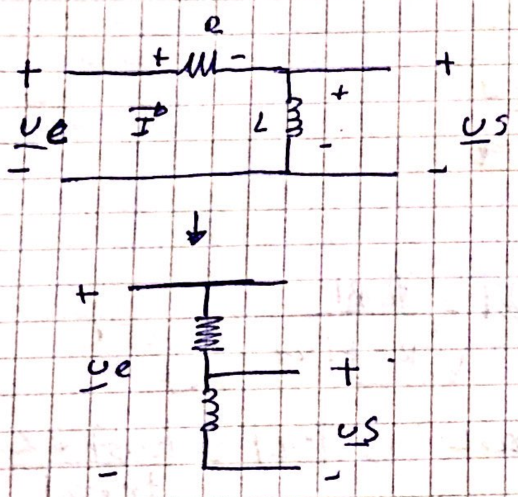
TP 5 Explicación respuesta en frecuencia y poliarmónicas

Se aplican filtros para obtener la señal que yo quiero

Ejercicio 2



$0 < F < \infty$

$v_e = v_R + v_L$

$v_e = IR + Ij\omega L$

$v_e = I(R + j\omega L)$

$v_s = v_L = I j\omega L$

$$\frac{v_s}{v_e} = \frac{\cancel{I} j\omega L}{\cancel{I}(R + j\omega L)}$$

$$= \frac{j\omega L}{R + j\omega L} \cdot \frac{j\omega L}{j\omega L}$$

$$= \frac{1}{R/j\omega L + 1}$$

generalmente la salida no es mayor que la entrada

$$\boxed{\frac{v_s}{v_e} = \frac{1}{1 - jR/\omega L}}$$

$$\boxed{\left|\frac{v_s}{v_e}\right| = \frac{1}{\sqrt{\left(\frac{R}{\omega}\right)^2 + 1^2}} = \frac{1}{\sqrt{2}}}$$

hay que dejarlo así

ω_c de corte $= \frac{R}{L}$

busca la frecuencia de corte

tiene que ser $\frac{1}{\sqrt{2}}$?

1^2

$\frac{\omega_c}{\omega}$

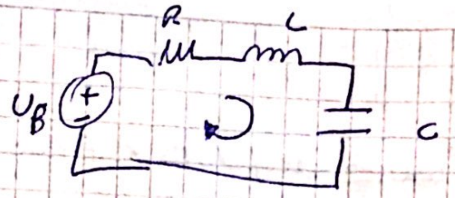
3) Datos

$L = 10mH$

$C = 100mF$

$R = 1\Omega$

$R_2 = 100 m\Omega$



a) $Zeq = R + j\omega L - \frac{j}{\omega C}$

$$|Zeq| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\underline{I} = \frac{U_B}{Zeq} = \frac{U_B}{R + j\left(\omega L - \frac{1}{\omega C}\right)} \Rightarrow |\underline{I}| = \frac{|U_B|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

b) $U_L = \underline{I}\, j\omega L = \frac{U_B}{Zeq} \cdot j\omega L \Rightarrow |U_L| = \frac{|U_B|\, \omega L}{|Zeq|}$

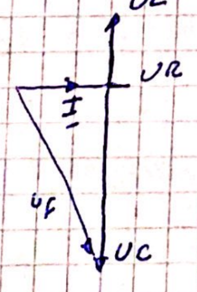
$$|U_L| = \frac{|U_B|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot \omega L$$ → esto es el módulo de $j\omega L$

$$\underline{U_C} = \underline{I}\left(\frac{-j}{\omega C}\right) = \frac{U_B}{Zeq}\left(\frac{-j}{\omega C}\right) \Rightarrow |\underline{U_C}| = \frac{|U_B|}{|Zeq|}\left(\frac{+1}{\omega C}\right)$$

$$|\underline{U_C}| = \frac{|U_B|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot \frac{1}{\omega C}$$

hay sobretensión cuando el módulo de un elemento reactivo es mayor que la tensión de la fuente?

$\omega_{resonancia} = \frac{1}{\sqrt{LC}}$



$|U_L| > |U_B| \quad |U_C| > |U_B|$

$\underline{Z}(\omega_0) = R$

$\omega_0 = \frac{1}{\sqrt{LC}} \Rightarrow \underline{I} = \frac{U_F}{\underline{Z}}$

$\underline{Z} = R + j(X_L - X_C)$

$= 0$

$X_L = X_C$

$\omega L = \frac{1}{\omega C}$

$\omega = \frac{1}{\sqrt{LC}}$

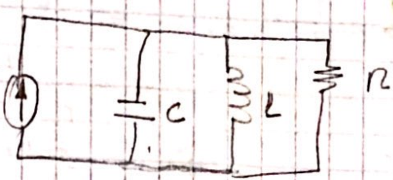
TP5

Datos

$|I_F| = 1$

$G = 1,25\ mS$

$L : 20\ mH$



$\frac{1}{R}$

a)- ω_0

$Zeq_{(\omega_0)} = R$

$$Zeq : \frac{1}{R} + \frac{1}{jX_L} + \frac{1}{jX_C}$$

$X_L = \omega L$

$X_C = \frac{1}{\omega C}$

$$= \frac{1}{R} + \frac{1}{j\omega L}\cdot\frac{j}{j} - \frac{\omega C}{j}\cdot\frac{j}{j}$$

$$= \frac{1}{R} - \frac{j}{\omega L} + \omega C j$$

$$= \frac{1}{R} - j\left(\frac{1}{\omega L} - \omega C\right)$$

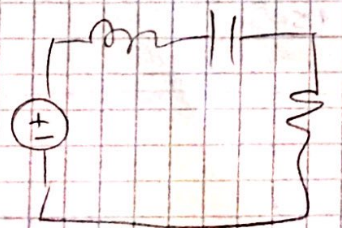
$$\frac{1}{\omega L} - \omega C = 0$$

$$\frac{1}{\omega L} = \omega C$$

$$\boxed{\frac{1}{\sqrt{LC}} = \omega_0}$$

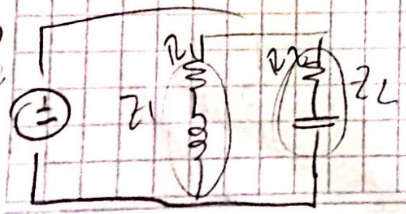
$$P_{max} = \frac{U_{max}^2}{R}$$

$$\frac{P_{max}}{2} = \frac{I_{m}^2 R}{2} = \left(\frac{I_{max}}{\sqrt{2}}\right)^2 R = \frac{I_{max}^2}{2} R = \frac{P_{max}}{2}$$



$$Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\omega L - \frac{1}{\omega C} = 0 \rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$



$$Zeq = \frac{Z_1 \cdot Z_2}{Z_1 + Z_2} = R + j\,\mathbb{I}$$

$= 0$

$\downarrow$

ω_0

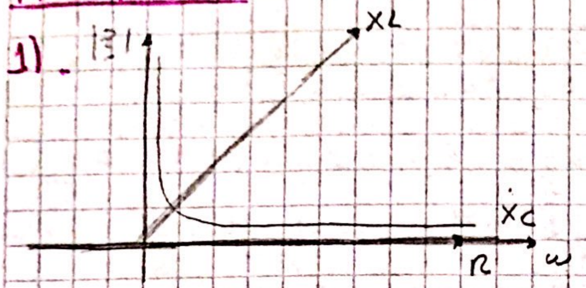
$Z_1 = R + j\omega L$

$Z_2 = R + \frac{1}{j\omega C}$

NOTA

Práctica 5

1).



$X_L = 0$ si $w = 0$
$X_L \to \infty$ si $w \to \infty$

Es un inductor en continua que se comporta como un corto.

$X_C \to \infty$ si $w = 0$
$X_C = 0$ si $w \to \infty$

Este sería el caso de un capacitor en continua, que se comporta como abierto

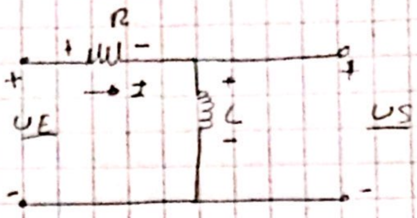
b). si $w \to 0$ $X_C \to \infty$ $\Rightarrow$ a bajas frecuencias, no hay circulación de corriente

si $w \to \infty$ $X_L \to \infty$? $\to$ a altas frecuencias se produce un corto.

2)_ Datos

$R = 10\Omega$

$L = 10mH = 10 \cdot 10^{-3} H$



a)_ US/UE en función de ω $\qquad 0 < f < \infty$

$UE - UR - UL = 0$

$UE = UR + UL$

$US = UL$ → porque están en paralelo

$$\Rightarrow \frac{US}{UE} = \frac{UL}{UR + UL} = \frac{I j X_L}{IR + I j X_L} = \frac{\cancel{I} j X_L}{\cancel{I}(R + jX_L)}$$

$$= \frac{jX_L}{R + jX_L} = \frac{j\omega L}{j\omega L\left(1 + \frac{R}{j\omega L}\right)} = \frac{1}{1 + \frac{R}{j\omega L}} = \boxed{\frac{1}{1 - j\frac{R}{\omega L}}}$$

b)_

$$\Rightarrow \left|\frac{US}{UE}\right| = \frac{|US|}{|UE|} = \frac{1}{\sqrt{1 + \left(\frac{R}{\omega L}\right)^2}}$$

$$\arg\left(\frac{US}{UE}\right) = \arg\left(\frac{1}{1 - j\frac{R}{\omega L}}\right) = \arg(1) - \arg\left(1 - j\frac{R}{\omega L}\right)$$

$$- \operatorname{arctg}\left(\frac{\frac{R}{\omega L}}{1}\right)$$

$$\arg\left(\frac{US}{UE}\right) = \boxed{-\operatorname{arctg}\left(\frac{R}{\omega L}\right)}$$

c)_ ωc es la condición de corte

$$1/\sqrt{1 + \left(\frac{R}{\omega L}\right)^2} = \frac{1}{\sqrt{2}}$$

$$1/\ 1 + \left(\frac{R}{\omega L}\right)^2 = \frac{1}{2}$$

$$2 = 1 + \left(\frac{R}{\omega L}\right)^2$$

$$1 = \left(\frac{R}{\omega L}\right)^2$$

$$1 = R/\omega L$$

$$\boxed{\omega c = \frac{R}{L}} \cong 1000 \text{ rad/seg}$$

Siempre!

$$\Rightarrow \frac{1}{\sqrt{1 + \left(\frac{R}{\omega L}\right)^2}} = \frac{1}{\sqrt{1 + \left(\frac{R}{L} \cdot \frac{L}{R}\right)^2}} = \boxed{\frac{1}{\sqrt{2}}} \rightarrow \cong 0,707$$

NOTA

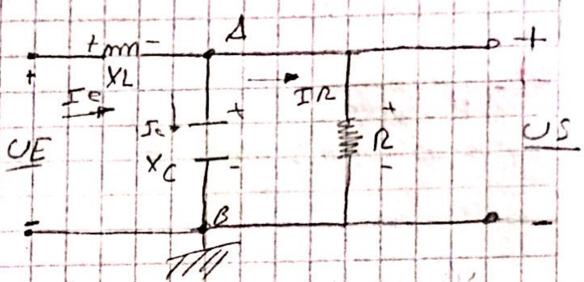
4). Datos

11). M A L!

$R = 20\Omega$

$C = 20\,mF = 20 \cdot 10^{-3}\,F$

$L = 40\,mH = 40 \cdot 10^{-3}\,H$



a) $\frac{Us}{Ue}$

$Ie = \frac{U}{Ze}$

$$Ie = Ic + IR$$

$$\frac{Ue - UA}{XL} = \frac{UA}{XC} + \frac{UA}{R}$$

$U_{AB} = Us$

$$\frac{Ue}{jXL} = UA\left(\frac{1}{jXC} + \frac{1}{R} + \frac{1}{jXL}\right)$$

$\omega L \frac{1}{R} = 0.$

$$Ue \cdot BL = UA(BC + BL + G)$$

$\frac{1}{XC} = Bc$ $\qquad \frac{1}{R} = G$

$$\boxed{\frac{jBL}{jBc + jBL + G} = \frac{UA}{Ue} = \frac{US}{Ue}}$$

$\frac{1}{XL} = BL$

$$\frac{1}{(a+jb)} \cdot \frac{(a-jb)}{(a-jb)}$$

No!

$$\cancel{\frac{1}{R} + jXL - \frac{j}{\omega C}}$$

$$\frac{1}{R} + j\left(XL - \frac{1}{\omega C}\right)$$

$= 0$

$$\omega L - \frac{1}{\omega C} = 0$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$\boxed{\omega = \frac{1}{\sqrt{LC}}}$$

$\Rightarrow \omega = 2\pi F$

$$\frac{1}{\sqrt{LC}} = 2\pi F$$

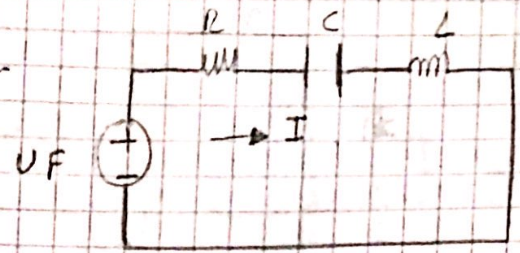
$$\frac{1}{2\pi\sqrt{LC}} = F$$

NOTA

HOJA N°

FECHA

3)



a) $Z(\omega) = R + \frac{1}{j\omega C} + j\omega L$

$= R - \frac{j}{\omega C} + j\omega L$

$Z(\omega) = R + j\left(\omega L - \frac{1}{\omega C}\right)$

$|I(\omega)| = \frac{|UF|}{|Z(\omega)|} = \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$ $\Rightarrow$ $\left(\frac{1}{\sqrt{LC}} L - \frac{\sqrt{LC}}{C}\right)$

$\frac{1}{C} \cdot \frac{1}{\sqrt{LC}} \quad \frac{\sqrt{LC}}{C}$

b) $U_L = I\, j\omega L$

$= \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot j\omega L$

$\omega_0 = \frac{1}{\sqrt{LC}}$ frecuencia de resonancia

$|U_L| = |I|\,|j\omega L|$

$|U_L| = \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot \omega L$

$XL = \omega L$

$\omega L - \frac{1}{\omega C} = 0$

$\omega L = \frac{1}{\omega C}$

$\omega^2 = \frac{1}{LC}$

$\boxed{\omega = \frac{1}{\sqrt{LC}}}$

$\boxed{|U_L| = \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot XL}$

$UC = I\left(\frac{j}{\omega C}\right)$

$|UC| = |I|\left(-\frac{j}{\omega C}\right)$

$= \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot \frac{1}{\omega C}$

$XC = \frac{1}{\omega C}$

$\boxed{|UC| = \frac{|UF|}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \cdot XC}$

NOTA

f) - $\Delta\omega$ $\quad R1 = 1\Omega \quad R2 = 100\times10^{-3}\Omega$

$$|I(\omega)| = \frac{|I(\omega_0)|}{\sqrt{2}} \qquad |I(\omega_0)| = \frac{|V_F|}{|Z|} \Rightarrow (Z = R)$$

$$\frac{\cancel{|V_F|}}{|Z_{eq}|} = \frac{1}{\sqrt{2}} \frac{\cancel{|V_F|}}{|Z|}$$

$$\frac{1}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{1}{\sqrt{2}} \frac{1}{R}$$

$$(\sqrt{2}\,R)^2 = \left(\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}\right)^2$$

$$2R^2 = R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2$$

$$\sqrt{R^2} = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$R = \omega L - \frac{1}{\omega C}$$

$$\omega R = \omega . \omega L - \omega . \frac{1}{\omega C}$$

$$\omega R = \omega^2 L - \frac{1}{C}$$

$$0 = \omega^2 L - \omega R - \frac{1}{C}$$

$\omega_{R1} = 100.00\ rad/seg \qquad 9{,}99\times10^{-6}\ \angle 180° \rightarrow$ ¡Esta no!

$\omega_{R2} = 10\ rad/seg!$

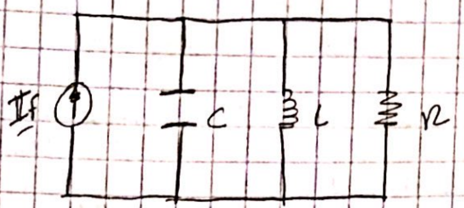
g) - $R1 = 1\Omega$

Como R es grande entonces no hay sobretensión porque $|V_L|\ \wedge\ |V_C| < |V_F|$

$R2 = 100m\Omega = 100\times10^{-3}\Omega$

Como R es chica entonces hay sobretensiones porque $|V_L|\ \wedge\ |V_C| > |V_F|$

4) -



Datos:

$|I_F| = 1\,mA$

$G = 1,25\,mS \Rightarrow G = \frac{1}{R}$

$L = 20\,mH$

$C = 8\,\mu F$

a) - $|I_F| = \frac{|U_F|}{|Z|} \Rightarrow |U_F| = \frac{|I_F|}{|Z|}$

Para obtener w_0 necesito la frecuencia de resonancia

$$|Z| = \sqrt{G^2 + \left(wC - \frac{1}{wL}\right)^2} \Rightarrow |Z(w_0)| = G \Rightarrow$$

$$wC - \frac{1}{wL} = 0$$

$$wC = \frac{1}{wL}$$

$$w^2 = \frac{1}{\sqrt{LC}}$$

$$w_0 = \frac{1}{\sqrt{LC}} = 2500 \text{ rad/seg}$$

$$\Rightarrow |U_0| = \frac{|I_F|}{|Z|} = \frac{|I_F|}{R} = 1,25 \times 10^{-6}$$

$$|U(w)| = \frac{1}{\sqrt{2}} |U(w_0)|$$

$$\frac{|I_F|}{|Z|} = \frac{1}{\sqrt{2}} \frac{|I_F|}{|Z(w_0)|}$$

$$\frac{1}{\sqrt{G^2 + \left(wC - \frac{1}{wL}\right)^2}} = \frac{1}{\sqrt{2}} \frac{1}{G}$$

$$(\sqrt{2}\,G)^2 = \left(\sqrt{G^2 + \left(wC - \frac{1}{wL}\right)^2}\right)^2$$

$$2G^2 = G^2 + \left(wC - \frac{1}{wL}\right)^2$$

$$\sqrt{G^2} = \sqrt{\left(wC - \frac{1}{wL}\right)^2}$$

$$G = wC - \frac{1}{wL}$$

$$wG = w^2 C - \frac{1}{L}$$

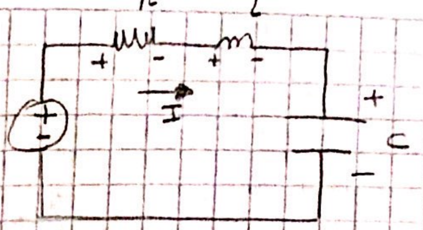
$$0 = w^2 C - wG - \frac{1}{L}$$

$\rightarrow 156,20$

$\rightarrow 0,0400$

5)- Datos

$U_F = 1000\,V$
$R = 5\,\Omega$
$L = 10\times10^{-3}\,H$
$C = 24\times10^{-6}\,F$



a)- $|Z_{eq}| = \sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}$

$F = \dfrac{1}{2\pi\sqrt{LC}}$

$\omega = 2\pi F$

$F =$

$|I_F| = \dfrac{|U_F|}{|Z_{eq}|} =$

$|U_L| = |I|\,|jX_L|$

$= \dfrac{|U_F|}{|Z_{eq}|} X_L < |U_F|$

$X_L < |Z_{eq}|$

$(X_L)^2 < \left(\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}\right)^2$

$X_L^2 < R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2$

$X_L^2 < R^2 + (\omega L)^2 - 2\omega L \cdot \dfrac{1}{\omega C} + \dfrac{1}{(\omega C)^2}$

$\cancel{X_L^2 - (\omega L)^2} < R^2 - \dfrac{2L}{C} + \dfrac{1}{(\omega C)^2}$

$\dfrac{2L}{C} - R^2 < \dfrac{1}{(\omega C)^2}$

$(\omega C)^2 < \dfrac{1}{\dfrac{2L}{C} - R^2}$

$\omega C < \dfrac{1}{\sqrt{\dfrac{2L}{C} - R^2}}$

$\omega < \dfrac{\dfrac{1}{\sqrt{\dfrac{2L}{C} - R^2}}}{C}$

$\omega < 1465{,}52$

$F = \dfrac{\omega}{2\pi} \Rightarrow 233.24\ Hz$

Si $F > 233{,}24\ Hz$ va a haber

Sobre tensión en L!

$|V_C| = |I|\,|-jX_C|$

$= \frac{|V_F|}{|Z_{eq}|} X_C < |V_F|$

$X_C < |Z_{eq}|$

$(X_C)^2 < \left(\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}\right)^2$

$X_C^2 < R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2$

$X_C^2 < R^2 + (\omega L)^2 - 2\omega L \frac{1}{\omega C} + \frac{1}{(\omega C)^2}$

$\cancel{X_C^2 - \frac{1}{(\omega C)^2}} < R^2 + (\omega L)^2 - \frac{2L}{C}$

$\frac{2L}{C} - R^2 < (\omega L)^2$

$\sqrt{\frac{2L}{C} - R^2} < \omega L$

$\frac{\sqrt{\frac{2L}{C} - R^2}}{L} < \omega$

$2843{,}12 > \omega$

$F = 452{,}5 \text{ HZ}$

$\Rightarrow$ Si $F < 452{,}5$ HZ hay sobretensión en C

b) _

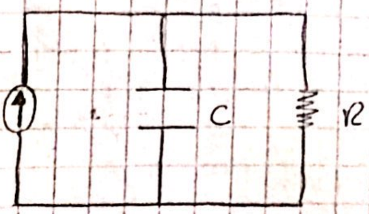
7). Datos

$f = 50\,Hz$

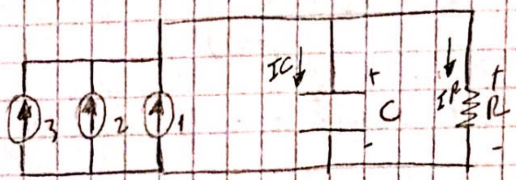
$$i_F(t) = \overbrace{5\,sen(\omega t)}^{1} + \overbrace{0{,}3\,sen(3\omega T + 30°)}^{2} + \overbrace{0{,}1\,sen(5\omega T + 150°)}^{3}\ A$$

$R = 10\,\Omega$

$C = 300\,\mu F = 3\times10^{-4}$



b)_



$U_C = I_C\, X_C$
$U_C = I_C \dfrac{1}{\omega C}$

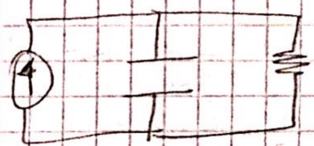
$I_F = I_C + I_R$

$U_C - U_R = 0$
$U_C = U_R$

$\omega_1 = 100\pi$
$\omega_2 = 300\pi$
$\omega_3 = 500\pi$

$$\frac{1}{Z_{eq}} = \frac{1}{R} + j\omega C = 0{,}14\ \angle 43{,}30 \Rightarrow Z_{eq} :$$

$\Rightarrow$



$\Rightarrow$

$\omega = 2\pi F$

$U_1 = I_1\, Z_{eq} = 0{,}68\ \angle 43.30$

Capacitivo la corriente adelanta a la tensión

$Z_{eq2} = 0{,}3\ \angle 72{,}52 =$

$U_R = I_F\, R \Rightarrow 50V$

$$\frac{1}{Z_{eq}} = \frac{1}{R} + j\omega C \Rightarrow Z_{eq} : \frac{1}{\frac{1}{R} + j\omega C} = 7{,}27\ \angle -43{,}30$$

$U_1 = |I_{F1}|\,|Z_{eq}| = 36{,}38\ \angle -43{,}30$

$U_2 = |I_{F2}|\,|Z_{eq}| = 1\ \angle -41$

$U_3 = 0{,}21\ \angle 71$

$\Rightarrow U_F(t) =$

b)_ $I_C = \dfrac{U_C}{Z_C} \Rightarrow I_{C1} = \dfrac{U_{C1}}{\frac{1}{j\omega C}} = U_{C1} \cdot j\omega C = 3{,}42\ \angle 46$

$= U_{C2} \cdot j\omega C$

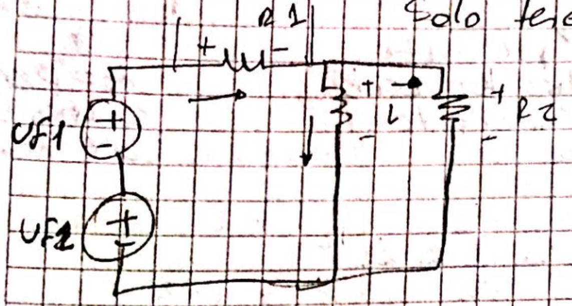
$I_{C2} =$

Valor eficaz =

8) $I_L(t) = I_0 + I_1 \operatorname{sen}(\omega t)$

continua

Solo tenemos dos terminos



Anulamos UF2

$UF1 - UR_1 - UL = 0$

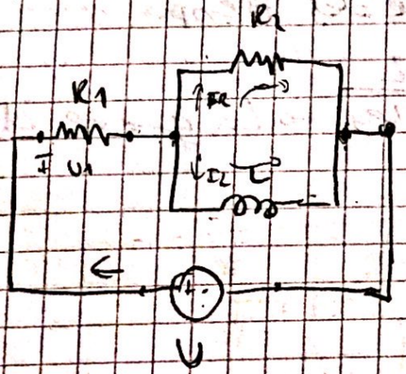
$UF1 = UR1 + UL$

$UF1 - UR1 - UR2 = 0$

$UF1 = UR1 + UR2$

$UL = L \dfrac{di(t)}{dt} \rightarrow$ Como es una constante es igual a cero!

$\therefore UL = 0$



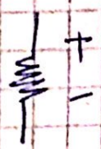
$U = U_1 + U_{R_2L}$

$= I \cdot R_1 + I$

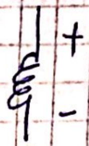
$R^{E}{}_{I}$

Explicación Práctica 6

Ecuaciones constitutivas

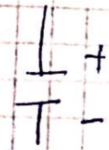


$v_R = I_R R$



$v_L = L \frac{di_L}{dt}$

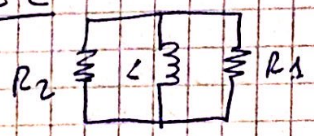
No permite saltos bruscos de corriente!



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

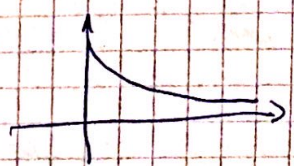
No permite saltos bruscos de tensión

Eje 2



a) - $E_L = \frac{1}{2} L i_L^2$

Estado permanente



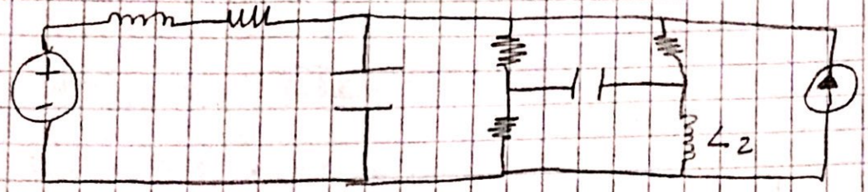
se descarga el inductor => todo cero

τ = cte del tiempo

$\tau = \frac{L}{R_{eq}} \to$ La que ve el inductor

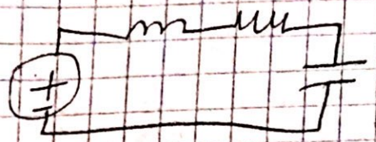
Práctica nro 6

1)_



a)_ Inicialmente $T=0$

$v_{C1} = v_{C2} = 0$
$I_{L1} = I_{L2} = 0$ } Condiciones iniciales o también se pueden utilizar las ecuaciones constitutivas

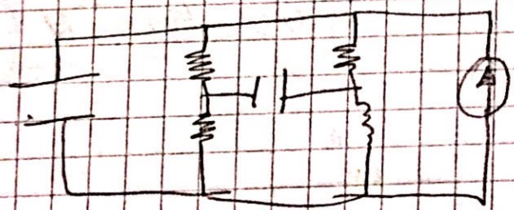


Si aplico Kirchoff o condición inicial

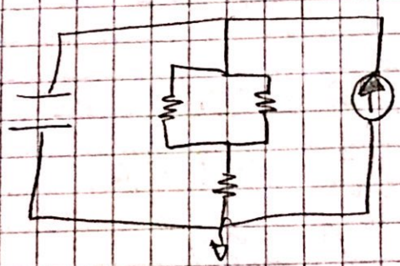
$$v_F - v_{L1} - \cancel{v_{R1}}^{\text{condición}} - \cancel{v_{C1}} = 0$$

$$\Rightarrow v_F = v_{L1}$$

ahora



$\Rightarrow$



por esta rama no pasa corriente ya que está en paralelo con el capacitor y este se encuentra descargado por lo que su tensión es cero.

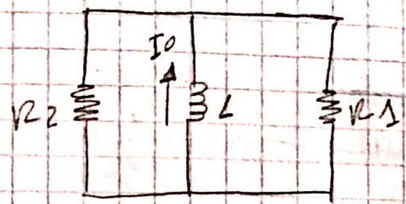
_ Datos

$I_0 = 20A$

$R_1 = 6\Omega$

$R_2 = 3\Omega$

$L = 2H$

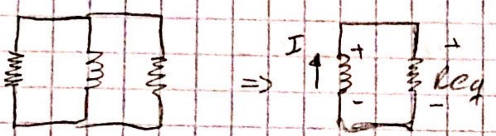


a)_ $E_L = \frac{1}{2} L I_L^2$

$E_L = 400\ j$

b)_ En estudo permanente se va a descargar el inductor por lo tanto su corriente será cero

c)_ $I_L = 20e^{-T} A$



$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{6} \Rightarrow$

$R_{eq} = 2$

$V_L - V_R = 0$

$V_L = V_R$

$V_L = IR$

$V_L = 20e^{-T} A \cdot 2\Omega$

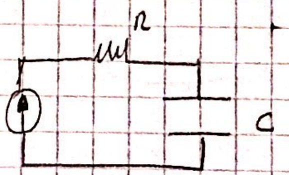
$\boxed{V_L = 40e^{-T} V.}$

3)_ Datos

$I_F = 1.5A$

$R = 5\Omega$

$C = 200mF$

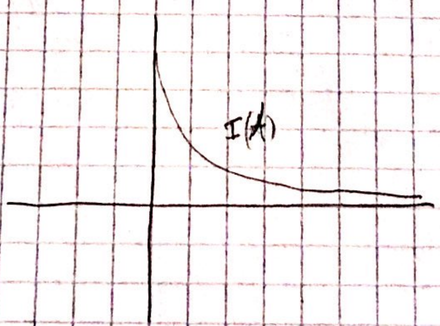


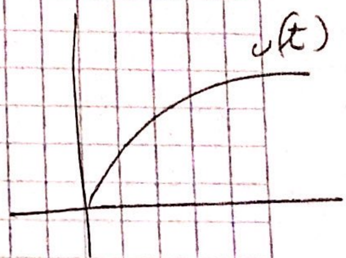
a)_ El capacitor esta inicialmente cargado utilizo su constitutiva

$V_C = \frac{1}{C} \int \overset{cte}{I_F}\, dt$

$V_C = \frac{1}{C} I_F T$

$V_C = 7.5T\ V$





b) _ $U_C(t=2) = 7{,}5\ (2)\ V$

$U_C(t=2) = 15\ V$

c) _ Aplico Kirchoff

$U_{IF} = U_R + U_C$

$U_{IF} = I_F R + \frac{1}{C} \int I_F \, dt$

$U_{IF} - I_F R = \frac{1}{C} I_F T$

$\frac{(U_{IF} - I_F R)\, C}{I_F} = T$

$\boxed{12\ seg = T}$

5) _