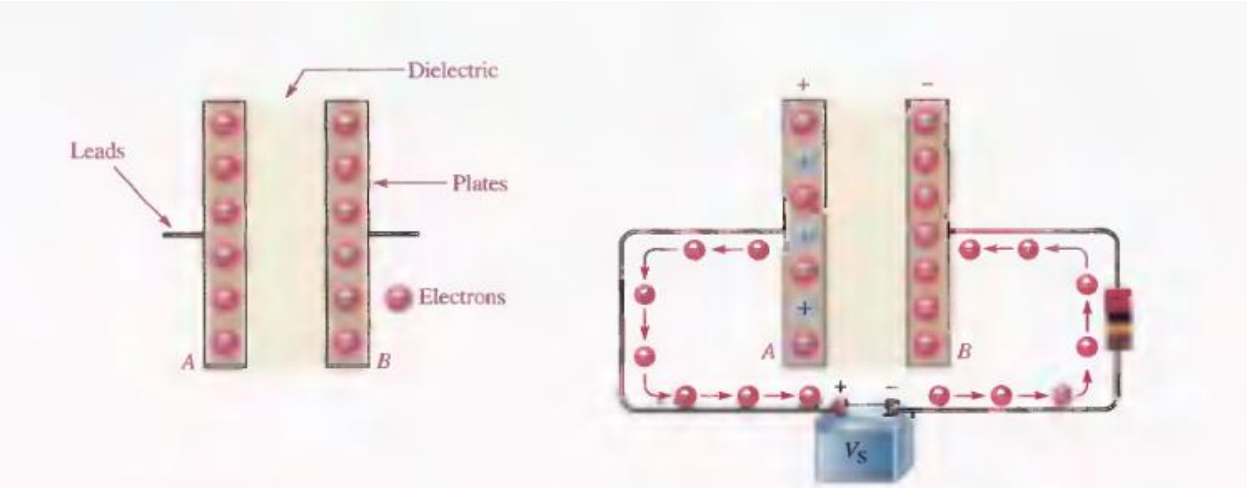
1. has the ability to store charge which neither a resistor nor an inductor can do;
2. opposes any change of voltage in the circuit in which it is connected*;
3. blocks the passage of direct current through it.



Dielectric is an insulating material between plates of a capacitor. Dielectric can be air, plastic, mica, ceramic, polyester etc.

Capacitor connected to a battery

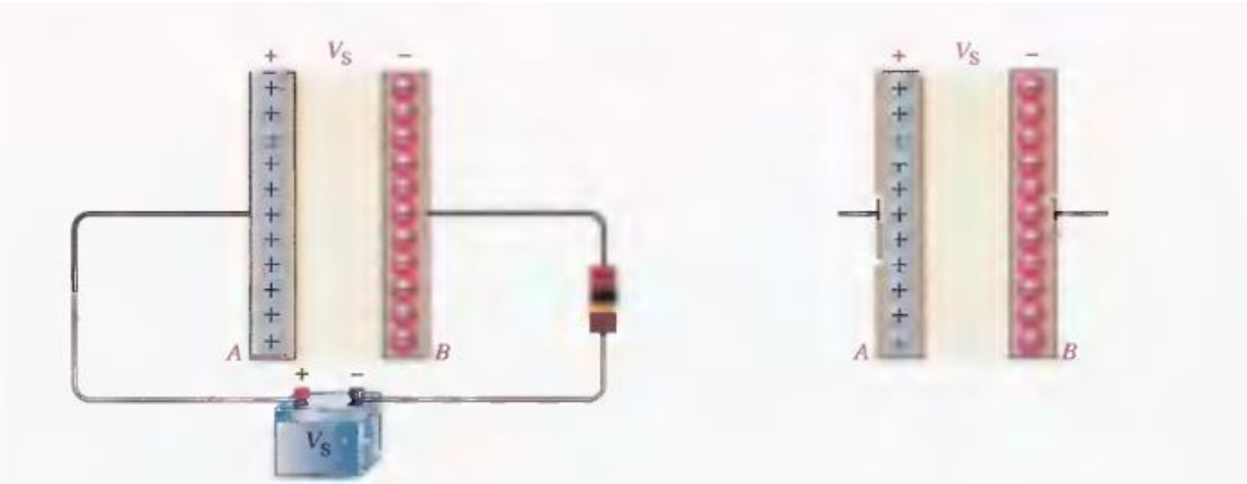
In neutral state both plates have equal number of free electrons. When connected with battery, electrons are removed from plate A and collected on plate B so plate A become positive and B become negative. All the electrons flow through the wires only.



(a) Neutral (uncharged) capacitor (same charge on both plates)

(b) Electrons flow from plate A to plate B as the capacitor charges when connected to a voltage source.

At start motion of charges is fast then decreases slowly. When voltage across capacitor become equal to source voltage then motion of electrons stops. Capacitor retains the stored charge for some time when disconnected from the battery.



(c) After the capacitor charges to V_S, no electrons flow while connected to the voltage source.

(d) Ideally, the capacitor retains charge when disconnected from the voltage source.

Important points

1. Current flows only through the wires, not through capacitor.

2. The voltage should not exceed the dielectric strength of the dielectric. Dielectric strength is the maximum voltage which a material can withstand without breakdown. Excess voltage can cause permanent damage to the capacitor and it conducts electricity. Its value is different for every material e.g. for air as dielectric its value is 80V for 1mm separation between the plates.

3. Due to charges on the plates, electric field is established between the plates given as E = V/d

Capacitance

It is the ability of a capacitor to store charge given as

C = Q/V

Where Q is charge in coulomb and V is potential difference between the plates. Its unit is farad (F). Its other units are µF, nF and pF.

Convert the following values to microfarads:

(a) 0.00001 F **(b)** 0.0047 F **(c)** 1000 pF **(d)** 220 pF

(a) $0.00001\ F \times 10^6\ \mu F/F = \mathbf{10\ \mu F}$ **(b)** $0.0047\ F \times 10^6\ \mu F/F = \mathbf{4700\ \mu F}$

(c) $1000\ pF \times 10^{-6}\ \mu F/pF = \mathbf{0.001\ \mu F}$ **(d)** $220\ pF \times 10^{-6}\ \mu F/pF = \mathbf{0.00022\ \mu F}$

Factors controlling Capacitance

Capacitance is directly proportional to plate area and inversely proportional to plate separation. It also depends upon dielectric constant (relative permittivityε_r)

Relative permittivity ε_r

It is the material’s ability to establish an electric field.

$$C = \frac{\varepsilon_o \varepsilon_r A}{d}$$

$$\varepsilon_o = 8.854 \times 10^{-12} F/m$$