Linear Circuit Theory

L01: Property of Electrical Elements and voltage current relation

- Basic property of electrical Elements
- Voltage current relation in electrical elements
- Basic numerical Example

Basic property of electrical Element

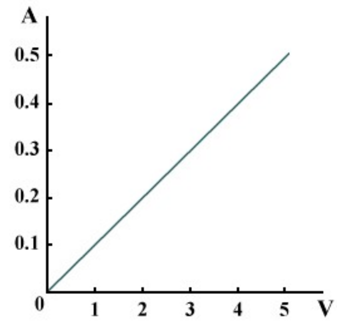
(Resistance (R), Inductance (L), Capacitance(C))

- **Linear and non linear:** Proportionality ratio between input and output remain constant

$$y(t) = f\big(x(t)\big), \quad \frac{y(t)}{x(t)} = k$$

(a) $y(t) = 2x(t)$ (b) $y(t) = 2x(t)$ +3 (c) $y(t) = 2x^2(t)$

- Resistance (R ,) ⟶ V(t)=R I(t)
- Capacitor (C,) ⟶ Q(t)=CV(t)
- Inductor (L,) ⟶ $\emptyset(t) = L\, I(t)$

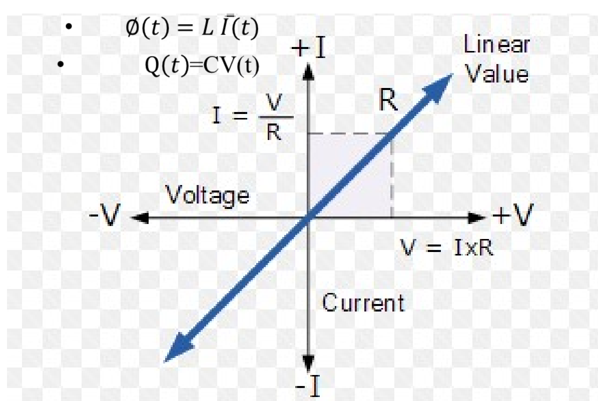


*Equation V(t)= 2I(t) + 3 is a linear relationship or not ???

➢ Unilateral and Bilateral Elements:

characteristics of an element does not change after changing the polarity of energy source

- Electrical Elements (R,L,C) are bilateral Elements
- Electronics elements (diode ,transistor etc.) are Unilateral elements



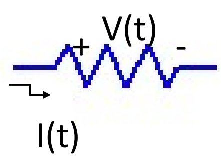
- **Active and Passive Components**:

  Response (Output) across the elements cant be greater then excitation

  - Electrical Elements (R,L,C) are Passive Elements
  - Electronics elements (diode ,transistor etc.) are Active elements

Voltage and current relation in R,L , C

Resistance

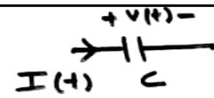


$$V(t) = RI(t)$$

$$I(t) = \frac{V(t)}{R}$$

- Same behavior for both AC and DC Supply

Capacitor

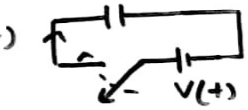


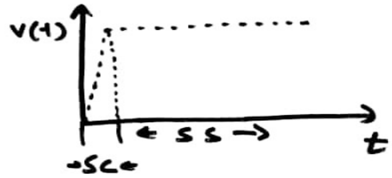
$Q(t) = C\,V(t)$

$I(t) = C \frac{\partial V(t)}{\partial t}$

$V(t) = \frac{1}{C} \int V(t)\,dt$

For DC supply :





In SC Condition

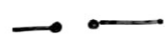
$\frac{\partial V(t)}{\partial t} \rightarrow$ very high

$I(t) \rightarrow$ very high

Short circuit

In SS Condition

$\frac{\partial V(t)}{\partial t} = 0$ $\quad I(t) = 0$



open circuit

- Capacitor voltage does not change Instaneously $V_c(0^-) = V_c(0^+)$
- Equivalent model

For AC

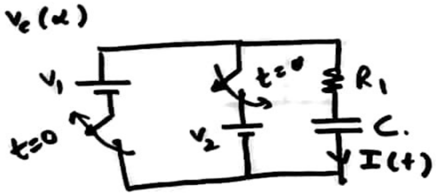
$V_c(t) = \frac{1}{C} \int I(t)\,dt$

$V_c(s) = \frac{1}{C} \frac{I(s)}{s} \pm \frac{V_c(0)}{s}$

$V_c(s) = \frac{1}{C} \frac{I(s)}{s}$ $\quad [\, V_c(0) = 0 \,]$

$V_c(t) = \frac{1}{|WC|} \cdot I(t - 90)$ (voltage lag by current 90° degr.

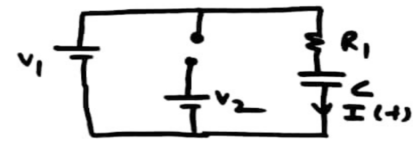
Q. Calculate $I(0)$, $V_c(0)$, $I(\alpha)$, $V_c(\alpha)$



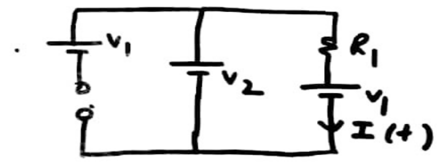
for $t<0$ Capacitor work as open Ck.T

$I(0^-) = 0 \quad V_c(0^-) = V_1$

$V_c(0^-) = V_c(0) = V_c(0^+) = V_1$

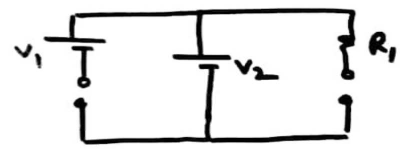


at $t=0$ $\boxed{I(0) = \frac{V_2 - V_1}{R_1}}$

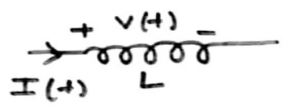


at $t = \infty$ $I(\infty) = 0$

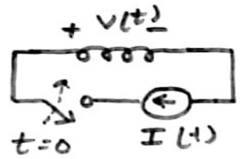
$V_c(\infty) = V_2$

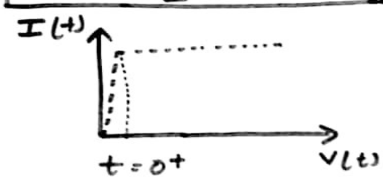


Inductance



$$V(t) = L\frac{\partial}{\partial t}I(t)$$
$$I(t) = \frac{1}{L}\int V(t)\,dt$$





For DC supply:

→ between $t=0 \leftrightarrow 0^+$ (switching cond) $\frac{\partial I(t)}{\partial t}$ (very high)

$V(t)$ = very high →  (open circuit)

→ Steady state Condition → $\frac{\partial I(t)}{\partial t} = 0$, $V(t) = 0$  (short circuit)

For- AC supply: $V(s) = L[sI(s) - I(0)]$

$V(s) = [LsI(s)]$ [if $I(0) = 0$] $s = j\omega$

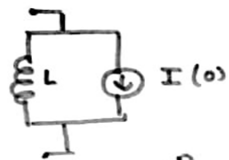
$V(j\omega) = j\omega L\, I(s)$

$V(t) = |NL|\, I(t+90)$, $V_L(t) \xrightarrow{\text{Lead}} I(t)$ by 90°

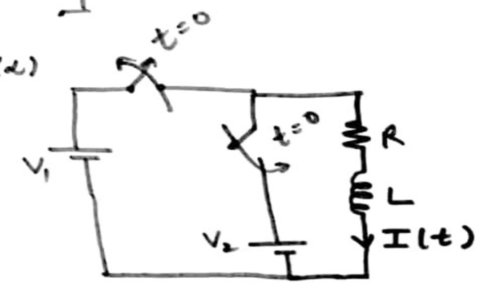
- Inductor current does not change Instaneously

$$I_L(0^-) = I_L(0^+)$$

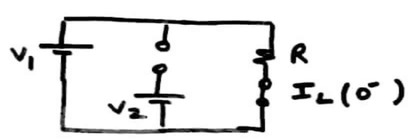
- Equivalent model



Prob.: $I(0)$, $I(\infty)$, $V_L(0)$, $V_L(\infty)$

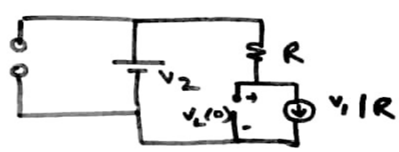


t<0 $\quad I_L(0^-) = \frac{V_1}{R} = I_L(0)$



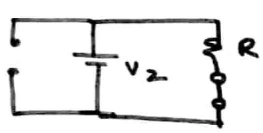
t=0 $\quad -V_2 + R\left(\frac{V_1}{R}\right) + V_L(0) = 0$

$$\boxed{V_L(0) = V_2 - V_1}$$



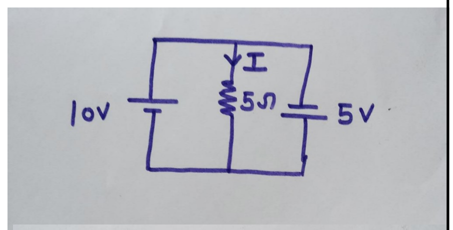
t=∞ $\quad \boxed{I_L(\infty) = \frac{V_2}{R}}$

$$\boxed{V_L(\infty) = 0}$$

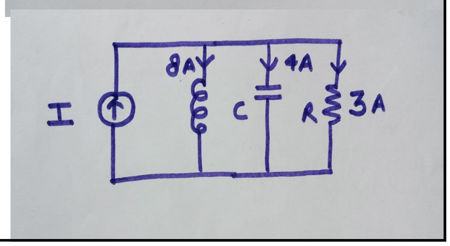


Conceptual Question:

1. Which one have more resistance 1KW Heater or 2KW and why



2. Calculate the current in both the figure as shown



In Coming Lecture

- Answer of previous seat question
- Complete study of nodal analysis
- concepts of super node
- Concepts of dependents source
- Numerical Example

Thank you