tr5frbj 12/08/24

Circuit Theory and Devices

Lab: LT Spice (2nd week onwards) → tut as well

book: Engineering Circuit Analysis (9th Edition)

Relative grading

Labs	20%
Quiz (every 2 weeks (n−1))	20%
Mid sem	30%
End sem	30%

Scientific calc ⇐ { Mid sem, End sem }

Course {continuation of BE} : 9 modules chapter 10 onwards

* Lecture : 1

⇒ Linear Circuits

x (input) → [system] → y (output)

system is linear if

Kx → [sys] → Ky

where k is constant

"R" Resistor: $V = iR$ linear element ✓

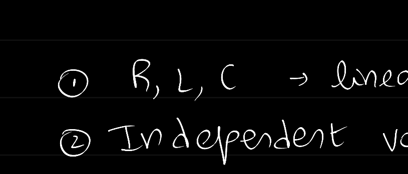
"L" Inductor: $V = L\frac{di}{dt}$ linear element ✓

"C" Capacitor: $i = C\frac{dv}{dt}$ linear element ✓

* Linear Electric Circuits :

consists of ⇒

1. R, L, C → linear elements
2. Independent voltage & current sources
3. linear dependent sources



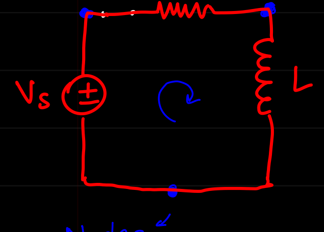
↙ example: would not have been linear if $V_s = KV_x^2$

NOTE: diode and transistors are non-linear elements

* Response of a linear circuit

① full response = transient response + Steady State

transient response	Steady State
temporary	persists $t \to \infty$
due to sudden change	due to source
also called natural response	also called forced response
depends on linear elements R, L, C	depends on current/voltage source



KVL : $-V_s + iR + L\frac{di}{dt} = 0$

$i_{final} = i_{transient} + i_{steady\ state}$

as $t \to \infty$, $i_{final} = i_{steady\ state}$

* Sinusoids & complex numbers

sinusoidally varying voltage source

$V_s(t) = V_m \cos(\omega t)$

$V_s(t) = V_m \sin(\omega t)$

$V_s(t) = V_m \sin(\omega t + \phi)$

② is leading ①, ① is lagging ② } by angle ϕ

* TRIGO

$\sin(-\theta) = -\sin(\theta)$

$\cos(-\theta) = \cos(\theta)$

$\sin(A+B) = \sin A \cos B + \cos A \sin B$

$\cos(A+B) = \cos A \cos B - \sin A \sin B$

sin +ve	All +ve
tan +ve	cos +ve

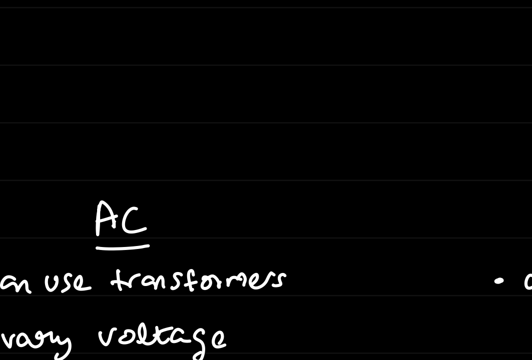
* Complex Numbers

Real : x

complex : $x + iy$ (rectangular form; x real part, y imaginary part; $i = \sqrt{-1}$ a.k.a. j)

⇒ Euler's identity : $e^{j\theta} = \cos\theta + j\sin\theta$ ($e^{j\theta}$ exponential form; $\cos\theta + j\sin\theta$ rectangular form)

Complex Number
- rectangular: $x + iy$
- exponential: $re^{j\theta}$ (≡ polar form : $r\angle\theta$)



$r = \sqrt{x^2 + y^2}$

$\theta = \tan^{-1}\left(\frac{y}{x}\right)$

$(r_1 e^{j\theta_1}) \times (r_2 e^{j\theta_2}) = (r_1 \cdot r_2)\, e^{j(\theta_1 + \theta_2)}$

AC	DC
• we can use transformers to vary voltage	• appliances need constant current
• transported easily over large distances	

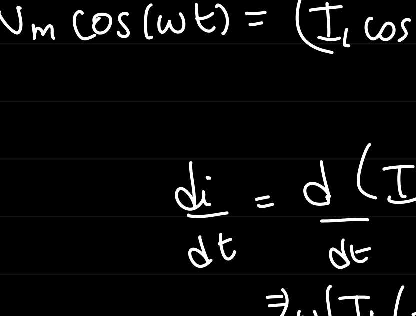
AC → DC : using rectifiers

* MODULE : 1 {CH = 10} 10:30 am

⇒ Sinusoidal steady state analysis

assuming transient has died out long back

Consider,



$V_s(t) = V_m \cos(\omega t)$ find $i(t)$

$V_s(t) = iR + L\frac{di}{dt}$

⇒ $V_m \cos(\omega t) = iR + L\frac{di}{dt}$ (both will take cos(ωt) form)

General form Solution : $i = I_1 \cos\omega t + I_2 \sin\omega t$

⇒ $V_m \cos(\omega t) = (I_1 \cos\omega t + I_2 \sin\omega t)R + L\frac{di}{dt}$

$\frac{di}{dt} = \frac{d}{dt}(I_1 \cos\omega t + I_2 \sin\omega t)$

$\Rightarrow \omega(I_1(-\sin\omega t) + I_2 \cos\omega t)$

$\Rightarrow \omega(I_2 \cos\omega t - I_1 \sin\omega t)$

$V_m \cos(\omega t) = (I_1 \cos\omega t + I_2 \sin\omega t)R + (I_2 \cos\omega t - I_1 \sin\omega t)L\omega$

⇒ $\cos\omega t \cdot (I_1 R + I_2 L) + \sin\omega t \cdot (I_2 R - I_1 L)$

⇒ $(I_1 R + I_2 L - V_m)\cos(\omega t) + (I_2 R - I_1 L)\sin(\omega t) = 0$

* at $t = 0$,
$(I_1 R + I_2 L - V_m)\cdot 1 + (I_2 R - I_1 L)\cdot 0 = 0$

$$\boxed{I_1 R + I_2 L = V_m}$$

* at $t = \frac{\pi}{2\omega}$, $(I_1 R + I_2 L - V_m)\cdot 0 + (I_2 R - I_1 L)\cdot 1 = 0$

$$\boxed{I_1 = I_2 \cdot \frac{R}{L}}$$