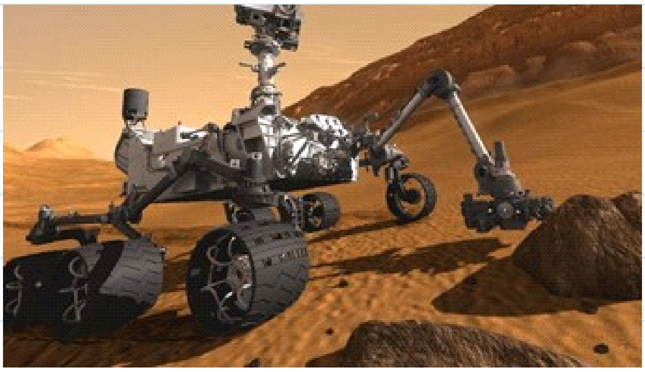
Reading

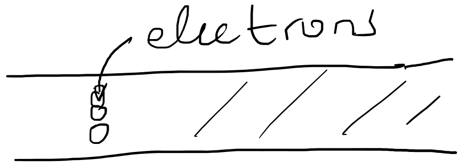
Fundamentals of Electric Circuits 5th Edition, McGrawHill, 2015
By Charles K. Alexander and Matthew N. O. Sadiku

- Chapter 1
- Chapter 2
- Chapter 6

Applications



Charge and Current



$$i \triangleq \frac{dq}{dt} \longleftrightarrow \boxed{Q \triangleq \int_{t_0}^{t} i\,dt}$$

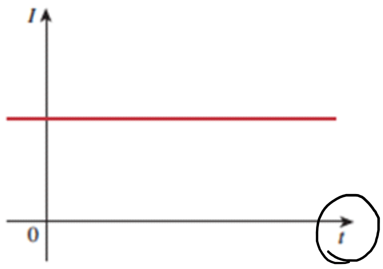
1 Coulomb of electrons ≈ 6,241,509,074,460,762,607 electrons

6×10^{18}

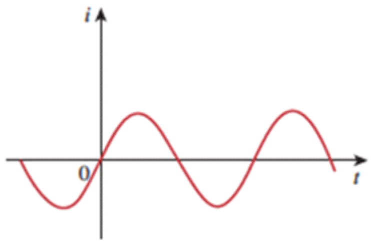
$$i = \frac{\Delta Q}{\Delta t}$$

$$\frac{1\,\text{Colomb}}{1\,s} = 1\,A$$

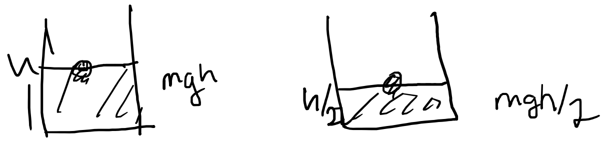
DC



AC



Voltage



$$v_{ab} \triangleq \frac{dw}{dq}$$

1 volt = 1 joule/coulomb = 1 newton-meter/coulomb

Power

$$p \triangleq \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = \frac{dw}{dt}$$

$$V \cdot I$$

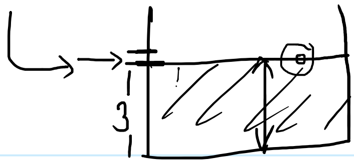
$$\int dw = \int p \cdot dt$$

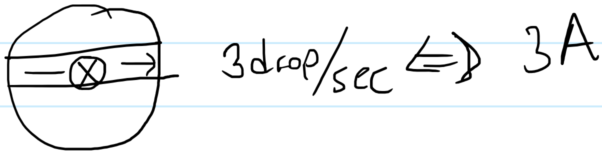
$$W = \int p\,dt$$

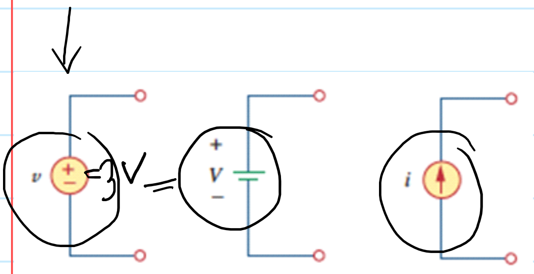
$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

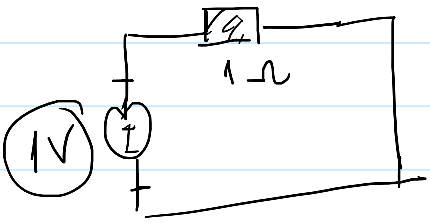
$$\boxed{\sum p = 0}$$

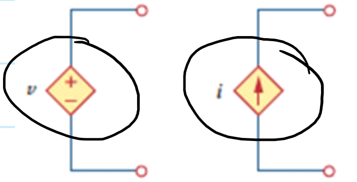
Active Circuit Elements

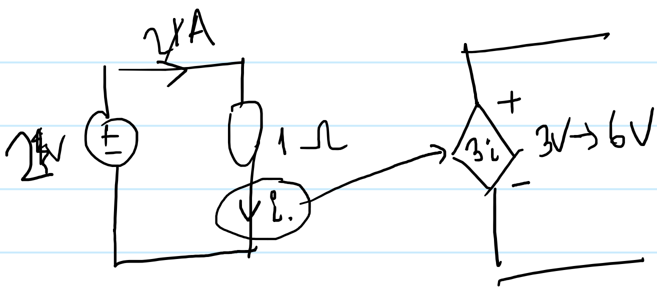




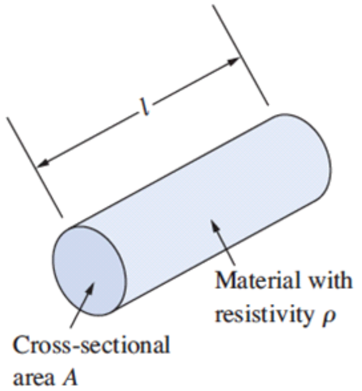


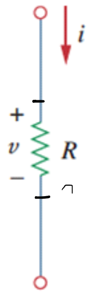






Ohm's Law





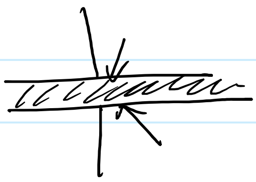
$$\boxed{v = iR}$$

$$\boxed{R = \frac{l \cdot \rho}{A}}$$

Resistivities of common materials.

Material	Resistivity (Ω·m)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

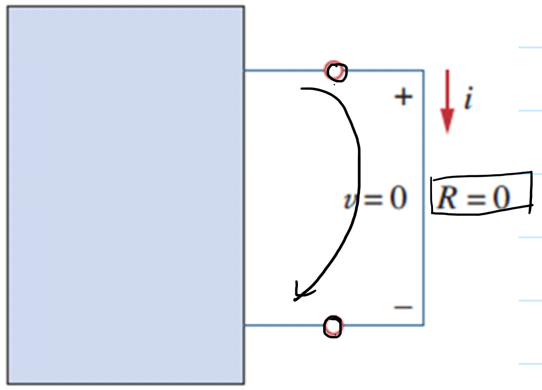
R



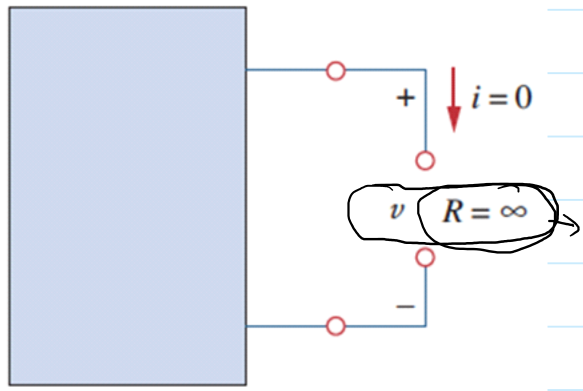
Short and Open Circuit

$v = iR \leftarrow 0$

$v \to 0$, $\uparrow$



$= 0.00001\ \Omega$



$v = iR$

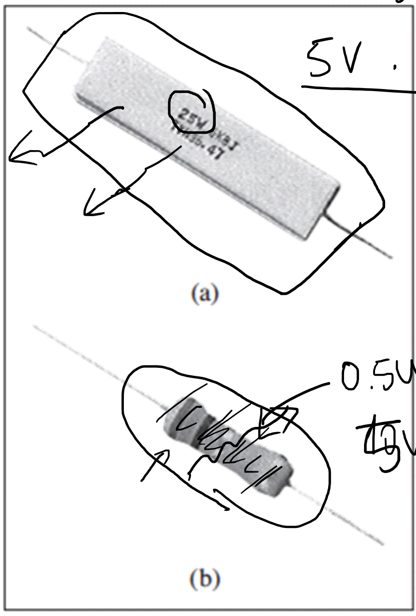
v: 0, $i \to 0$, $R \to \infty$

$V < 1000$

Types of Resistors

=25 . 1A

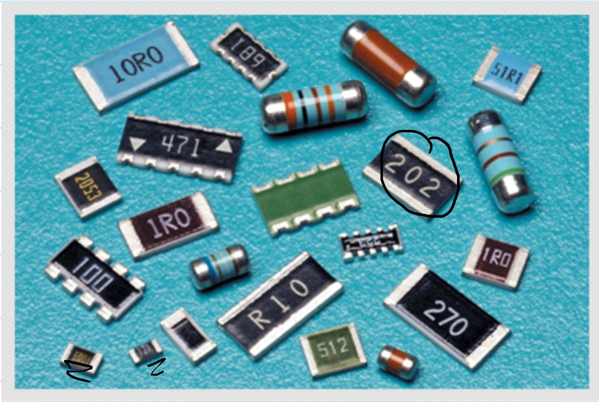
5V . 5A

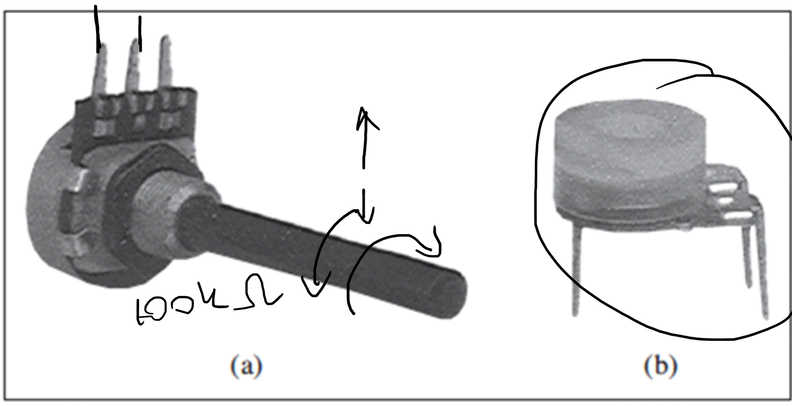


(a)

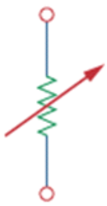
(b)

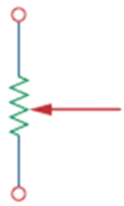
SMD



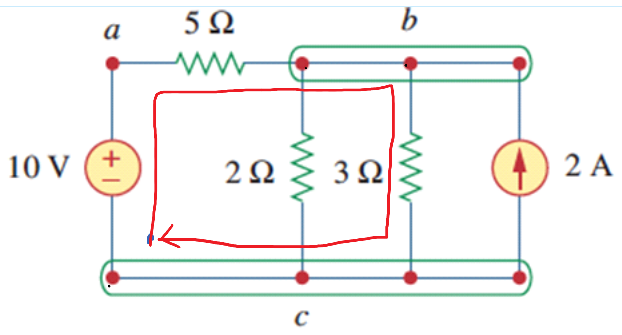


(a) (b)





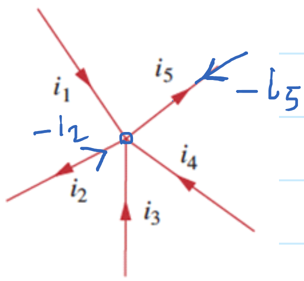
Branch, Node and Loop



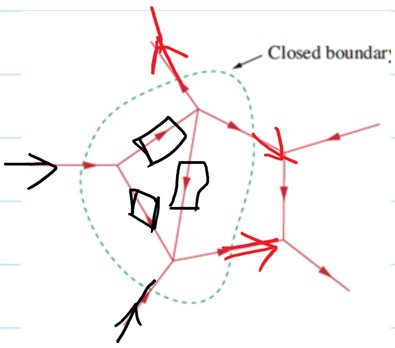
Kirchhoff's Laws - KCL

$$Q = \int i \, dt$$

$$\boxed{\int i_1 + i_4 + i_3 \, dt} = \boxed{\int i_2 + i_5 \, dt}$$

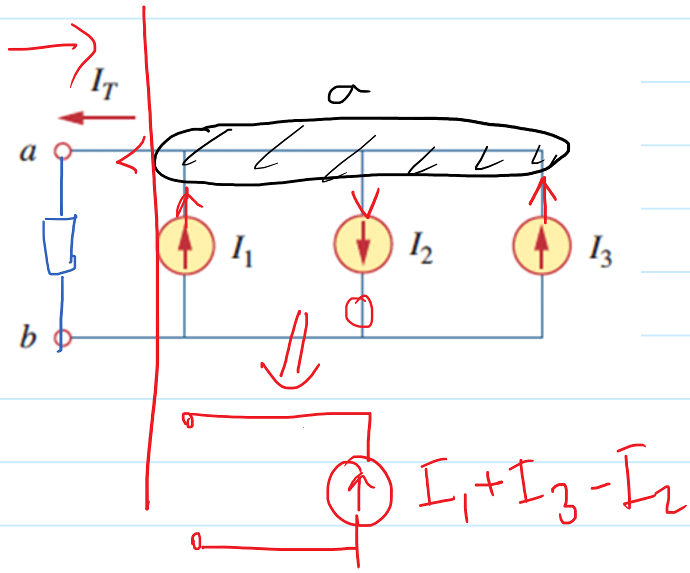


$$\boxed{\sum_{n=1}^{N} i_n = 0}$$



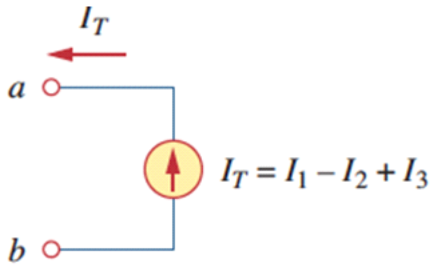
KCL

Kirchhoff's Laws - KCL

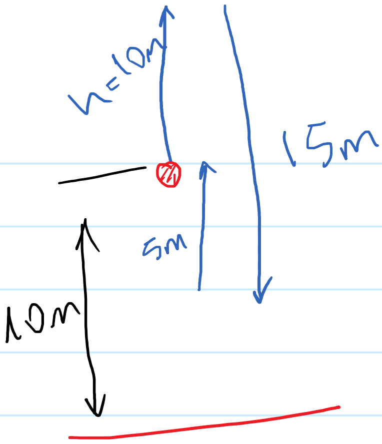


$$I_1 + I_3 = I_T + I_2$$

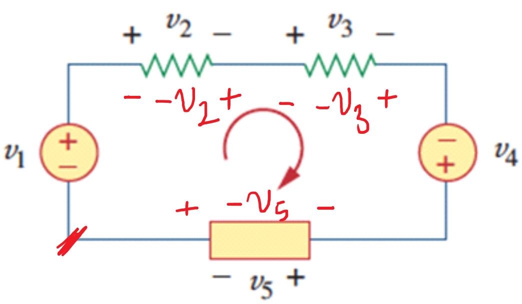
$$I_T = I_1 + I_3 - I_2$$



Kirchhoff's Laws - KVL



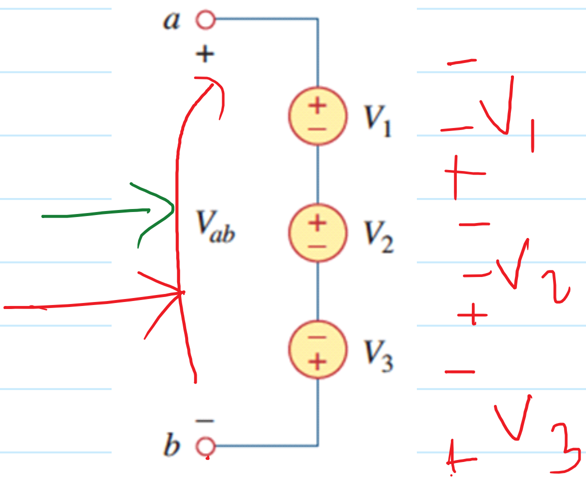
$$\boxed{\sum_{m=1}^{M} v_m = \underline{\underline{0}}}$$



$$\boxed{v_4 + v_1 = \boxed{v_2 + v_3 + v_5}}$$

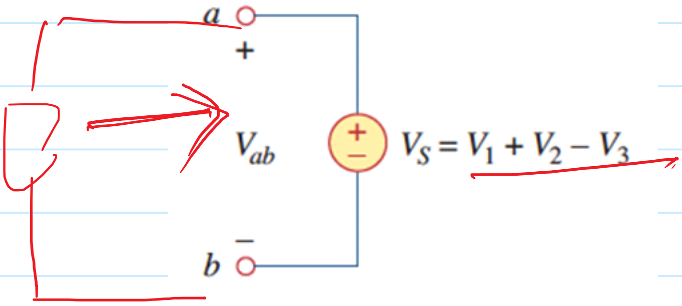
$$0 = v_1 + \underline{(-v_2)} + \underline{(-v_3)} + v_4 + \underline{(-v_5)}$$

Kirchhoff's Laws - KVL



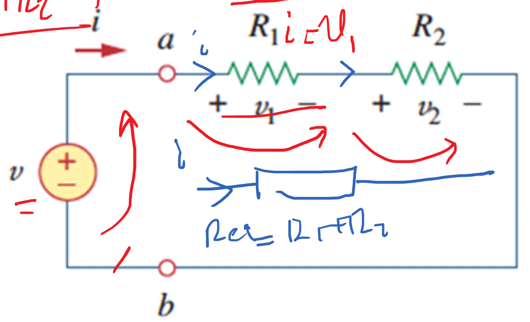
$$V_{ab} + (-V_1) + (-V_2) + V_3 = 0$$

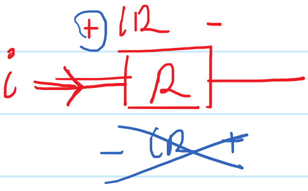
$$\underline{V_{ab} = V_1 + V_2 - V_3}$$



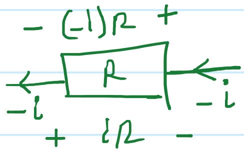
Series Resistors and Voltage Division

$$\boxed{v_1 = v\,\frac{R_1}{R_1+R_2}}$$

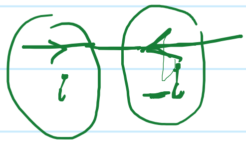




$v = iR$



$$R_{eq} = R_1 + R_2$$



$$v + (-v_1) + (-v_2) = 0$$

$$v = v_1 + v_2$$

$$v = iR_1 + iR_2 = i\underbrace{(R_1 + R_2)}_{R_{eq}}$$

$$i = \frac{v}{R_1+R_2}$$

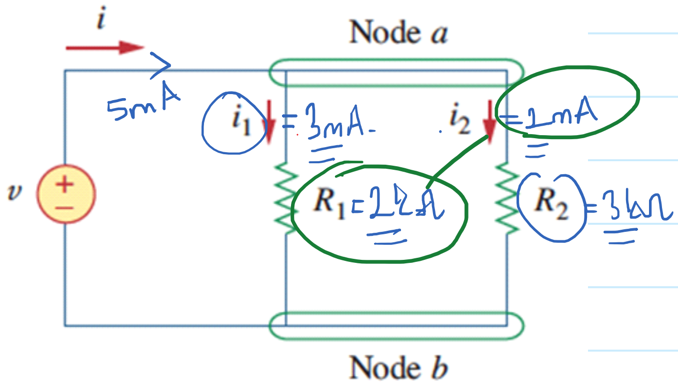
$$v_1 = \frac{R_1}{R_1 + R_2}\,v, \qquad v_2 = \frac{R_2}{R_1 + R_2}\,v$$

$$v_1 = R_1 i = R_1 \frac{v}{R_1+R_2}$$

$$v_1 = v \cdot \frac{R}{R_1+R_2}$$

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

Parallel Resistors and Current Division

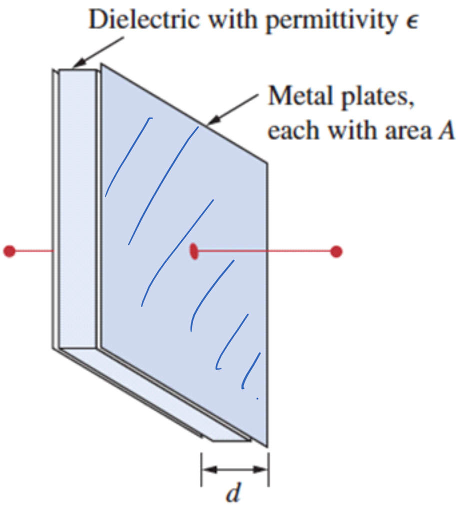


$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

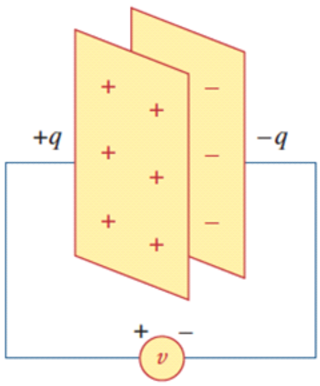
$$i_1 = \frac{R_2\, i}{R_1 + R_2}, \qquad i_2 = \frac{R_1\, i}{R_1 + R_2}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

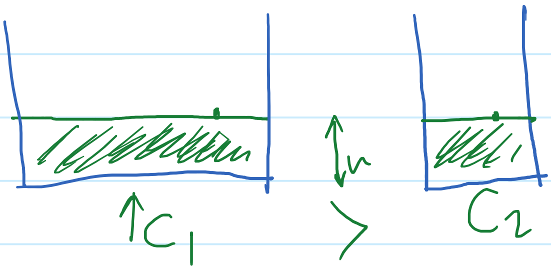
Capacitance



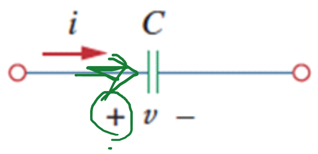
$$\boxed{C = \frac{\epsilon A}{d}}$$

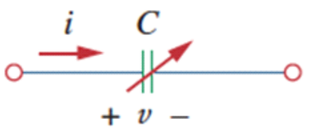


$$\boxed{q = Cv}$$

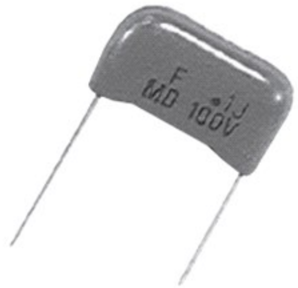


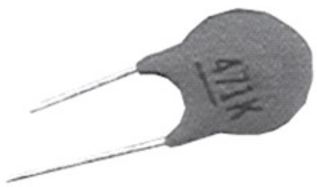
Types of Capacitors

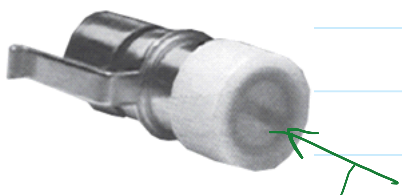




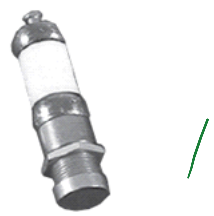
$$i = C\frac{dv}{dt}$$







(a)



(b)

Capacitors

$v = iR$

$\hookrightarrow i = \frac{1}{R} v$

$$\boxed{q = Cv}$$

$$\underbrace{\frac{dq}{dt}}_{i} = C\frac{dv}{dt}$$

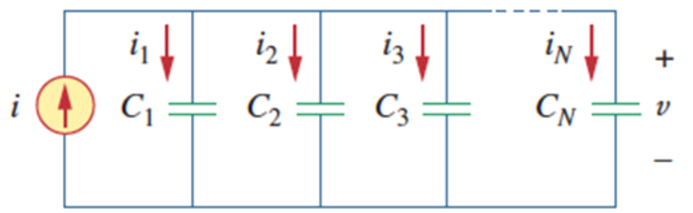
$$\boxed{i = C\frac{dv}{dt}}$$

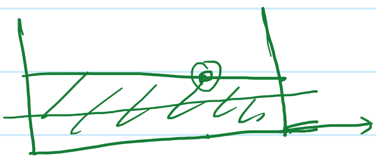
$w = \int p\,dt = v \cdot i\,dt$

$+\ v\ -$ C

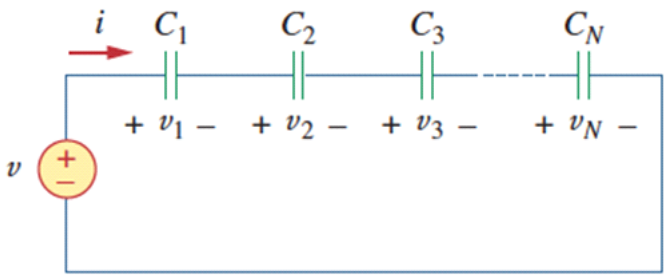
$$\boxed{W = \frac{1}{2}CV^2}$$

$$w = \int_{-\infty}^{t} p(\tau)\,d\tau = C\int_{-\infty}^{t} v\frac{dv}{d\tau}\,d\tau = C\int_{v(-\infty)}^{v(t)} v\,dv = \frac{1}{2}Cv^2\Big|_{v(-\infty)}^{v(t)}$$



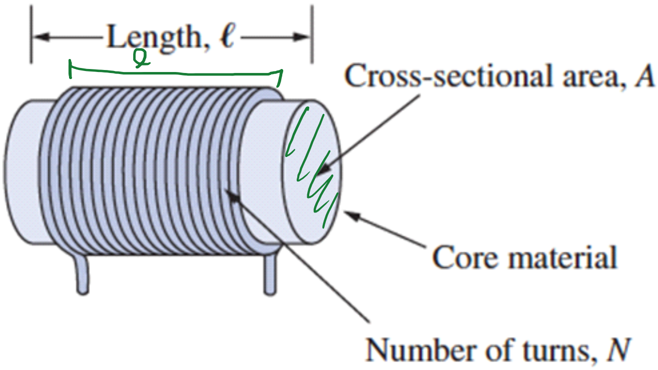


$$\boxed{C_{eq} = C_1 + C_2 + C_3 + \cdots + C_N}$$



$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_N}}$$

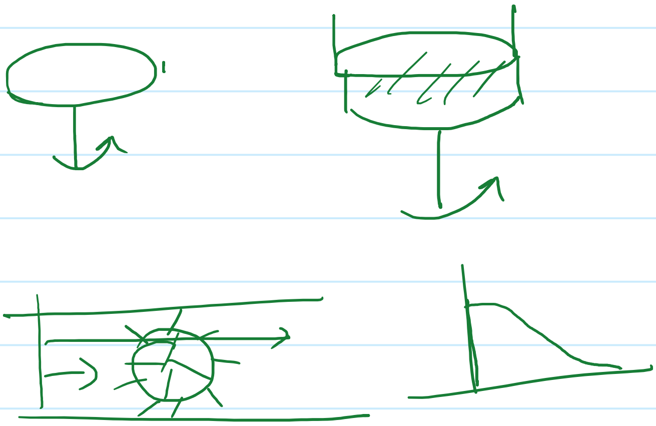
Inductance



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

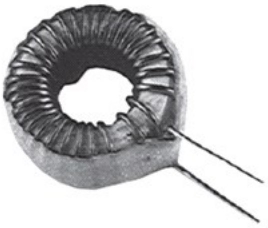
$$\boxed{v = L\frac{di}{dt}}$$

$$i = C\frac{dv}{dt}$$

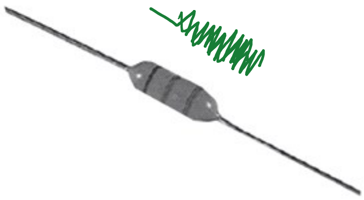


Types of Inductors

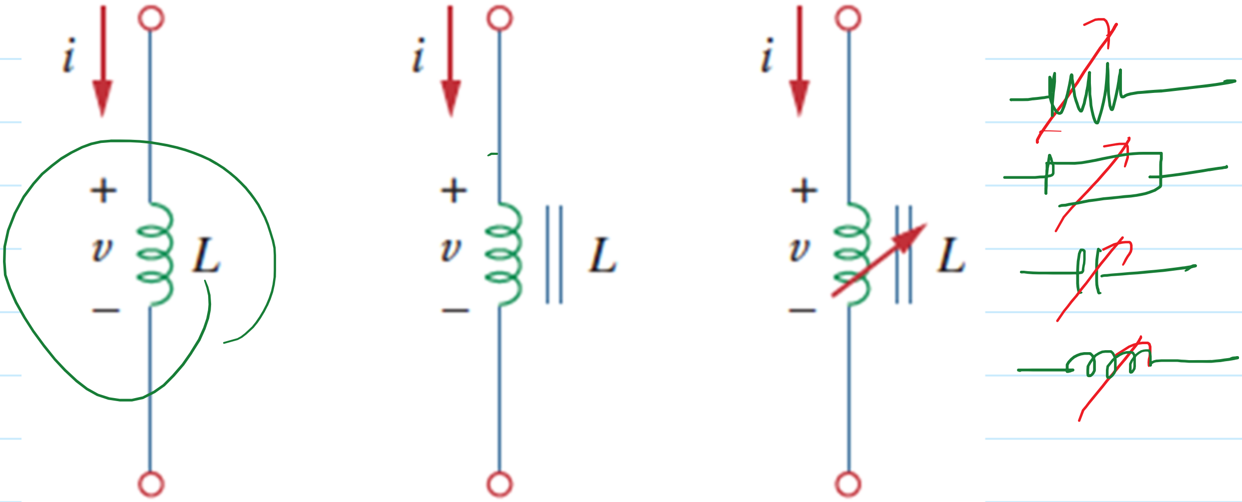
(a)



(b)



(c)



air-core iron-core variable iron-core

Inductor

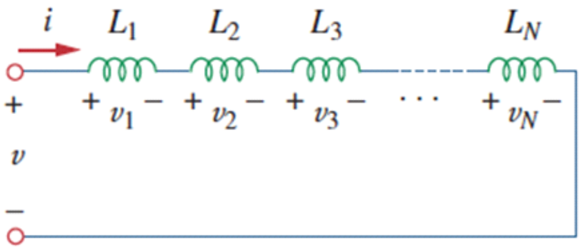
$V = R\,i$

$$\boxed{v = L\frac{di}{dt}}$$

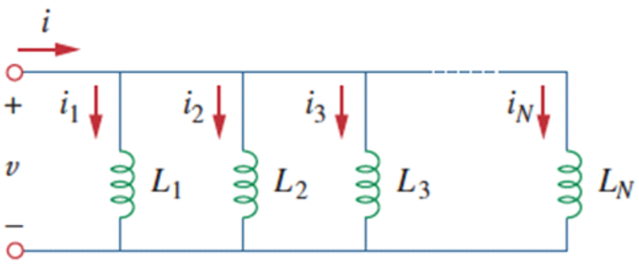
$\frac{1}{2} I^2 L$

$$w = \int_{-\infty}^{t} p(\tau)\,d\tau = L\int_{-\infty}^{t} \frac{di}{d\tau}\, i\,d\tau = L\int_{-\infty}^{t} i\,di = \frac{1}{2}Li^2(t) - \frac{1}{2}Li^2(-\infty)$$

$$\boxed{w = \frac{1}{2}Li^2}$$



$$\boxed{L_{eq} = L_1 + L_2 + L_3 + \cdots + L_N}$$



$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_N}}$$

Summary

Relation	Resistor (R)	Capacitor (C)	Inductor (L)
v-i:	$v = iR$	$v = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + v(t_0)$	$v = L\frac{di}{dt}$
i-v:	$i = v/R$	$i = C\frac{dv}{dt}$	$i = \frac{1}{L}\int_{t_0}^{t} v(\tau)d\tau + i(t_0)$
p or w:	$p = i^2R = \frac{v^2}{R}$	$w = \frac{1}{2}Cv^2$	$w = \frac{1}{2}Li^2$
Series:	$R_{eq} = R_1 + R_2$	$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
Parallel:	$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \frac{L_1L_2}{L_1 + L_2}$
At dc:	Same	Open circuit	Short circuit
Circuit variable that cannot change abruptly:	Not applicable	v	i