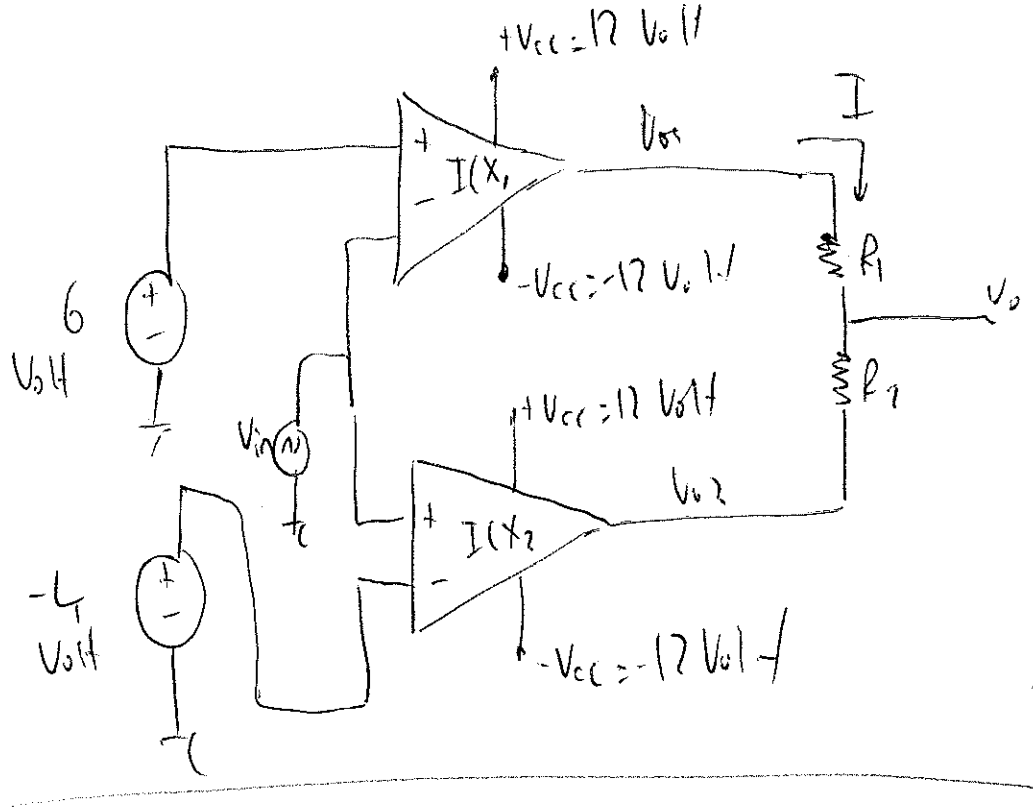
Q1



For $I(X_1$ if $6 \geq V_{in} \Rightarrow V_{o1} = 2(V_{in} - 6)$

if $6 < V_{in} \Rightarrow V_{o1} = 3(6 - V_{in})$

V_{o1} saturates at +12 and -12 volt

1 puan

For $I(X_2$ if $V_{in} \geq -4 \Rightarrow V_{o2} = 2(-4 - V_{in})$

if $V_{in} < -4 \Rightarrow V_{o2} = 3(V_{in} - (-4)) = 3(V_{in} + 4)$

V_{o2} saturates at +12 and -12 Volt

1 puan

if $V_{in} = 0$ $V_{o1} = -12$ Volt (saturates

if $V_{in} = 10$ $V_{o1} = -12$ Volt

~~if $V_{in} = 0$ $V_{o2} = -12$ Volt (saturates~~

if $V_{in} = -8$ $V_{o2} = -12$ Volt (saturates)

if $V_{in} = 2$ Volt $V_{o2} = -12$ Volt (saturates)

important points 10, 6, 2, 0, -4, -8

3 puan

~~if $6 < V_{in} \Rightarrow V_{o1} = 3(6 - V_{in})$~~

if $V_{in} > 10$ $\quad V_{o1} = -12$ Volt $\quad V_{o2} = -12$ Volt

$$I = \frac{V_{o1} - V_{o2}}{R_1 + R_2} = \frac{-12 - (-12)}{1000 + 2000} = 0 \text{ Ampere}$$

(1 point)

$$V_o = V_{o1} - I R_1 = -12 - 0 \times 1000 = -12 \text{ Volt}$$

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if $6 < V_{in} < 10$ $\quad V_{o1} = 3(6 - V_{in})$ $\quad V_{o2} = -12$ Volt

$$I = \frac{3(6 - V_{in}) - (-12)}{3000} = \frac{30 - 3V_{in}}{3000} \text{ Ampere}$$

(2 point)

$$V_o = V_{o1} - I R_1 = 3(6 - V_{in}) - \frac{30 - 3V_{in}}{3000} \times 1000 = 18 - 3V_{in} - 10 + V_{in} = 8 - 2V_{in} \text{ Volt}$$

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if $2 < V_{in} \leq 6$

$V_{o1} = 2(V_{in} - 6)$ $\quad V_{o2} = -12$ Volt

(2 point)

$$I = \frac{2(V_{in} - 6) - (-12)}{3000} = \frac{2V_{in}}{3000} \text{ Ampere}$$

$$V_o = V_{o1} - I R_1 = 2(V_{in} - 6) - \frac{2V_{in}}{3000} \times 1000$$

$$= 2V_{in} - 12 - \frac{2V_{in}}{3} = \frac{4V_{in}}{3} - 12 = \frac{4V_{in} - 36}{3} \text{ Volt}$$

$0 < V_{in} < 2$ $\quad V_{o1} = 2(V_{in} - 6)$ $\quad V_{o2} = 2(-4 - V_{in})$

(2 point)

$$I = \frac{V_{o1} - V_{o2}}{3000} = \frac{2V_{in} - 12 - (-8 - 2V_{in})}{3000} = \frac{-4 + 4V_{in}}{3000} \text{ Ampere}$$

$$V_o = V_{o1} - I R_1 = 2V_{in} - 12 - \left(\frac{-4 + 4V_{in}}{3000}\right) 1000 \quad \rightarrow \quad V_o = 2V_{in} - 12 + \frac{4}{3} - \frac{4}{3}V_{in} = \frac{2V_{in} - 32}{3}$$

$-4 < V_{in} < 0$ $\quad V_{o1} = -12$ $\quad V_{o2} = 2(-4 - V_{in})$

(2 point)

$$I = \frac{V_{o1} - V_{o2}}{3000} = \frac{-12 + (8 + 2V_{in})}{3000} = \frac{-4 + 2V_{in}}{3000}$$

$$V_o = V_{o1} - I R_1 = -12 - \left(\frac{-4 + 2V_{in}}{3000}\right) 1000 = -12 + \frac{4}{3} - \frac{2V_{in}}{3} = \frac{-32 - 2V_{in}}{3} \text{ //}$$

$-8 < V_{in} < -4$ $\quad V_{o1} = -12$ $\quad V_{o2} = 3(V_{in}/4)$

$$I = \frac{V_{o1} - V_{o2}}{3000} = \frac{-12 - 3V_{in} - 12}{3000} \Rightarrow \frac{-24 - 3V_{in}}{3000} \text{ Amp}$$

$$V_o = V_{o1} - I R_1 = -12 - \left(\frac{-24 - 3V_{in}}{3000}\right) 1000 = -12 + \frac{24}{3} + \frac{3V_{in}}{3}$$

$$= -4 + V_{in} \text{ Volt}$$

2 poin

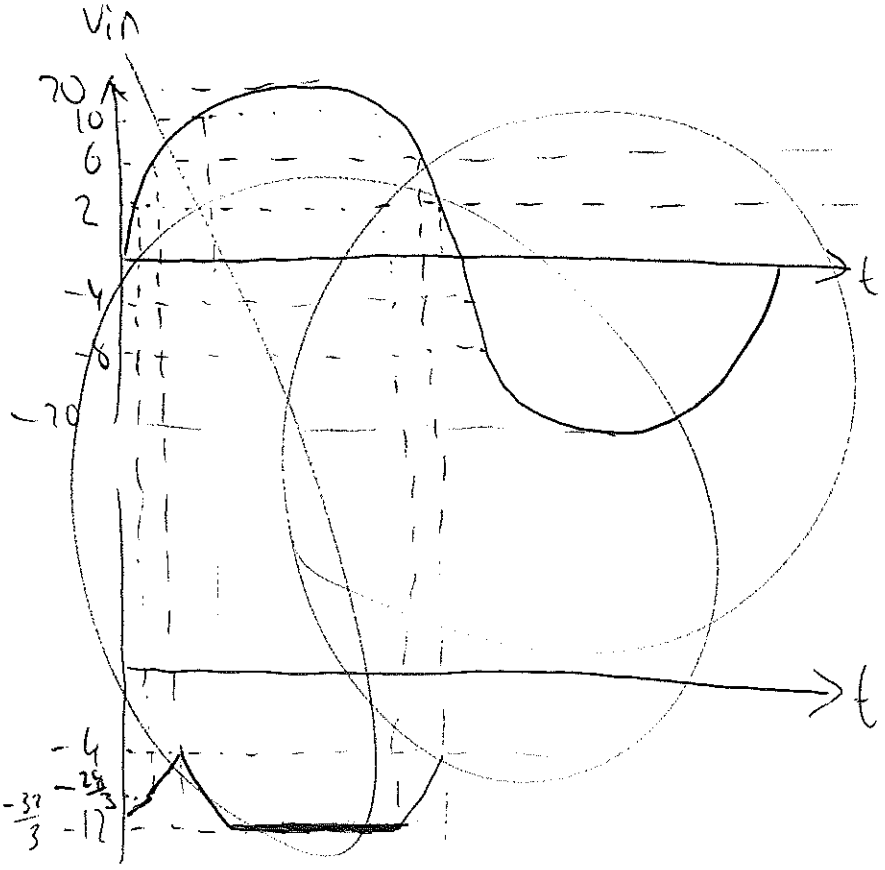
$V_{in} < -8$

$V_{o1} = -12$ $\quad V_{o2} = -12$

2 poin

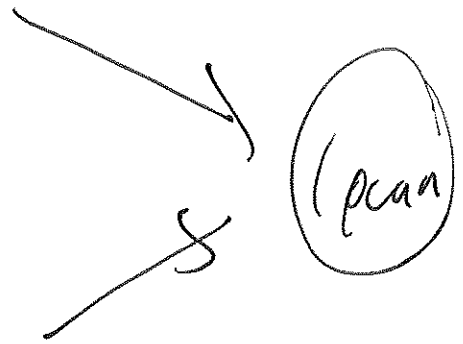
$$I = \frac{V_{o1} - V_{o2}}{3000} = \frac{-12 - (-12)}{3000} = 0 \text{ Ampere}$$

$$V_o = V_{o1} - I R_1 = -12 - 0 \times 1000 = -12 \text{ Volt}$$

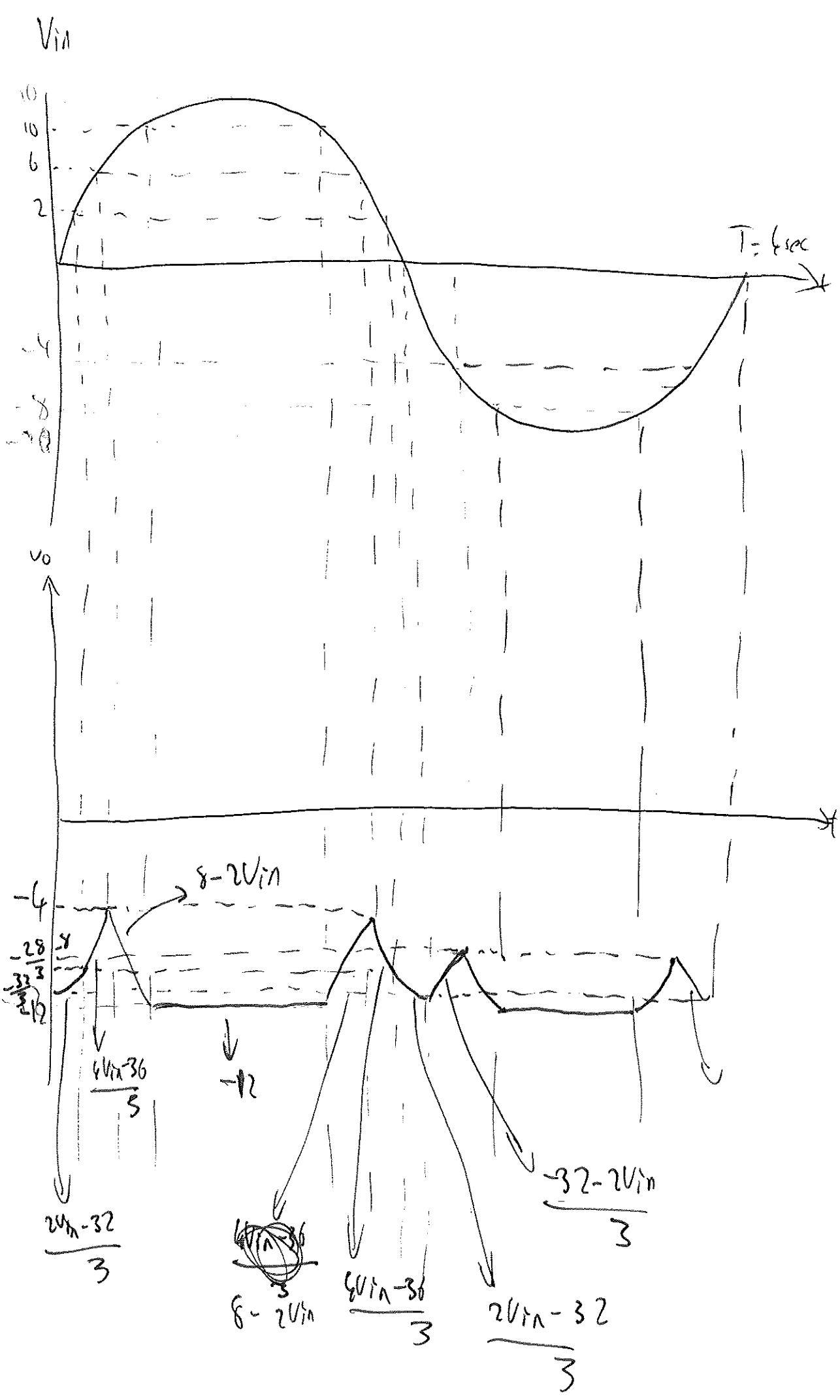


$$V_o = \begin{cases} -12, & V_{in} > 10 \\ 8 - 2V_{in}, & 6 < V_{in} < 10 \\ \frac{4V_{in} - 36}{3}, & 2 < V_{in} < 6 \\ \frac{2V_{in} - 32}{3}, & 0 < V_{in} < 2 \\ \frac{-32 - 2V_{in}}{3}, & -4 < V_{in} < 0 \\ -4V_{in}, & -8 < V_{in} < -4 \\ -12, & V_{in} < -8 \end{cases}$$ in Volt

$$I = \begin{cases} 0, & V_{in} > 10 \\ \frac{36 - 3V_{in}}{3000}, & 6 < V_{in} < 10 \\ \frac{2V_{in} - 36}{3000}, & 2 < V_{in} < 6 \\ \frac{-4V_{in}}{3000}, & 0 < V_{in} < 2 \\ \frac{-4 - 2V_{in}}{3000}, & -4 < V_{in} < 0 \\ \frac{-24 - 3V_{in}}{3000}, & -8 < V_{in} < -4 \\ 0, & V_{in} < -8 \end{cases}$$ in Ampere



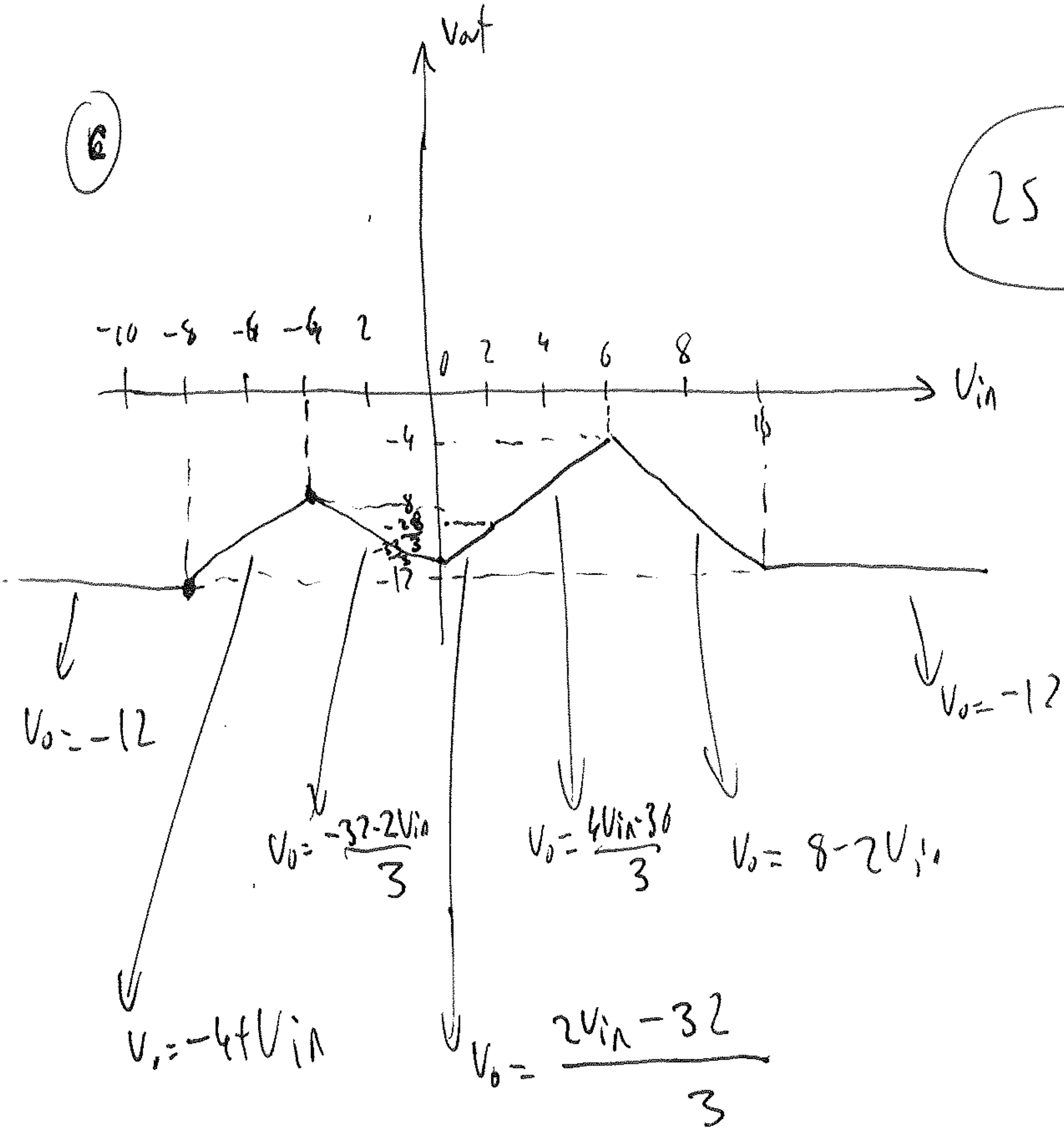
(b)


V_{in}
10
6
2
-4
T = 4 sec
V_o
$8-2V_{in}$
-4
$-\frac{28}{3}$
$-\frac{32}{3}$
-12
$\frac{4V_{in}-36}{3}$
-12
$\frac{2V_{in}-32}{3}$
$8-2V_{in}$
$\frac{4V_{in}-36}{3}$
$\frac{2V_{in}-32}{3}$
$\frac{-32-2V_{in}}{3}$

25 pum

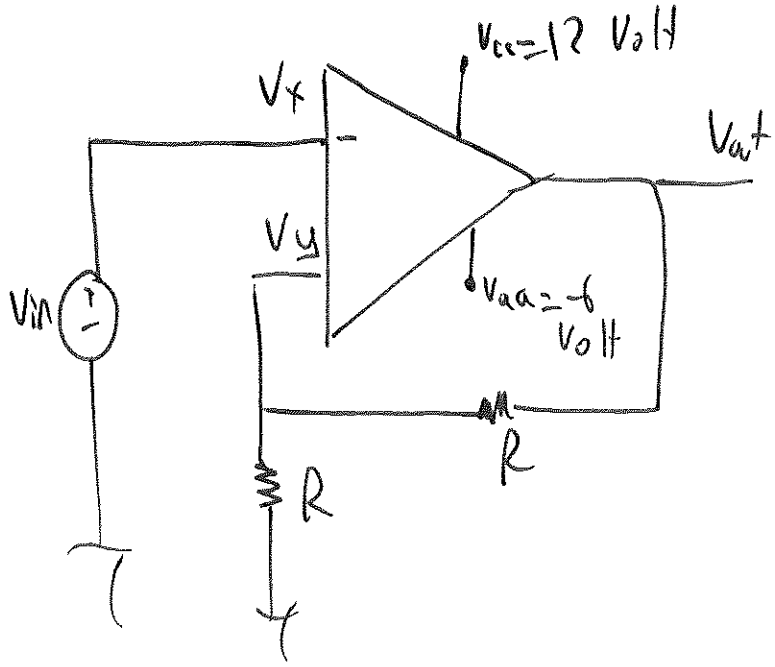
6

25 puan



Vout
Vin
-10 -8 -6 -4 2
0 2 4 6 8 10
-4
-8
-12
$V_0 = -12$
$V_0 = -12$
$V_0 = \frac{-32-2V_{in}}{3}$
$V_0 = \frac{4V_{in}-36}{3}$
$V_0 = 8-2V_{in}$
$V_0 = -4+V_{in}$
$V_0 = \frac{2V_{in}-32}{3}$

Q2



$V_y = \frac{V_{out}}{2R} \times R$

puan $V_y = \frac{V_{out}}{2}$

$V_{out} = 2V_y$

Let $V_x = V_{in} > V_y \Rightarrow V_{out} = \frac{1}{2}\left[V_{aa} + (V_y - V_{in})\right]$

$V_{out} = \frac{1}{2}\left[-6 + \frac{V_{out}}{2} - V_{in}\right]$

$V_{out} = -3 + \frac{V_{out}}{4} - \frac{V_{in}}{2}$

$\frac{3V_{out}}{4} = -3 - \frac{V_{in}}{2}$

puan $V_{out} = -4 - \frac{2V_{in}}{3}$ *

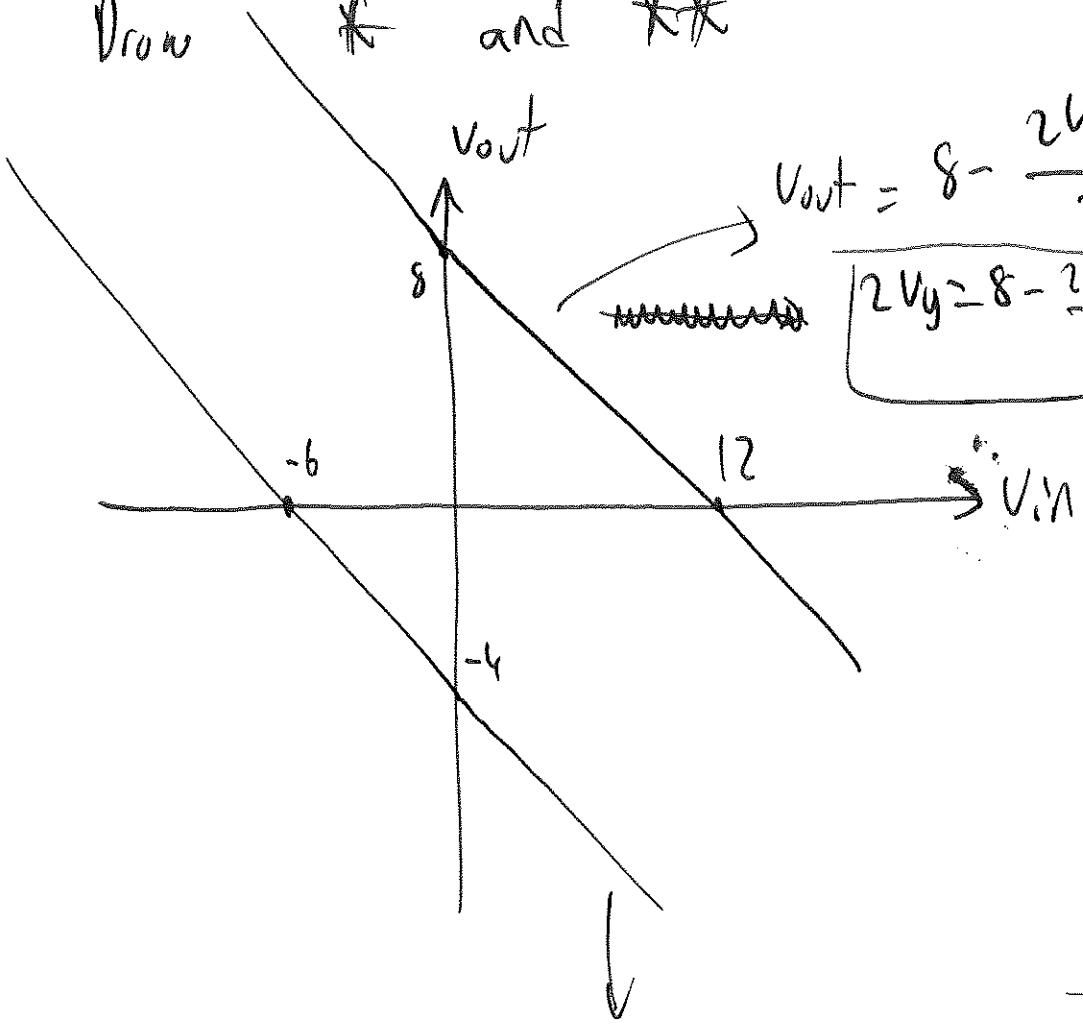
Let $V_x = V_{in} < V_y$ $V_{out} = \frac{1}{2}\left[V_{cc} + (V_y - V_{in})\right]$

$V_{out} = \frac{1}{2}\left[12 + \frac{V_{out}}{2} - V_{in}\right]$

puan $V_{out} = 6 + \frac{V_{out}}{4} - \frac{V_{in}}{2}$ **

$\frac{3V_{out}}{4} = 6 - \frac{V_{in}}{2} \Rightarrow$ $V_{out} = 8 - \frac{2V_{in}}{3}$

Draw * and **



$V_{out} = 8 - \frac{2V_{in}}{3}$

$2V_y = 8 - \frac{2V_{in}}{3}$

$V_y = \frac{V_{out}}{2}$

$V_{out} = -4 - \frac{2V_{in}}{3} \Rightarrow 2V_y = -4 - \frac{2V_{in}}{3}$

Find the points on these lines wher $V_{in} = V_x = V_y = \frac{V_{out}}{2}$

$2V_y = 8 - \frac{2V_{in}}{3}$ $\xrightarrow{V_y = V_{in}}$ $2V_{in} = 8 - \frac{2V_{in}}{3}$ $\frac{8V_{in}}{3} = 8$ $V_{in} = 3$

if $V_{in} = 3$ $V_y = 3$ $V_{out} = 6$ critical point (3 point)

$2V_y = -4 - \frac{2V_{in}}{3}$ $\xrightarrow{V_y = V_{in}}$ $2V_{in} = -4 - \frac{2V_{in}}{3}$ $\frac{8V_{in}}{3} = -4$ $V_{in} = -1.5$ Volt

if $V_{in} = -1.5$ $V_y = -1.5$ $V_{out} = -3$ (3 point)

Let $V_{in} = -12$ and increase V_{in} until $V_{in} = 3$

if $-12 < V_{in} < 3$ and $V_{in} \nearrow$ $V_{out} = 8 - \frac{2V_{in}}{3}$

(1 part) when $V_{in} = 3$ $V_{out} = 6 \Rightarrow V_y = 3$

after this point $V_{in} > V_y$ then V_{out} jumps to

$V_{out} = -4 - \frac{2 \times 3}{3} = -6$ Volt

Let $V_{in} = 3$ and increase V_{in} until $V_{in} = 12$

(part) if $3 < V_{in} < 12$ and $V_{in} \nearrow$ $V_{out} = -4 - \frac{2V_{in}}{3}$

when $V_{in} = 3$ $V_{out} = -6 \Rightarrow V_y = -3$

$V_{in} > V_y$ then V_{out} is

$V_{out} = -4 - \frac{2V_{in}}{3}$

Let $V_{in} = 12$ and decrease V_{in} until $V_{in} = -1.5$

if $-1.5 < V_{in} < 12$ and $V_{in} \searrow$ $V_{out} = -4 - \frac{2V_{in}}{3}$

(1 part) when $V_{in} = -1.5$ $V_{out} = -3$ $V_y = -1.5$

after this point $V_{in} < V_y$ then V_{out} jumps to

$V_{out} = 8 - \frac{2 \times (-1.5)}{3} = 9$ Volt

Let $V_{in} = -1.5$ and decrease V_{in} until $V_{in} = -12$

(1 part) if $-12 < V_{in} < -1.5$ and $V_{in} \searrow$ $V_{out} = 8 - \frac{2V_{in}}{3}$

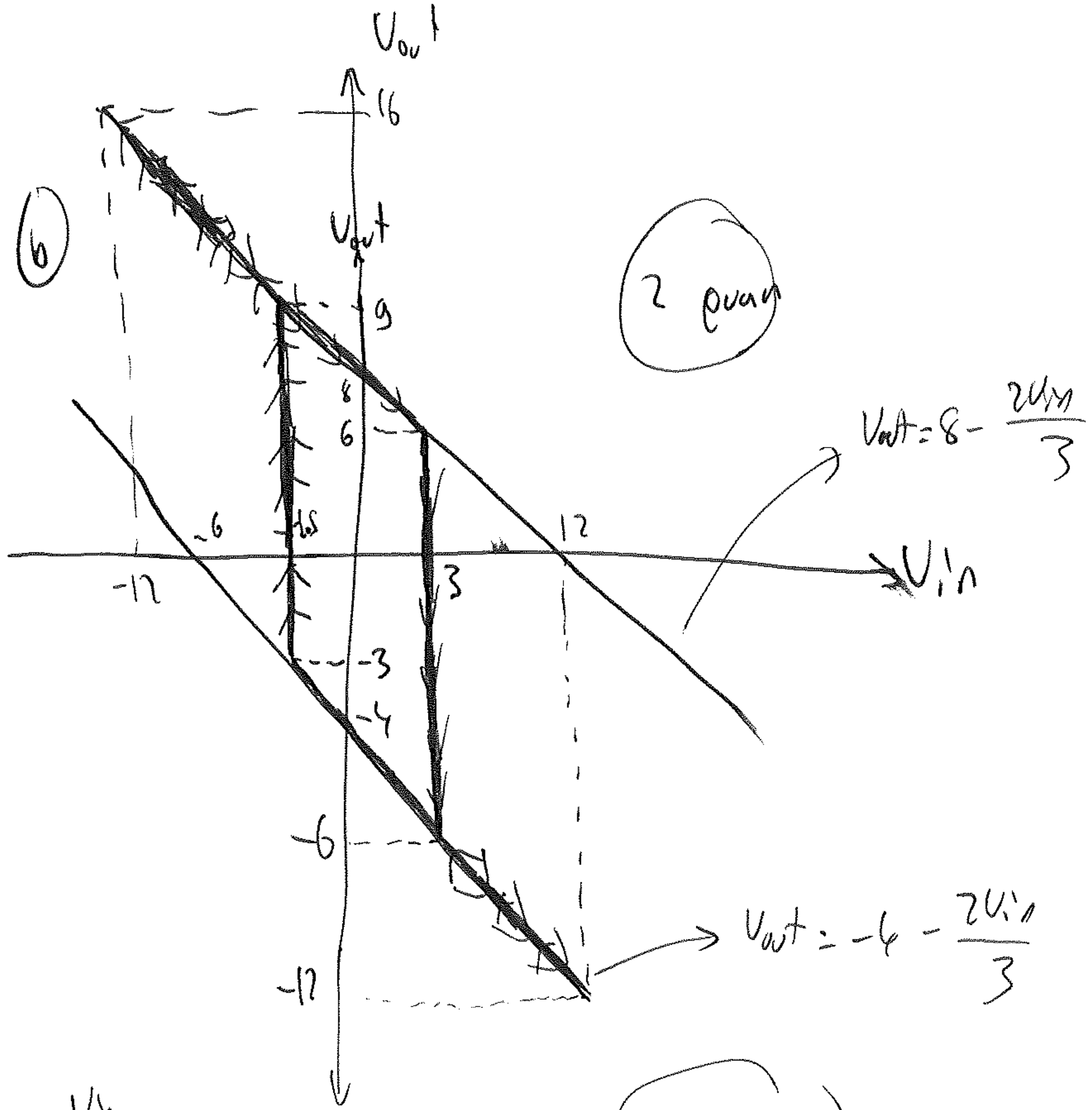
when $V_{in} = -1.5$ $V_{out} = 9$ $V_y = 4.5$

$V_{in} < V_y$ then V_{out} is

$V_{out} = 8 - \frac{2V_{in}}{3}$

(b)

2 puan



(a)

15 puan