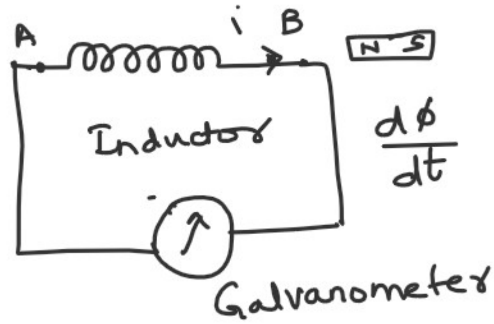
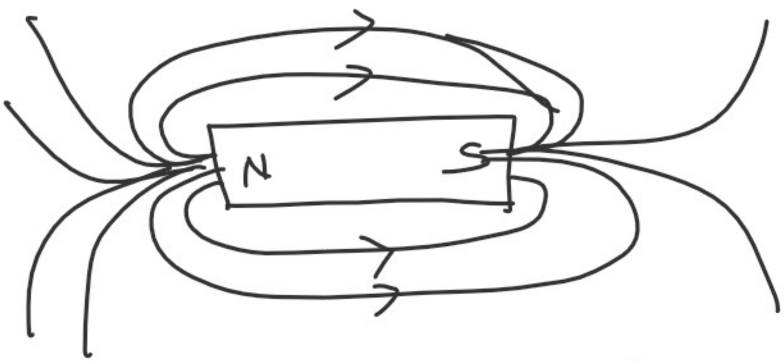
Inductor and Capacitor - Theoretical and Practical aspects

Faraday's Electromagnetic Induction Law

The induced electromotive force in any closed circuit is equal to the negative of the time rate of change of the magnetic flux enclosed by the circuit. "Faraday's Law, which states that the electromotive force around a closed path is equal to the negative of the time rate of change of magnetic flux enclosed by the path" . Mathematically,

$$\epsilon = -N\frac{dB}{dt} = -NL\frac{dI}{dt}$$





Loop | Coil | Solenoid

Factor's affecting Inductance of Inductor

No. of turns

$L \propto N$

$L\downarrow$

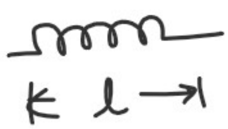
$L\uparrow$

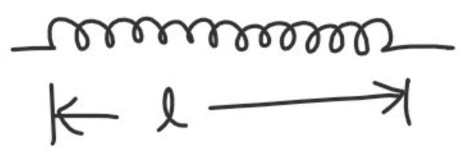
Coil area

$L\downarrow$ $L\uparrow$

$L \propto A$

Coil length



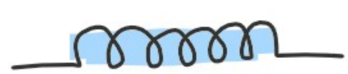


$L \propto \frac{1}{l}$

$L\uparrow$ $L\downarrow$

Core material

air core



→ Ferrite

Core material

air core

$\mu = 1$

→ Ferrite

→ Iron soft

$\mu = 600$

$L \propto \mu$

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

X_L = Inductive Reactance $= 2\pi f L$

π: 3.14

L: Inductance

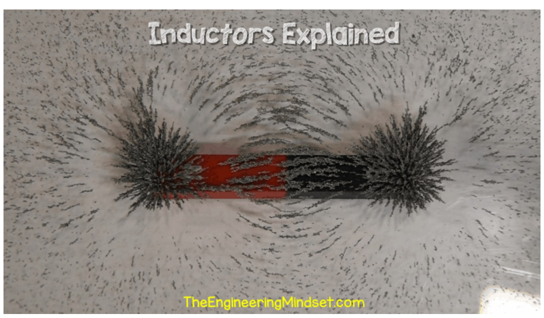
freq:- 50Hz

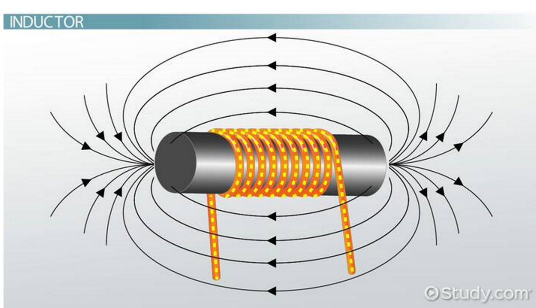
freq: 60 Hz

Def:- 1 Henry $= \frac{1 \text{ Amp}}{1 \text{ sec}}$

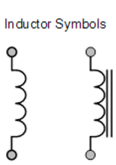
when the current thro the coil is made to change @ $1\,\frac{\text{Amp}}{\text{sec}}$ inducing a voltage of 1V.

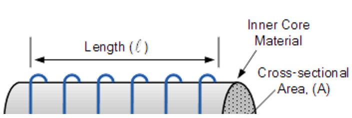
1. How to form an Inductor
2. Definition
3. Types of Inductors
4. Inductive reactance
5. Self inductance
6. V-I relationship
7. Energy

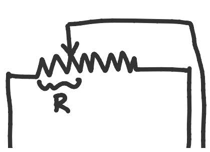


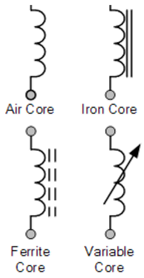


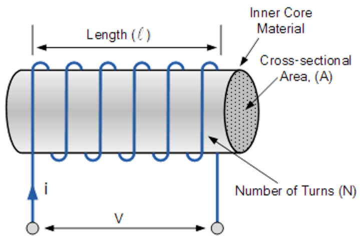
Types of Inductors

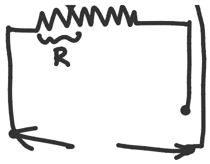




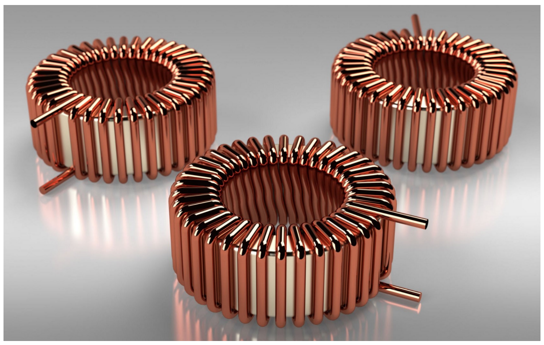


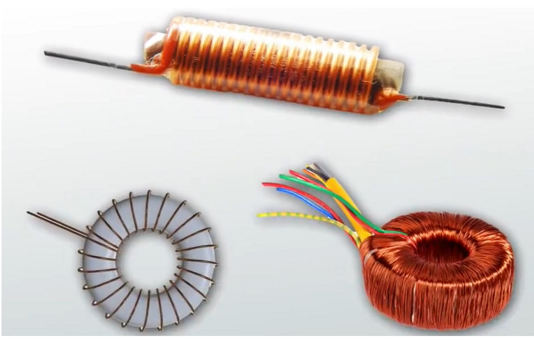


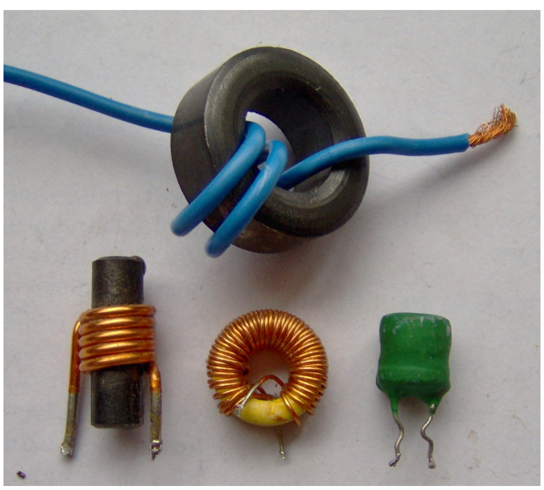




Rheostat

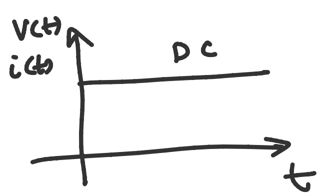


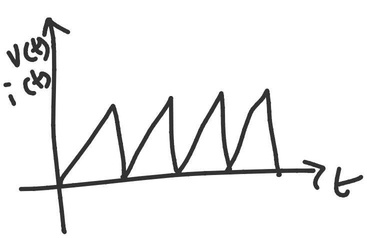


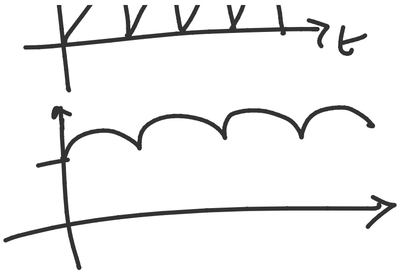


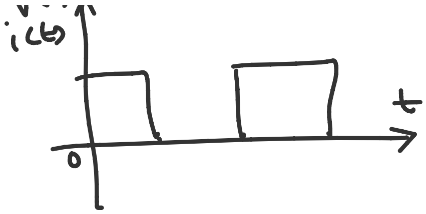
$$V_L = L\frac{di}{dt} \Rightarrow \frac{di}{dt} = \frac{1}{L}\int v\,dt.$$

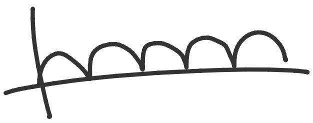
$$P = V\cdot I = v(t)\,i(t)$$







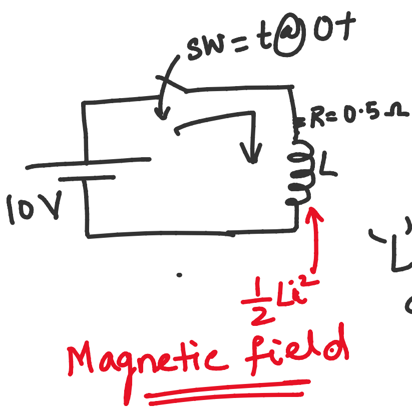




$$P = V\,i = L\frac{di}{dt}\,i = L\,i\,\frac{di}{dt}.$$

$$\left.\begin{array}{l}\text{Energy by `L'}\\ \text{Stored/Dissipated}\end{array}\right\} = \int_0^t \left(L\,i\,\frac{di}{dt}\right)dt$$

$$= \underline{\underline{\frac{1}{2}L\,i^2}}$$



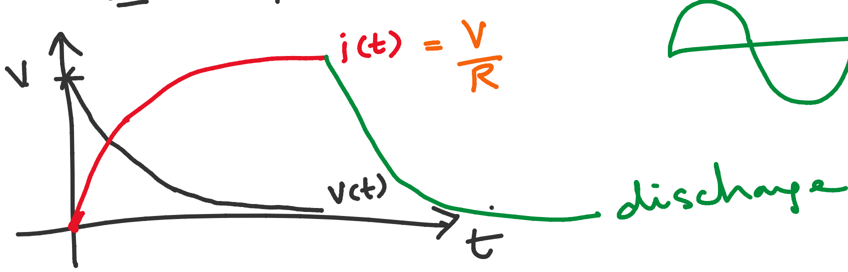
L^* property

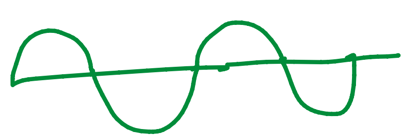
$$V_L = L\frac{di}{dt}.$$

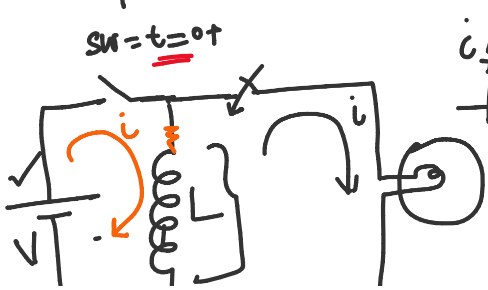
'L' → resists sudden change in current

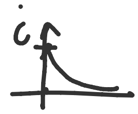
@t=0+ $i=0$ 'L' acts like an Open ckt

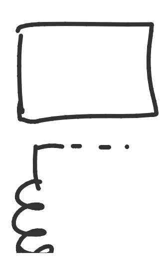
@ $t=\infty$ $i = \frac{V}{R}$ 'L' acts like an S.C

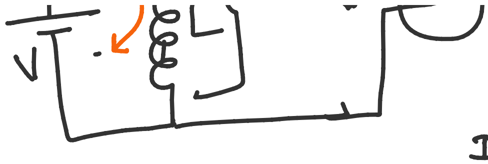


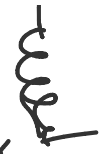












Inductor

Choke — Electronic

Reactor ← Electric.

Capacitor:

mF, μF, nF, pF

10^{-3} ; 10^{-6} ; 10^{-9} ; 10^{-12}

capacitor:

1 Farad

EV's

Super Capacitor

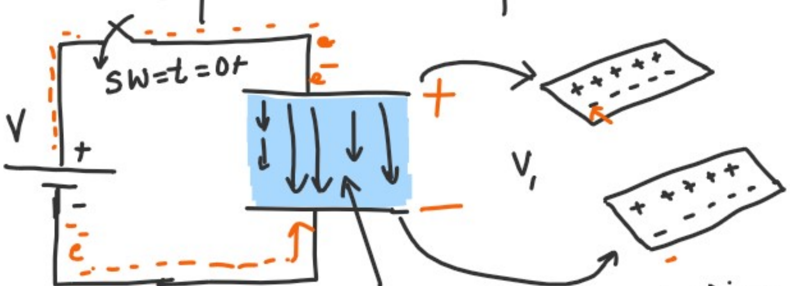
ultra capacitor

Practical Applications of Inductor

Tube light (Choke): The purpose of the choke is to provide a very high voltage initially between the filaments (across the two ends of the tube light). Again once the gas in the tube is ionized the choke provides a low voltage. A choke is a coil of wire.

Practical Applications of Capacitor: Ceiling Fan- for starting the Fan

capacitor : ||el plate



Diectric / → Insulating

Glass, ceramic, plastic film, mica, Air.
insulating paper, wax, oxide layer

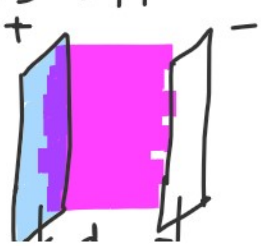
10 C → A → 5V

10 C → B → 2V

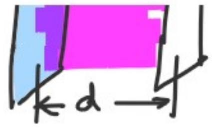
$$C_A = \frac{q}{V} = \frac{10}{5} = 2F$$

$$C_B = \frac{10}{2V} = 5F$$

Factors affecting capacitance



① Area of Each plate
② Distance b/w plates
③ ϵ : permittivity



③ ϵ : permittivity of Diectric material

$\underbrace{\epsilon_0 \ \epsilon_r}$

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

Farad

$$\boxed{\frac{Q}{V} = C}$$

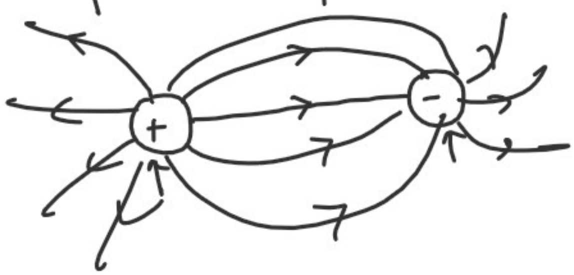
$V = L\frac{di}{dt}$

$\boxed{V\text{-}I}$ $$\boxed{i = C\frac{dV}{dt}}$$

Power : $P = Vi = VC\frac{dv}{dt}$

Energy :- $\int_0^t P\,dt = \int_0^t CV\frac{dv}{\cancel{dt}}\cancel{dt}$

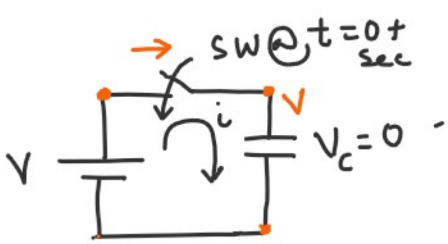
Energy stored or dissipatedin Capacitor $\Big\} = \frac{1}{2}CV^2$



Capacitive Reactance :- $X_C = \frac{1}{2\pi f C}$

$f \rightarrow$ freq @ 50 Hz

$C \rightarrow$ Capacitance in Farad



$L \rightarrow \frac{di}{dt} \leftarrow$

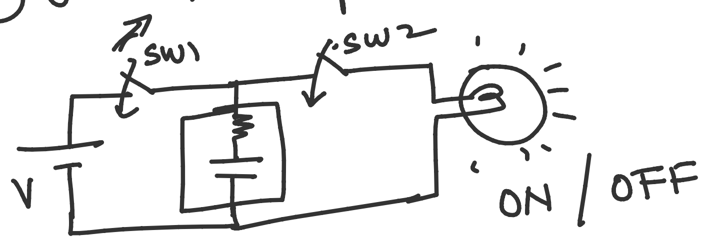
$C \rightarrow \frac{dv}{dt}$

A capacitor Resists

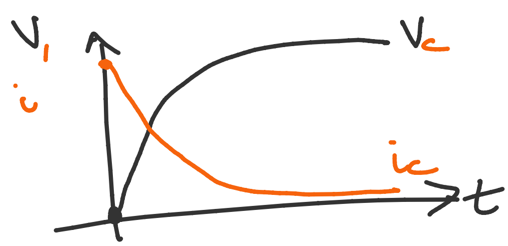
A capacitor Resists fast change in voltage $\hookrightarrow \frac{dv}{dt}$

@ $t = 0+$; capacitor acts like S.C

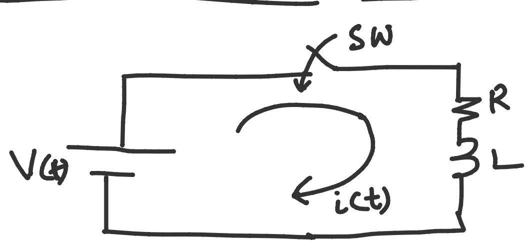
@ $t \to \infty$; capacitor " " O.C



SW1 ✓



R-L. Response due to DC excitation



✓ ① differentiation

✓ ② Laplace Transfor

$$\underbrace{V - iR}_{u} - L\frac{di}{dt} = 0$$

$$u = L\frac{di}{dt}.$$

$$u = V - iR$$

$$\frac{du}{di} = -R$$

$$di = \frac{-du}{R}$$

Integrate on both sides

$$\int_0^t \frac{dt}{L} = \int_0^i \frac{di}{u}$$

$$\frac{t}{L} = \int_0^i -\frac{du}{R.u} \Rightarrow \frac{-1}{R}\Big|\log_e u\Big|_0^i$$

$$\frac{t}{L} = \int_0 \frac{\quad}{R\cdot u} \quad Rl \quad |_0$$

$$\frac{t}{L} = \frac{-1}{R}\Big[\log_e (V-iR)\Big]_0^i$$

$$= \frac{-1}{R}\Big[\ln(V-iR) - \ln V\Big]$$

$$= \frac{-1}{R}\Big[\ln\Big[\frac{V-iR}{V}\Big]\Big]$$

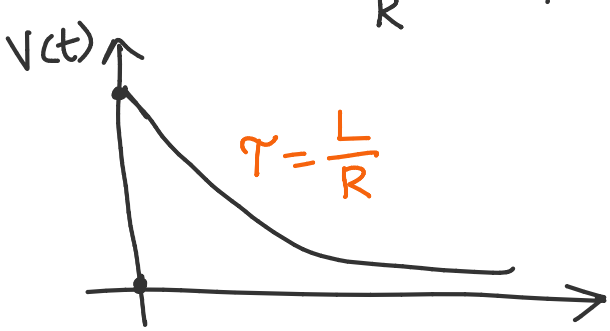
$$\frac{\text{antilog}}{\text{antilog}}\Big[\log_e\Big(\frac{V-iR}{V}\Big)\Big] = -\frac{Rt}{L}$$

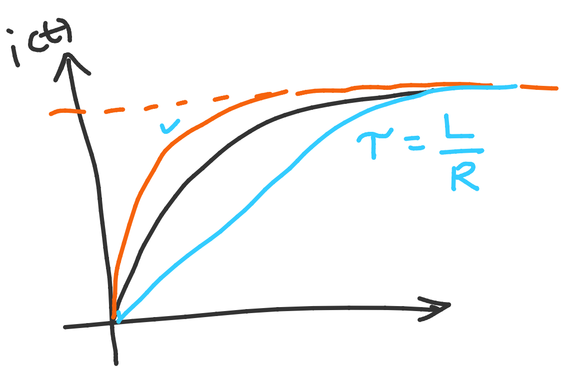
$$\frac{V-iR}{V} = e^{-Rt/L}$$

$$1 - \frac{iR}{V} = e^{-Rt/L}$$

$$\boxed{i(t) = \frac{V}{R}\Big[1 - e^{\frac{-Rt}{L}}\Big]}$$

$$i(t) = \frac{V}{R} - \frac{V}{R}e^{\frac{-Rt}{L}} \leftarrow$$





$$V_R = i\cdot R = V\Big[1 - e^{\frac{-Rt}{L}}\Big]$$

$$-Rt \quad]$$

$$V_R = i\cdot R = V\left[1 - e^{-Rt/L}\right]$$

$$V_L = L\frac{di}{dt} = \frac{V}{\cancel{R}}\cdot \cancel{L}\left[\frac{\cancel{R}}{\cancel{L}}\cdot e^{-\frac{Rt}{L}}\right]$$

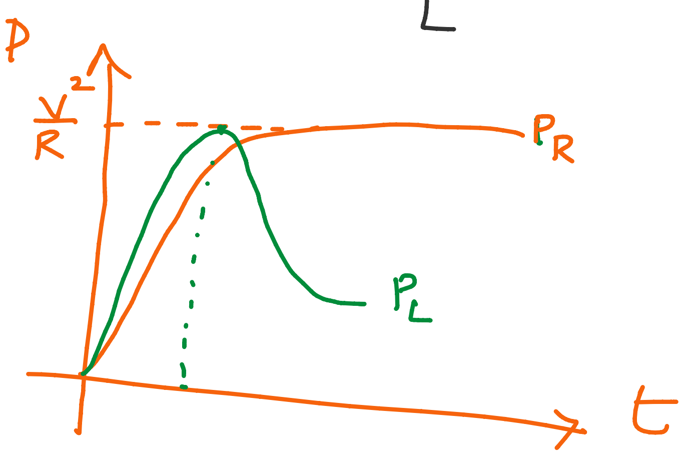
$$V_L = V e^{-Rt/L}$$

$$P_R = V_R\cdot i = V\left[1 - e^{-\frac{Rt}{L}}\right]\frac{V}{R}\left[1 - e^{-\frac{Rt}{L}}\right]$$

$$= \frac{V^2}{R}\left[1 + e^{-2Rt/L} - 2e^{-Rt/L}\right]$$

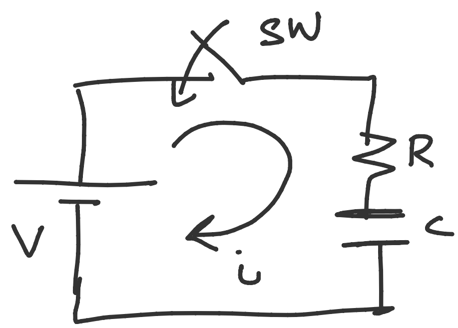
$$P_L = V_L\cdot i = V\cdot\frac{V}{R}e^{-Rt/L}\left[1 - e^{-Rt/L}\right]$$

$$= \frac{V^2}{R}\left[e^{-Rt/L} - e^{-2Rt/L}\right]$$



② Response due to DC excitation in an R-C circuit.

$$C = \frac{q}{V_c}$$



$\overrightarrow{V_c}$

$$i = \frac{dq}{dt}$$

$$V = iR + \frac{1}{C}\int i\,dt$$

$$V = \frac{dq}{dt}R + \frac{q}{C}$$

$$V - \frac{q}{C} = u$$

$$\frac{du}{dq} = \frac{-1}{C}$$

$$dq = -du \cdot C$$

$$\left(V - \frac{q}{C}\right) = \frac{dq}{dt} \cdot R$$

$$\int_0^t \frac{dt}{R} = \int_0^q \frac{dq}{\left(V - \frac{q}{C}\right)}$$

$$\frac{t}{R} = -C\left[\ln\left(V - \frac{q}{C}\right)\right]_0^q$$

$$\frac{-t}{RC} = \left[\ln\left(V - \frac{q}{C}\right) - \ln V\right]$$

$$\frac{-t}{RC} = \ln\left[\frac{V - q/C}{V}\right]$$

antilog

$$\frac{V - q/C}{V} = e^{-t/RC}$$

$$1 - \frac{q}{} = e^{-t/RC}$$

$$1 - \frac{q}{VC} = e$$

$$\frac{q}{VC} = \left[1 - e^{-t/RC}\right] \Rightarrow \frac{q}{C} = V\left[1 - e^{-t/RC}\right]$$

$$V_c = V\left[1 - e^{-t/RC}\right]$$

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

$$= CV\left[- e^{-t/RC}\left(\frac{-1}{RC}\right)\right]$$

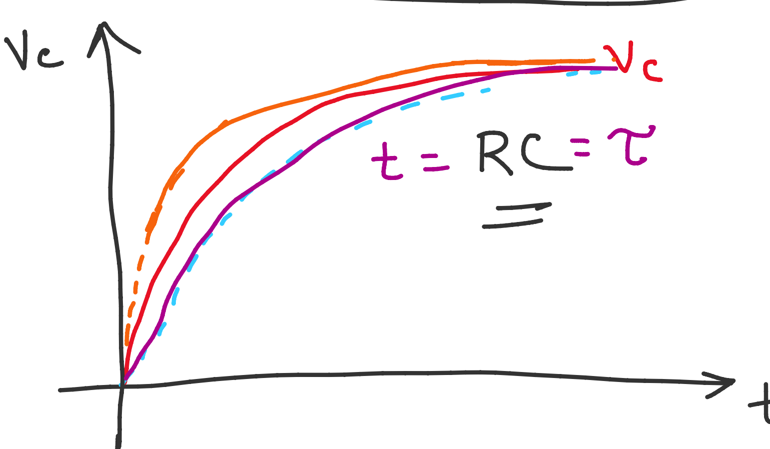
$$\boxed{i(t) = \frac{V}{R}\left[e^{-t/RC}\right]}$$

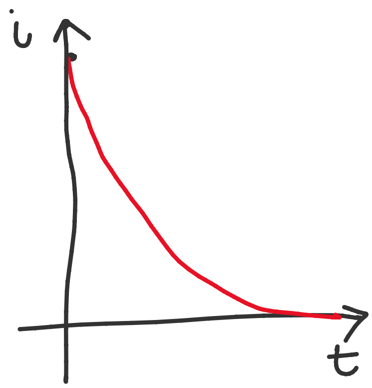
V_R

V_C

P_R

P_C





$$V_R = iR = \frac{V}{R} e^{-t/RC} \cdot R = V e^{-t/RC}$$

$$V_c = V\left[1 - e^{-t/RC}\right]$$

$$P_R = V_R i = V e^{-t/RC} \cdot \frac{V}{R} e^{-t/RC} = \frac{V^2}{R} e^{-2t/RC}$$

$$P_R = V_R i = V e \quad \frac{V}{R} e \quad = \frac{V}{R} e$$

$$P_C = V_C \cdot i = V\left[1 - e^{-t/RC}\right]\frac{V}{R}\left[e^{-t/RC}\right]$$

$$= \frac{V^2}{R}\left[e^{-t/RC} - e^{-2t/RC}\right]$$

$t = 0$; $P_C = 0$

$t = \infty$; $P_C = 0$