# Chapter 5

Electrical circuits

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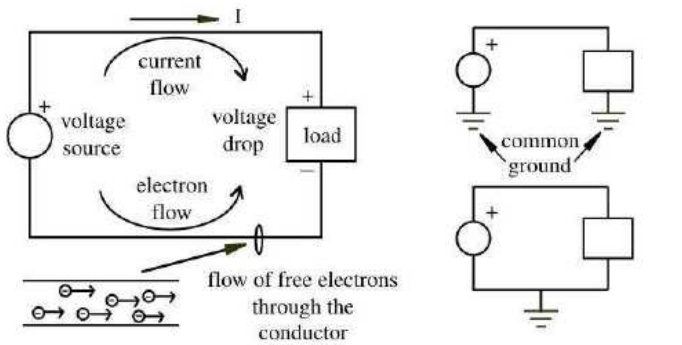
## Basic Electrical Circuits & Components



### Electrical Circuit Terminology




(a) Electric circuit

(b) Alternative schematic representations of the circuit

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- *Anode* : +ve side of source where electrons are attracted.
- *Cathode* : -ve side from where electrons are released.
- *Ground* : a reference point where voltage is assumed zero.
- *Load* : network of circuit elements that dissipate or store electrical energy.

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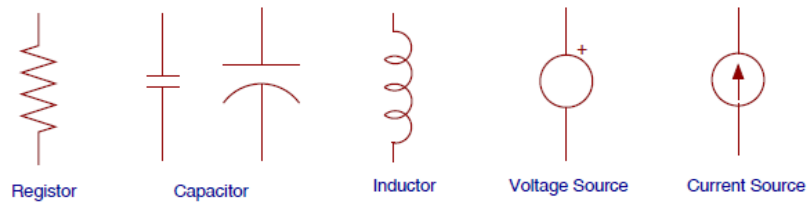
### Basic Electrical Elements




- There are three basic passive elements: the resistor (R), capacitor (C) and inductor (L).
- Passive elements require no additional power supply, as active elements such as integrated circuits.
- There are two types of ideal energy sources: a voltage source (V) and a current source (I).
- Ideal sources contain no internal resistance, inductance or capacitance.

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### Resistor

☐ Resistor dissipates electrical energy into heat.

$$V = IR \qquad P = I^2R \qquad R = ab \cdot 10^c \pm tol$$

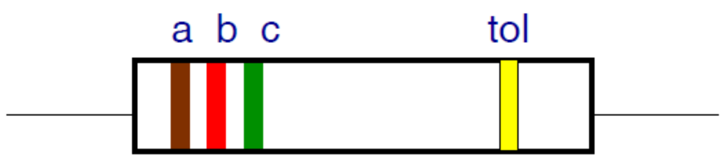


Table: $a$, $b$, and $c$ Bands

| Color | Black | Brown | Red | Orange | Yellow | Green | Blue | Violet | Gray | White |
|---|---|---|---|---|---|---|---|---|---|---|
| Value | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

Table: $tol$ Band

| Color | Gold | Silver | Nothing |
|---|---|---|---|
| Value | ±5% | ±10% | ±20% |

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### Capacitor

- Capacitor is a passive element that stores energy in the form of an electric field, resulted from a separation of electrical charge.
- An ideal capacitor generates a voltage potential difference between its two nodes proportional to the stored electrical charge.

$$v_C(t) = \frac{Q(t)}{C} = \frac{1}{C}\int_0^t i(\tau)d\tau \qquad i(t) = C\frac{dv_C}{dt}$$

where, $C$ = Capacitance (Farad = Coulomb/Volt)

- Since the voltage across a capacitor is the integral of the displacement current the voltage cannot change instantaneously.
- An ideal capacitor induces a $90^o$ phase angle between its voltage and current across its terminals due to the integral function.

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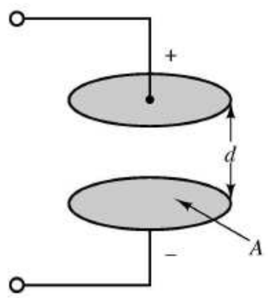


Parallel-plate capacitor with air gap $d$ (air is the dielectric)

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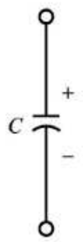


$C = \frac{\varepsilon A}{d}$

$\varepsilon$ = permittivity of air

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

Circuit symbol

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- Capacitance is a property of the dielectric material, the plate geometry and separation.
- Capacitors block DC voltage and pass the AC voltage. DC voltage will build a potential difference in the capacitor until they are equal. AC voltage simply alternates the charge and discharge of the capacitor and is passed, not blocked, in a circuit.

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### Inductor

- Inductor is a passive energy storage element that stores energy in the form of a magnetic field.
- An ideal inductor generates a potential difference proportional to the rate of change of current passing through it.

$$v_L(t) = L\frac{di}{dt} = \frac{d\lambda}{dt} \qquad i(t) = \frac{1}{L}\int_0^t v_L(\tau)\,d\tau$$

$\lambda$ = Magnetic flux through the coil due to current (Weber),
$L$ = Inductance of the coil (Henry), assumed to be constant.

↬ Current through an inductor cannot change instantaneously because it is an integral of the voltage. Motor, electromagnetic relays or solenoids have large inductance, so it is difficult to turn these ON or OFF very fast.

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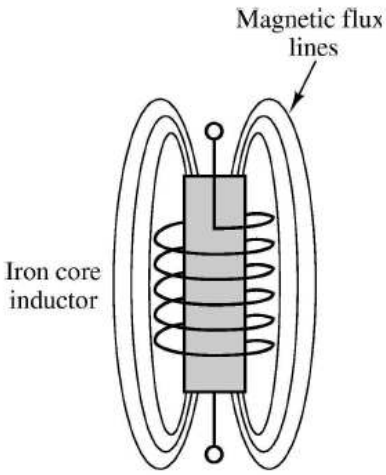


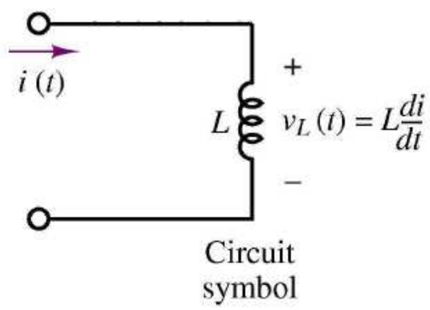


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The inductor is made by a coil of conductor around a core like a solenoid.

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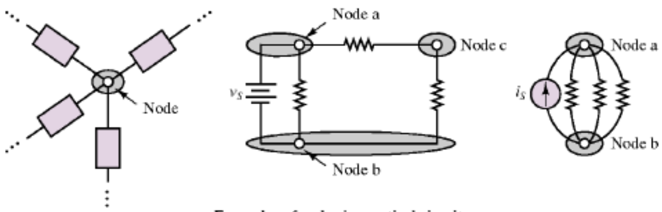
Circuit

# Node & Loop




Examples of nodes in practical circuits

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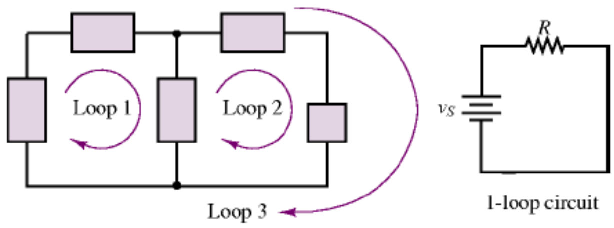
A node is the junction of 2 or more branches.




e386.eps A loop is any closed connection of branches.

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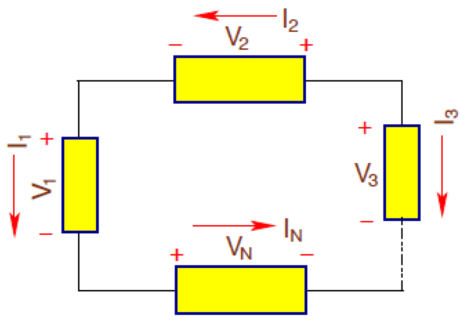
Circuit

# Kirchoff's Voltage Law (KVL)

- Sum of voltages around a closed loop is zero, $\sum_{i=1}^{N} V_i = 0$
- In clockwise or counterclockwise loop direction, form the sum of the voltages across each element, assign to each voltage the first algebraic sign encountered at each element.




$$-V_1 - V_2 + V_3 + \cdots - V_N = 0$$



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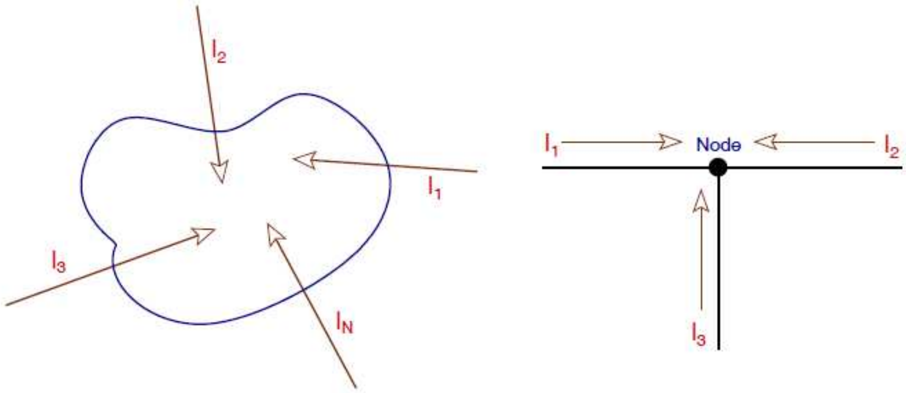
## Kirchoff's Current Law (KCL)

- Sum of the currents flowing into a closed surface or node is zero, $\sum_{i=1}^{N} I_i = I_1 + I_2 + \cdots + I_N = 0$.




- If the calculated result for a current is negative, the current actually flows in opposite direction.

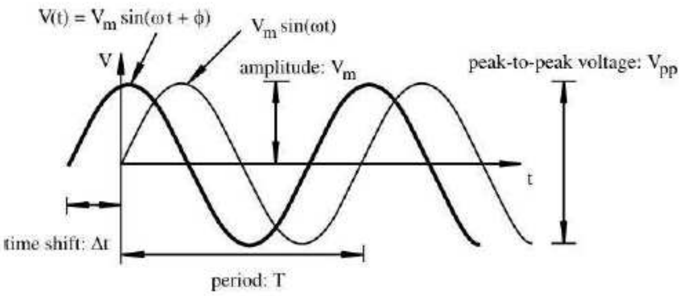








## Sinusoidal Waveform




- frequency: $f = \frac{1}{T} = \frac{\omega}{2\pi}$ time shift: $\Delta t = \frac{\phi}{\omega}$
- if $\phi$ is +ve $\rightarrow$ occurs earlier on time axis $\rightarrow$ lagging.
- $V_{rms} = \sqrt{\frac{1}{T}\int_0^T V(t)^2\,dt} = \sqrt{\frac{1}{T}\int_0^T V_m^2\cos^2(\omega t)\,dt} = \frac{V_m}{\sqrt{2}}$
- $I_{rms} = \sqrt{\frac{1}{T}\int_0^T I(t)^2\,dt} = \sqrt{\frac{1}{T}\int_0^T I_m^2\cos^2(\omega t - \theta)\,dt} = \frac{I_m}{\sqrt{2}}$
- $P(t) = V(t)I(t) = 2V_{rms}I_{rms}\cos(\omega t)\cos(\omega t - \theta)$
- $P_{av} = \frac{1}{T}\int_0^T P(t)\,dt = V_{rms}I_{rms}\cos\theta$