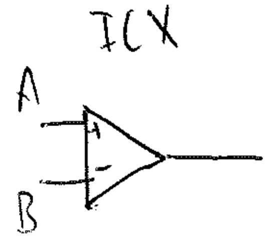
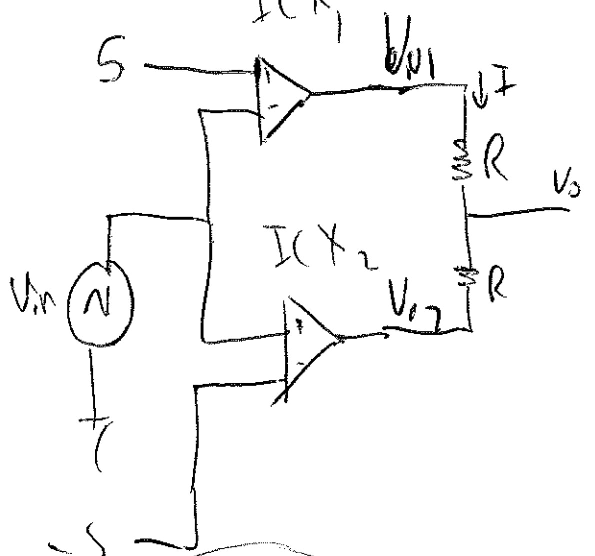
Q1



$A > B \quad (A - B)$

$B > A \quad (B - A)$



$V_{in} = 10 \sin(2\pi f t)$

$f = 0.25$ Hertz

$R = 1\Omega$

(a)

for ICX_1 if $V_{in} > 5$ $\quad V_{o_1} = V_{in} - 5$

ICX_2 if $V_{in} > 5$ $\quad V_{o_2} = V_{in} - (-5) = V_{in} + 5$

$$I = \frac{V_{o1} - (+V_{o2})}{2 \times 1} = \frac{V_{o1} - V_{o2}}{2R} = \frac{(V_{in} - 5) - (V_{in} + 5)}{2 \times 1} = \frac{-10}{2} = -5 \text{ Ampere}$$

$$V_o = V_{o1} - RI = V_{in} - 5 - 1 \times (-5) = V_{in}$$

for ICX_1 if $-5 < V_{in} < 5$ $\quad V_{o1} = 5 - V_{in}$

ICX_2 if $-5 < V_{in} < 5$ $\quad V_{o2} = V_{in} - (-5) = V_{in} + 5$

$$I = \frac{V_{o1} - (V_{o2})}{2R} = \frac{5 - V_{in} - (V_{in} + 5)}{2 \times 1} = \frac{-2V_{in}}{2 \times 1} = -V_{in} \text{ Ampere}$$

$$V_o = V_{o1} - RI = 5 - V_{in} - 1 \cdot (-V_{in}) = 5 - V_{in} + V_{in} = 5$$

3 point

For IC_{Y_1} if $V_{in} < -5$ $\quad V_{o1} = \cancel{5} - \cancel{V_{in}}$

IC_{Y_2} if $V_{in} < -5$ $\quad V_{o2} = (-5 - V_{in})$

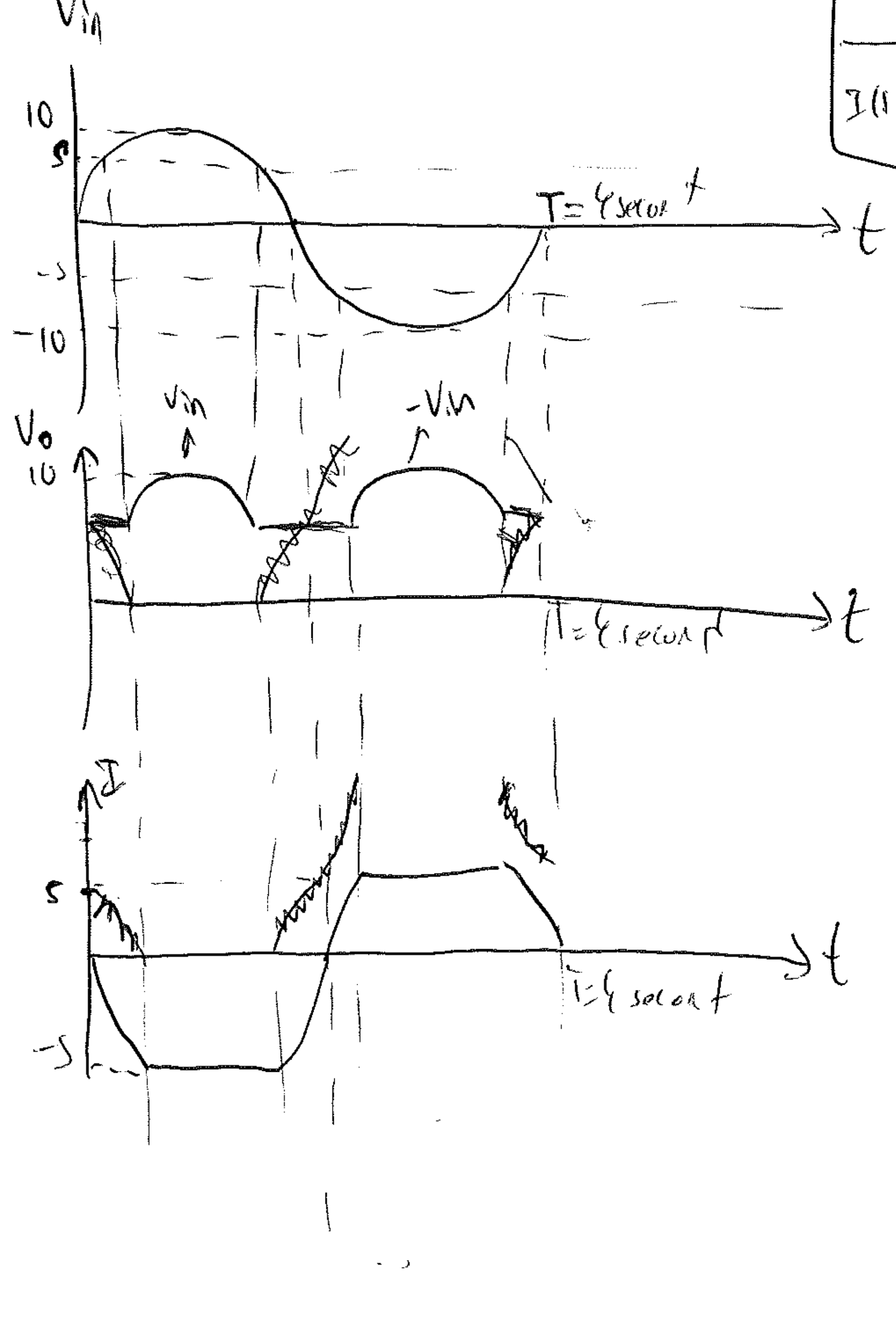
$$I = \frac{V_{o1} - V_{o2}}{2R} = \frac{\cancel{5} - \cancel{V_{in}} - (-5 - V_{in})}{2 \times 1} = \frac{5 - V_{in} + 5 + V_{in}}{2} = \frac{10}{2} = 5A$$

$$V_0 = V_{o1} - RI = 5 - V_{in} - 1 \times 5 = -V_{in}$$

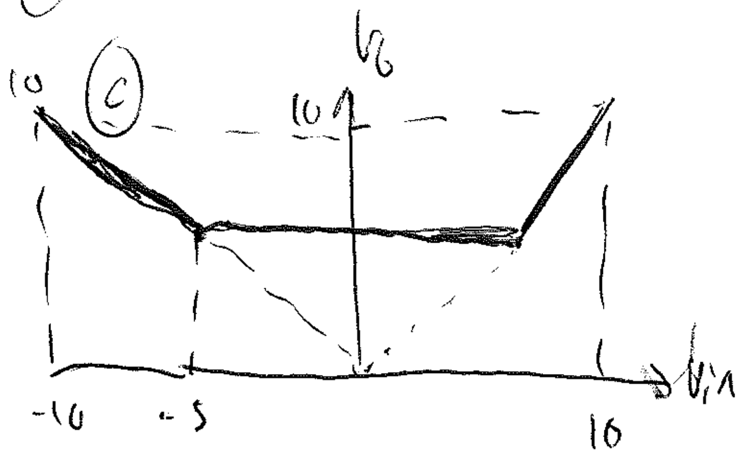
$$V_0(t) = \begin{cases} V_{in}, & V_{in} > 5 \\ 5, & -5 < V_{in} < 5 \\ -V_{in}, & V_{in} < 5 \end{cases}$$

$$I(t) = \begin{cases} -5, & V_{in} > 5 \\ -V_{in}, & -5 < V_{in} < 5 \\ 5, & V_{in} < 5 \end{cases}$$

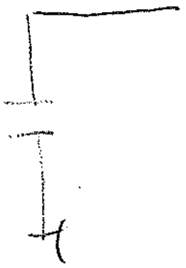
(b)



(c)



Q2

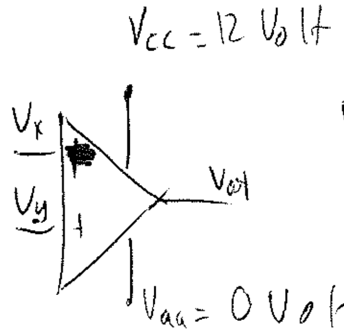


(a, b) → Gidiş 8 puan

Grafikler

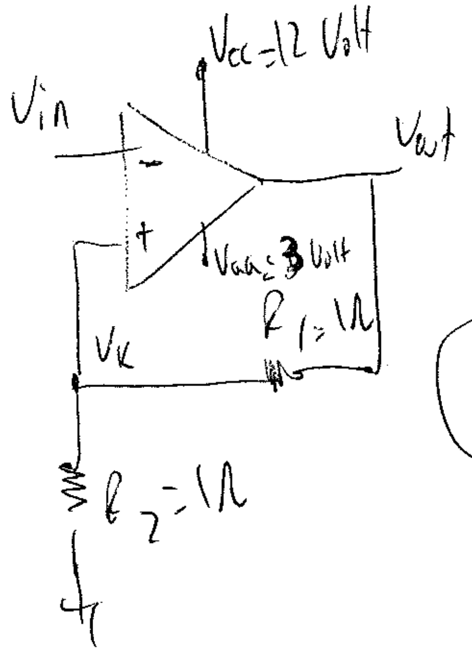
(a) → 4 puan

b → 4 puan



$V_y \geq V_x$ $V_{out} = V_{cc}$

$V_x > V_y$ $V_{out} = V_{aa}$



$V_{in} = 10 \sin(2\pi f t)$ $f = \frac{1}{4}$ Hertz

region 1 $\Rightarrow t_1$ Let $0 < V_{in} \leq 6$ and $V_{out} = 12$ Volt $V_k = 6$ Volt

$V_k > V_{in}$ $V_{out} = 12$ remains unchanged

region 2 $\Rightarrow t_2$ Let $V_{in} \geq 6$ and $V_{out} = 12$ Volt $\Rightarrow V_k = \frac{V_{out}}{R_1 + R_2} R_2 = \frac{12}{2} \times 1 = 6$ Volt

$V_{in} \geq V_k$

then $\underset{\text{change}}{V_{out} = 3}$ Volt $\Rightarrow V_k = \frac{V_{out}}{R_1 + R_2} R_2 = \frac{3}{2} \times 1 = 1.5$ Volt

change

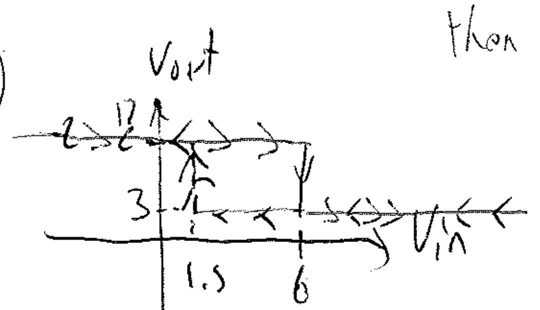
region 3 $\Rightarrow t_3$ Let $1.5 \leq V_{in} < 6$ and $V_{out} = 3$ Volt $\Rightarrow V_k = 1.5$ Volt $V_{in} \geq V_k$

then $V_{out} = 3$ Volt unchanged

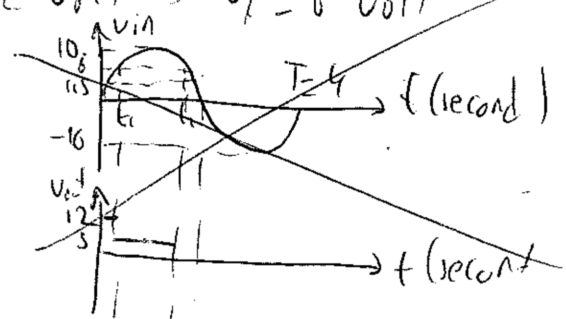
4 Let $1.5 \geq V_{in}$ and $V_{out} = 3 \Rightarrow V_k = 1.5$ Volt $V_{in} < V_k$

then $V_{out} = 12$ Volt $\Rightarrow V_k = 6$ Volt

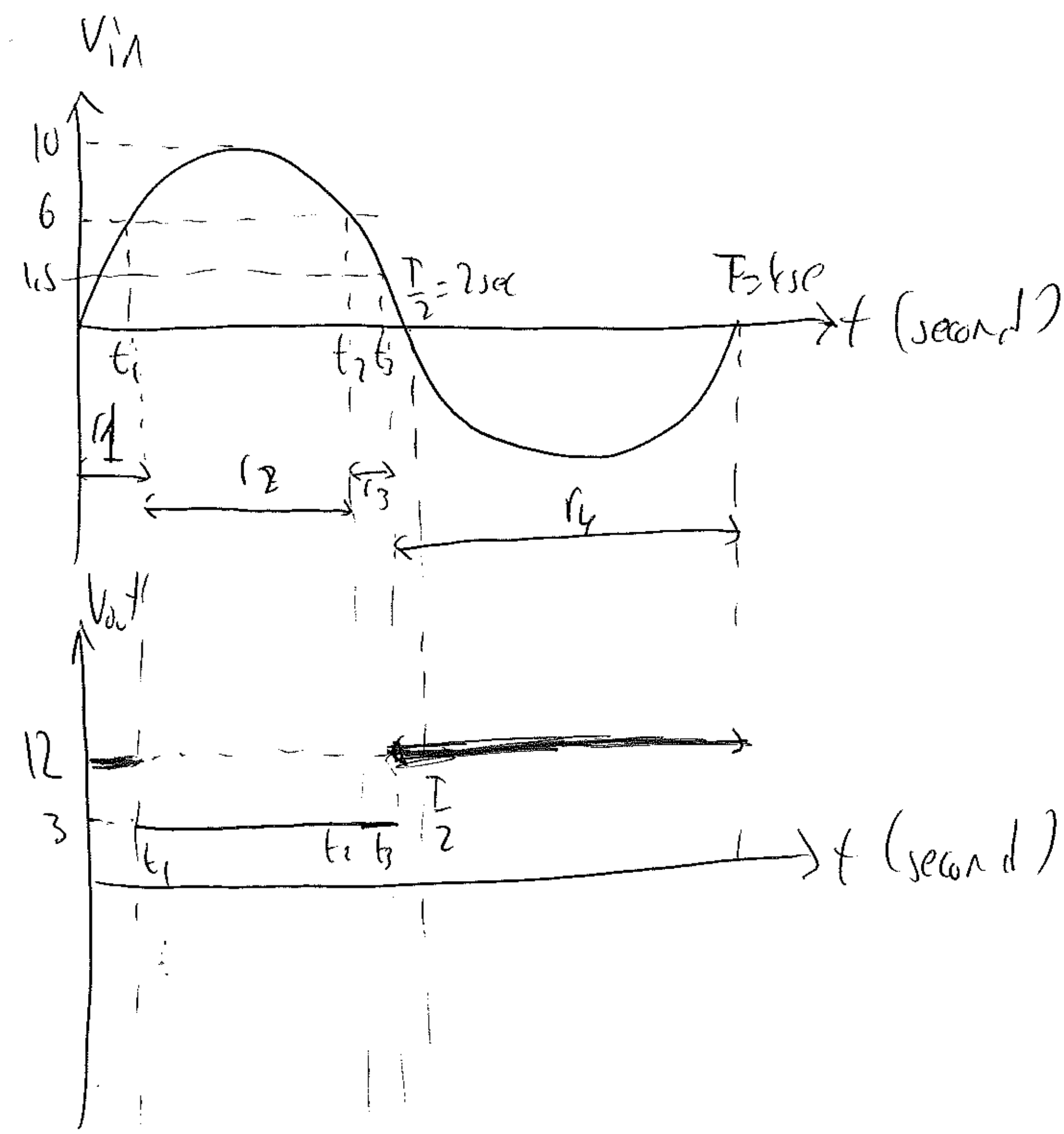
(b)



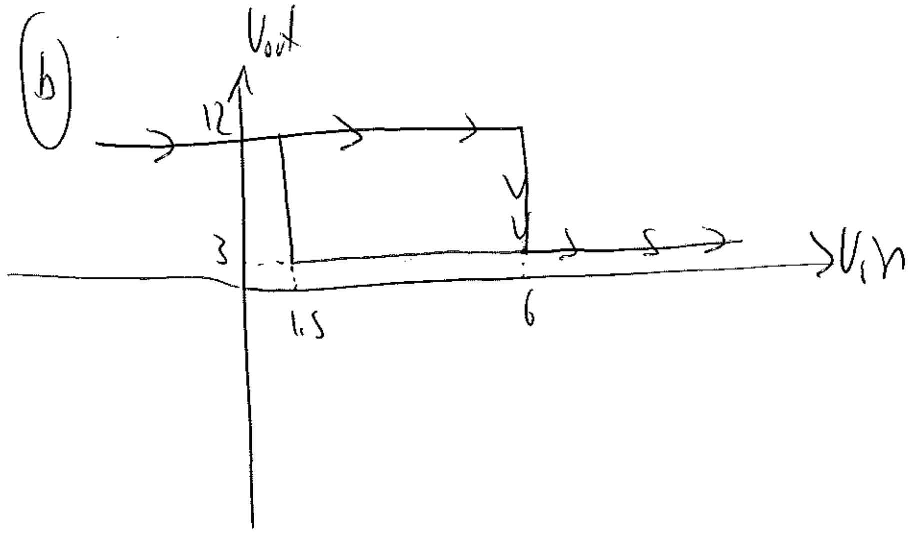
(a)



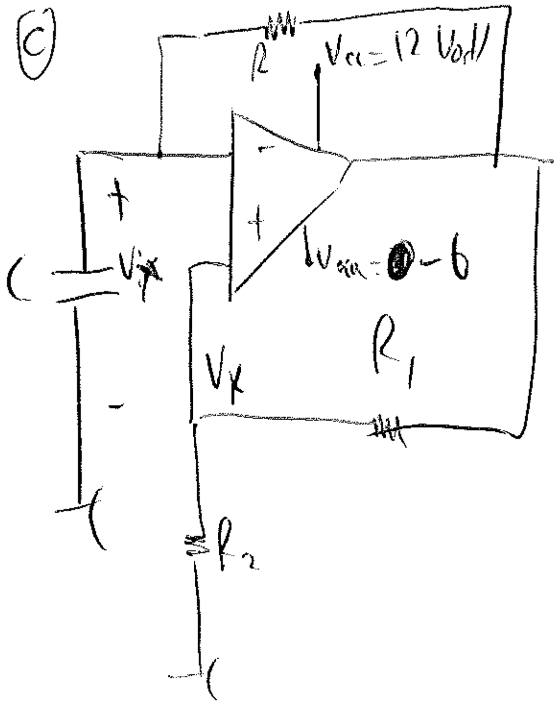
(a)


Vin
10
6
1.5
T/2 = 2sec
T=4sec
t (second)
t1
t2 t3
r1
r2
r3
r4
Vout
12
3
t1
t2 t3
T/2
t (second)

(b)


Vout
12
3
1.5
6
Vin

(c)



$$C\frac{dV_x}{dt} + \frac{V_x - V_{out}}{R} = 0$$

(1 puan) Limits of V_{out} 12 Volt and −6 Volt

V_x will oscillate between 6 Volt and −3 Volt

Let $V_{out} = 12$ Volt $V_k = 6$ Volt $V_x = -3$ Volt (initial condition)

5 puan

$C\frac{dV_x}{dt} + \frac{V_x}{R} = \frac{V_{out}}{R}$ $R = 1\Omega$ $C = 1F$

$\frac{dV_x}{dt} + V_x = 12$ $V_x(0) = -3$ Volt (Vx should increase until it becomes $V_x = 6$ Volt)

$V_x = 12 + Ke^{-t}$ $V_x(0) = -3 = 12 + Ke^0$ $K = -15$

$V_x = 12 - 15e^{-t}$ let $t = t_m$ $V_x(t_m) = 6 = 12 - 15e^{-t_m}$

$15e^{-t_m} = 6$

$2.5 = e^{t_m}$

$t_m = \ln 2.5$

~~$t_m = \ln\frac{10.5}{6}$~~

when $t = t_m$ V_x becomes 6 Volt $\Rightarrow$ $V_{out} = -6$ Volt $V_k = -3$ Volt

$C\frac{dV_x}{dt} + \frac{V_x}{R} = \frac{V_{out}}{R}$ $R = 1\Omega$ $C = 1F$

$\frac{dV_x}{dt} + V_x = -6$ $V_x(t_m) = 6$ Volt

~~$V_x = -6 + Me^{-(t-t_m)}$ $V_x(t_m) = 6 = -6 + Me^0$ $M = 12$ $V_x(t) = -6 + 12e^{-(t-t_m)}$~~

$V_x(t_m) = 3+3 = 6$

$V_x(t_\ell) = 1.5$ Volt $= 3 + 3e^{-(t_\ell - t_m)}$

$1.5 = 3 + 3e^{-(t_\ell - t_m)}$

$$\frac{dV_x}{dt} + V_x = -6 \quad , \quad V_x(t_m) = 6 \text{ Volt}$$

$$\Downarrow$$

$$V_x(t) = -6 + M e^{-(t - t_m)}$$

5 puan

$$V_x(t_m) = 6 = -6 + M e^{-(t_m - t_m)}$$

$$12 = M$$

$$V_x(t) = -6 + 12 e^{-(t - t_m)}$$

$$V_x(t_k) = -3 = -6 + 12 e^{-(t_k - t_m)}$$

$$3 = 12 e^{-(t_k - t_m)}$$

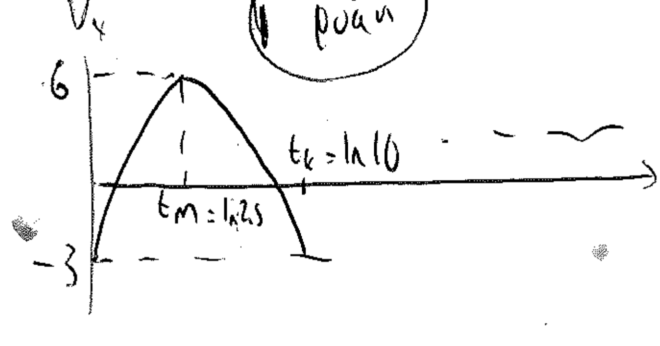
$$e^{(t_k - t_m)} = 4$$

$$t_k - t_m = \ln 4$$

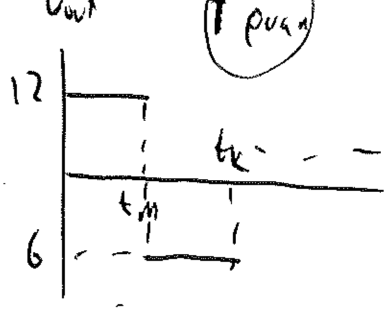
1 puan

$$t_k = \ln 4 + \ln 2.5 = \ln 10$$

1 puan

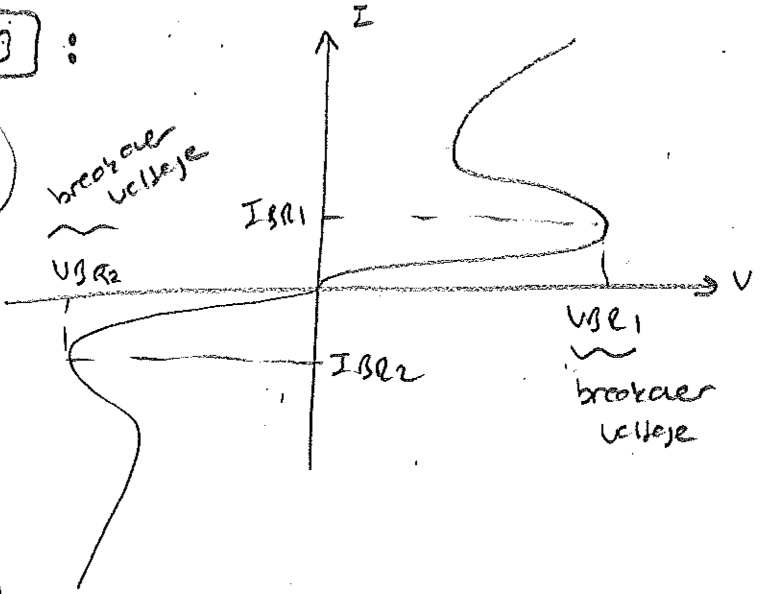


1 puan



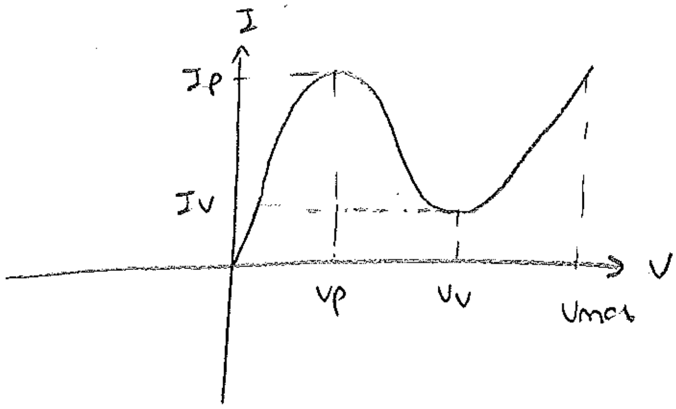
Q.3 :

2



2

Q4 :



6

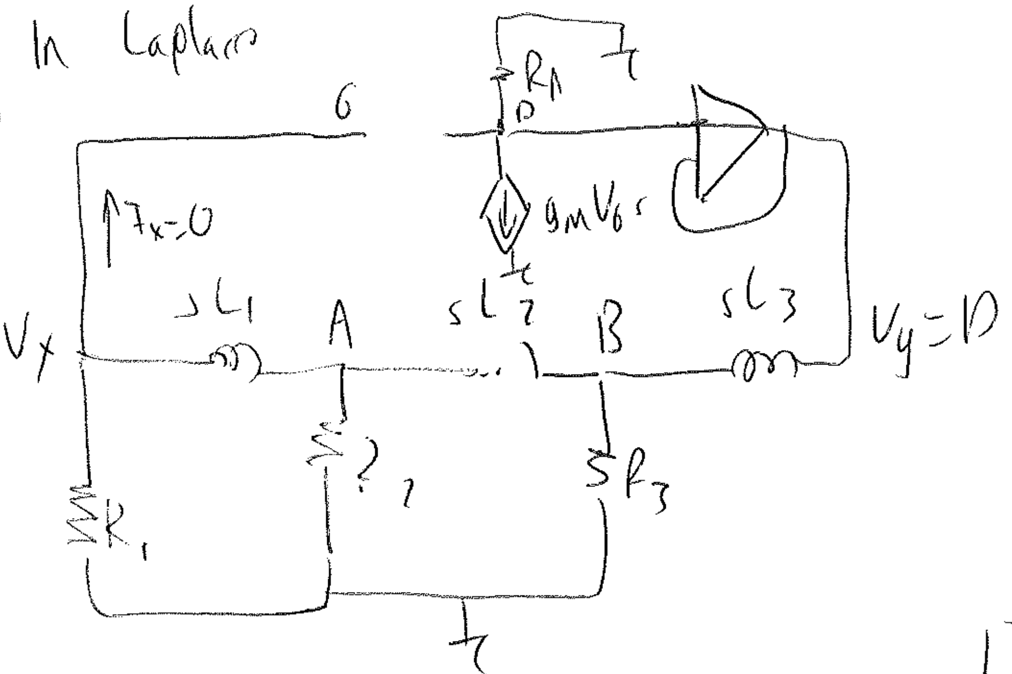
Q-5 : If $R_L \uparrow$, $v_{out} \uparrow$ $V_S \uparrow$ and $I_L \uparrow$

V_B is constant due to zener diode. Thus $V_{BE} \downarrow$. If $V_{BE} \downarrow$

transistor less current so $V_S \downarrow$ $I_L \downarrow$, $v_{out} \downarrow$. Thus R_L decreases.

In Laplace

(Q6)



$$\frac{A - V_x}{sL_1} = \frac{V_x}{R_1} \qquad AR_1 = (R_1 + sL_1)V_x \qquad \boxed{A = \frac{R_1 + sL_1}{R_1} V_x}$$

$$\frac{A - V_x}{sL_1} + \frac{A}{R_2} = \frac{B - A}{sL_2} \qquad \boxed{A\left[\frac{1}{sL_1} + \frac{1}{R_2} + \frac{1}{sL_2}\right] = \frac{V_x}{sL_1} + \frac{B}{sL_2}}$$

Let $R_1 = 1000 = R_2$ · $L_1 = L_2 = 1$ Henry

$$\boxed{A = \frac{1000 + s}{1000} V_y} \ast \qquad A\left(\frac{1}{s} + \frac{1}{1000} + \frac{1}{s}\right) = \frac{V_x}{s} + \frac{B}{s}$$

$$A(s + 2000) = 1000V_x + 1000B$$

$$\boxed{A = \frac{1000[V_x + B]}{s + 2000}} \ast\ast$$

$$\frac{V_y - B}{sL_3} = \frac{B}{R_3} + \frac{B - A}{sL_2} \rightarrow \frac{V_y - B}{s} = \frac{B}{1000} + \frac{B - A}{s}$$

$$1000V_y - 1000B = sB + 1000B - 1000A$$

$$\left[(s+2000)^2(s+1000)-10^6(s+2000)\right]V_x = 10^9 V_y + 10^6(1000+s)V_x$$

$$\left[(s+2000)^2(s+1000)-10^6(s+2000)-10^6(s+1000)\right]V_x = 10^9 V_y$$

$$\left((s+2000)^2(s+1000)-10^6 \times 1000\right)V_x = 10^9 V_y$$

$$\left[(s^2+4000s+4\times10^6)(s+1000)-10^9\right]V_x = 10^9 V_y$$

$$\cancel{s^3+(4\times10^6+4\times10^6)s^2}$$

$$\left[s^3+5000s^2+8\times10^6 s+4\times10^9-10^9\right]V_x = 10^9 V_y$$

$$\left(s^3+5000s^2+8\times10^6 s+3\times10^9\right)V_x = 10^9 V_y$$

$$\frac{V_x}{V_y} = \frac{10^9}{s^3+5000s^2+8\times10^6 s+3\times10^9}$$

$$H(j\omega) = \frac{V_x(j\omega)}{V_y(j\omega)} = \frac{10^9}{(3\times10^9-5000\omega^2)+8\times10^6(j\omega)-j\omega^3} = \frac{10^9}{(3\times10^9-5000\omega^2)+j\omega(8\times10^6-\omega^2)}$$

Let the imaginary part of $H(j\omega)$ be equal to zero

$8\times10^6-\omega^2=0 \qquad \omega^2=8\times10^6 \qquad \omega=2\sqrt{2}\times10^3 \Rightarrow f=\dfrac{2\sqrt{2}\times10^3}{2\pi}$

$$1000(V_y + A) = (s+2000)B$$

$$\boxed{B = \frac{1000(V_y+A)}{s+2000}} \quad **$$

$*$ and $**$

$$\frac{1000+s}{1000} V_x = \frac{1000(V_x+B)}{s+2000}$$

$$(s+2000)(s+1000)V_x = 10^6(V_x+B) \longrightarrow \text{put } ** \text{ inside}$$

$$(s+2000)(s+1000)V_x = 10^6\left(V_x + \frac{1000(V_y+A)}{(s+2000)}\right)$$

$$(s+2000)^2(s+1000)V_x = 10^6\left((s+2000)V_x + 1000(V_y+A)\right)$$

$$\left[(s+2000)^2(s+1000) - 10^6(s+2000)\right]V_x = 10^9(V_y+A)$$

$$\left[(s+2000)^2(s+1000) - 10^6(s+2000)\right]V_x = 10^9\left(V_y + \frac{1000+s}{1000}V_x\right)$$

$w = 2\sqrt{2}\times10^3 \ \frac{rad}{sec} \Rightarrow f = \frac{2\sqrt{2}\times10^3}{2\pi}$ Hertz → frequency of oscillations

if $w = 2\sqrt{2}\times10^3 \ \frac{rad}{sec}$

$$\left|\frac{V_x(jw)}{V_y(jw)}\right|_{w=2\sqrt{2}\times10^3} = \left|\frac{10^9}{(3\times10^9 - 5000w^3)}\right| = \frac{10^9}{3\times10^9 - 5000\times8\times10^6}$$

$$= \frac{10^9}{3\times10^9 - 40\times10^9} = \frac{10^9}{-37\times10^9} = -\frac{1}{37}$$

Hence $\left|\frac{V_x(jw)}{V_y(jw)}\right| = \frac{1}{39}$

Due to barkhausen criteria $\left|\frac{V_{out}}{V_{in}}\right| \times A = 1$

$$\frac{1}{37}\times A = 1 \quad A = 37 = (-g_m R_D)$$

$$V_{in} = \left[\left[2+\frac{1}{sCR}\right]\left(2+\frac{1}{sCR}\right]-1\right]B - \left(2+\frac{1}{sCR}\right]V_{out}$$

put *** inside

$$V_{in} = \left[\left(2+\frac{1}{sCR}\right)\left(2+\frac{1}{sCR}\right)-1\right]\left(1+\frac{1}{sCR}\right)V_{out} - \left(2+\frac{1}{sCR}\right)V_{out}$$

$$V_{in} = \left[4+\frac{1}{s^2C^2R^2}+\frac{4}{sCR}-1\right]\left(1+\frac{1}{sCR}\right)V_{out} - \left(2+\frac{1}{sCR}\right)V_{out}$$

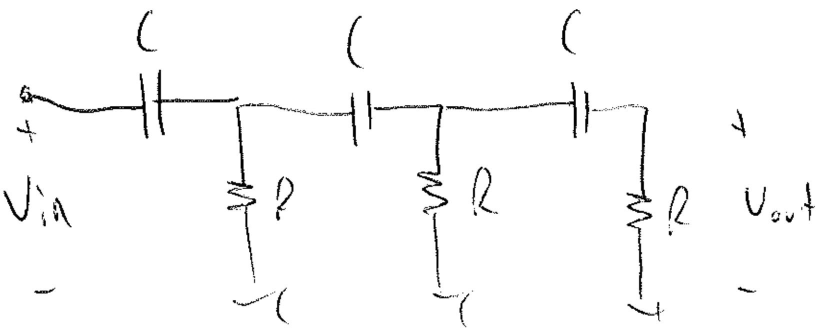
$$V_{in} = \left[\left(3+\frac{1}{s^2C^2R^2}+\frac{4}{sCR}\right)\left(1+\frac{1}{sCR}\right) - \left(2+\frac{1}{sCR}\right)\right]V_{out}$$

$$V_{in} = \left[3+\frac{7}{sCR}+\frac{5}{s^2C^2R^2}+\frac{1}{s^3C^3R^3}-2-\frac{1}{sCR}\right]V_{out}$$

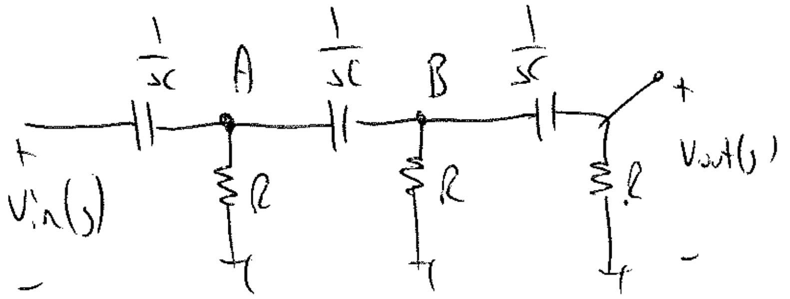
$$V_{in} = \left[1+\frac{6}{sCR}+\frac{5}{s^2C^2R^2}+\frac{1}{s^3C^3R^3}\right]V_{out}$$

$$V_{in} = \left[\frac{s^3C^3R^3+6s^2C^2R^2+5sCR+1}{s^3C^3R^3}\right]V_{out}$$

$$\frac{V_{out}}{V_{in}} = \frac{s^3C^3R^3}{s^3C^3R^3+6s^2C^2R^2+5sCR+1}$$



$\Big\downarrow$ $\mathcal{L}$aplace



$$\frac{V_{in} - A}{\frac{1}{sC}} = \frac{A}{R} + \frac{A - B}{\frac{1}{sC}} \qquad \frac{A - B}{\frac{1}{sC}} = \frac{B}{R} + \frac{B - V_{out}}{\frac{1}{sC}}$$

$$* \quad \boxed{sCV_{in} = \left[2sC + \frac{1}{R}\right] A - sCB} \qquad \boxed{sCA = \left(2sC + \frac{1}{R}\right] B - sCV_{out}}$$

$$** \quad \boxed{A = \left(2 + \frac{1}{sCR}\right] B - V_{out}} \qquad \frac{B - V_{out}}{\frac{1}{sC}} = \frac{V_{out}}{R} \qquad \boxed{BsC = \left[sC + \frac{1}{R}\right] V_{out}}$$

$$\boxed{B = \left[1 + \frac{1}{sCR}\right] V_{out}} \quad ***$$

$*$ and $**$

$$sCV_{in} = \left[2sC + \frac{1}{R}\right]\left\{\left[2 + \frac{1}{sCR}\right] B - V_{out}\right\} - sCB$$

$$sCV_{in} = \left(2sC + \frac{1}{R}\right)\left(2 + \frac{1}{sCR}\right) B - \left[2sC + \frac{1}{R}\right] V_{out} - sCB$$

$$V_{in} = \left[2 + \frac{1}{sCR}\right]\left(2 + \frac{1}{sCR}\right] B - \left(2 + \frac{1}{sCR}\right] V_{out} - B$$

put $s = j\omega$

$$H(j\omega) = \frac{V_{out}(j\omega)}{V_{in}(j\omega)} = \frac{-j\omega^3 C^3 R^3}{(1-\omega^2 6 C^2 R^2) + (5 j\omega CR - j\omega^3 C^3 R^3)}$$

$$\angle H(j\omega) = 180^0 \Rightarrow \quad 1 - \omega^2 6 C^2 R^2 = 0 \quad \omega_0^2 = \frac{1}{6C^2R^2} \quad \omega_0 = \frac{1}{\sqrt{6}\,CR}$$

for oscillation

$$f_0 = \frac{1}{2\pi\sqrt{6}\,CR}$$

Let's find $|H(j\omega)|\Big|_{\omega=\omega_0=\frac{1}{\sqrt{6}CR}}$

$$|H(j\omega)| = \frac{\omega^3 C^3 R^3}{\sqrt{\left[1-\omega^2 6 C^2 R^2\right]^2 + \left[5\omega CR - \omega^3 C^3 R^3\right]^2}}$$

$$|H(j\omega)|\Big|_{\omega=\omega_0=\frac{1}{\sqrt{6}CR}} = \frac{\frac{C^3R^3}{6\sqrt{6}\,C^3R^3}}{\sqrt{0 + \left[5\frac{1}{\sqrt{6}CR}CR - \left(\frac{1}{\sqrt{6}CR}\right)^3 C^3R^3\right]^2}}$$

$$= \frac{\frac{1}{6\sqrt{6}}}{\sqrt{0 + \left[\frac{5}{\sqrt{6}} - \frac{1}{6\sqrt{6}}\right]^2}} = \frac{\frac{1}{6\sqrt{6}}}{\frac{29}{6\sqrt{6}}} = \frac{1}{29}$$