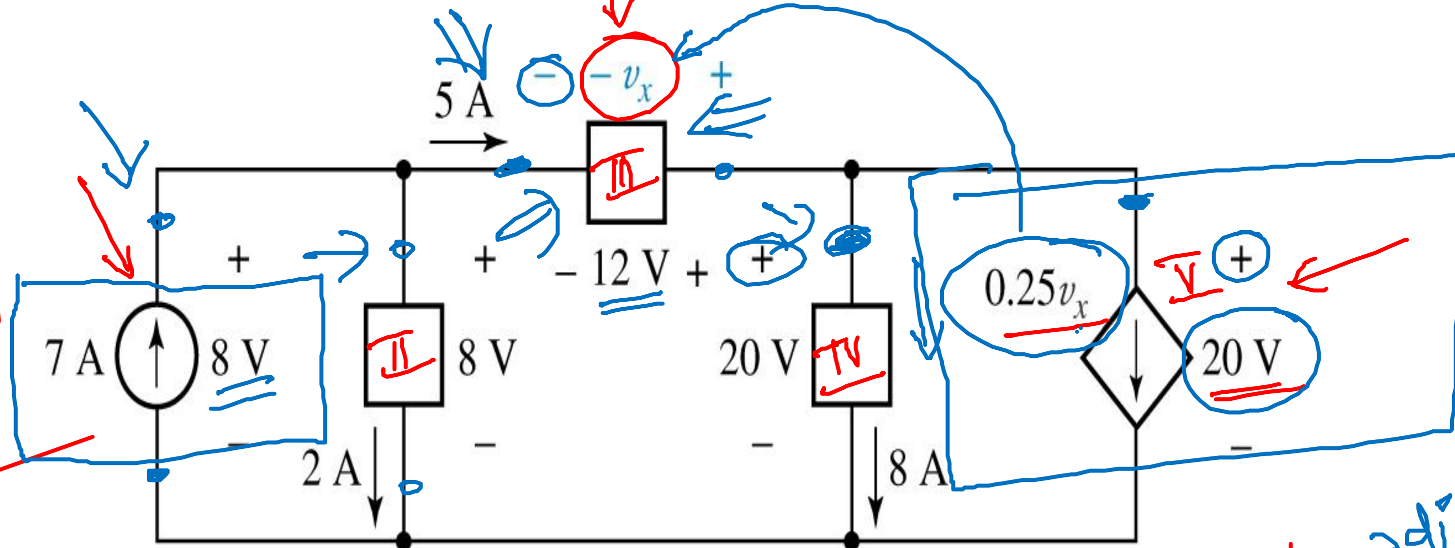
# Unit - I
# 1.3 Passive Components

**Dr.Santhosh.T.K.**

# Power

**Find the power absorbed by each element in the circuit below.**




supplier

I → 56W.

dissipate

II → 16W

supplier

III → 60W

IV → 160W → dissipate

dissipate

V → $20 \times 0.25 V_x$

$20 \times 0.25 \times 12$

# AC/DC.

Loads

- → charger / Gadget → DC
- → Light → DC
- → TV → DC
- → Refrigrator → DC
- → Fans → Ac/DC
- → UPS → DC
- → AC → DC
- → washing machine → DC
- → motors → AC

~ 70% of ~~the~~ loads

DC

→ Transmission → DC

80 – 30

# Syllabus

**UNIT – I** **10 Periods**

**Introduction and Basic Concepts:** Concept of Potential difference, voltage, current - Fundamental linear passive and active elements to their functional current-voltage relation - Terminology and symbols in order to describe electric networks - Concept of work, power, energy and conversion of energy- Principle of batteries and application.

**Principles of Electrostatics:** Electrostatic field - electric field intensity - electric field strength - absolute permittivity - relative permittivity - capacitor composite – dielectric capacitors - capacitors in series & parallel - energy stored in capacitors - charging and discharging of capacitors.

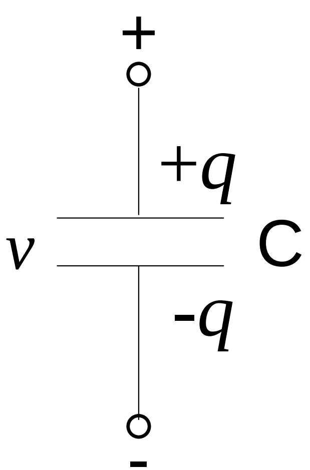
# Capacitors and Inductors

- **Capacitors**
- Inductors

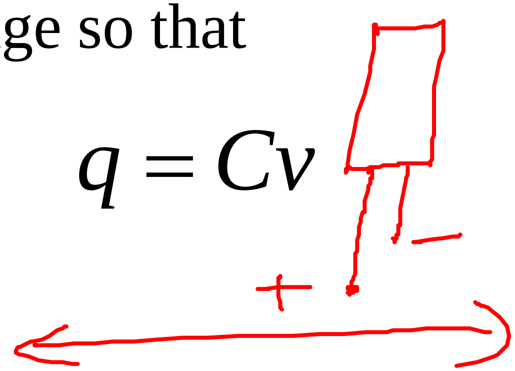
We will introduce two new **linear elements**, the *capacitor* and the *inductor*. Unlike resistors, which can only dissipate energy, these two elements can only store energy, which can then be retrieved at a later time.

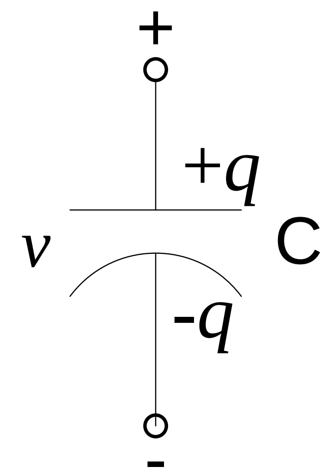
# Capacitors

A capacitor is a passive element that stores energy in its electric field. A capacitor consists of two conducting plates separated by an insulator (or dielectric). When a voltage source is connected to the capacitor, the source deposits a positive charge, $+q$, on one plate and a negative charge, $-q$, on the other. The amount of charge is directly proportional to the voltage so that




$$q = Cv$$



# Capacitors

*C*, called the capacitance of the capacitor, is the constant of proportionality. *C* is measured in Farads (F). From

$$q = Cv$$

we define:

***Capacitance is the ratio of the charge on one plate of a capacitor to the voltage difference between the two plates, measured in Farad (F).*** *Thus,* ***1F = 1 coulomb/volt***

In reality, the value of *C* depends on the surface area of the plates, the spacing between the plates, and the permitivity of the material.

# Capacitors

$$q = Cv$$

$$\frac{dq}{dt} = i(t) = C\frac{dv(t)}{dt}$$

$$\text{Note: } v(t_0) = \frac{q(t_0)}{C}$$

$$v(t) = \frac{1}{C}\int_{-\infty}^{t} i(x)dx = \frac{1}{C}\int_{-\infty}^{t_0} i(x)dx + \frac{1}{C}\int_{t_0}^{t} i(x)dx$$

$$v(t) = v(t_0) + \frac{1}{C}\int_{t_0}^{t} i(x)dx$$

We see that the capacitor voltage depends on the past history of the capacitor current. Thus, we say that the capacitor has a memory – a property we can exploit.

# Energy stored in the capacitor

The instantaneous power delivered to the capacitor is

$$p(t) = vi = Cv\frac{dv}{dt}$$

The energy stored in the capacitor is thus

$$w = \int p(t)dt = C\int_{-\infty}^{t} v\frac{dv}{dt}dt = C\int_{-\infty}^{t} vdv$$

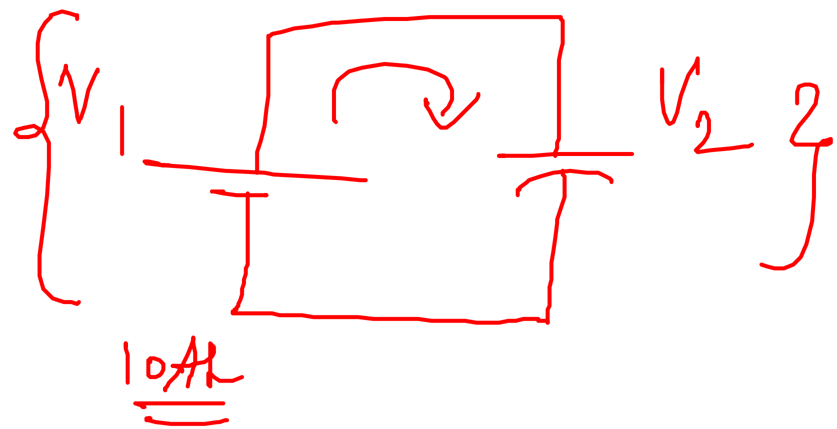
$$w = \frac{1}{2}Cv^2(t) \ \text{ joules}$$

# Energy stored in the capacitor

Assuming the capacitor was uncharged at $t$ = -∞, and knowing that

$$q = Cv$$

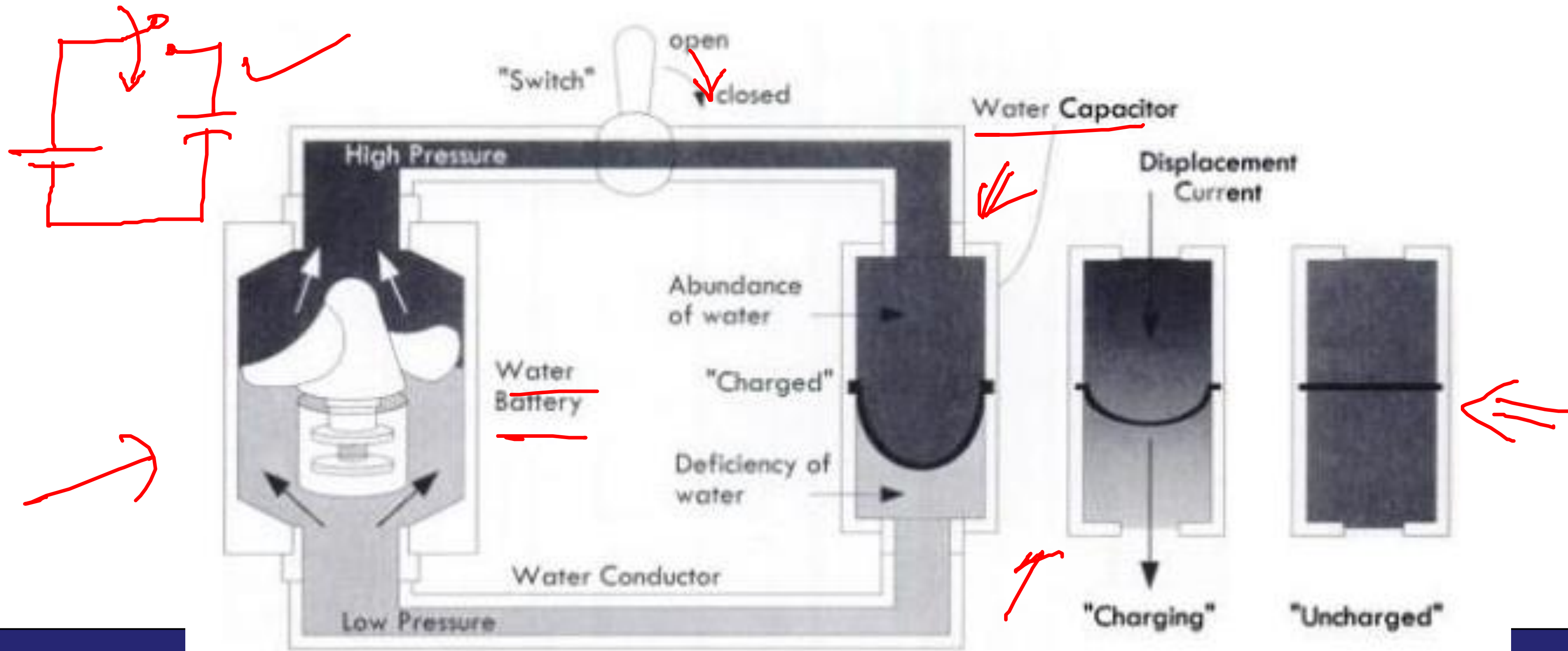
$$w = \frac{1}{2}Cv^2(t) = \frac{q^2(t)}{2C}$$




represents the energy stored in the electric field established between the two plates of the capacitor. This energy can be retrieved. And, in fact, the word capacitor is derived from this element's ability (or capacity) to store energy.

# Capacitor Water Pipe Analogy

- Water capacitor: a tube with a rubber membrane in the middle
- Rubber membrane analogous to the dielectric, two chambers analogous to two capacitor plates
- When no water pressure is applied on the water capacitor, the two chambers contain same amount of water (uncharged)
- When pressure is applied on the top chamber, the membrane is pushed down causing the water to be displaced from the bottom chamber (appearance of current flow → displacement current)



# Capacitor Properties

1. When the voltage across a capacitor is constant (not changing with time) the current through the capacitor:

$$i = C\,dv/dt = 0$$

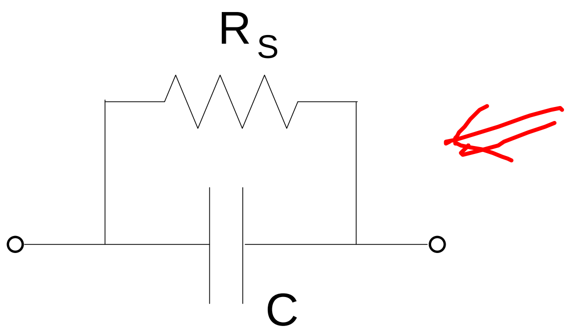
Thus, **a capacitor is an open circuit to dc.** If, however, a dc voltage is suddenly connected across a capacitor, the capacitor begins to charge (store energy).

2. The voltage across a capacitor must be continuous, since a jump (a discontinuity) change in the voltage would require an infinite current, which is physically impossible. Thus, a capacitor resists an abrupt change in the voltage across it, and **the voltage across a capacitor cannot change instantaneously,** whereas, the current can.

# Capacitor Properties

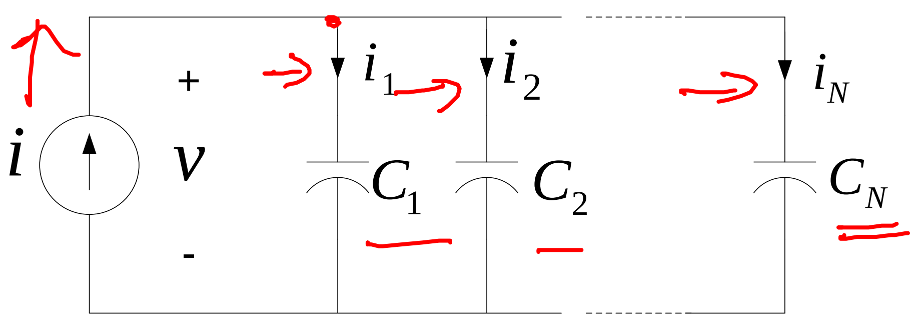
3. The ideal capacitor does not dissipate energy. It takes power from the circuit when storing energy and returns previously stored energy when delivering power to the circuit.

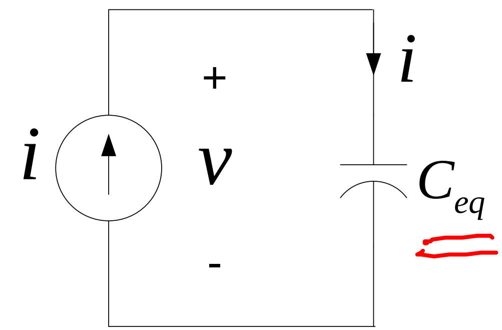
4. A real, non-ideal, capacitor has a "leakage resistance" which is modeled as shown below. The leakage resistance may be as high as 100MΩ, and can be neglected for most practical applications.




*In this course we will always assume that the capacitors are ideal.*

# Parallel Capacitors



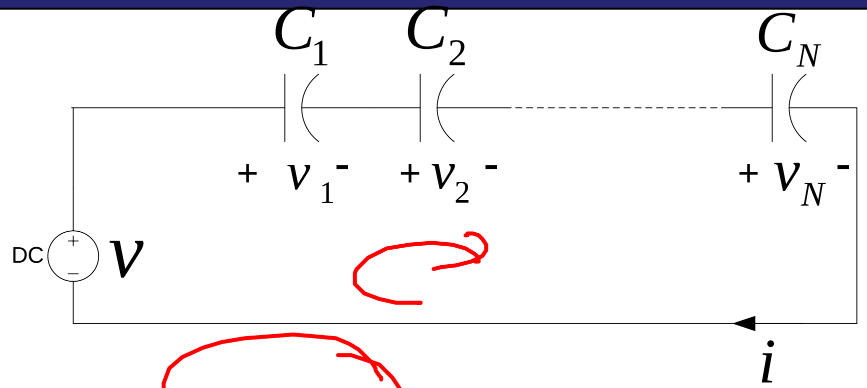

$$i_1 = C_1 \frac{dv}{dt} \qquad i_2 = C_2 \frac{dv}{dt} \qquad i_N = C_N \frac{dv}{dt}$$

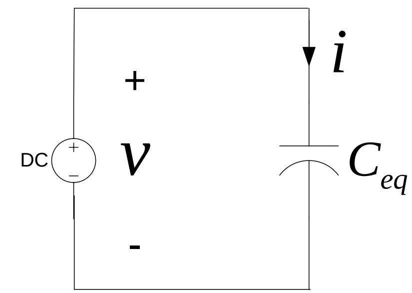
$$i = i_1 + i_2 + \cdots + i_N = \left(C_1 + C_2 + \cdots + C_N\right)\frac{dv}{dt} = C_{eq}\frac{dv}{dt}$$

$$C_{eq} = \sum_{k=1}^{N} C_k$$

Thus, ***the equivalent capacitance of N capacitors in parallel is the sum of the individual capacitances. Capacitors in parallel act like resistors in series.***

# Series Capacitors



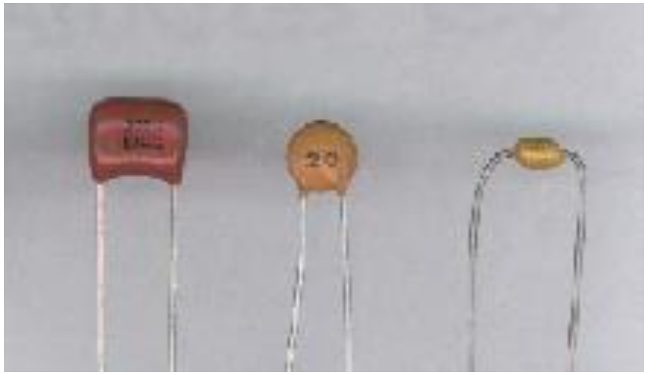

$$v_1 = \frac{1}{C_1}\int i dt \qquad v_2 = \frac{1}{C_2}\int i dt \qquad v_N = \frac{1}{C_N}\int i dt$$

$$v = v_1 + v_2 + \cdots + v_N = \left(\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}\right)\int i dt = \frac{1}{C_{eq}}\int i dt$$

$$\frac{1}{C_{eq}} = \sum_{k=1}^{N} \frac{1}{C_k}$$

***The equivalent capacitance of N series connected capacitors is the reciprocal of the sum of the reciprocals of the individual capacitors. Capacitors in series act like resistors in parallel.***

# Capacitor Variations



- Ceramic capacitors
  - –very popular nonpolarized capacitor
  - –small, inexpensive, but poor temperature stability and poor accuracy
  - –ceramic dielectric and a phenolic coating
  - –often used for bypass and coupling applications

Axial lead Radial lead

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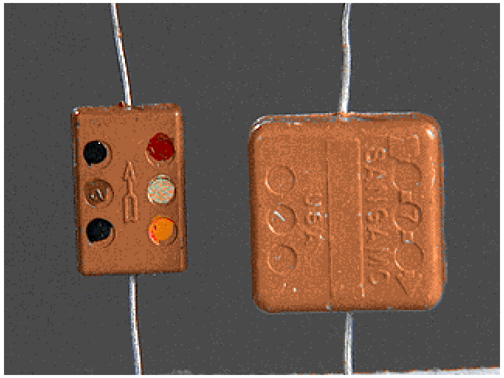
- Electrolytic
  - –Aluminum, tantalum electrolytic
  - –Tantalum electrolytic capacitor has a larger capacitance when compared to aluminum electrolytic capacitor
  - –Mostly polarized.
  - –Greater capacitance but poor tolerance when compared to nonelectrolytic capacitors.
  - –Bad temperature stability, high leakage, short lives

# Capacitor Variations


- Mylar
  - –very popular, nonpolarized
  - –reliable, inexpensive, low leakage
  - –poor temperature stability



- Mica
  - –extremely accurate, low leakage current
  - –constructed with alternate layers of metal foil and mica insulation, stacked and encapsulated
  - –small capacitance
  - –often used in high-frequency circuits (i.e. RF circuits)

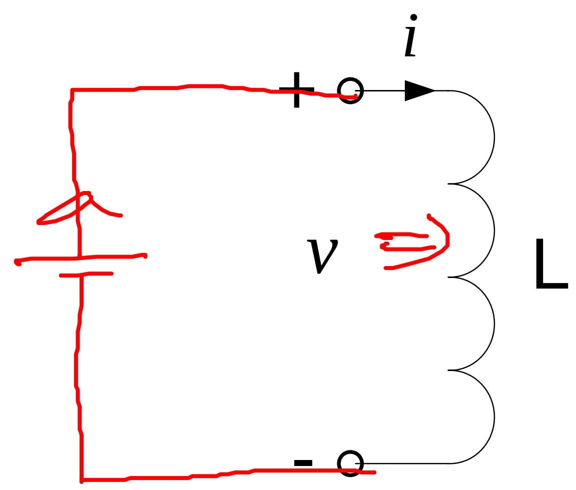
# Capacitors and Inductors

- Capacitors
- **Inductors**

# Inductors

An inductor is a passive element that stores energy in its magnetic field. Generally. An inductor consists of a coil of conducting wire wound around a core. For the inductor

$$v(t) = L\frac{di(t)}{dt}$$




where $L$ is the inductance in henrys (H), and 1 H = 1 volt second/ampere.

C → V
L → I

*Inductance is the property whereby an inductor exhibits opposition to the change of current flowing through it.*

# Inductors

$$v(t) = L\frac{di(t)}{dt}$$

$$i(t) = \frac{1}{L}\int_{-\infty}^{t} v(x)dx = \frac{1}{L}\int_{-\infty}^{t_0} v(x)dx + \frac{1}{L}\int_{t_0}^{t} v(x)dx$$

$$i(t) = i(t_0) + \frac{1}{L}\int_{t_0}^{t} v(x)dx$$

where $i(t_0)$ = the total current evaluated at $t_0$ and $i(-\infty) \equiv 0$ (which is reasonable since at some time there was no current in the inductor).

# Energy stored in an inductor

The instantaneous power delivered to an inductor is

$$p(t) = vi = Li\frac{di}{dt}$$

The energy stored in the magnetic field is thus

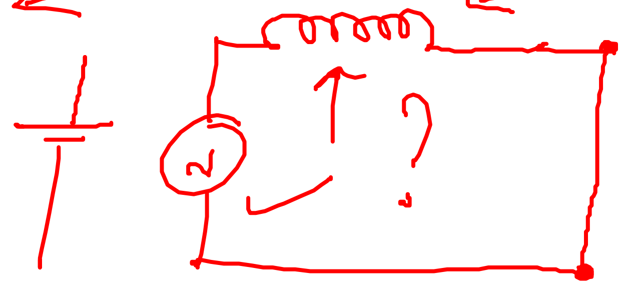
$$w_L(t) = \int p(t)dt = L\int_{-\infty}^{t} i\frac{di}{dt}dt = L\int_{-\infty}^{t} idi$$

$$w_L(t) = \frac{1}{2}Li^2(t) \text{ joules}$$

# Inductor Properties

1. **An inductor acts like a short circuit to dc**, since from

$$v(t) = L\frac{di(t)}{dt}$$



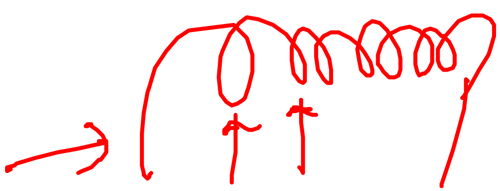

$v = 0$ when $i$ = a constant.

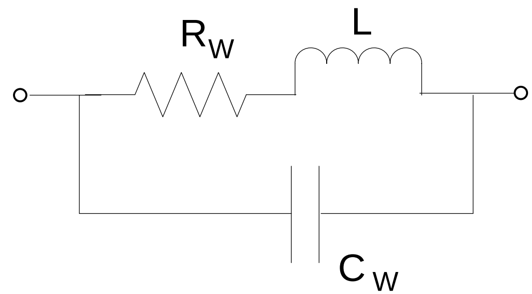
2. **The current through an inductor cannot change instantaneously**, since an instantaneous change in current would require an infinite voltage, which is not physically possible.

# Inductor Properties

3. Like the ideal capacitor, the ideal inductor does not dissipate energy.

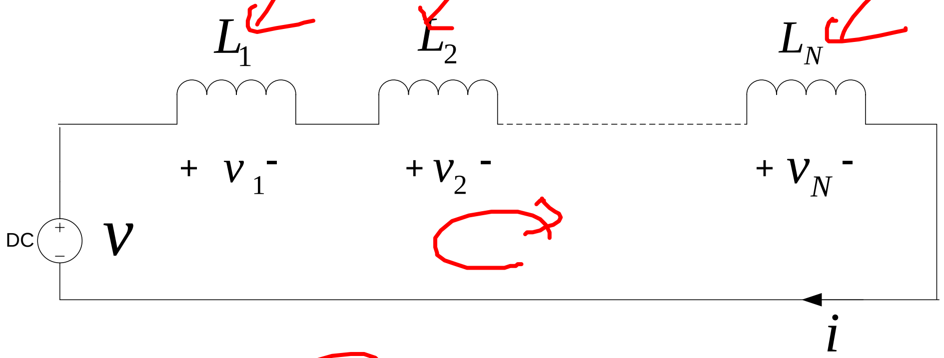
4. A real inductor has a significant resistance due to the resistance of the coil, as well as a “winding capacitance”. Thus, the model for a real inductor is shown below.

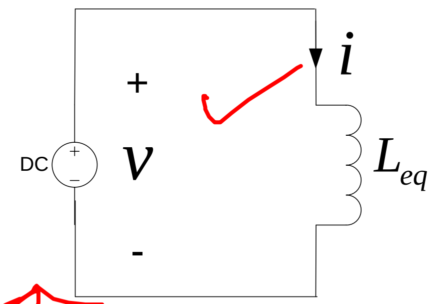





*In this course, however, we will use ideal inductors and assume that an ideal inductor is a good model.*

# Series Inductors



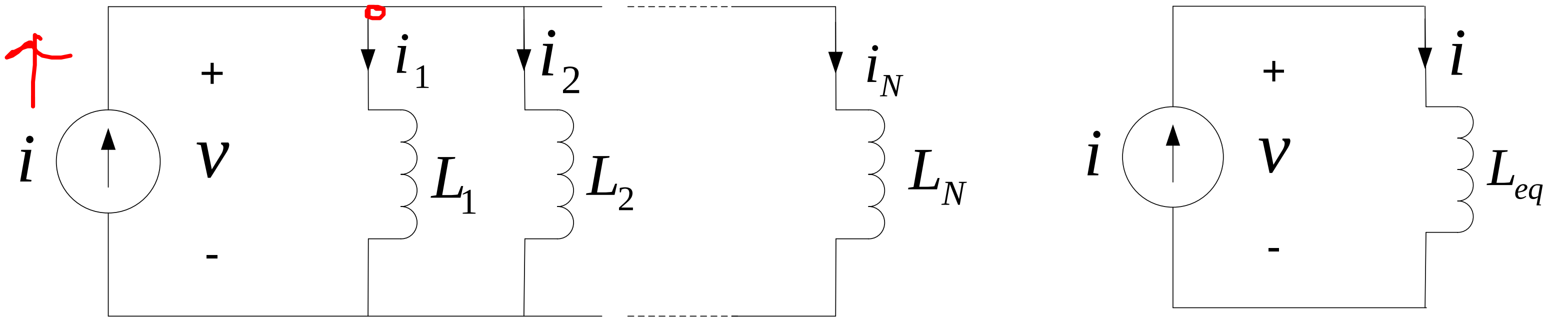

$$v_1 = L_1 \frac{di}{dt} \qquad v_2 = L_2 \frac{di}{dt} \qquad v_N = L_N \frac{di}{dt}$$

$$v = v_1 + v_2 + \cdots + v_N = \left(L_1 + L_2 + \cdots + L_N\right)\frac{di}{dt} = L_{eq}\frac{di}{dt}$$

$$\boxed{L_{eq} = \sum_{k=1}^{N} L_k}$$

***The equivalent inductance of series connected inductors is the sum of the individual inductances. Thus, inductances in series combine in the same way as resistors in series.***

# Parallel Inductors



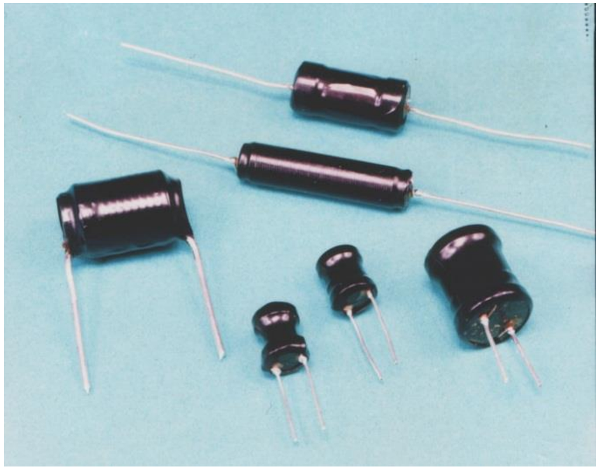

$$i_1 = \frac{1}{L_1}\int v dt \qquad i_2 = \frac{1}{L_2}\int v dt \qquad i_N = \frac{1}{L_N}\int v dt$$

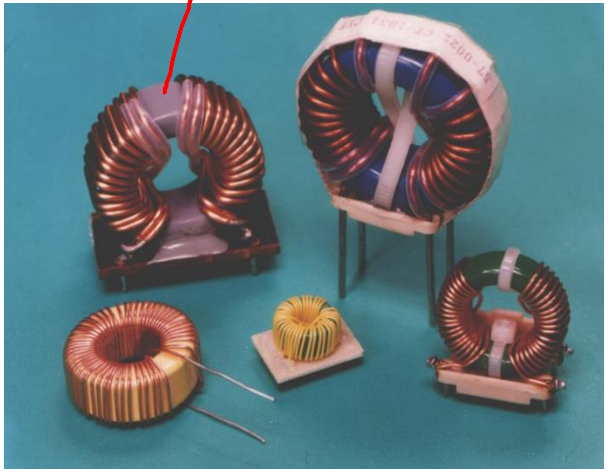
$$i = i_1 + i_2 + \cdots + i_N = \left(\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}\right)\int v dt = \frac{1}{L_{eq}}\int v dt$$

$$\frac{1}{L_{eq}} = \sum_{k=1}^{N} \frac{1}{L_k}$$

***The equivalent inductance of parallel connected inductors is the reciprocal of the sum of the reciprocals of the individual inductances.***

# Inductor Variations





- Chokes
  - –general-purpose inductors that act to limit or suppress fluctuating current.
  - –some use a resistor-like color code to specify inductance values.
- Toroidal coil
  - –resembles a donut with a wire wrapping
  - –high inductance per volume ratios, high quality factors, self-shielding, can be operated at extremely high frequencies

# Summary

| | Inductors | Capacitors |
|---|---|---|
| Storage | Electromagnetic | Electrostatic |
| Voltage | — | oppose sudden change |
| Current | oppose sudden change | |

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