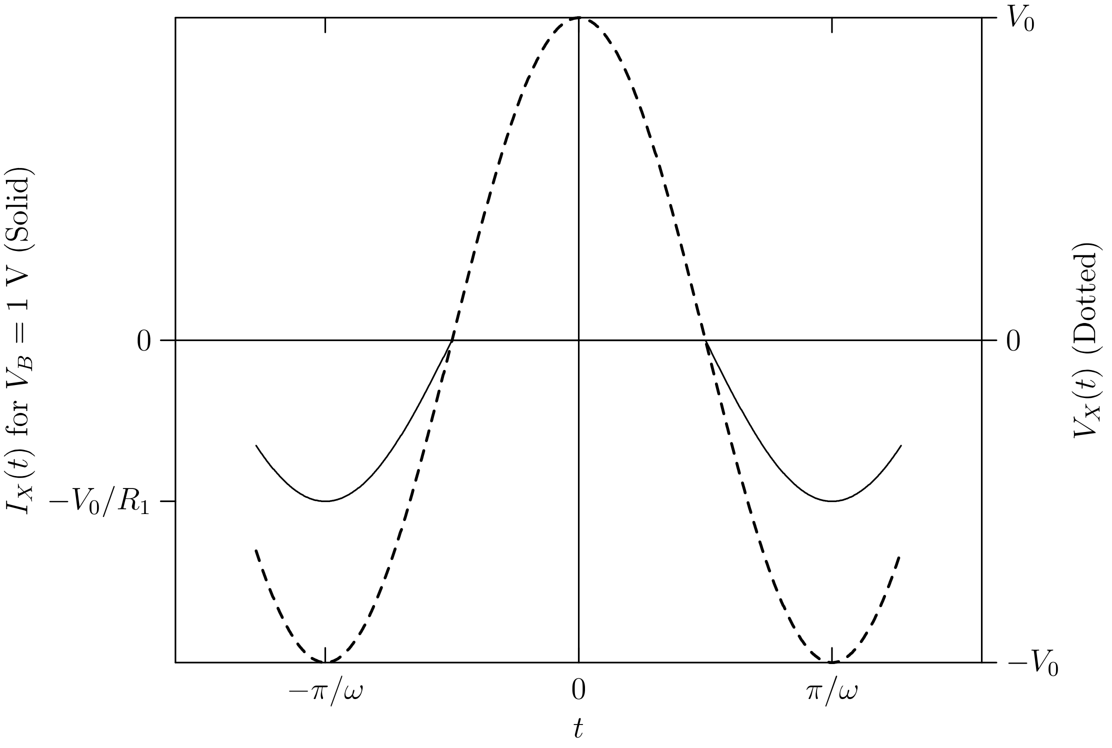
3.2

$$I_X = \begin{cases} \frac{V_X}{R_1} & V_X < 0 \\ 0 & V_X > 0 \end{cases}$$

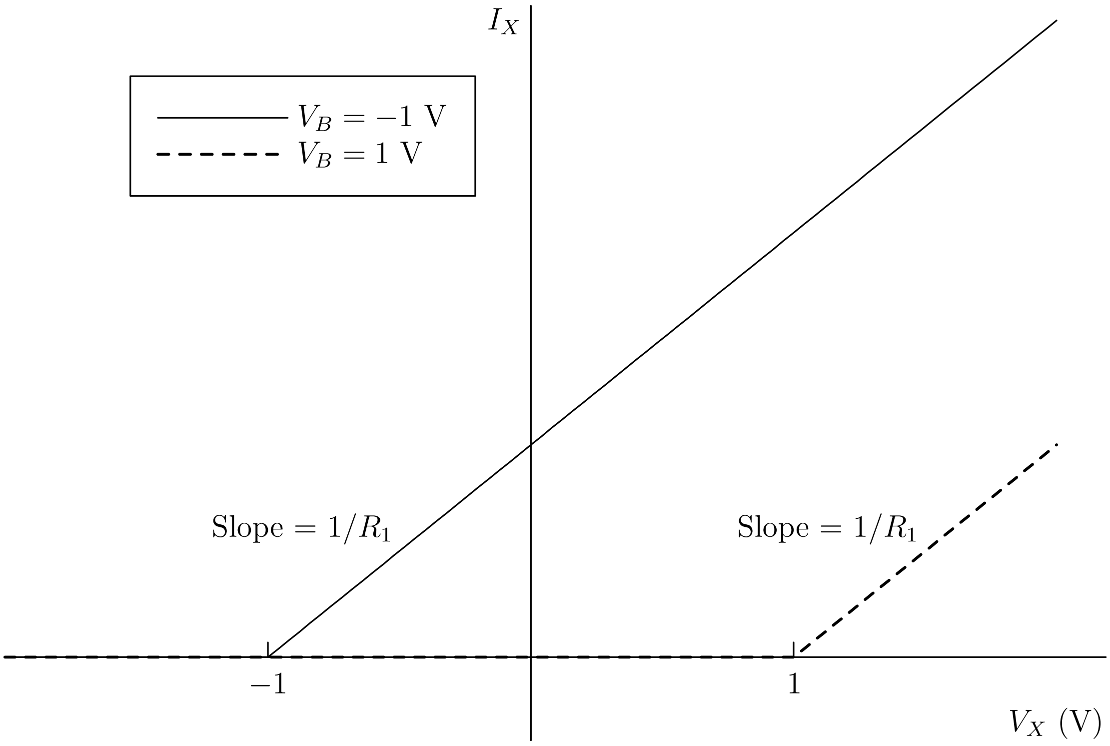
Plotting $I_X(t)$, we have



3.3

$$I_X = \begin{cases} 0 & V_X < V_B \\ \frac{V_X - V_B}{R_1} & V_X > V_B \end{cases}$$

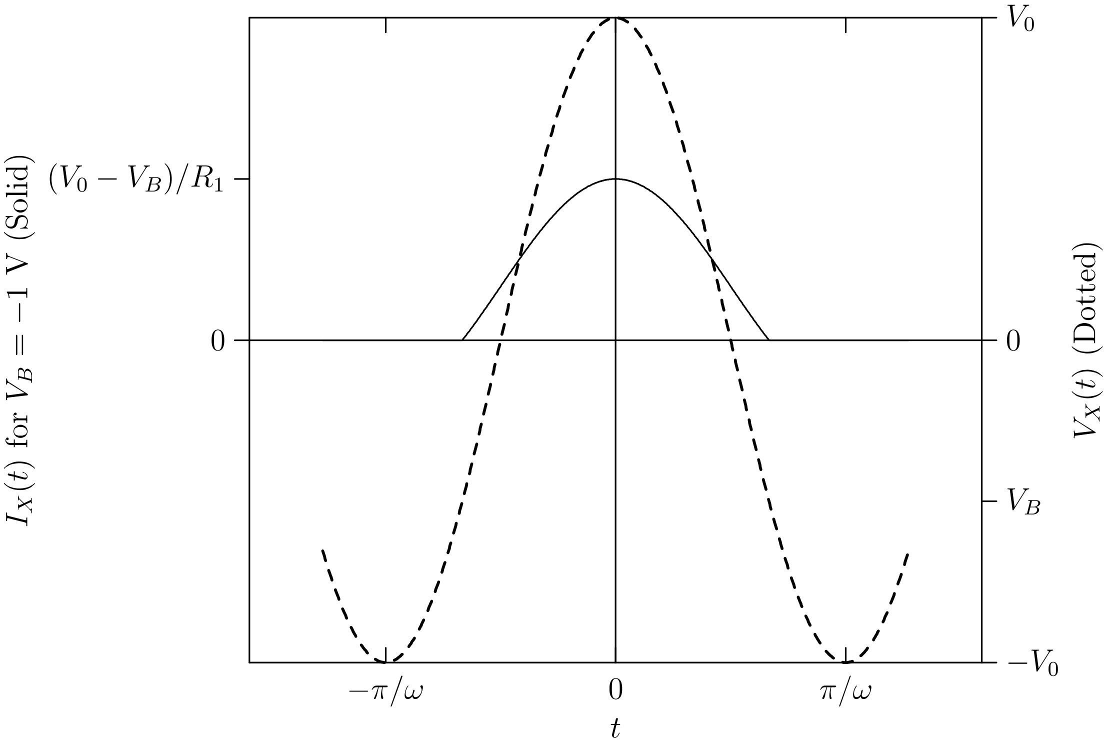
Plotting I_X vs. V_X for $V_B = -1$ V and $V_B = 1$ V, we get:



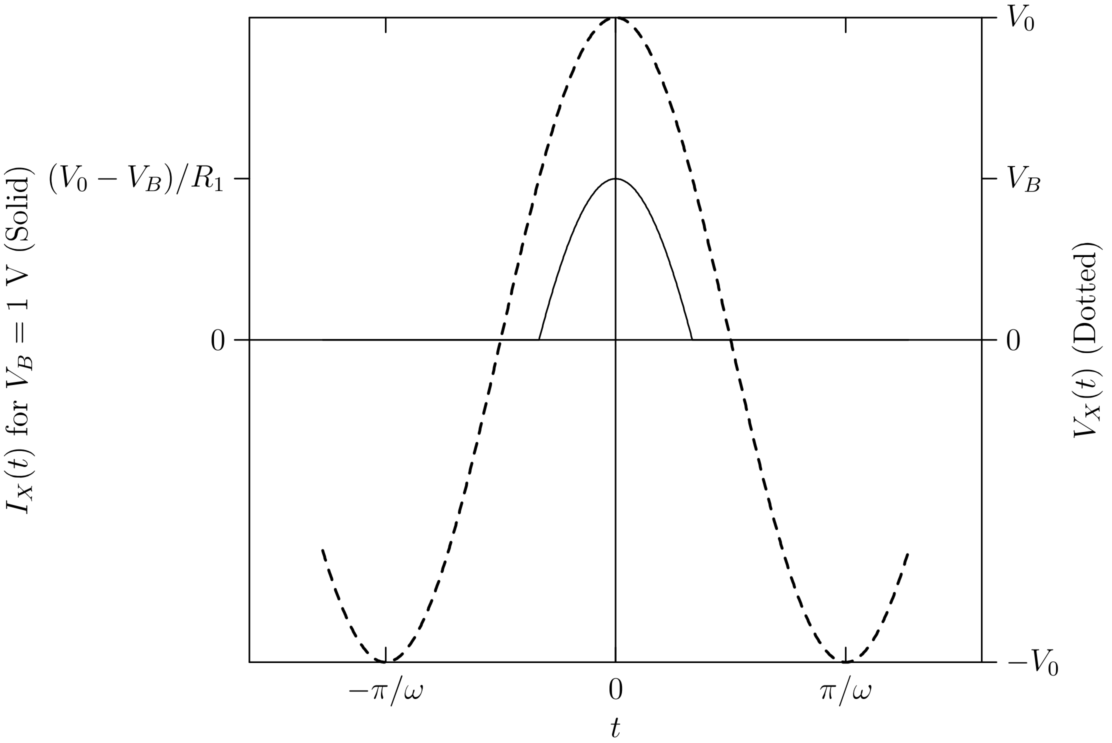
3.4

$$I_X = \begin{cases} 0 & V_X < V_B \\ \frac{V_X - V_B}{R_1} & V_X > V_B \end{cases}$$

Let's assume $V_0 > 1$ V. Plotting $I_X(t)$ for $V_B = -1$ V, we get



Plotting $I_X(t)$ for $V_B = 1$ V, we get

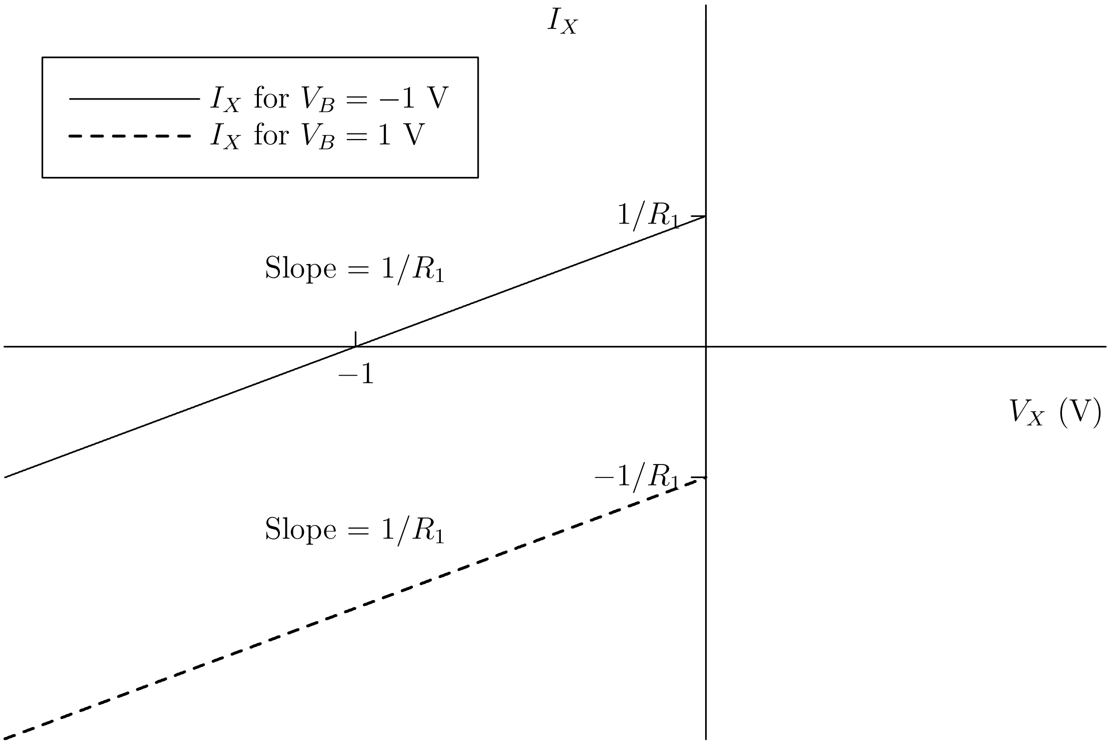


$I_X(t)$ for $V_B = 1$ V (Solid)
$(V_0 - V_B)/R_1$
0
V_0
V_B
0
$-V_0$
$V_X(t)$ (Dotted)
$-\pi/\omega$
0
π/ω
t

3.5

$$I_X = \begin{cases} \frac{V_X - V_B}{R_1} & V_X < 0 \\ \infty & V_X > 0 \end{cases}$$

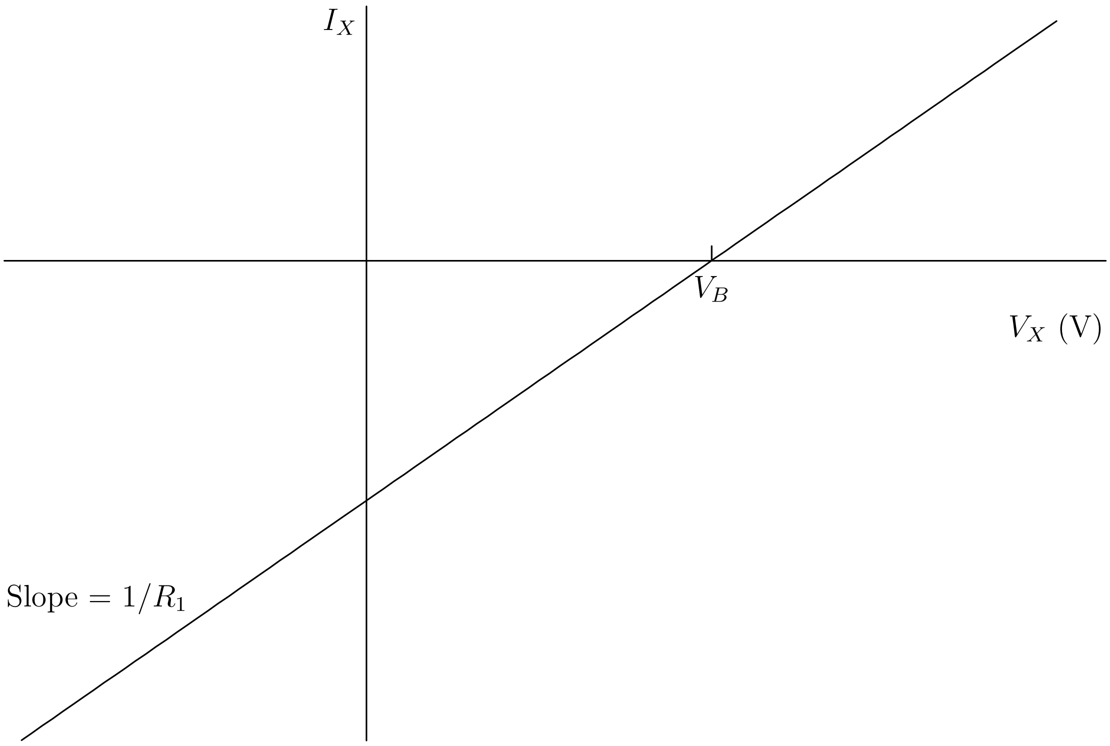
Plotting I_X vs. V_X for $V_B = -1$ V and $V_B = 1$ V, we get:



3.6 First, note that $I_{D1} = 0$ always, since D_1 is reverse biased by V_B (due to the assumption that $V_B > 0$). We can write I_X as

$$I_X = (V_X - V_B)/R_1$$

Plotting this, we get:

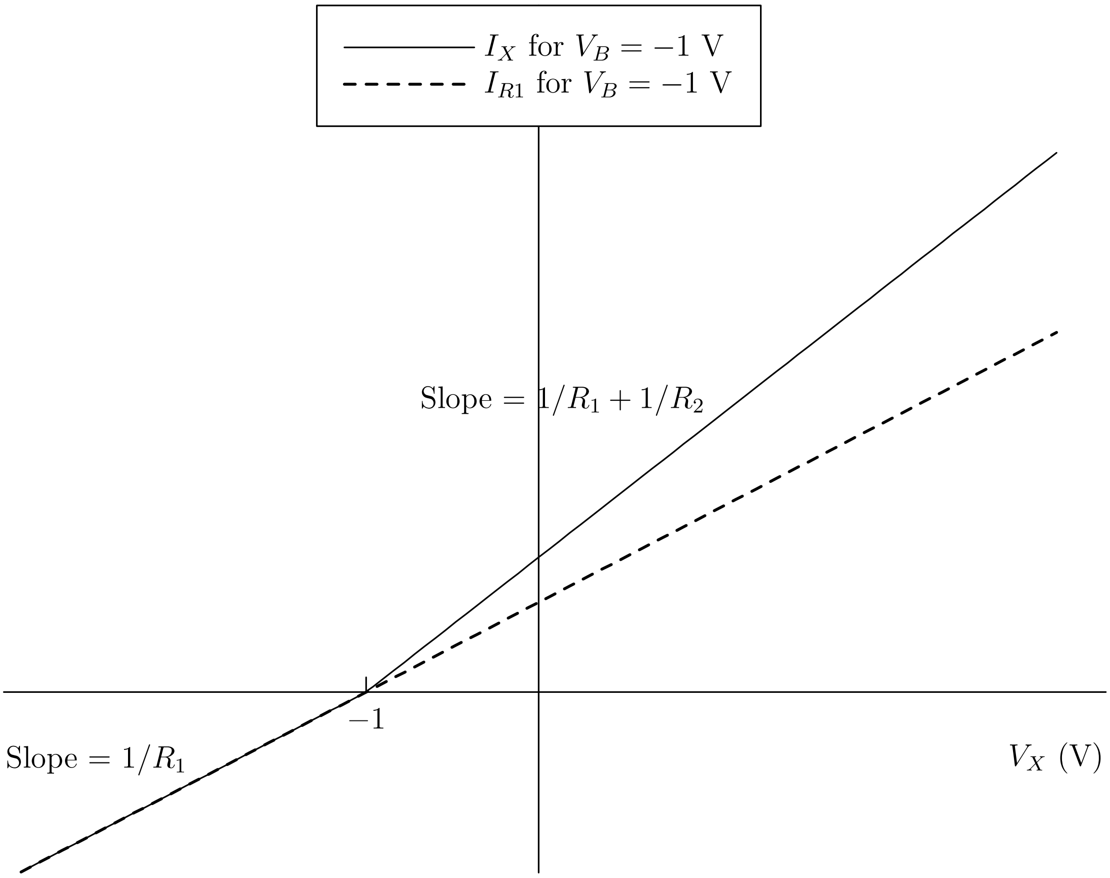


3.7

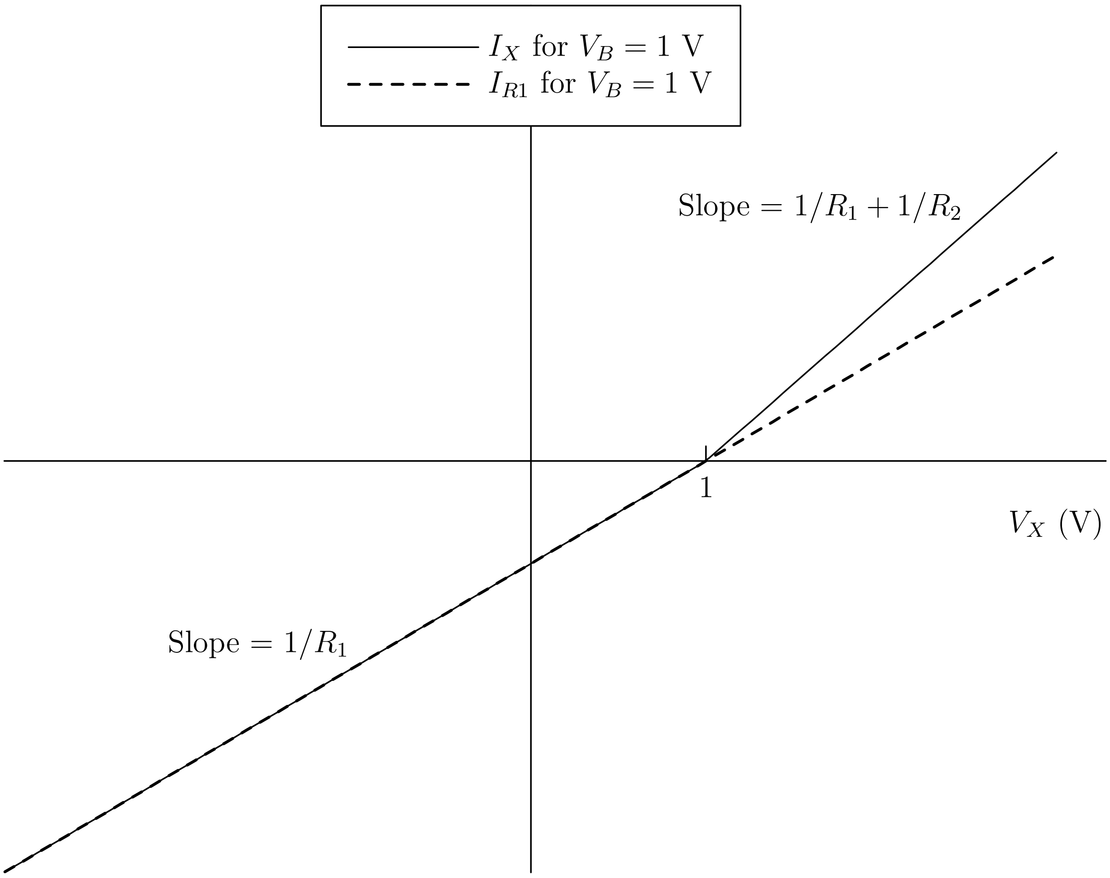
$$I_X = \begin{cases} \frac{V_X - V_B}{R_1} & V_X < V_B \\ \frac{V_X - V_B}{R_1 \| R_2} & V_X > V_B \end{cases}$$

$$I_{R1} = \frac{V_X - V_B}{R_1}$$

Plotting I_X and I_{R1} for $V_B = -1$ V, we get:



Plotting I_X and I_{R1} for $V_B = 1$ V, we get:

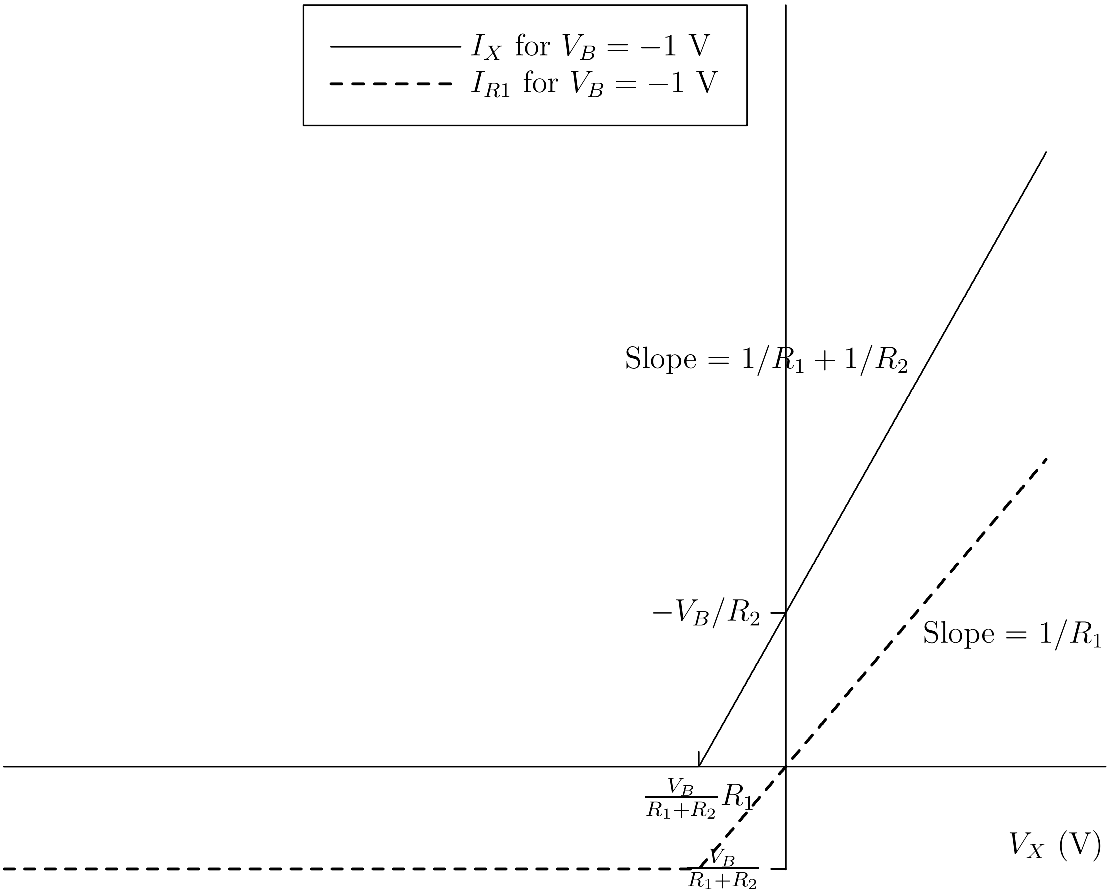

I_X for $V_B = 1$ V
I_{R1} for $V_B = 1$ V
Slope $= 1/R_1 + 1/R_2$
1
V_X (V)
Slope $= 1/R_1$

3.8

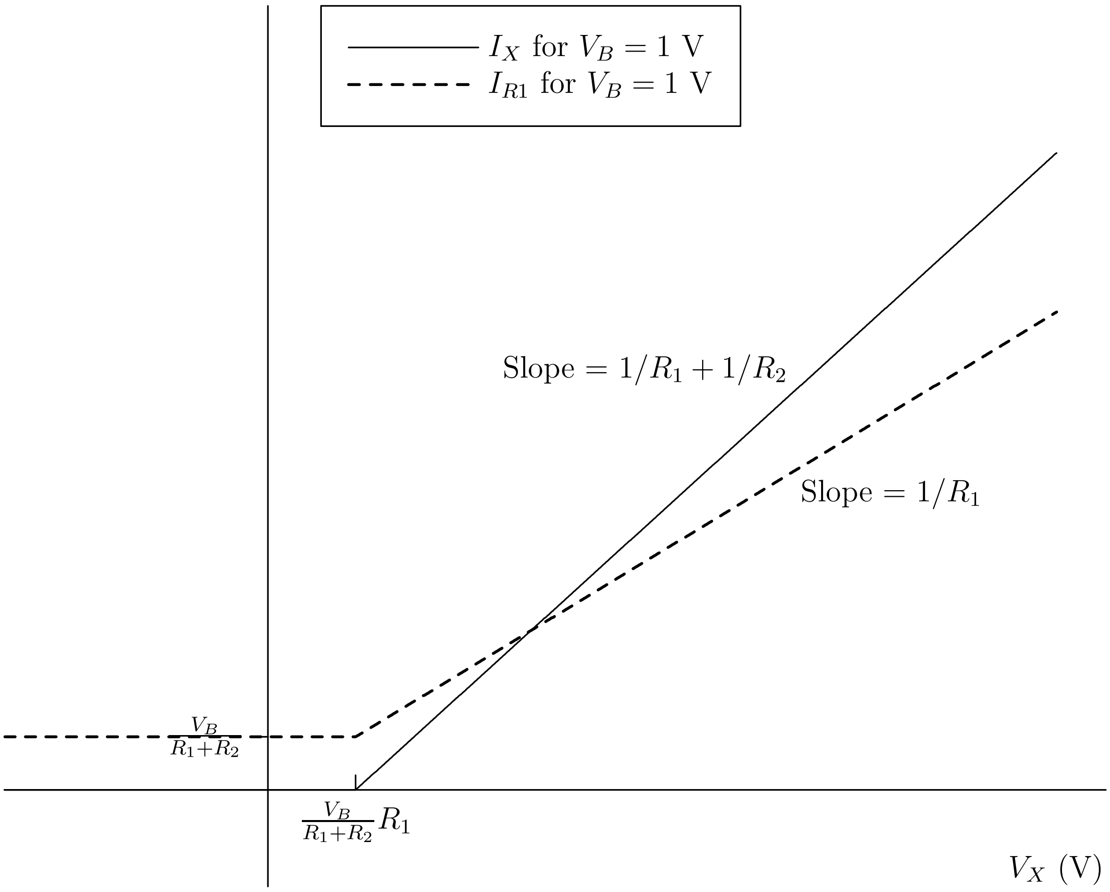
$$I_X = \begin{cases} 0 & V_X < \frac{V_B}{R_1+R_2} R_1 \\ \frac{V_X}{R_1} + \frac{V_X - V_B}{R_2} & V_X > \frac{V_B}{R_1+R_2} R_1 \end{cases}$$

$$I_{R1} = \begin{cases} \frac{V_B}{R_1+R_2} & V_X < \frac{V_B}{R_1+R_2} R_1 \\ \frac{V_X}{R_1} & V_X > \frac{V_B}{R_1+R_2} R_1 \end{cases}$$

Plotting I_X and I_{R1} for $V_B = -1$ V, we get:

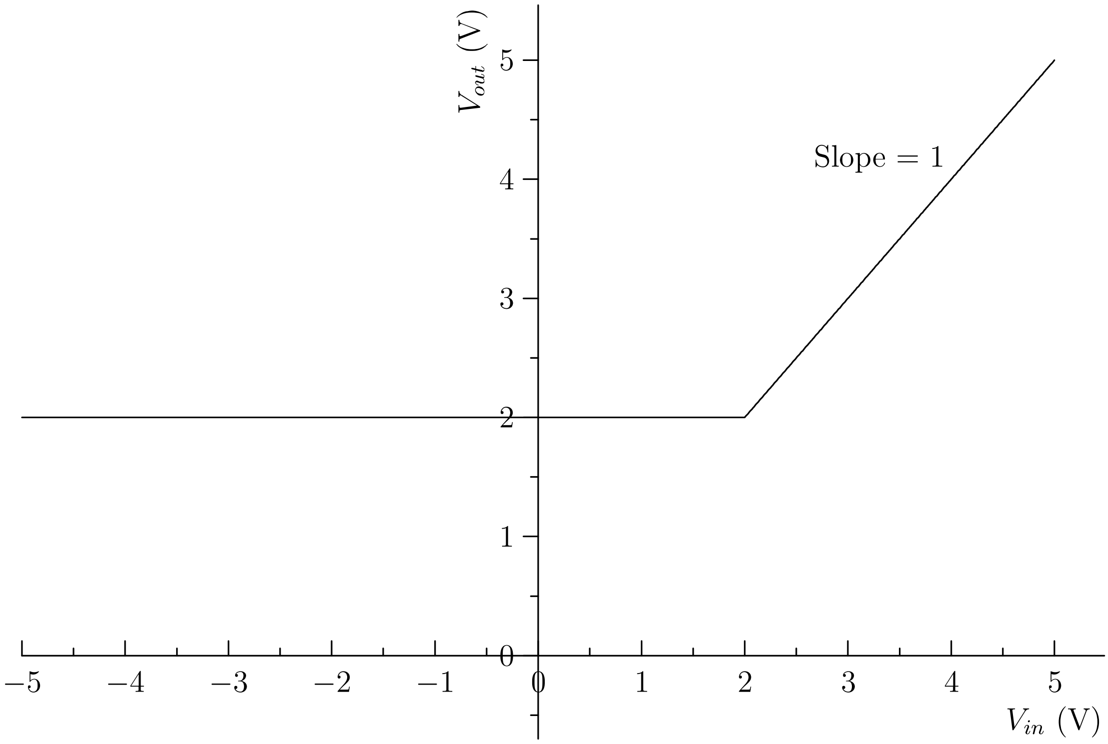


Plotting I_X and I_{R1} for $V_B = 1$ V, we get:


I_X for $V_B = 1$ V
I_{R1} for $V_B = 1$ V
Slope $= 1/R_1 + 1/R_2$
Slope $= 1/R_1$
$\frac{V_B}{R_1+R_2}$
$\frac{V_B}{R_1+R_2}R_1$
V_X (V)

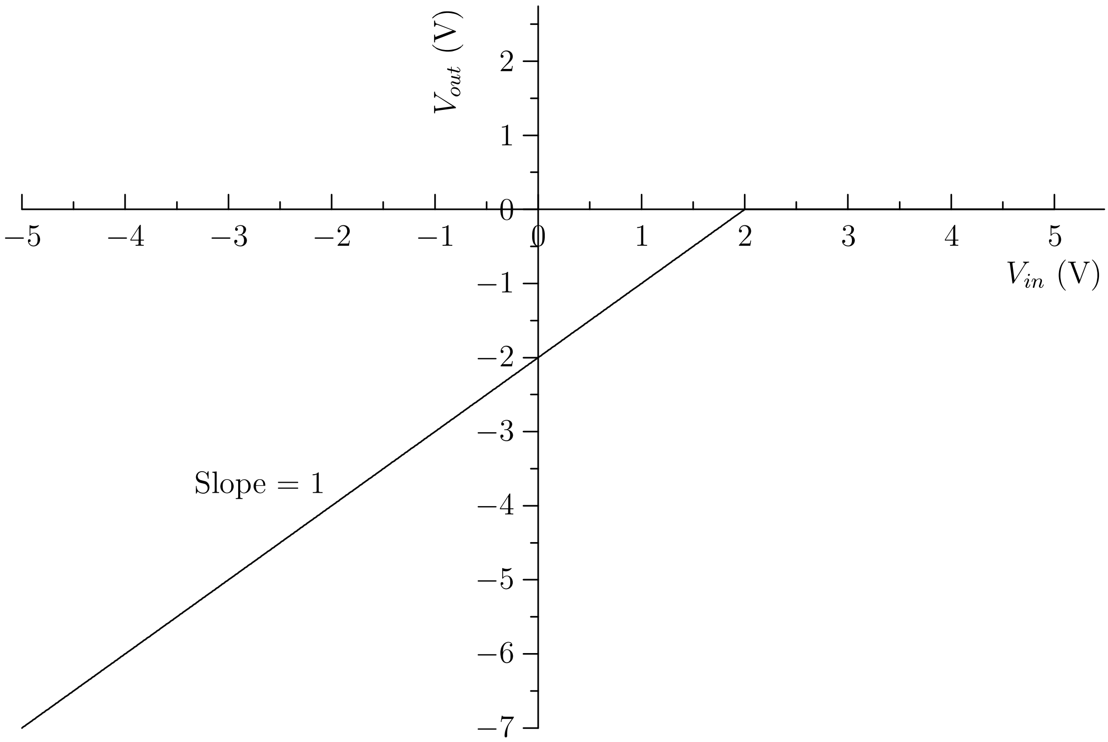
3.9 (a)

$$V_{out} = \begin{cases} V_B & V_{in} < V_B \\ V_{in} & V_{in} > V_B \end{cases}$$



(b)

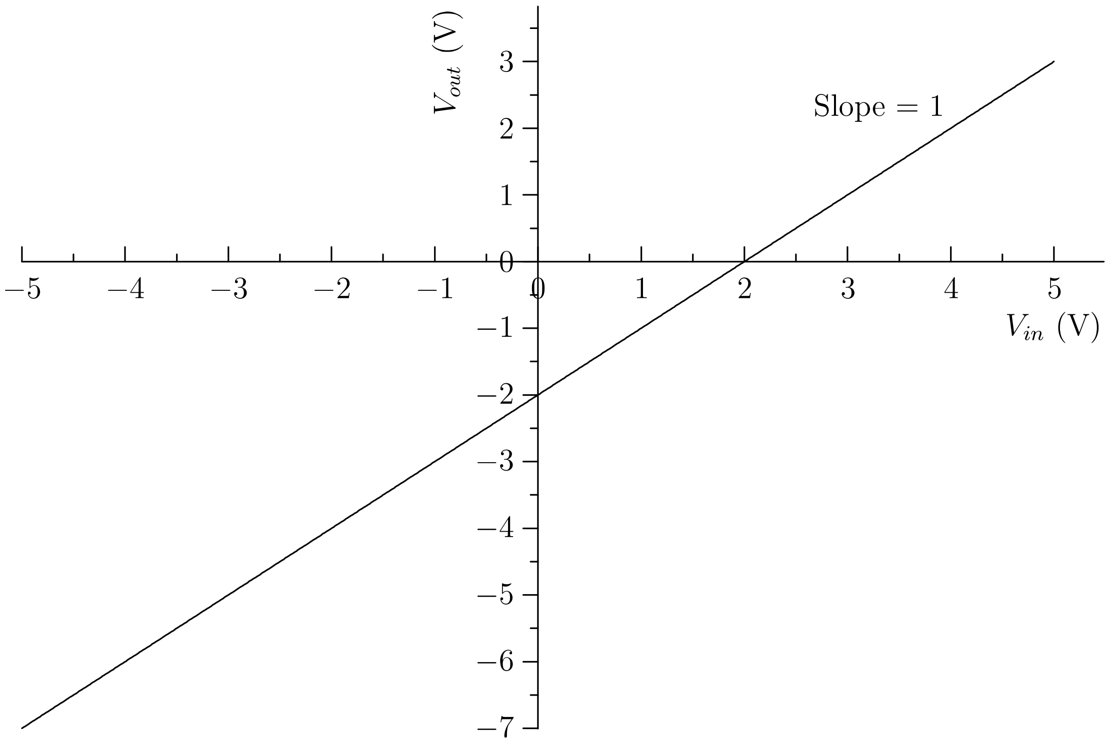
$$V_{out} = \begin{cases} V_{in} - V_B & V_{in} < V_B \\ 0 & V_{in} > V_B \end{cases}$$



V_{out} (V)
2
1
0
−1
−2
−3
−4
−5
−6
−7
−5
−4
−3
−2
−1
0
1
2
3
4
5
V_{in} (V)
Slope = 1

(c)

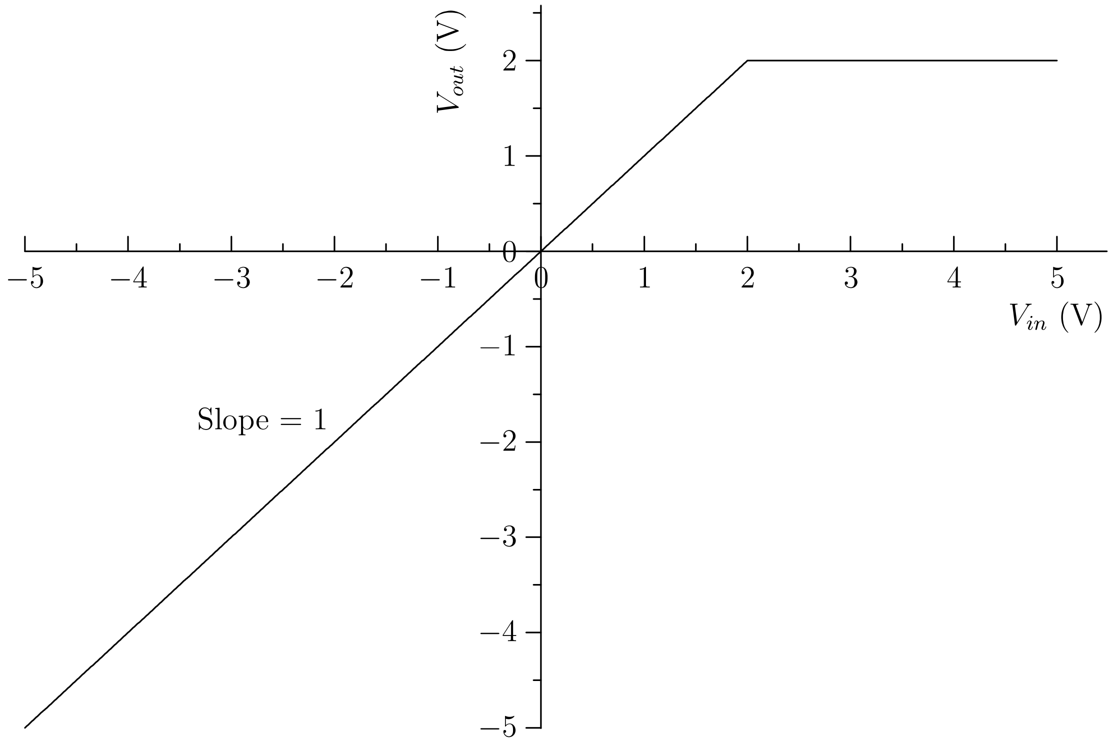
$$V_{out} = V_{in} - V_B$$



V_{out} (V)
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
−5
−4
−3
−2
−1
0
1
2
3
4
5
V_{in} (V)
Slope = 1

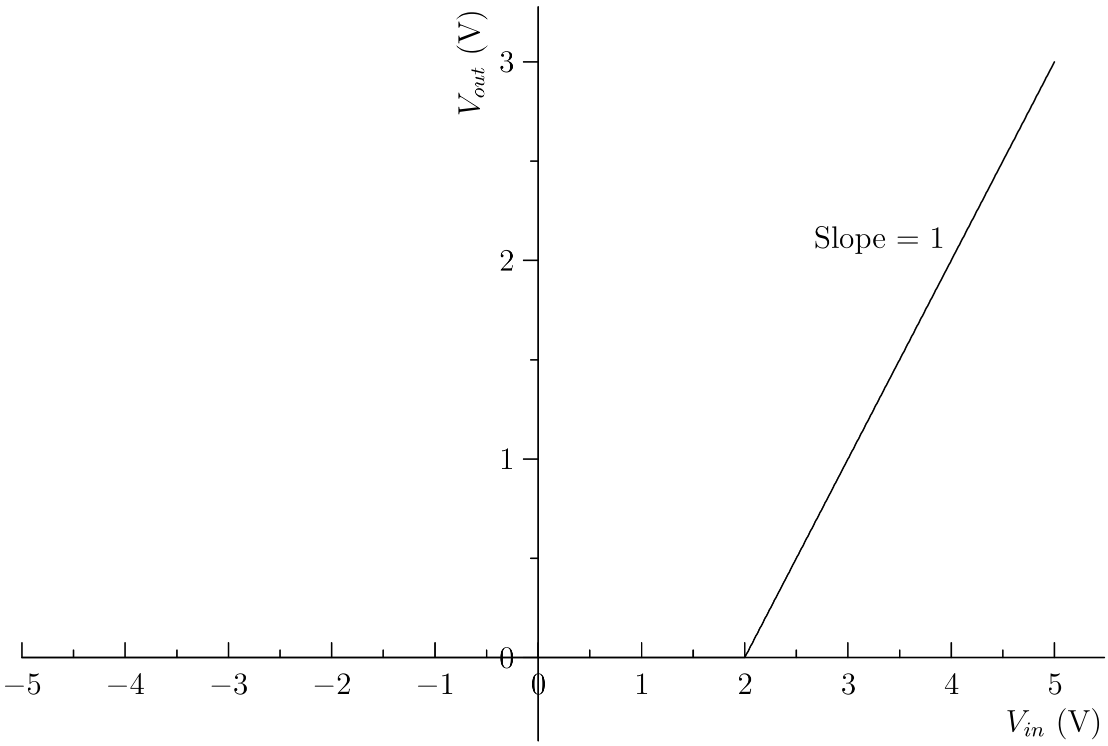
(d)

$$V_{out} = \begin{cases} V_{in} & V_{in} < V_B \\ V_B & V_{in} > V_B \end{cases}$$



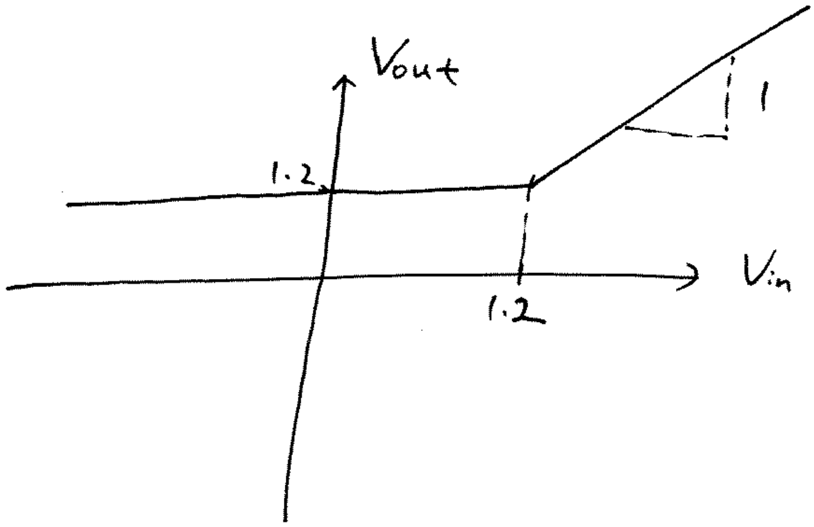
(e)

$$V_{out} = \begin{cases} 0 & V_{in} < V_B \\ V_{in} - V_B & V_{in} > V_B \end{cases}$$

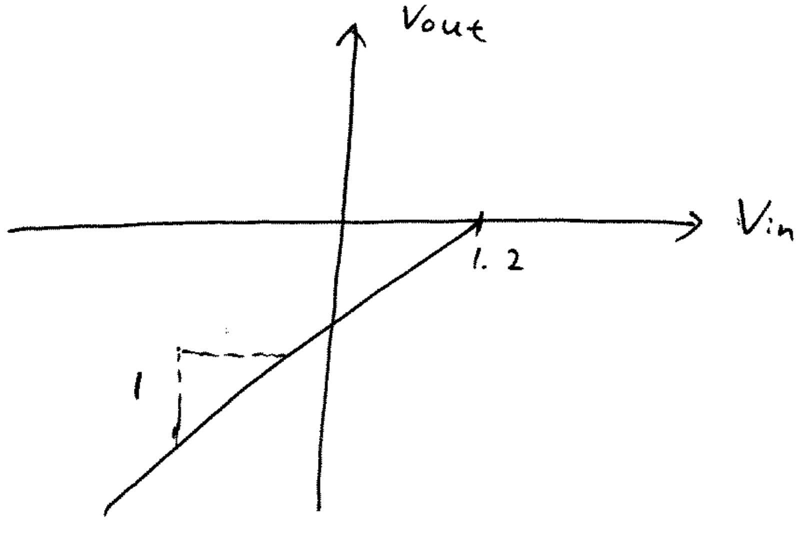


V_{out} (V)
3
2
1
0
Slope = 1
−5
−4
−3
−2
−1
0
1
2
3
4
5
V_{in} (V)

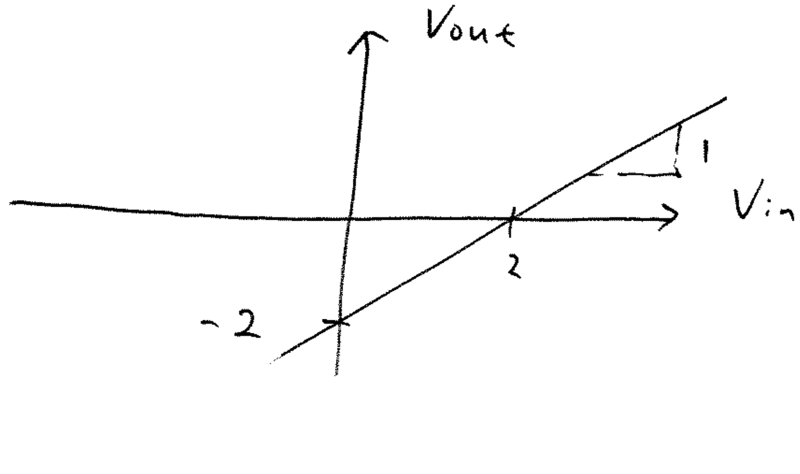
10 a)



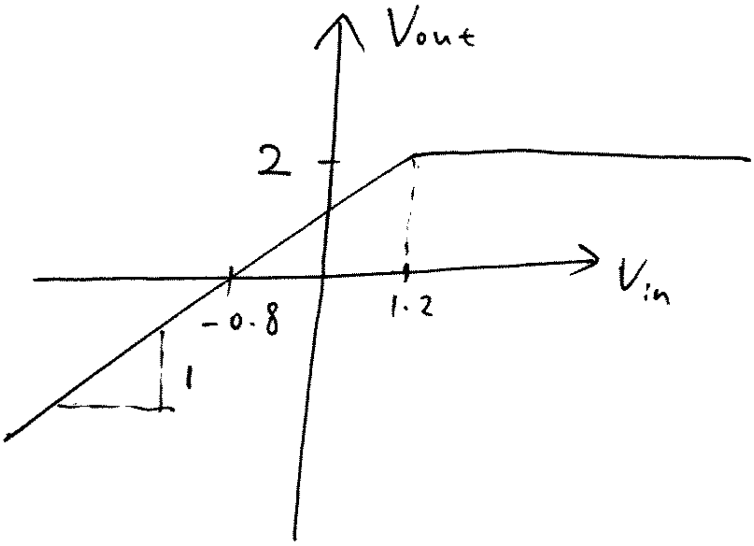
b)



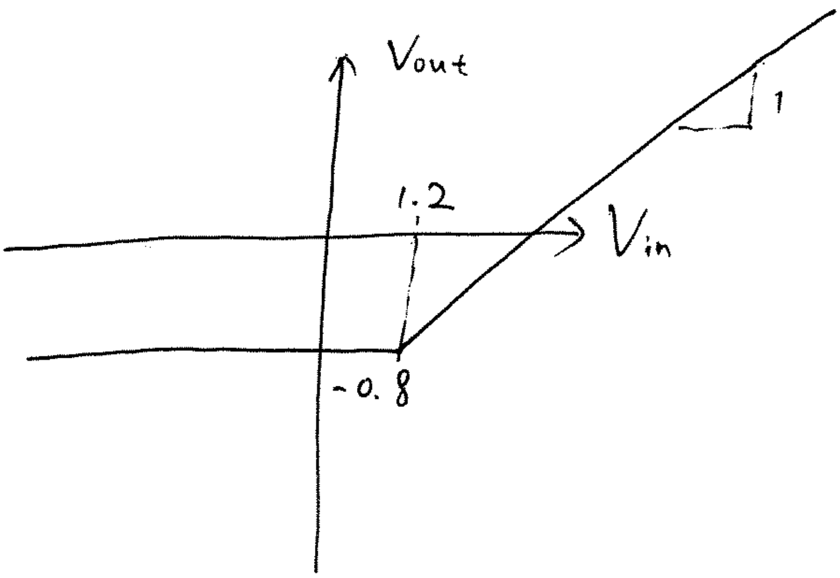
c)



d)



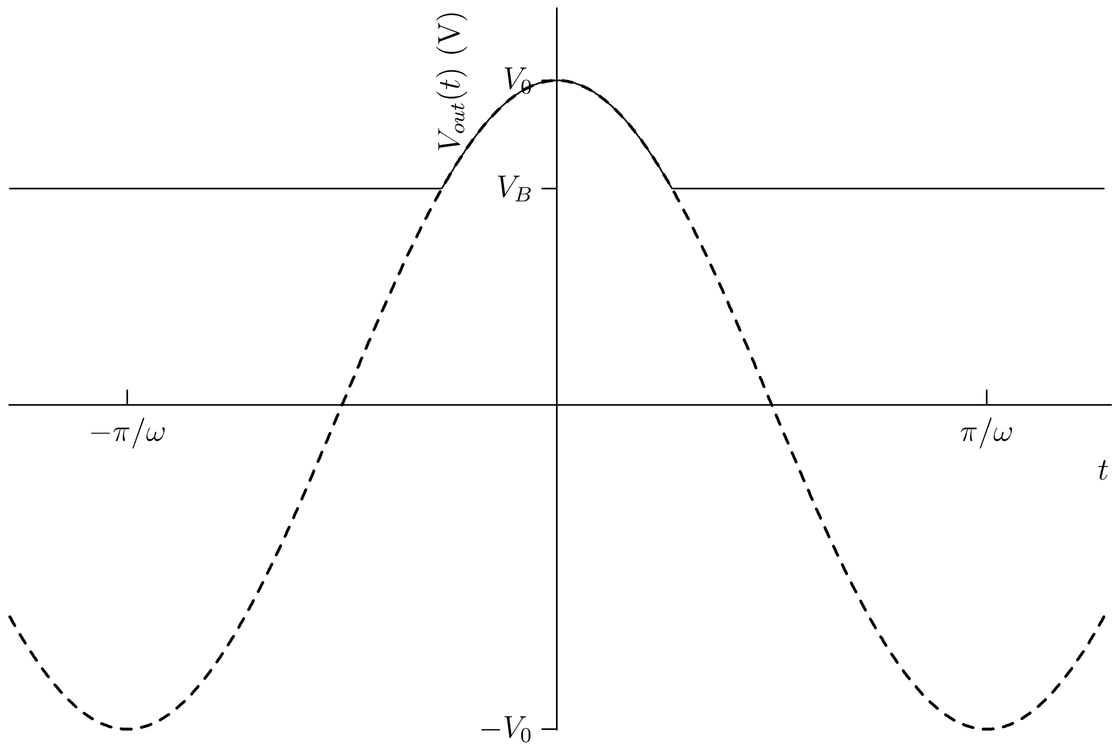
e)



3.11 For each part, the dotted line indicates $V_{in}(t)$, while the solid line indicates $V_{out}(t)$. Assume $V_0 > V_B$.

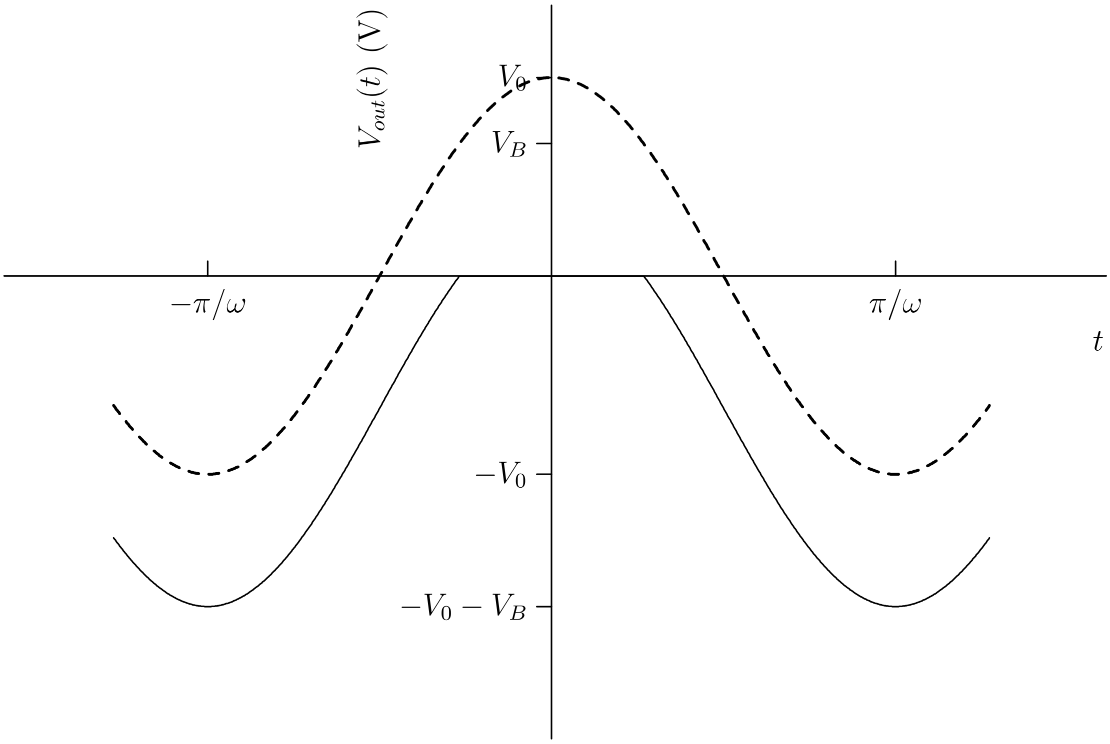
(a)

$$V_{out} = \begin{cases} V_B & V_{in} < V_B \\ V_{in} & V_{in} > V_B \end{cases}$$



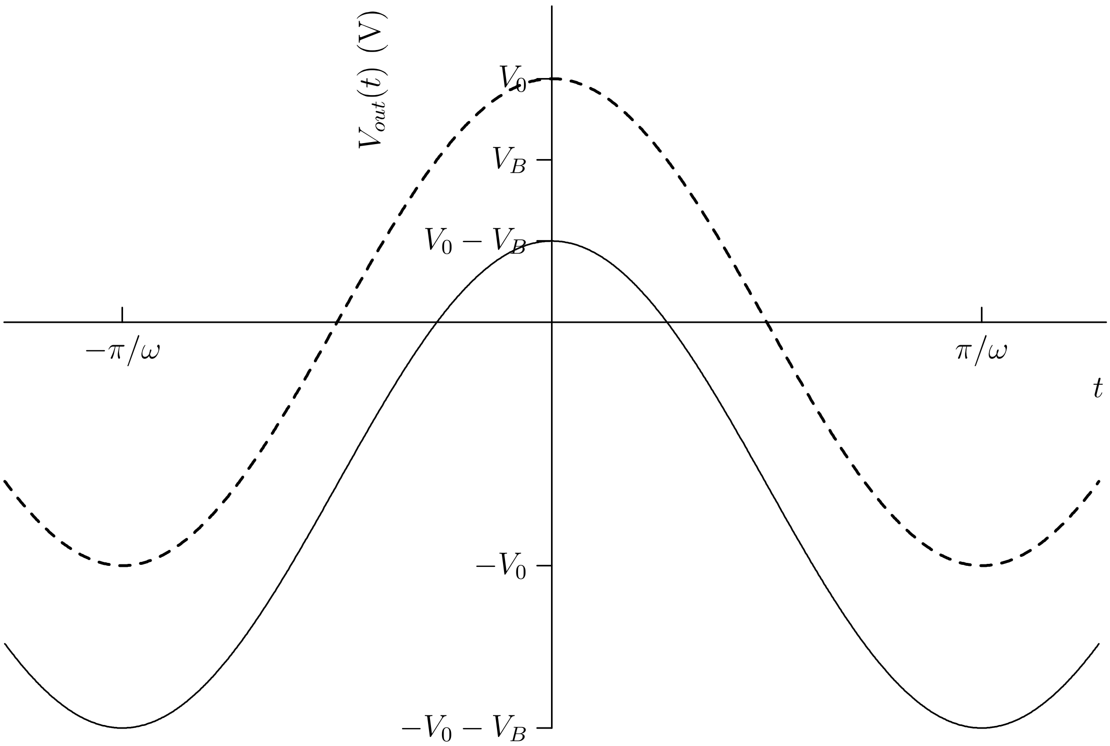
(b)

$$V_{out} = \begin{cases} V_{in} - V_B & V_{in} < V_B \\ 0 & V_{in} > V_B \end{cases}$$


$V_{out}(t)$ (V)
V_0
V_B
$-\pi/\omega$
π/ω
t
$-V_0$
$-V_0 - V_B$

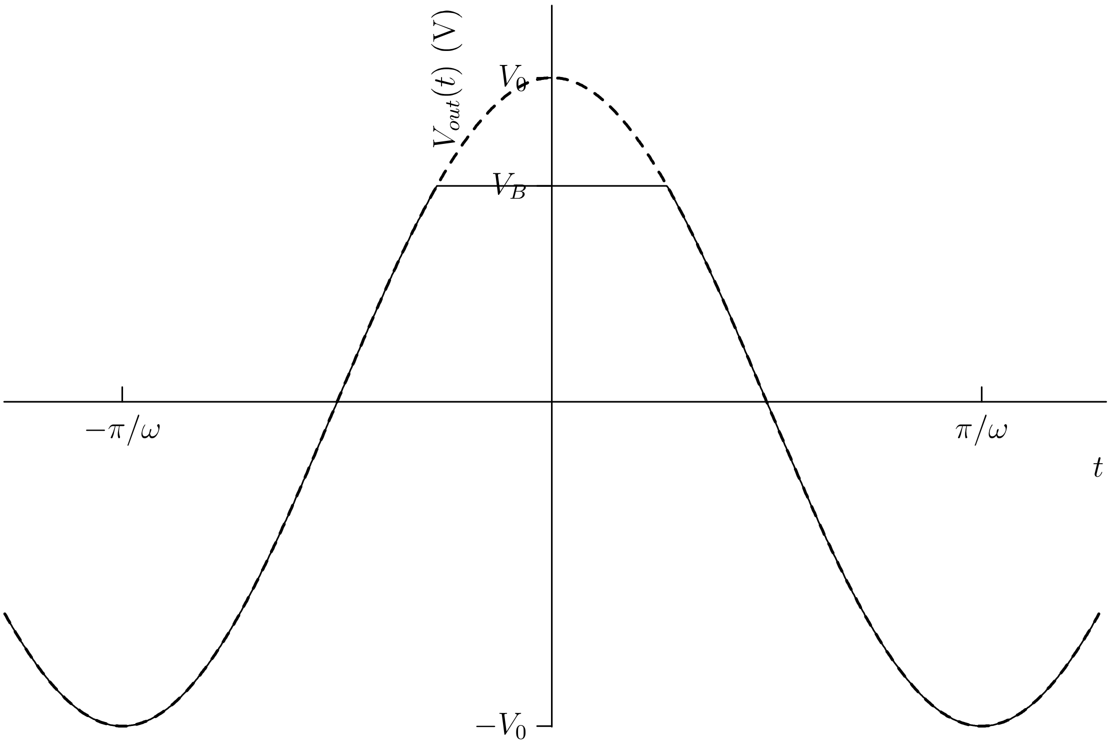
(c)

$V_{out} = V_{in} - V_B$


$V_{out}(t)$ (V)
V_0
V_B
$V_0 - V_B$
$-\pi/\omega$
π/ω
t
$-V_0$
$-V_0 - V_B$

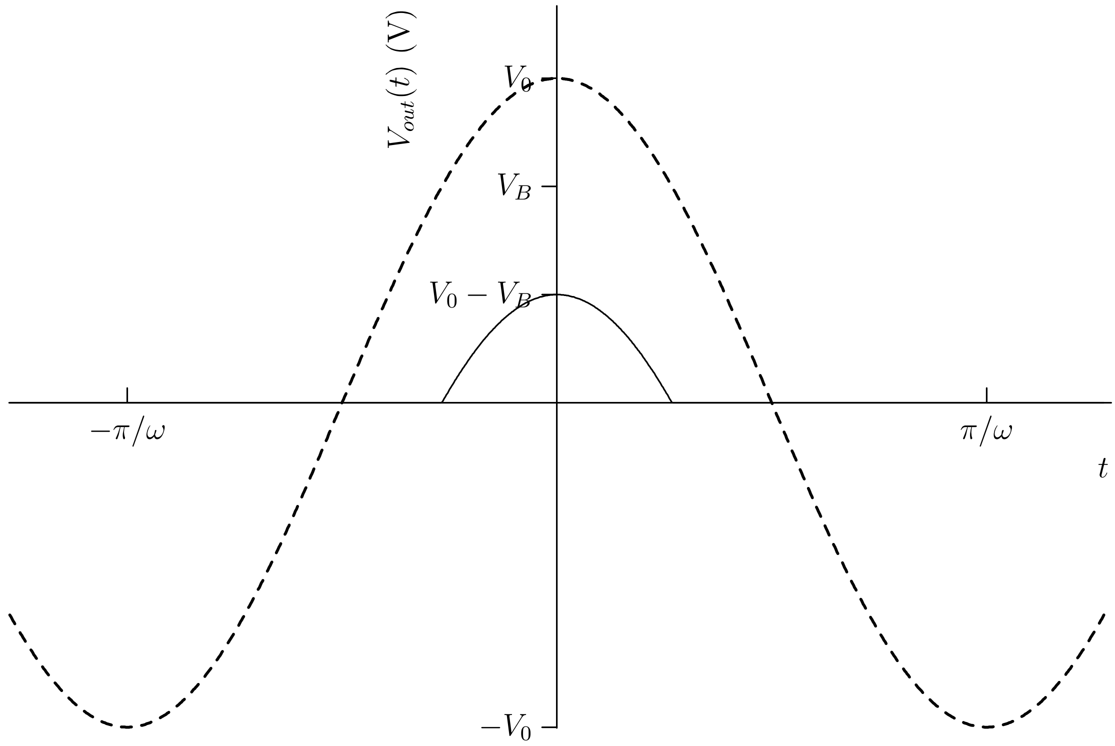
(d)

$$V_{out} = \begin{cases} V_{in} & V_{in} < V_B \\ V_B & V_{in} > V_B \end{cases}$$



(e)

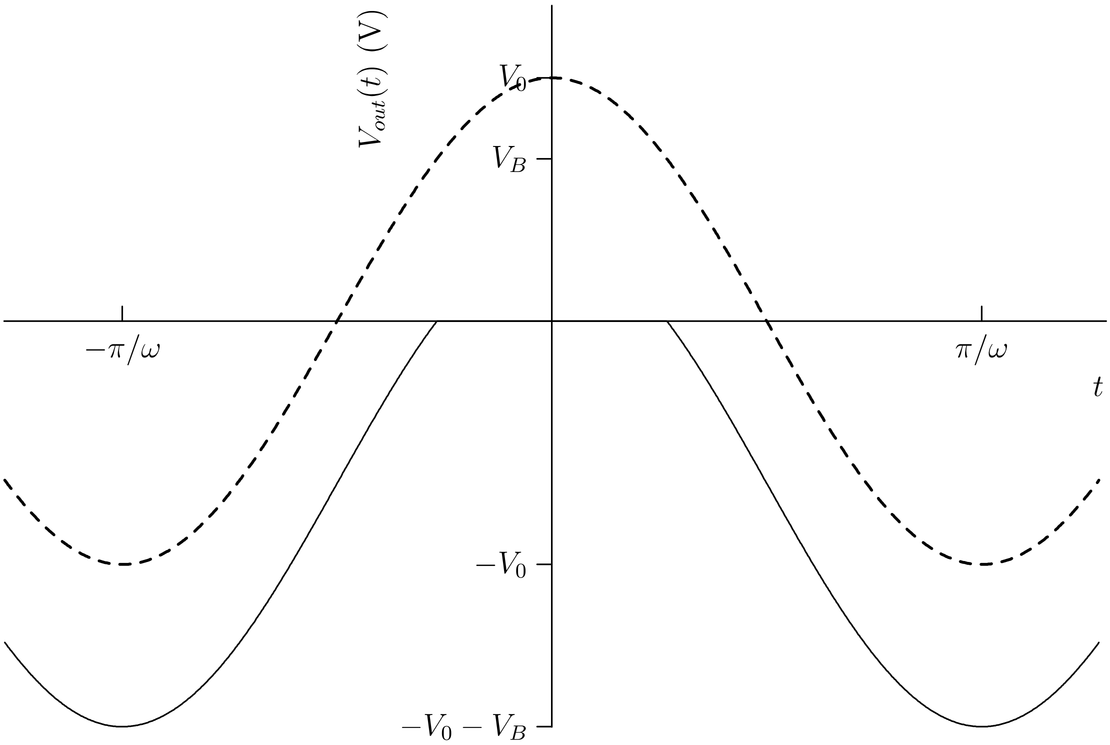
$$V_{out} = \begin{cases} 0 & V_{in} < V_B \\ V_{in} - V_B & V_{in} > V_B \end{cases}$$


$V_{out}(t)$ (V)
V_0
V_B
$V_0 - V_B$
$-\pi/\omega$
π/ω
t
$-V_0$

3.12 For each part, the dotted line indicates $V_{in}(t)$, while the solid line indicates $V_{out}(t)$. Assume $V_0 > V_B$.

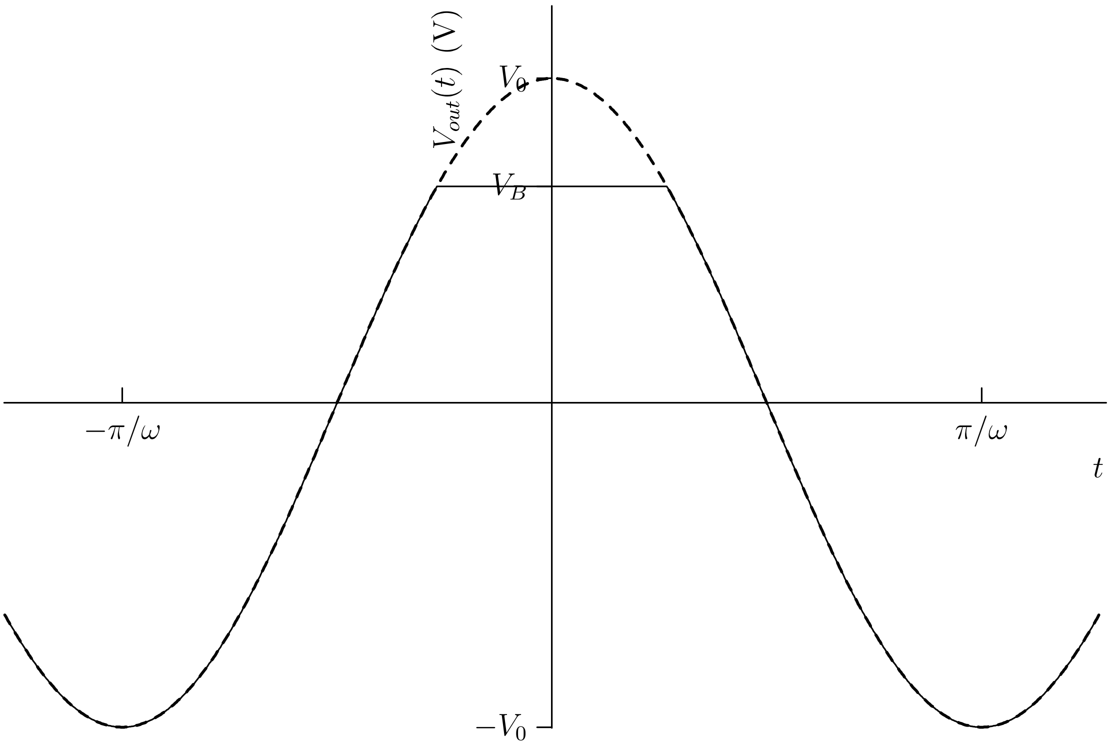
(a)

$$V_{out} = \begin{cases} V_{in} - V_B & V_{in} < V_B \\ 0 & V_{in} > V_B \end{cases}$$



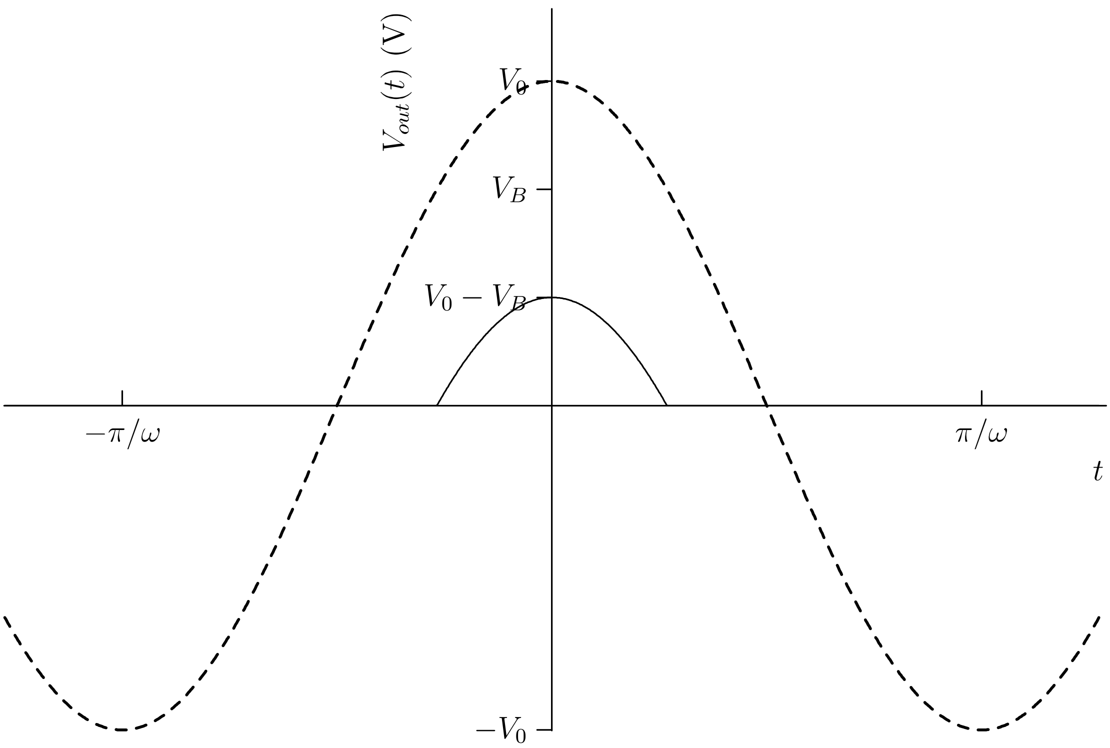
(b)

$$V_{out} = \begin{cases} V_{in} & V_{in} < V_B \\ V_B & V_{in} > V_B \end{cases}$$



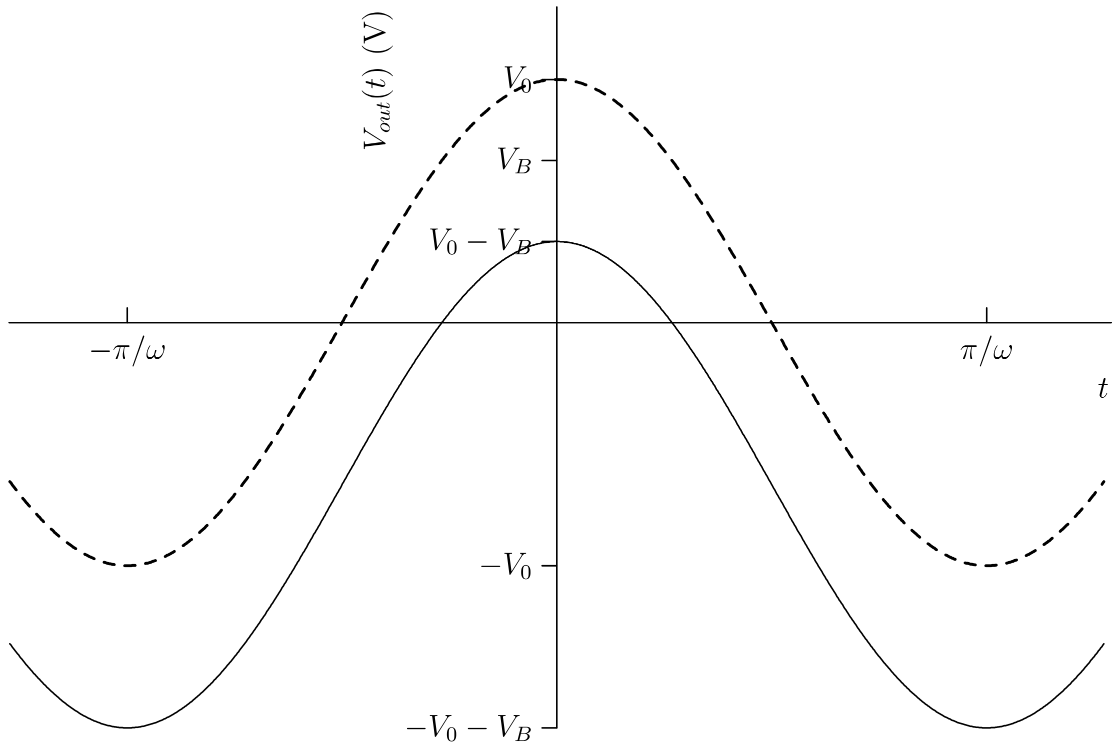
(c)

$$V_{out} = \begin{cases} 0 & V_{in} < V_B \\ V_{in} - V_B & V_{in} > V_B \end{cases}$$



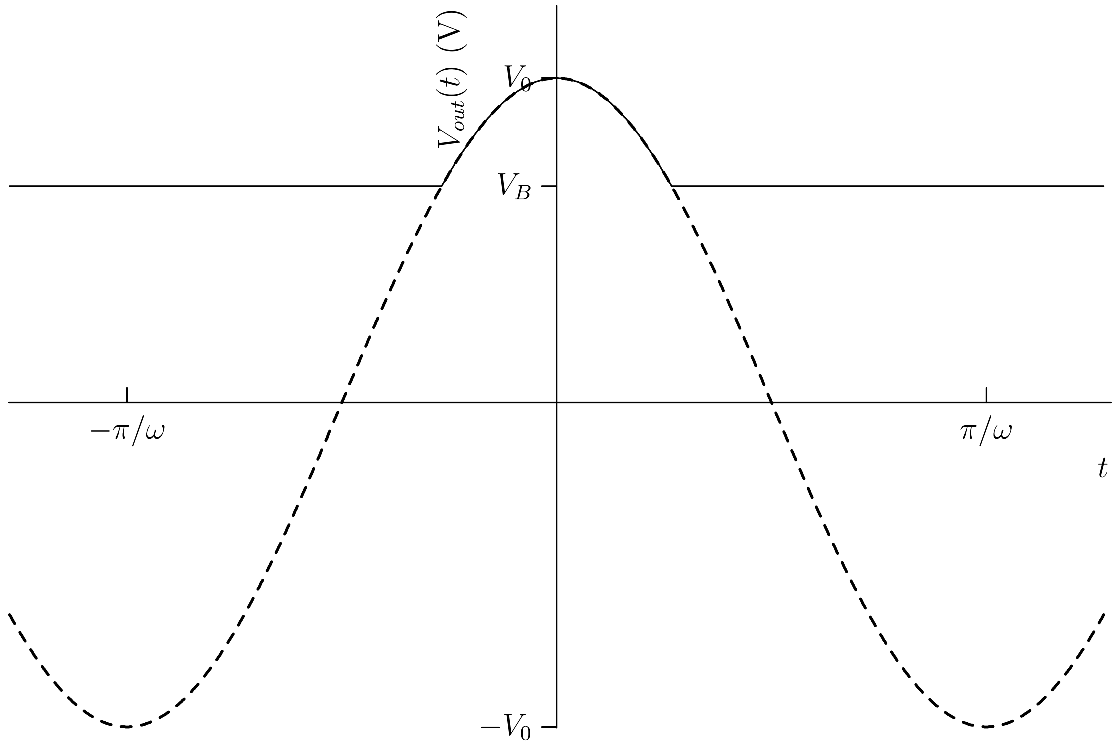
(d)

$$V_{out} = V_{in} - V_B$$

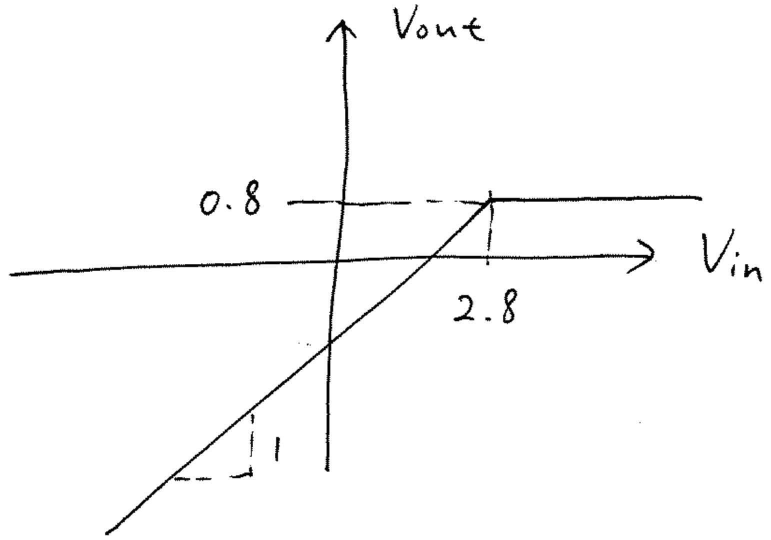


(e)

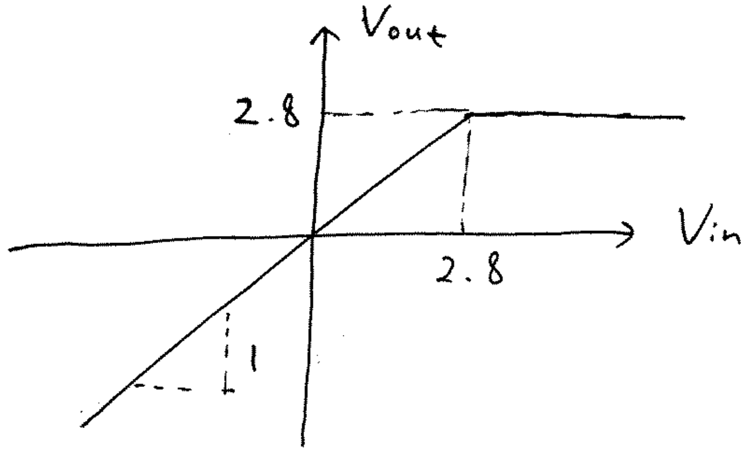
$$V_{out} = \begin{cases} V_B & V_{in} < V_B \\ V_{in} & V_{in} > V_B \end{cases}$$


$V_{out}(t)$ (V)
V_0
V_B
$-\pi/\omega$
π/ω
t
$-V_0$

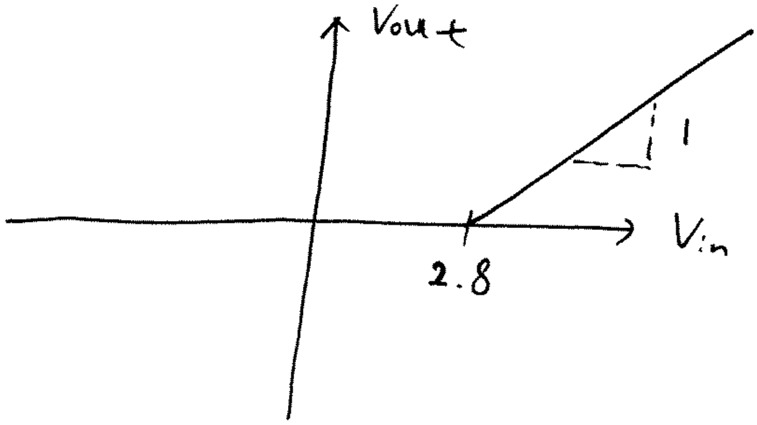
⑬ a)



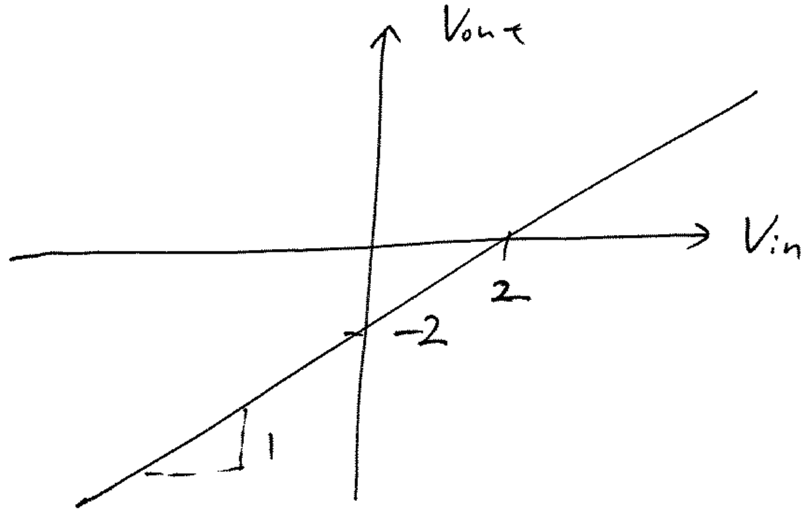
b)



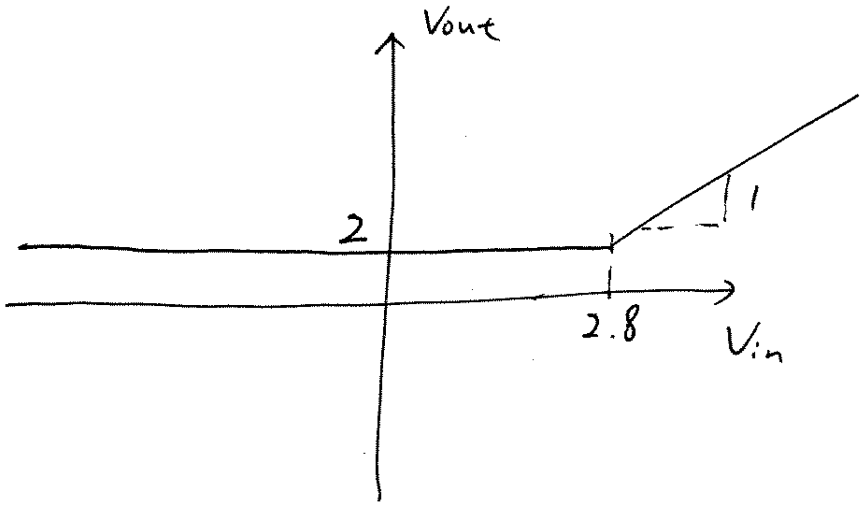
c)



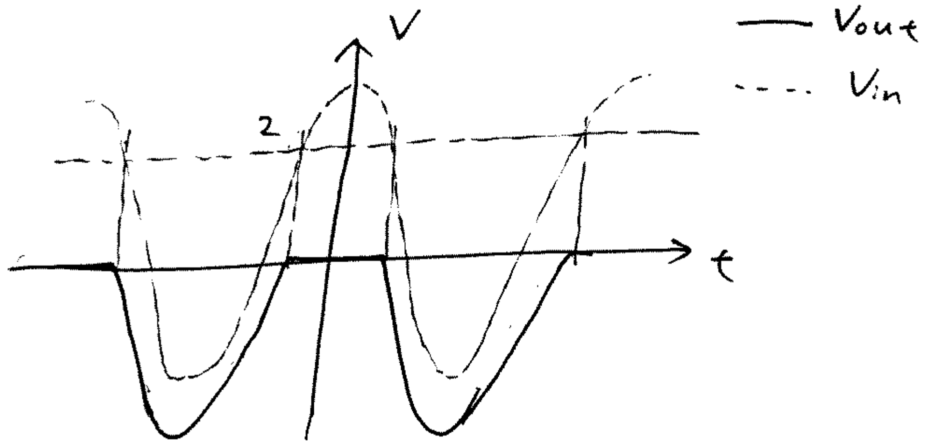
d)



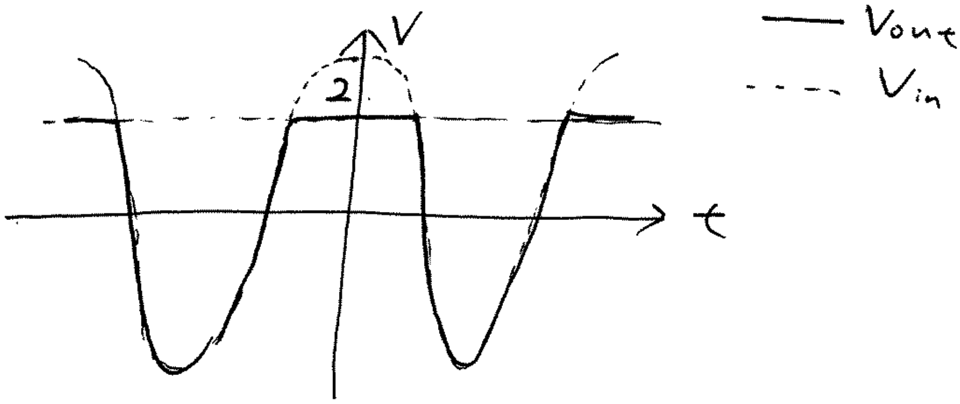
e)



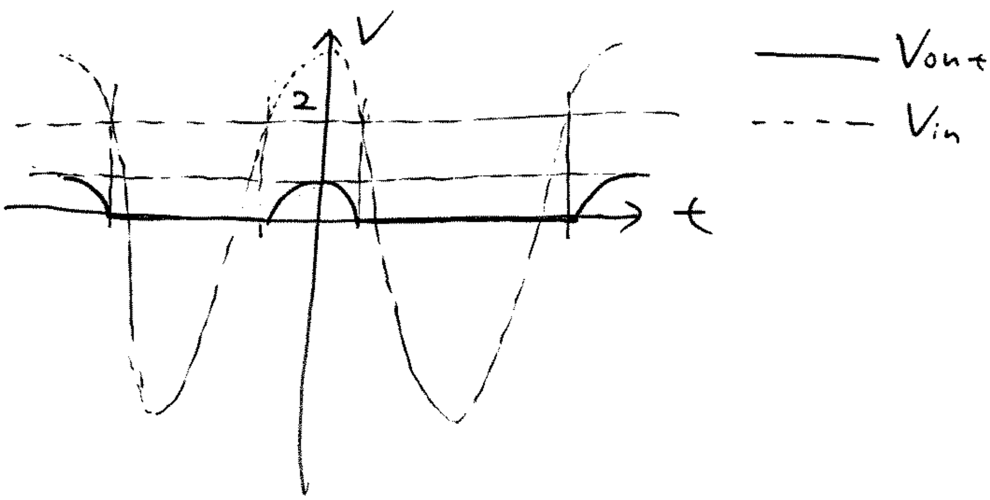
⑭ a)



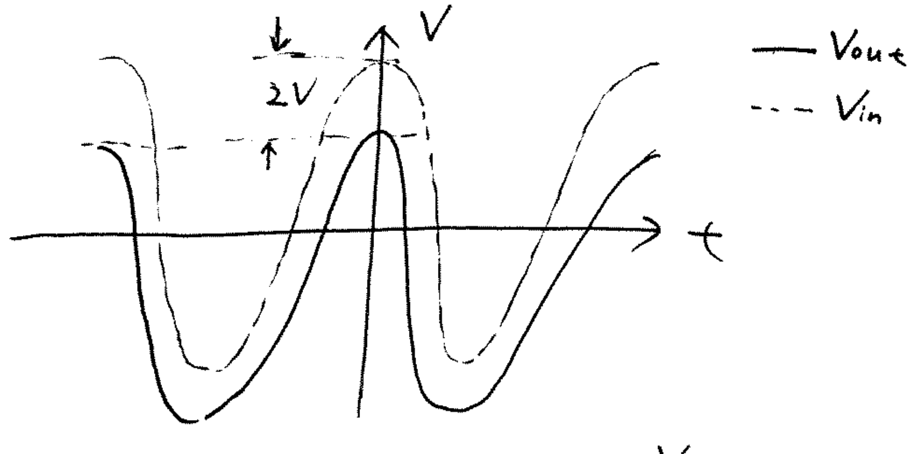
b)



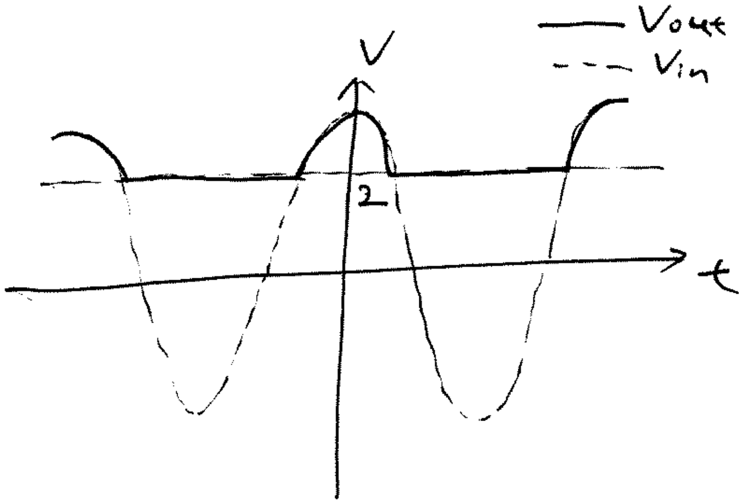
c)



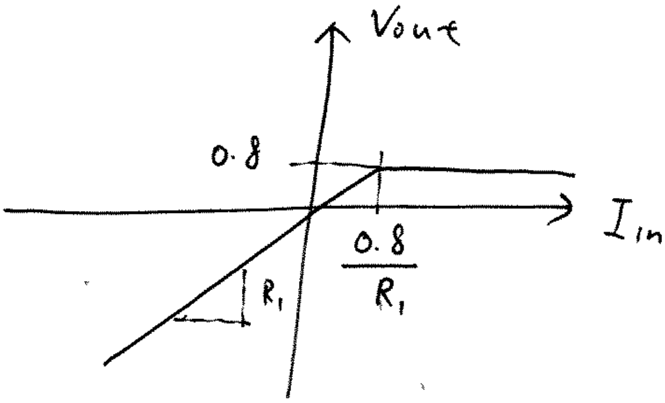
d)



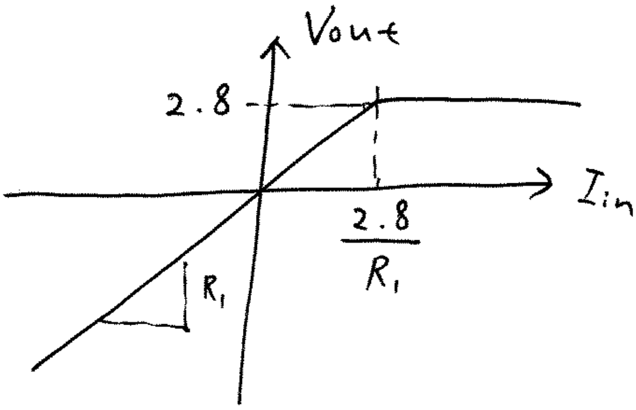
e).



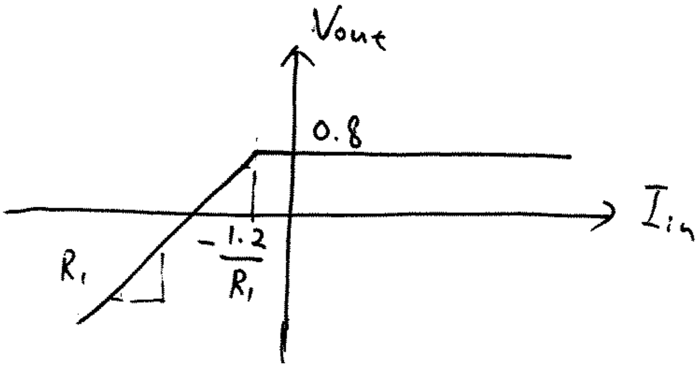
(15) a)


Vout
0.8
Iin
0.8
R1
R1

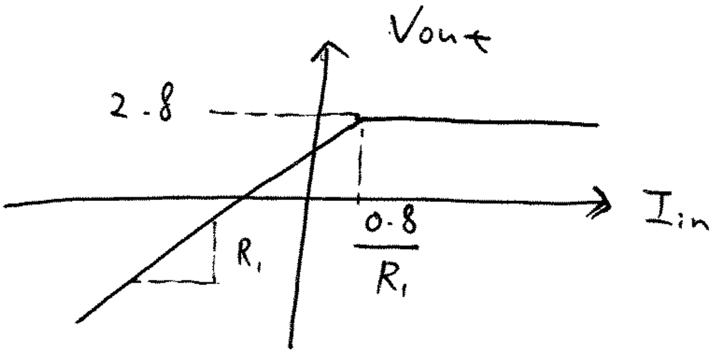
b)


Vout
2.8
Iin
2.8
R1
R1

c)

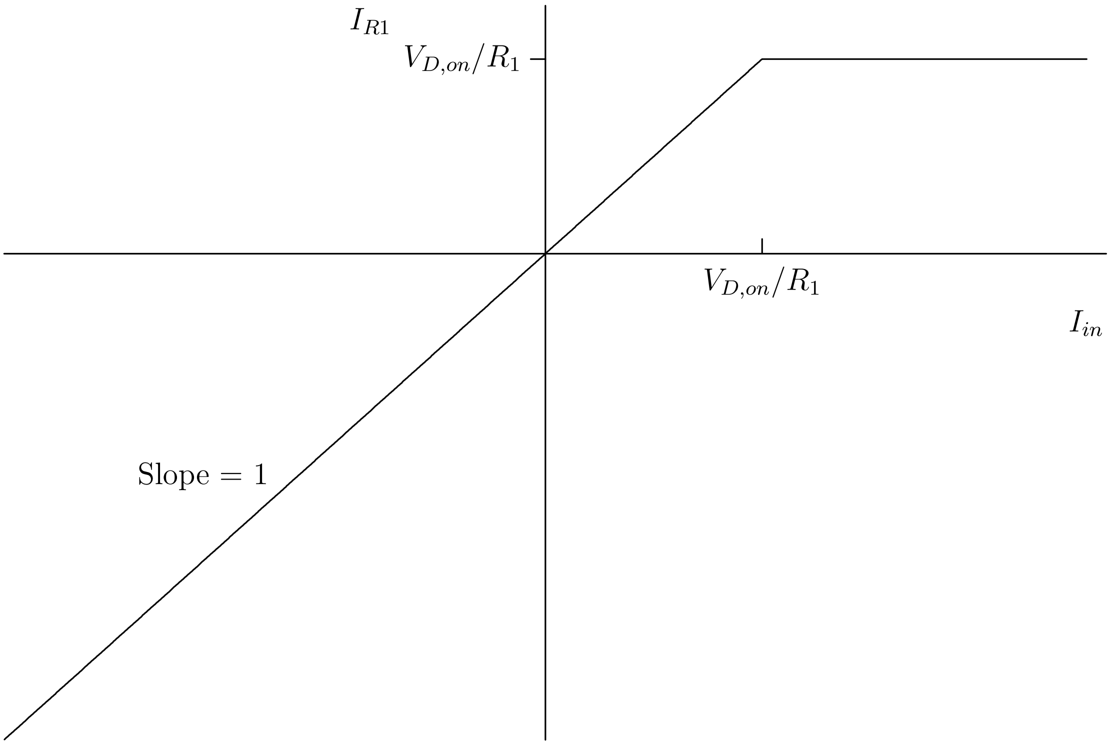

Vout
0.8
Iin
-1.2
R1
R1

d)


Vout
2.8
Iin
0.8
R1
R1

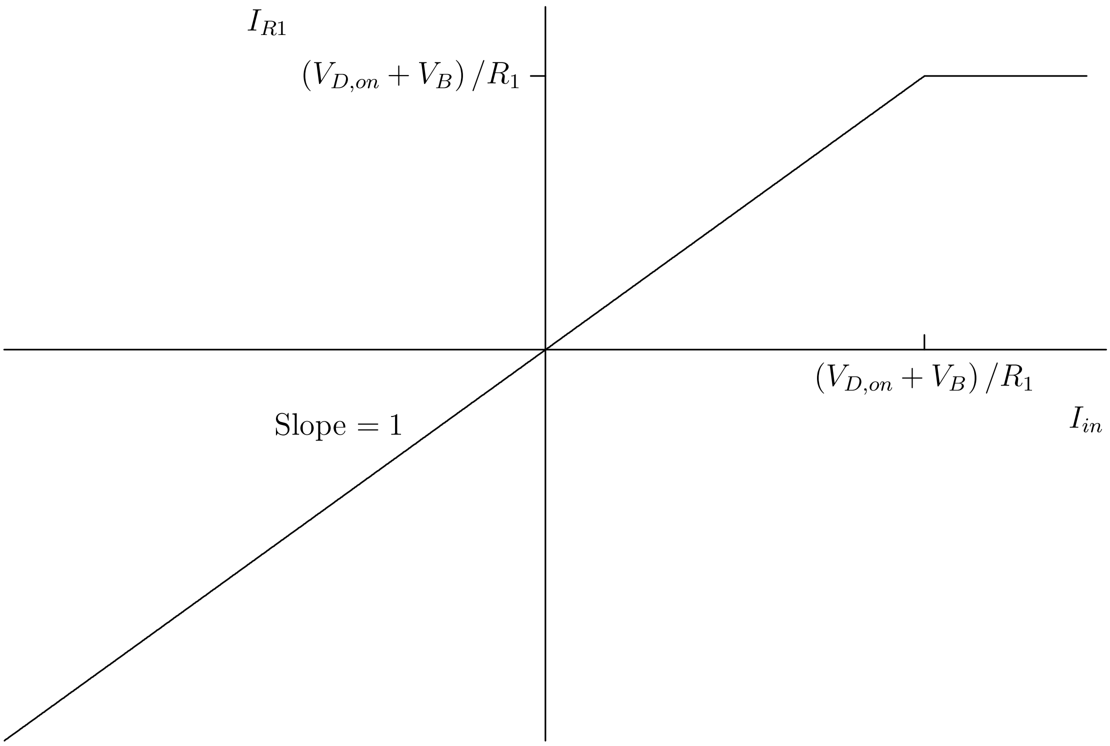
3.16 (a)

$$I_{R1} = \begin{cases} I_{in} & I_{in} < \frac{V_{D,on}}{R_1} \\ \frac{V_{D,on}}{R_1} & I_{in} > \frac{V_{D,on}}{R_1} \end{cases}$$



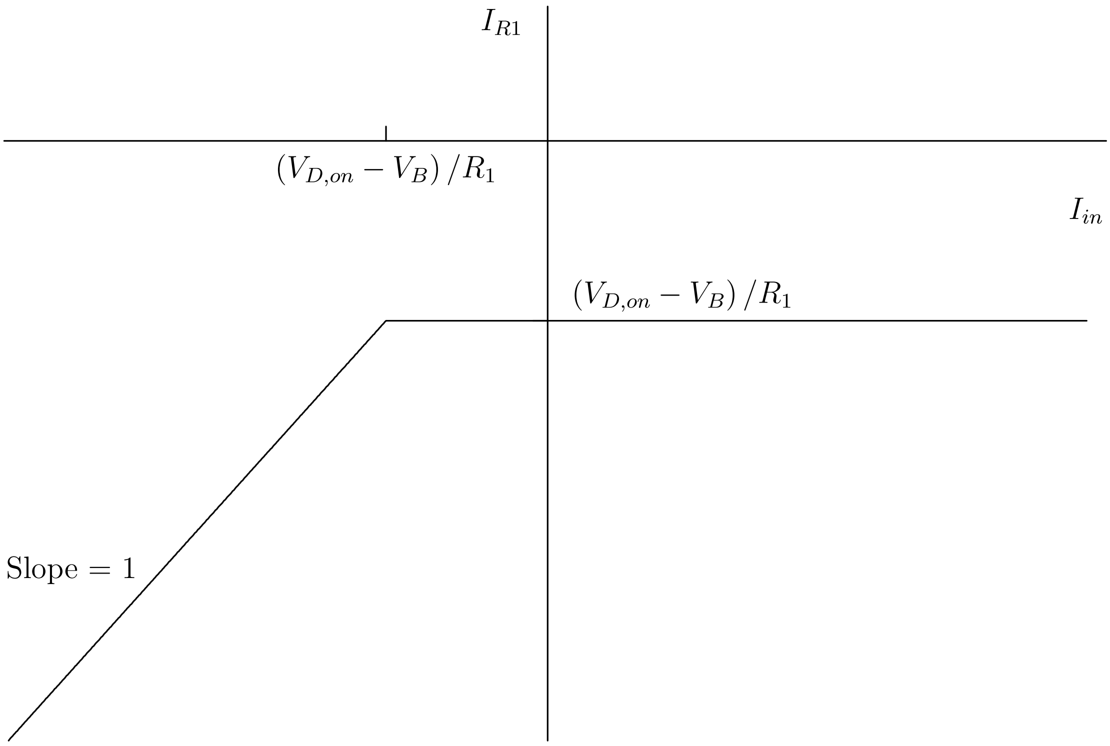
(b)

$$I_{R1} = \begin{cases} I_{in} & I_{in} < \frac{V_{D,on}+V_B}{R_1} \\ \frac{V_{D,on}+V_B}{R_1} & I_{in} > \frac{V_{D,on}+V_B}{R_1} \end{cases}$$



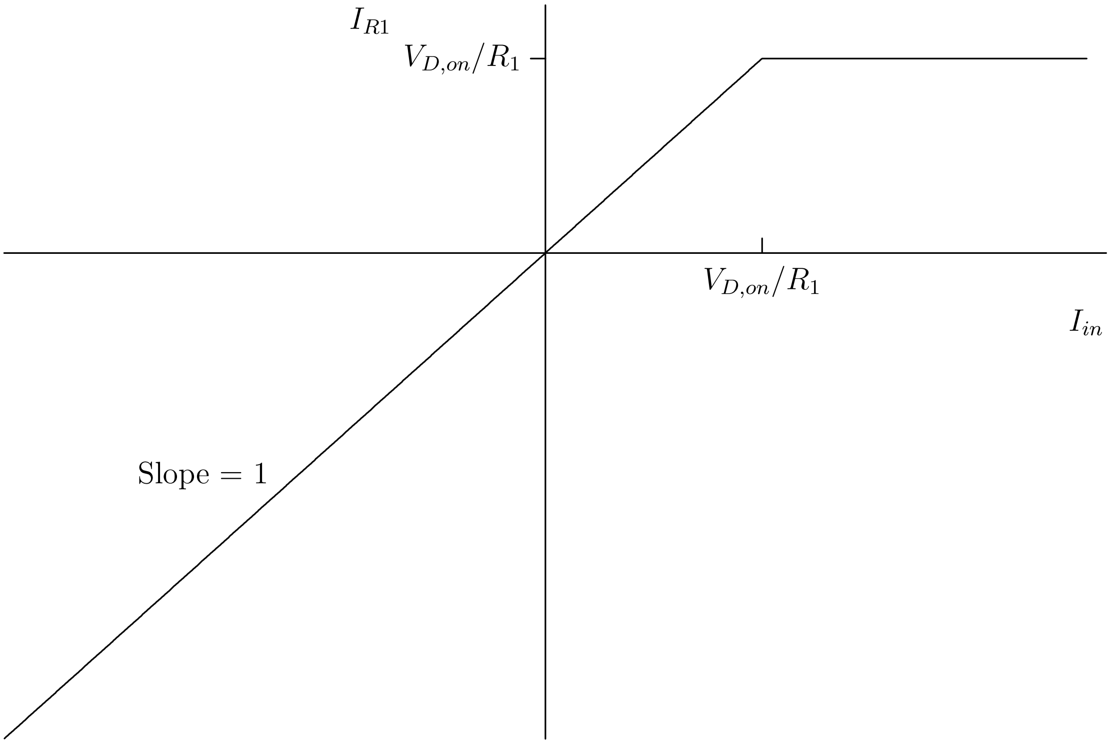
(c)

$$I_{R1} = \begin{cases} I_{in} & I_{in} < \frac{V_{D,on} - V_B}{R_1} \\ \frac{V_{D,on} - V_B}{R_1} & I_{in} > \frac{V_{D,on} - V_B}{R_1} \end{cases}$$



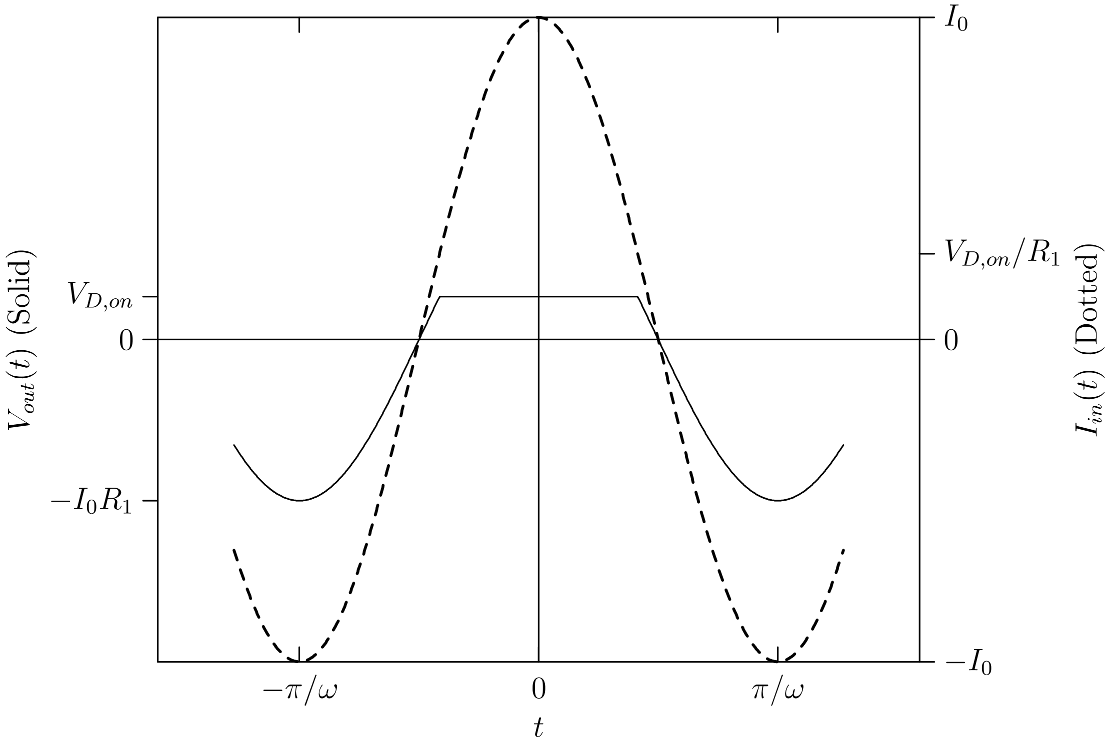
(d)

$$I_{R1} = \begin{cases} I_{in} & I_{in} < \frac{V_{D,on}}{R_1} \\ \frac{V_{D,on}}{R_1} & I_{in} > \frac{V_{D,on}}{R_1} \end{cases}$$



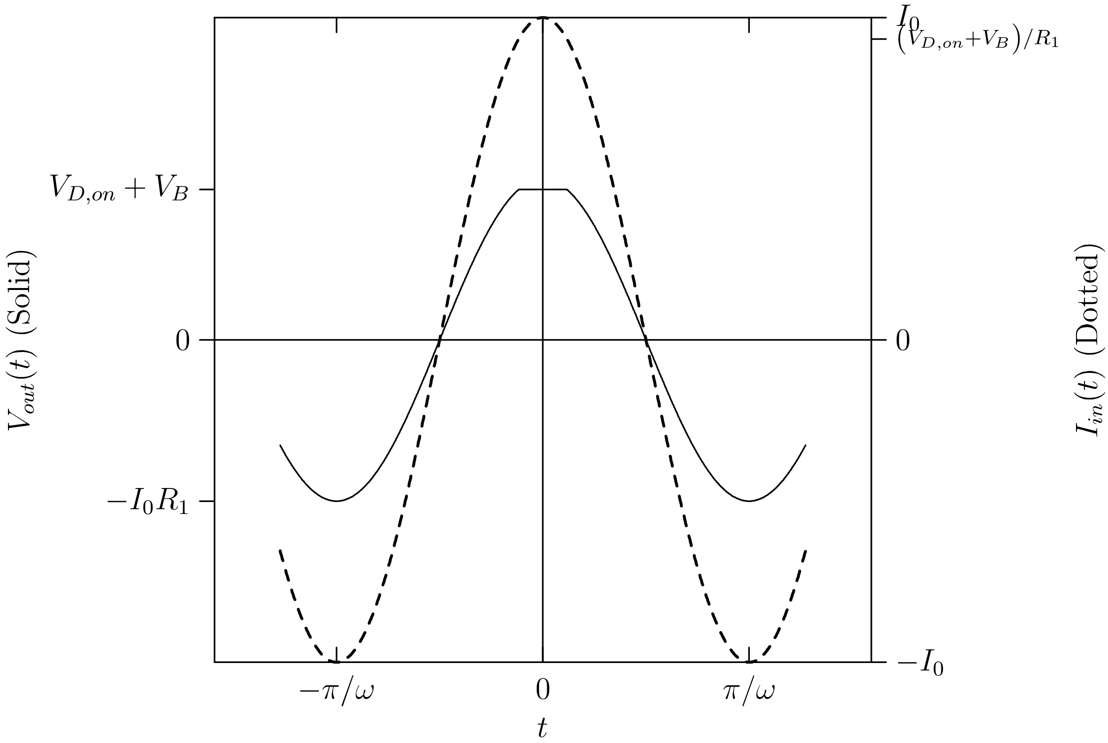
3.17 (a)

$$V_{out} = \begin{cases} I_{in}R_1 & I_{in} < \frac{V_{D,on}}{R_1} \\ V_{D,on} & I_{in} > \frac{V_{D,on}}{R_1} \end{cases}$$



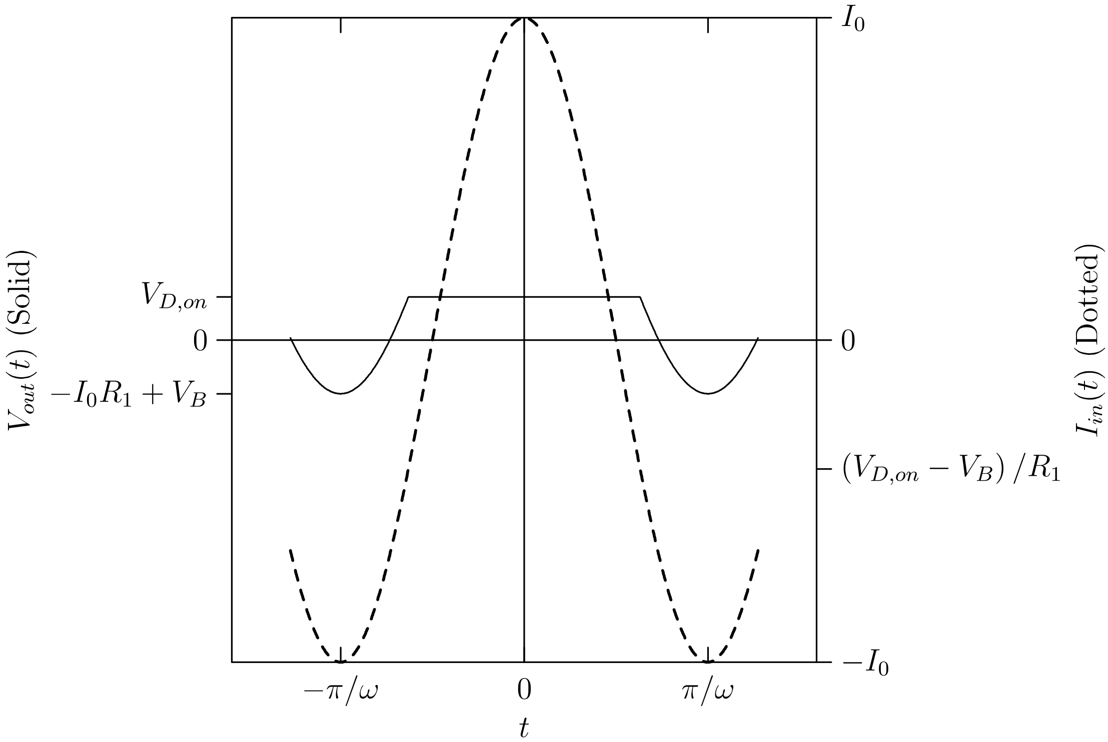
(b)

$$V_{out} = \begin{cases} I_{in}R_1 & I_{in} < \frac{V_{D,on}+V_B}{R_1} \\ V_{D,on}+V_B & I_{in} > \frac{V_{D,on}+V_B}{R_1} \end{cases}$$



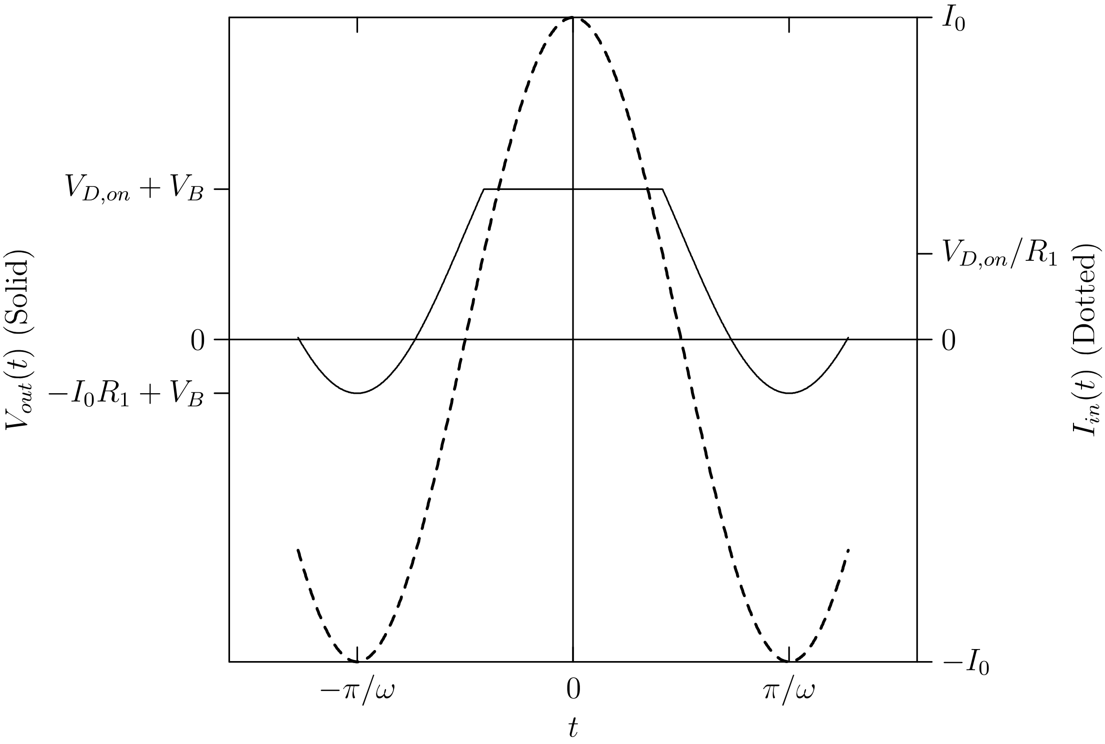
(c)

$$V_{out} = \begin{cases} I_{in}R_1 + V_B & I_{in} < \frac{V_{D,on}-V_B}{R_1} \\ V_{D,on} & I_{in} > \frac{V_{D,on}-V_B}{R_1} \end{cases}$$

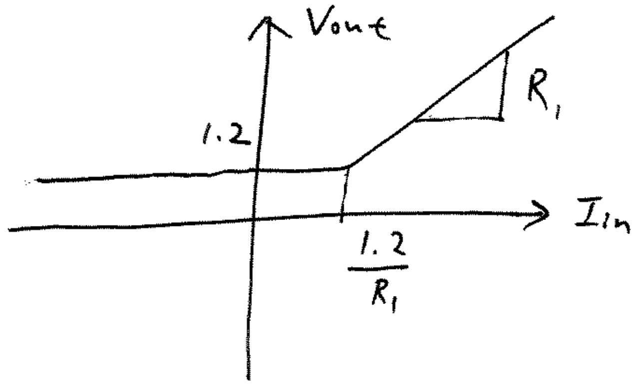


(d)

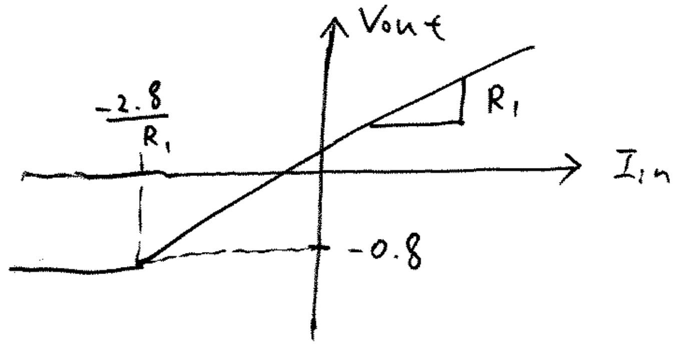
$$V_{out} = \begin{cases} I_{in}R_1 + V_B & I_{in} < \frac{V_{D,on}}{R_1} \\ V_{D,on} + V_B & I_{in} > \frac{V_{D,on}}{R_1} \end{cases}$$



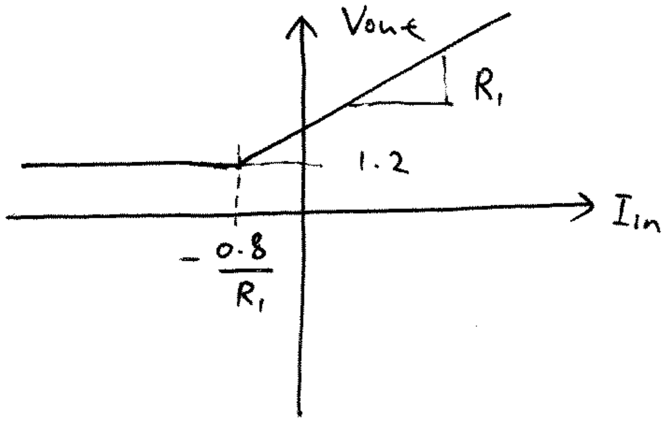
(18) a)



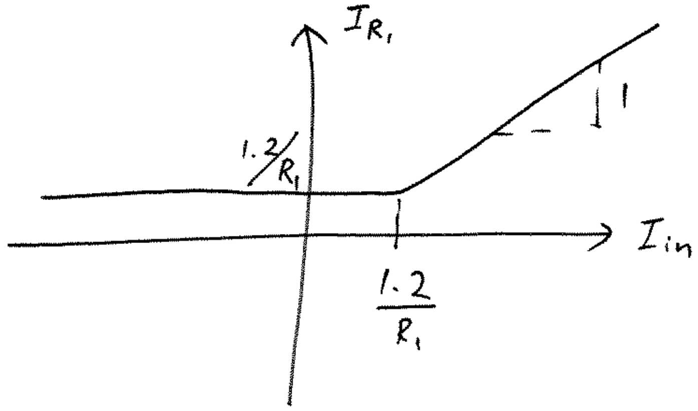
b)



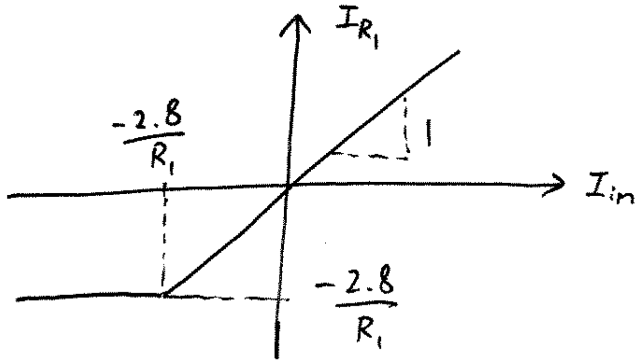
c)



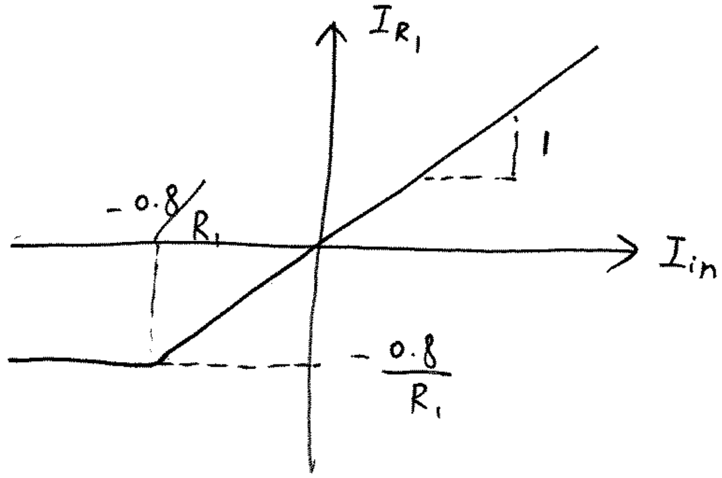
(19) a)


I_{R_1}
$1.2/R_1$
1
I_{in}
$\frac{1.2}{R_1}$

b)

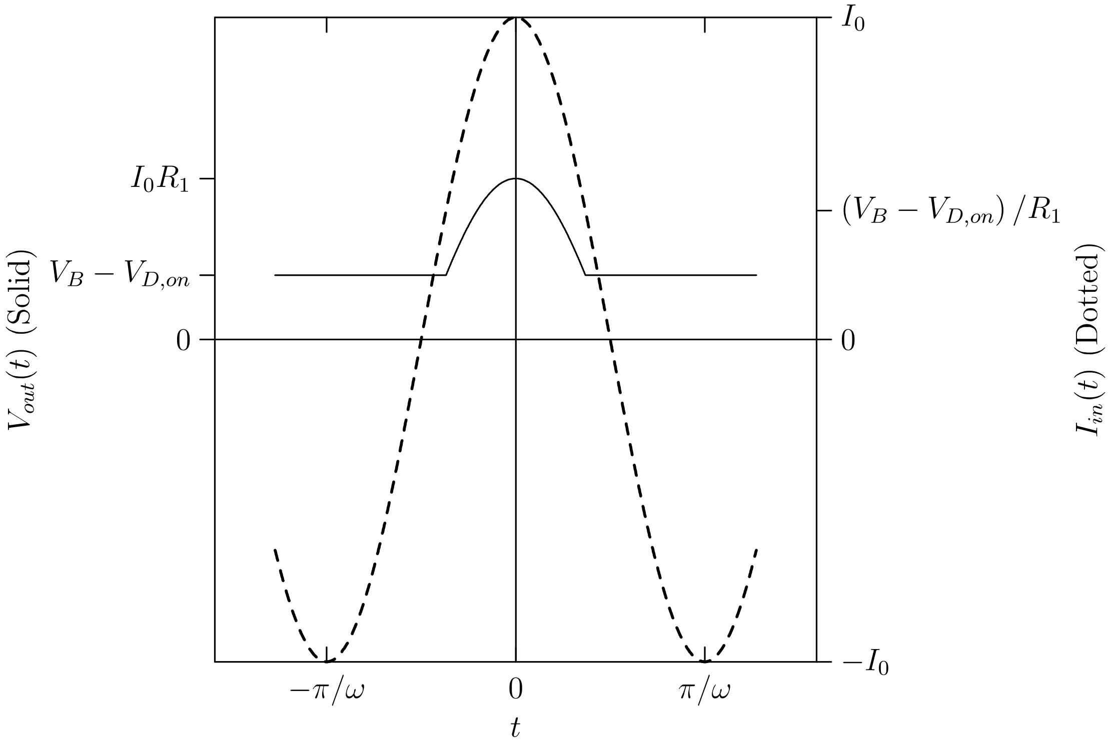

I_{R_1}
$\frac{-2.8}{R_1}$
1
I_{in}
$-\frac{2.8}{R_1}$

c)


I_{R_1}
1
$-0.8/R_1$
I_{in}
$-\frac{0.8}{R_1}$

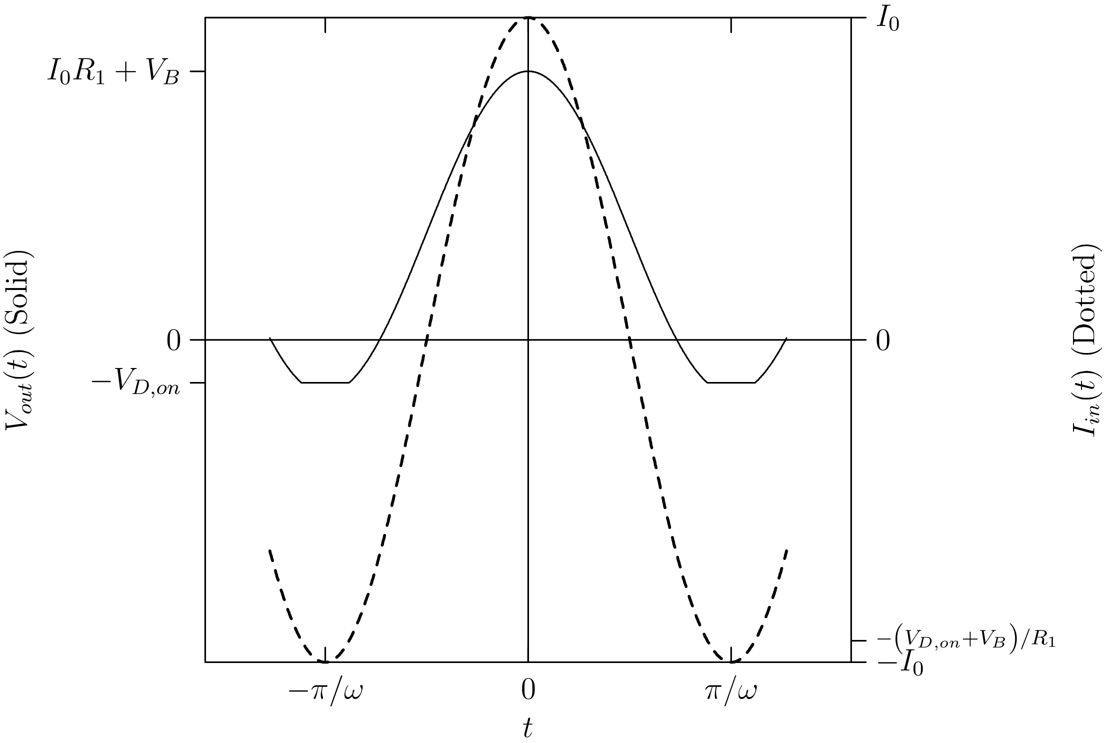
3.20 (a)

$$V_{out} = \begin{cases} I_{in}R_1 & I_{in} > \frac{V_B - V_{D,on}}{R_1} \\ V_B - V_{D,on} & I_{in} < \frac{V_B - V_{D,on}}{R_1} \end{cases}$$



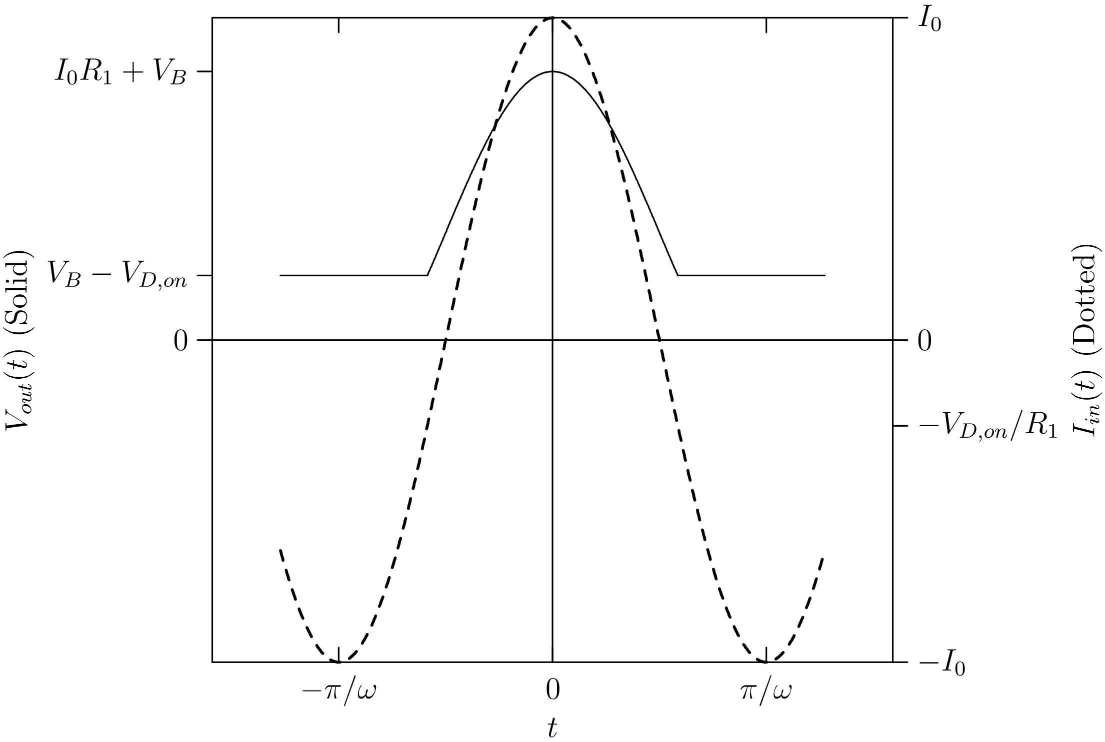
(b)

$$V_{out} = \begin{cases} I_{in}R_1 + V_B & I_{in} > -\frac{V_{D,on} + V_B}{R_1} \\ -V_{D,on} & I_{in} < -\frac{V_{D,on} + V_B}{R_1} \end{cases}$$

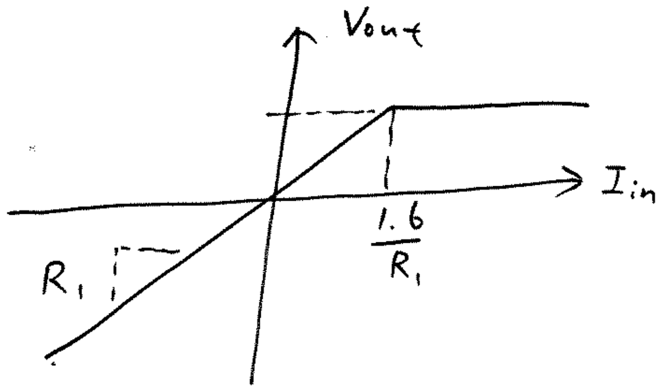


(c)

$$V_{out} = \begin{cases} I_{in}R_1 + V_B & I_{in} > -\frac{V_{D,on}}{R_1} \\ V_B - V_{D,on} & I_{in} < -\frac{V_{D,on}}{R_1} \end{cases}$$

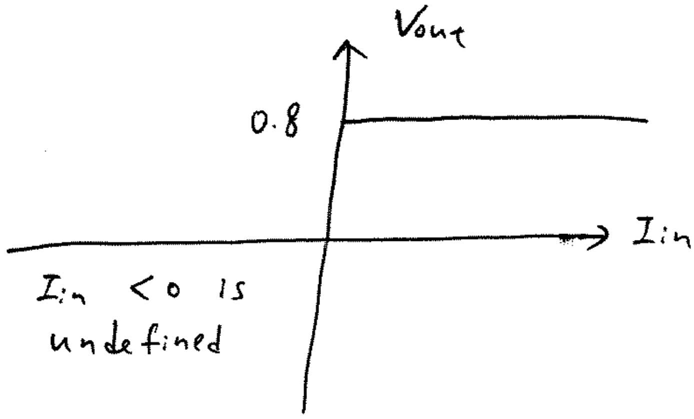


(21) a)



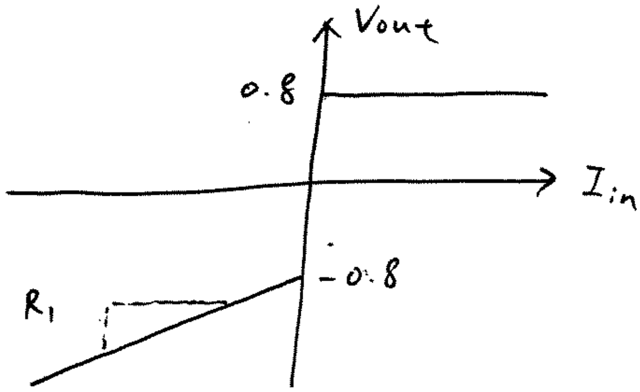
Vout
Iin
1.6
R1
R1

b)



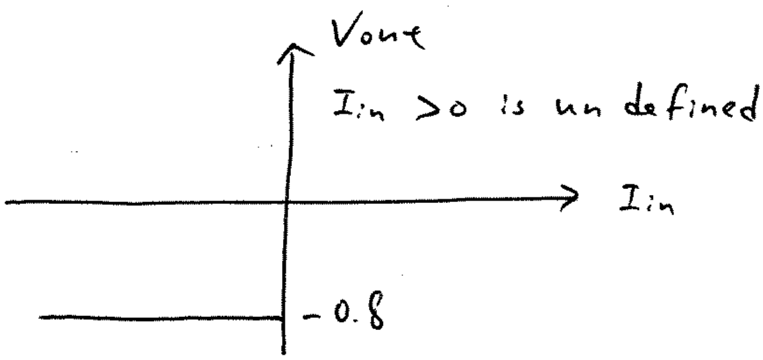
Vout
0.8
Iin
Iin < 0 is undefined

c)



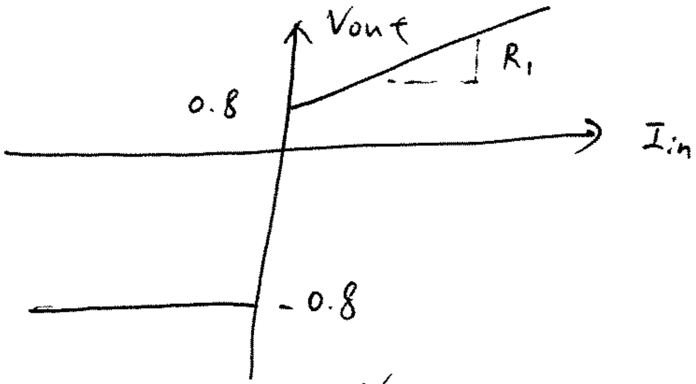
Vout
0.8
Iin
-0.8
R1

d)

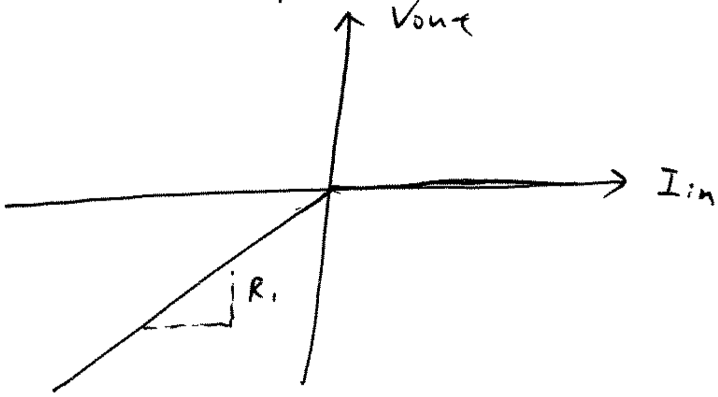


Vout
Iin > 0 is undefined
Iin
-0.8

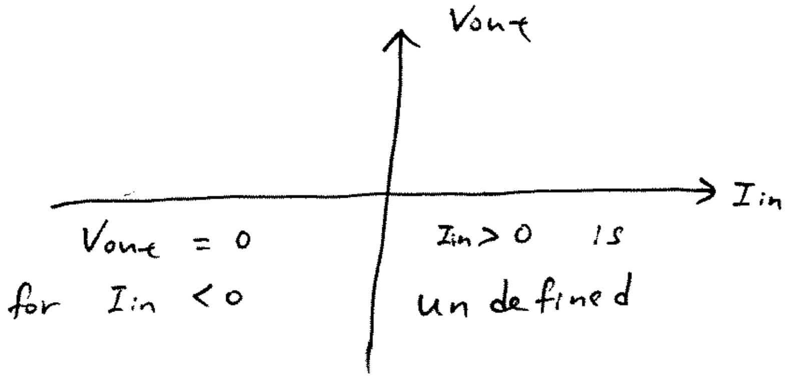
e)


Vout
R1
0.8
Iin
-0.8

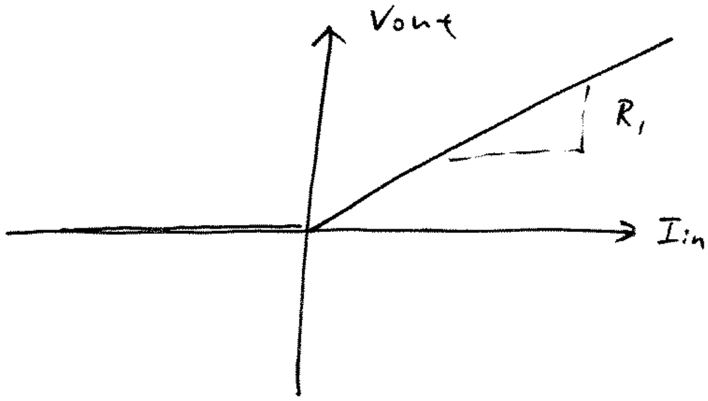
f)


Vout
Iin
R1

g)

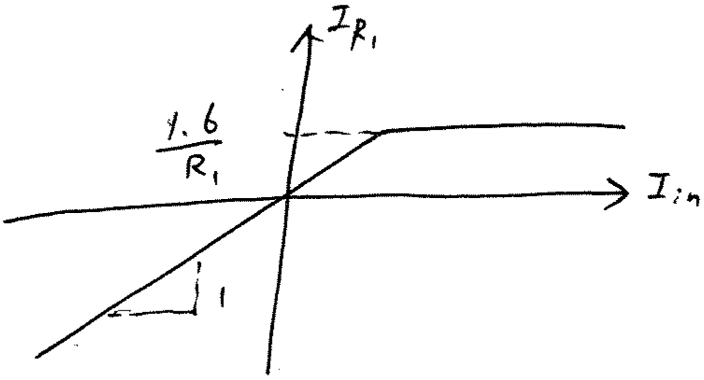

Vout
Iin
Vout = 0
for Iin < 0
Iin > 0 is
undefined

h)


Vout
R1
Iin

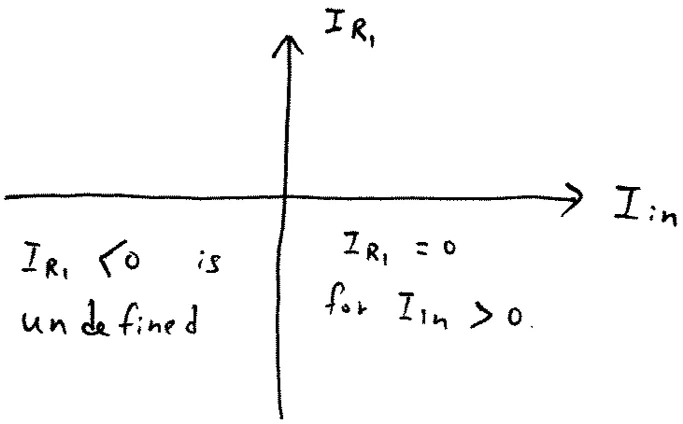
22

a)



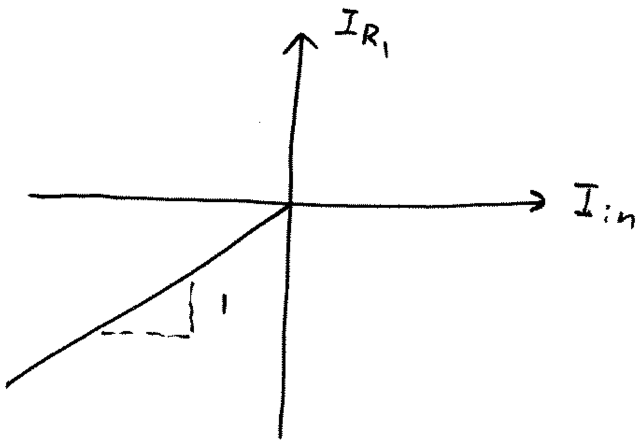
I_{R_1}
$\frac{1.6}{R_1}$
I_{in}
1

b)



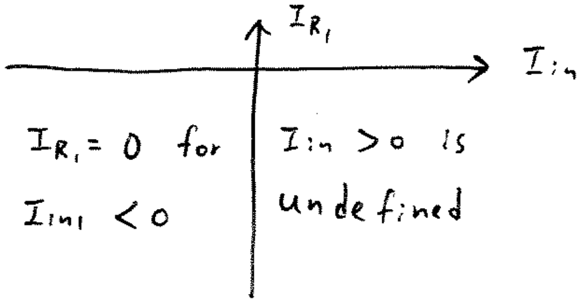
I_{R_1}
I_{in}
$I_{R_1} < 0$ is undefined
$I_{R_1} = 0$ for $I_{in} > 0$.

c)



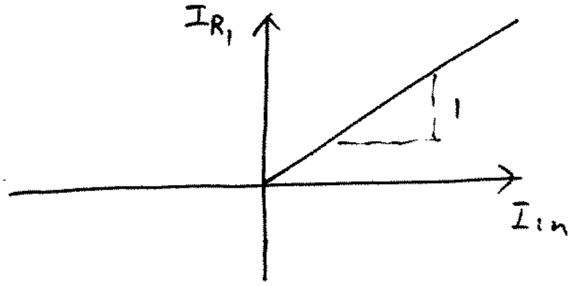
I_{R_1}
I_{in}
1

d)



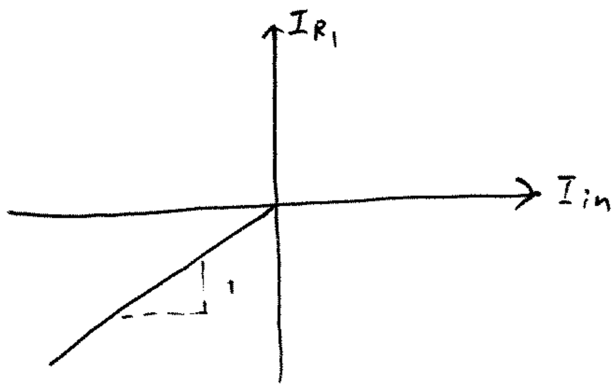
I_{R_1}
I_{in}
$I_{R_1} = 0$ for $I_{in} < 0$
$I_{in} > 0$ is undefined

e)



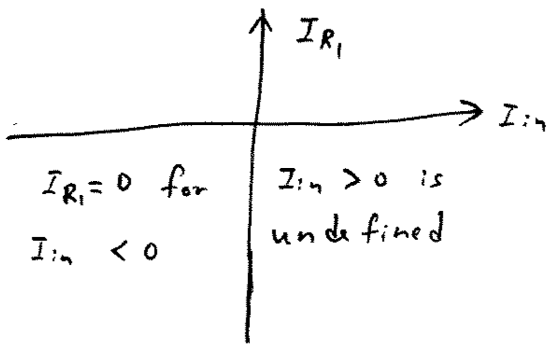
I_{R_1}
1
I_{in}

f)



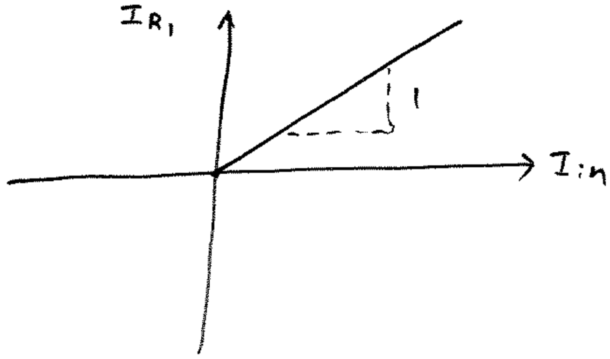
I_{R_1}
I_{in}
1

g)



I_{R_1}
I_{in}
$I_{R_1} = 0$ for $I_{in} < 0$
$I_{in} > 0$ is undefined

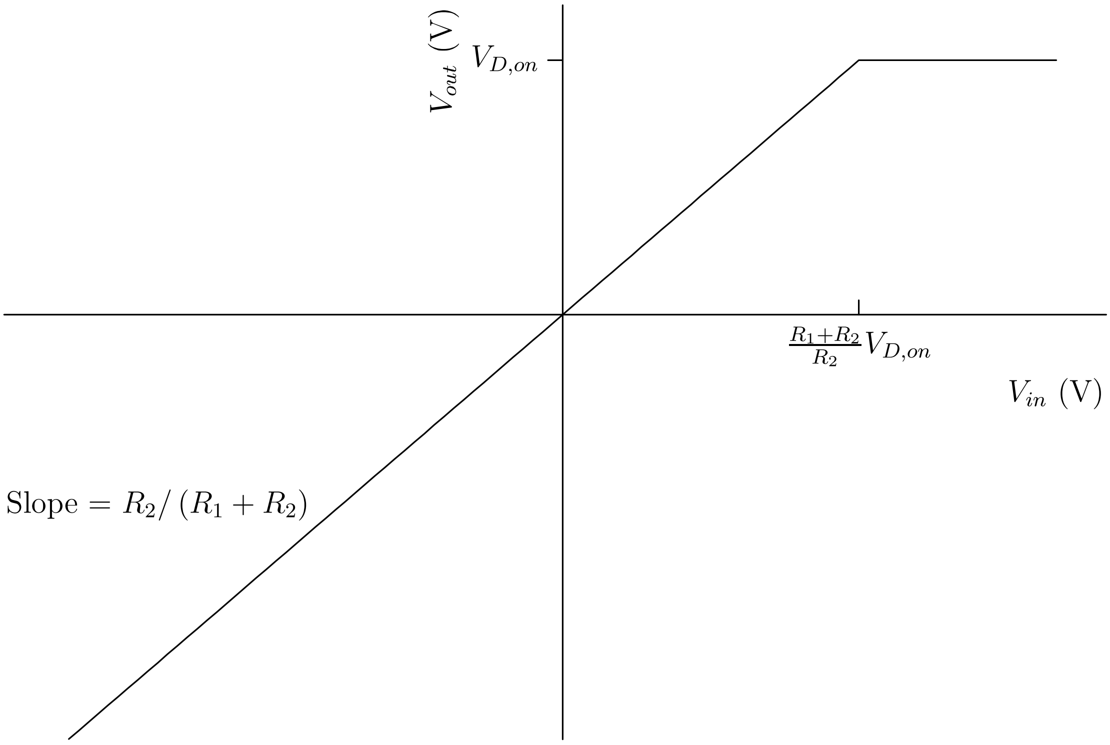
h)



I_{R_1}
1
I_{in}

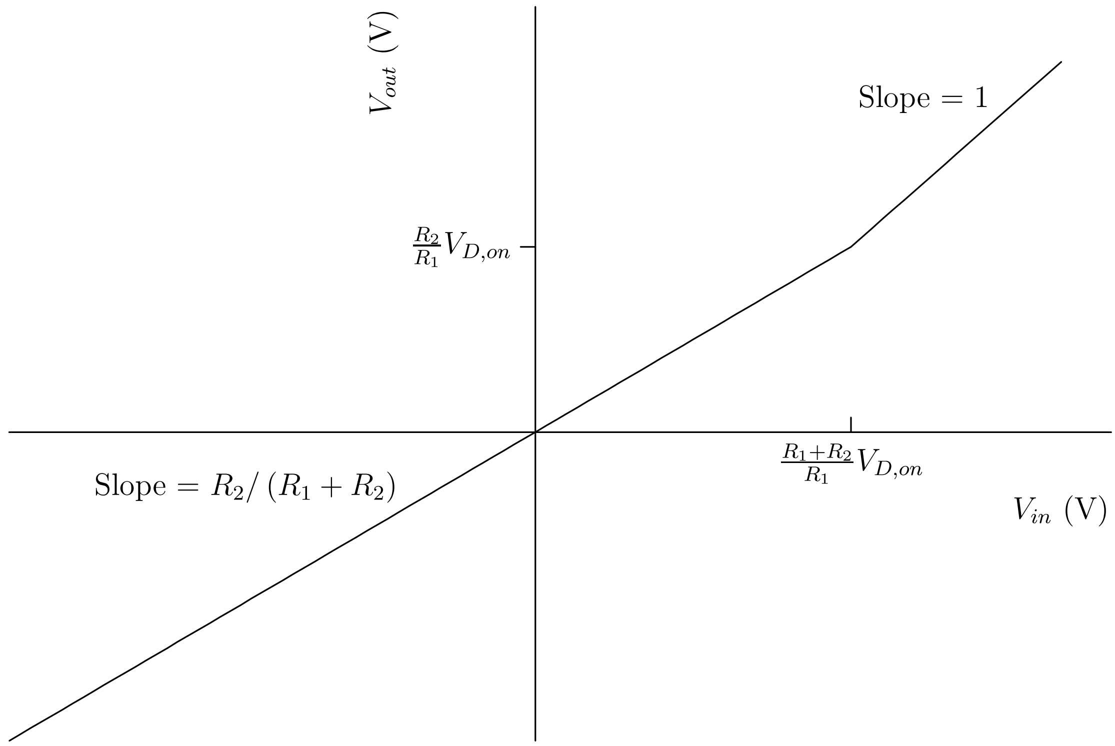
3.23 (a)

$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2} V_{in} & V_{in} < \frac{R_1+R_2}{R_2} V_{D,on} \\ V_{D,on} & V_{in} > \frac{R_1+R_2}{R_2} V_{D,on} \end{cases}$$



(b)

$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2} V_{in} & V_{in} < \frac{R_1+R_2}{R_1} V_{D,on} \\ V_{in} - V_{D,on} & V_{in} > \frac{R_1+R_2}{R_1} V_{D,on} \end{cases}$$

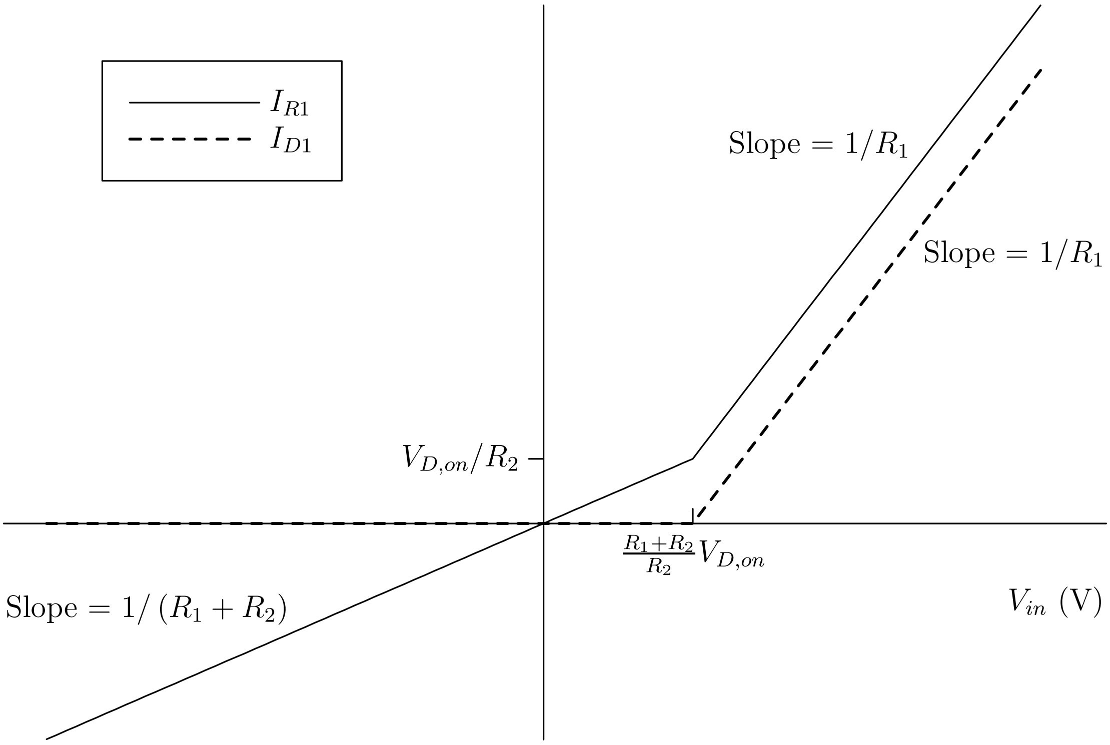


V_{out} (V)
Slope = 1
$\frac{R_2}{R_1}V_{D,on}$
Slope = $R_2/\left(R_1+R_2\right)$
$\frac{R_1+R_2}{R_1}V_{D,on}$
V_{in} (V)

3.24 (a)

$$I_{R1} = \begin{cases} \frac{V_{in}}{R_1+R_2} & V_{in} < \frac{R_1+R_2}{R_2} V_{D,on} \\ \frac{V_{in}-V_{D,on}}{R_1} & V_{in} > \frac{R_1+R_2}{R_2} V_{D,on} \end{cases}$$

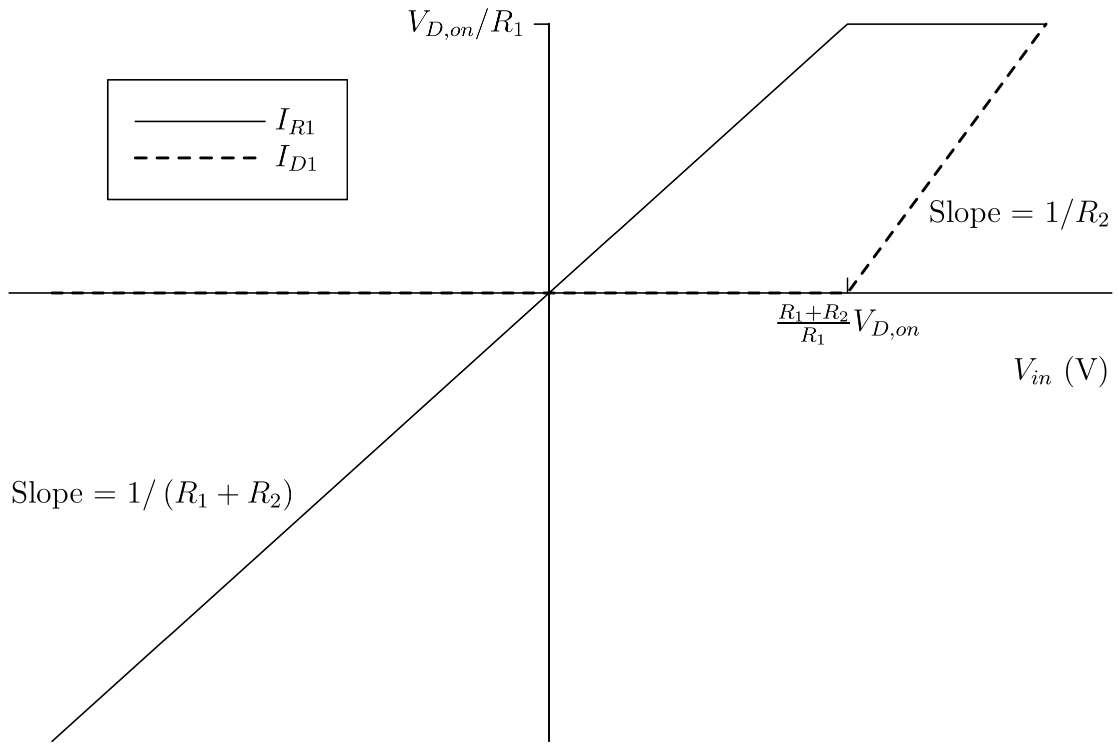
$$I_{D1} = \begin{cases} 0 & V_{in} < \frac{R_1+R_2}{R_2} V_{D,on} \\ \frac{V_{in}-V_{D,on}}{R_1} - \frac{V_{D,on}}{R_2} & V_{in} > \frac{R_1+R_2}{R_2} V_{D,on} \end{cases}$$



(b)

$$I_{R1} = \begin{cases} \frac{V_{in}}{R_1+R_2} & V_{in} < \frac{R_1+R_2}{R_1} V_{D,on} \\ \frac{V_{D,on}}{R_1} & V_{in} > \frac{R_1+R_2}{R_1} V_{D,on} \end{cases}$$

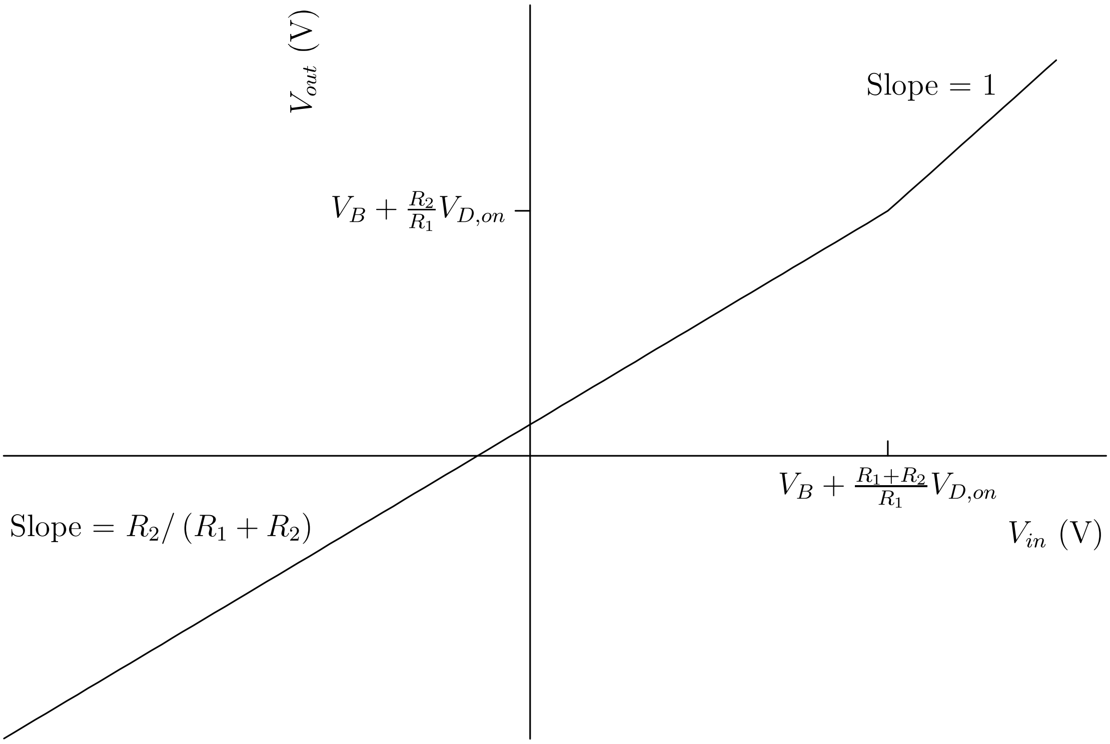
$$I_{D1} = \begin{cases} 0 & V_{in} < \frac{R_1+R_2}{R_1} V_{D,on} \\ \frac{V_{in}-V_{D,on}}{R_2} - \frac{V_{D,on}}{R_1} & V_{in} > \frac{R_1+R_2}{R_1} V_{D,on} \end{cases}$$



$V_{D,on}/R_1$
I_{R1}
I_{D1}
Slope = $1/R_2$
$\frac{R_1+R_2}{R_1}V_{D,on}$
V_{in} (V)
Slope = $1/(R_1+R_2)$

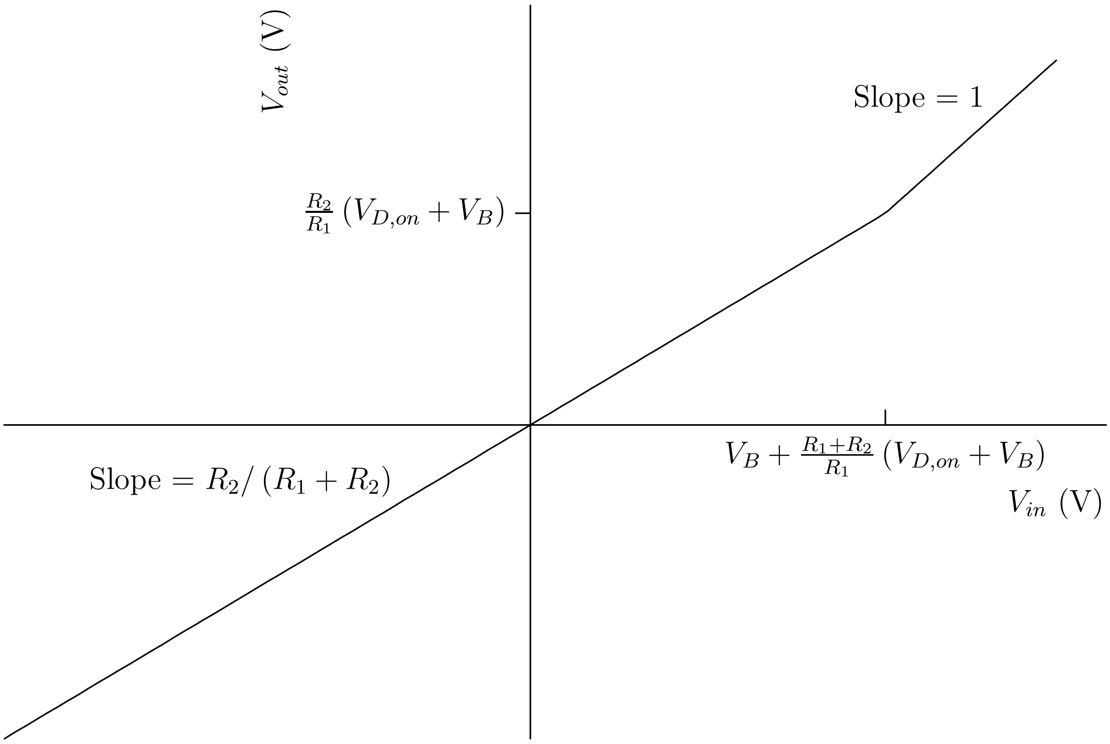
3.25 (a)

$$V_{out} = \begin{cases} V_B + \frac{R_2}{R_1+R_2}\left(V_{in} - V_B\right) & V_{in} < V_B + \frac{R_1+R_2}{R_1}V_{D,on} \\ V_{in} - V_{D,on} & V_{in} > V_B + \frac{R_1+R_2}{R_1}V_{D,on} \end{cases}$$



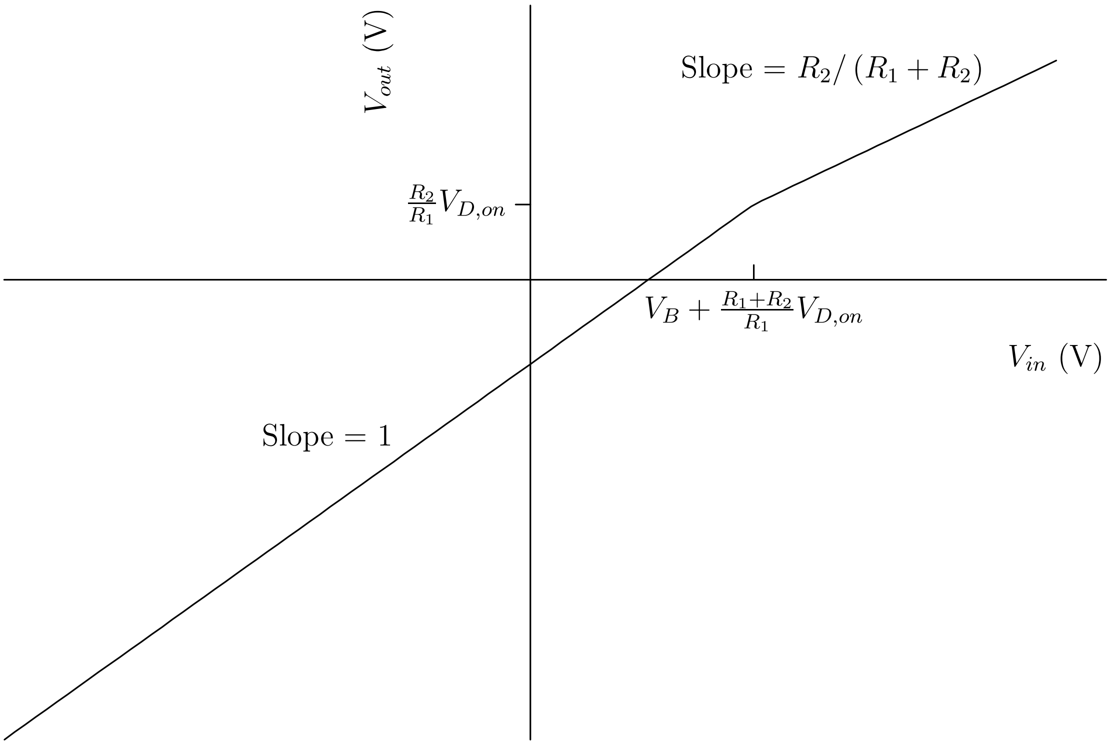
(b)

$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2}V_{in} & V_{in} < \frac{R_1+R_2}{R_1}\left(V_{D,on} + V_B\right) \\ V_{in} - V_{D,on} - V_B & V_{in} > \frac{R_1+R_2}{R_1}\left(V_{D,on} + V_B\right) \end{cases}$$



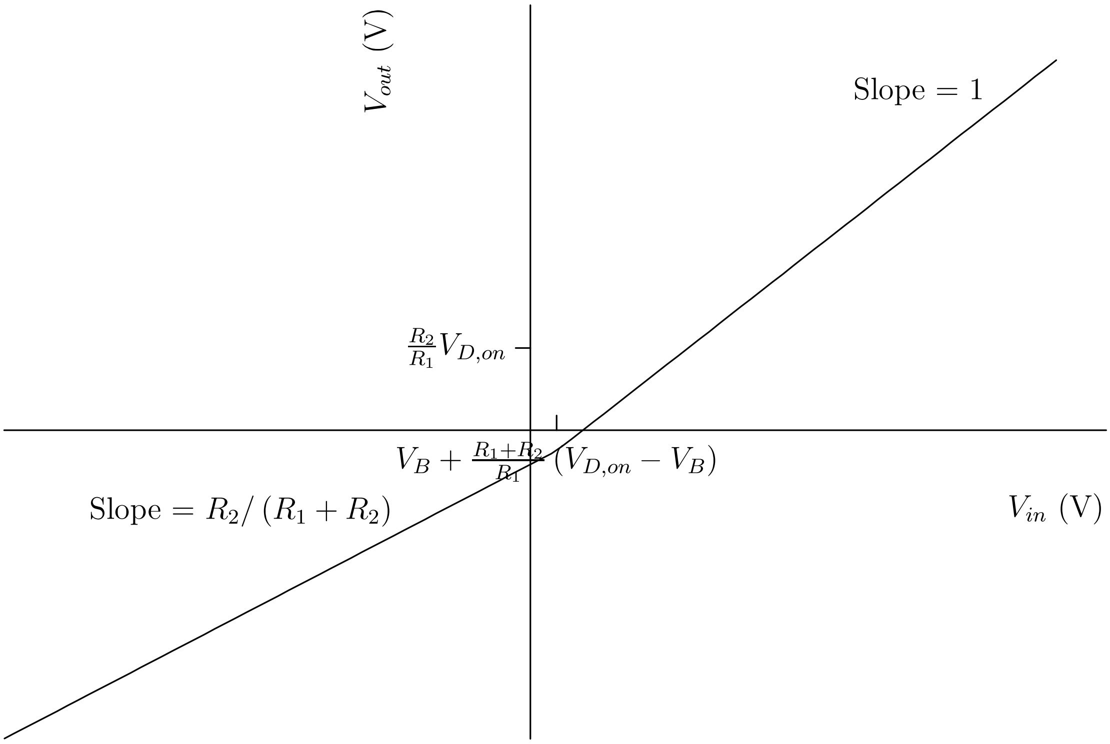
(c)

$$V_{out}=\begin{cases}\frac{R_2}{R_1+R_2}\left(V_{in}-V_B\right) & V_{in}>V_B+\frac{R_1+R_2}{R_1}V_{D,on}\\ V_{in}+V_{D,on}-V_B & V_{in}<V_B+\frac{R_1+R_2}{R_1}V_{D,on}\end{cases}$$



(d)

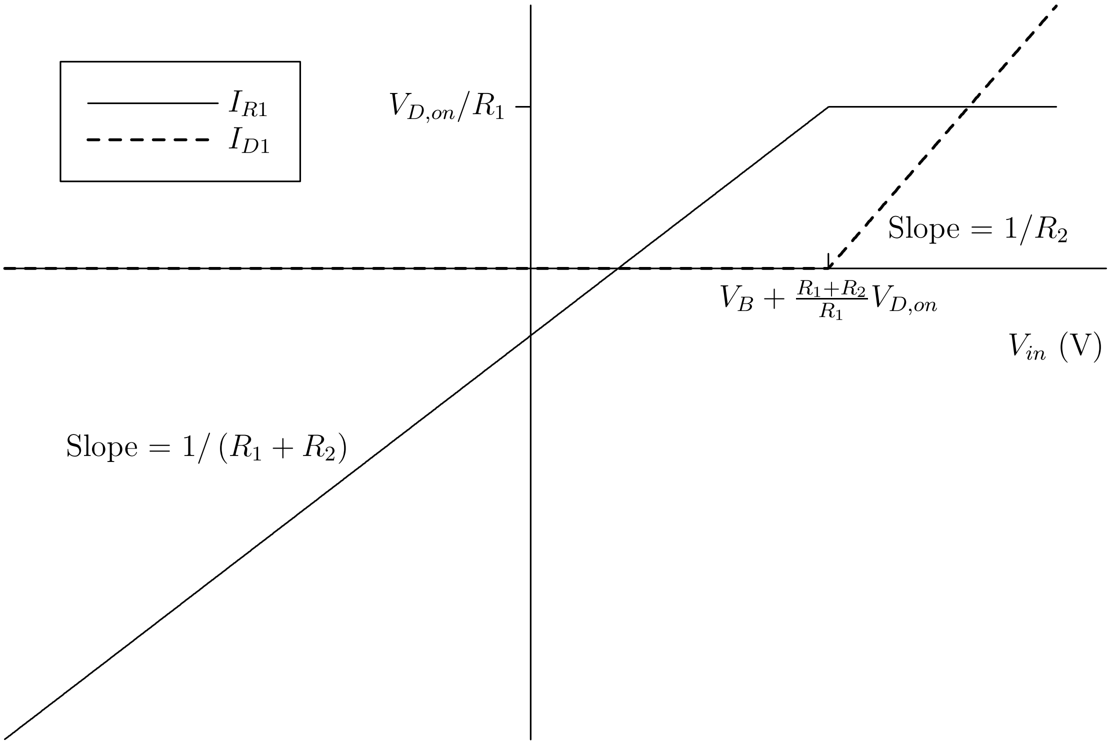
$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2}\left(V_{in} - V_B\right) & V_{in} < V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on} - V_B\right) \\ V_{in} - V_{D,on} & V_{in} > V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on} - V_B\right) \end{cases}$$



3.26 (a)

$$I_{R1} = \begin{cases} \frac{V_{in}-V_B}{R_1+R_2} & V_{in} < V_B + \frac{R_1+R_2}{R_1} V_{D,on} \\ \frac{V_{D,on}}{R_1} & V_{in} > V_B + \frac{R_1+R_2}{R_1} V_{D,on} \end{cases}$$

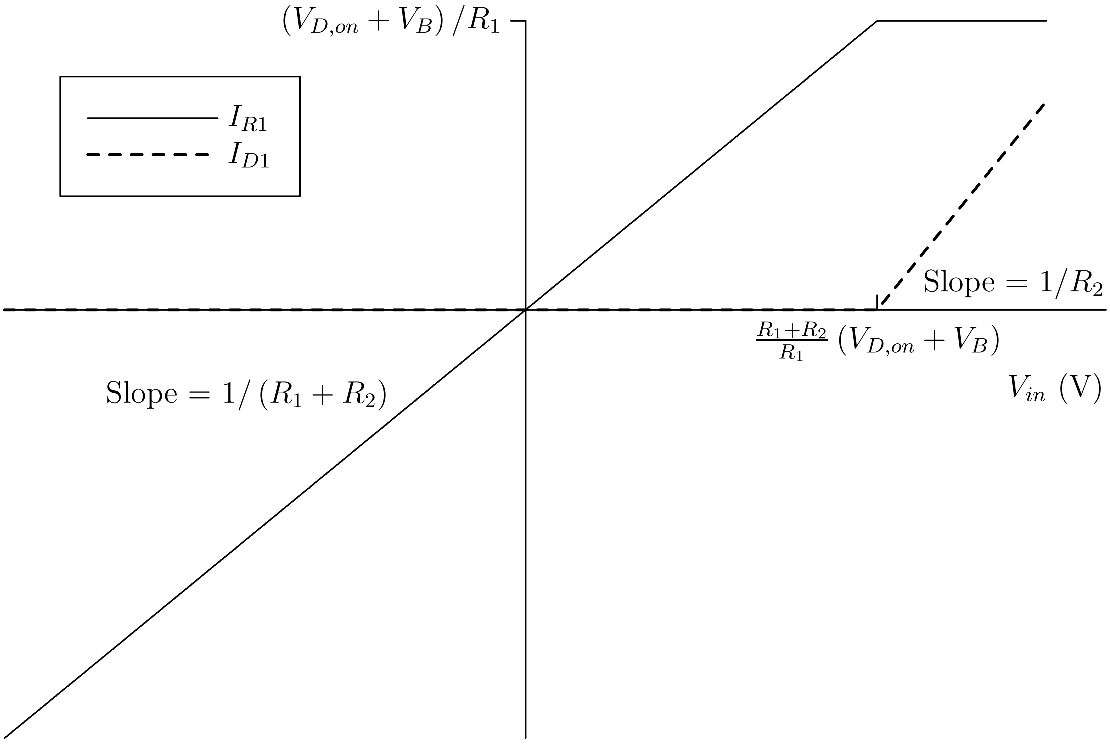
$$I_{D1} = \begin{cases} 0 & V_{in} < V_B + \frac{R_1+R_2}{R_1} V_{D,on} \\ \frac{V_{in}-V_{D,on}-V_B}{R_2} - \frac{V_{D,on}}{R_1} & V_{in} > V_B + \frac{R_1+R_2}{R_1} V_{D,on} \end{cases}$$



(b)

$$I_{R1} = \begin{cases} \frac{V_{in}}{R_1+R_2} & V_{in} < \frac{R_1+R_2}{R_1} (V_{D,on} + V_B) \\ \frac{V_{D,on}+V_B}{R_1} & V_{in} > \frac{R_1+R_2}{R_1} (V_{D,on} + V_B) \end{cases}$$

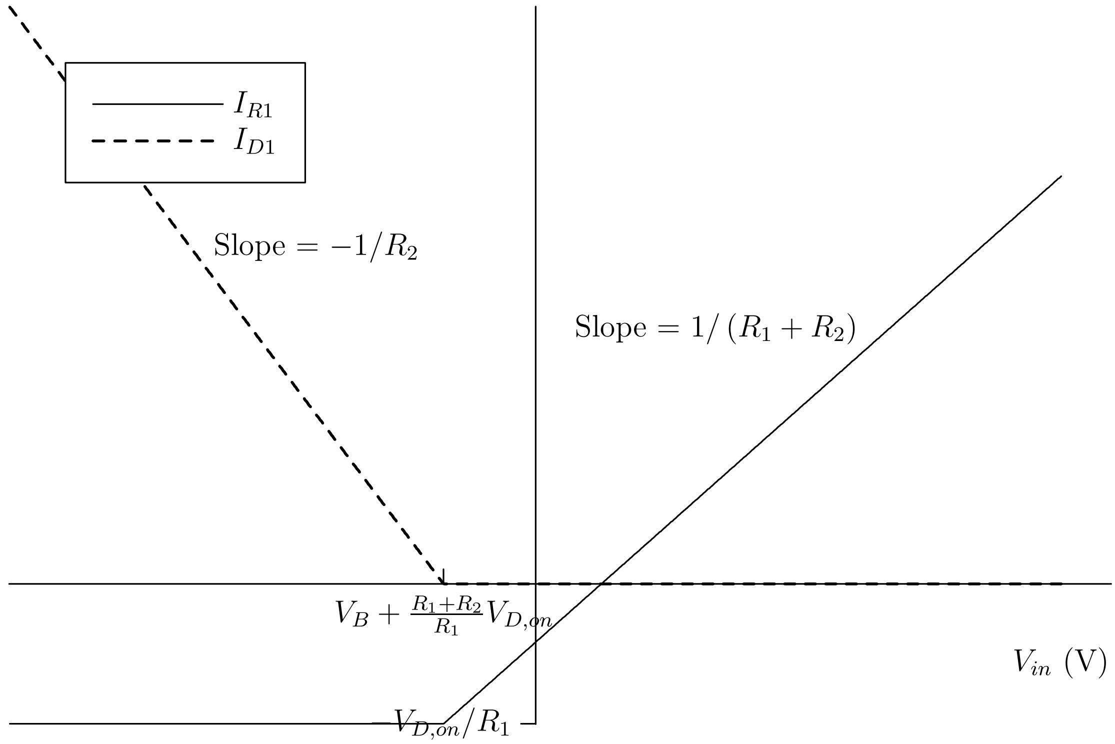
$$I_{D1} = \begin{cases} 0 & V_{in} < \frac{R_1+R_2}{R_1} (V_{D,on} + V_B) \\ \frac{V_{in}-V_{D,on}-V_B}{R_2} - \frac{V_{D,on}+V_B}{R_1} & V_{in} > \frac{R_1+R_2}{R_1} (V_{D,on} + V_B) \end{cases}$$



(c)

$$I_{R1}=\begin{cases}\frac{V_{in}-V_B}{R_1+R_2} & V_{in}>V_B-\frac{R_1+R_2}{R_1}V_{D,on}\\ -\frac{V_{D,on}}{R_1} & V_{in}<V_B-\frac{R_1+R_2}{R_1}V_{D,on}\end{cases}$$

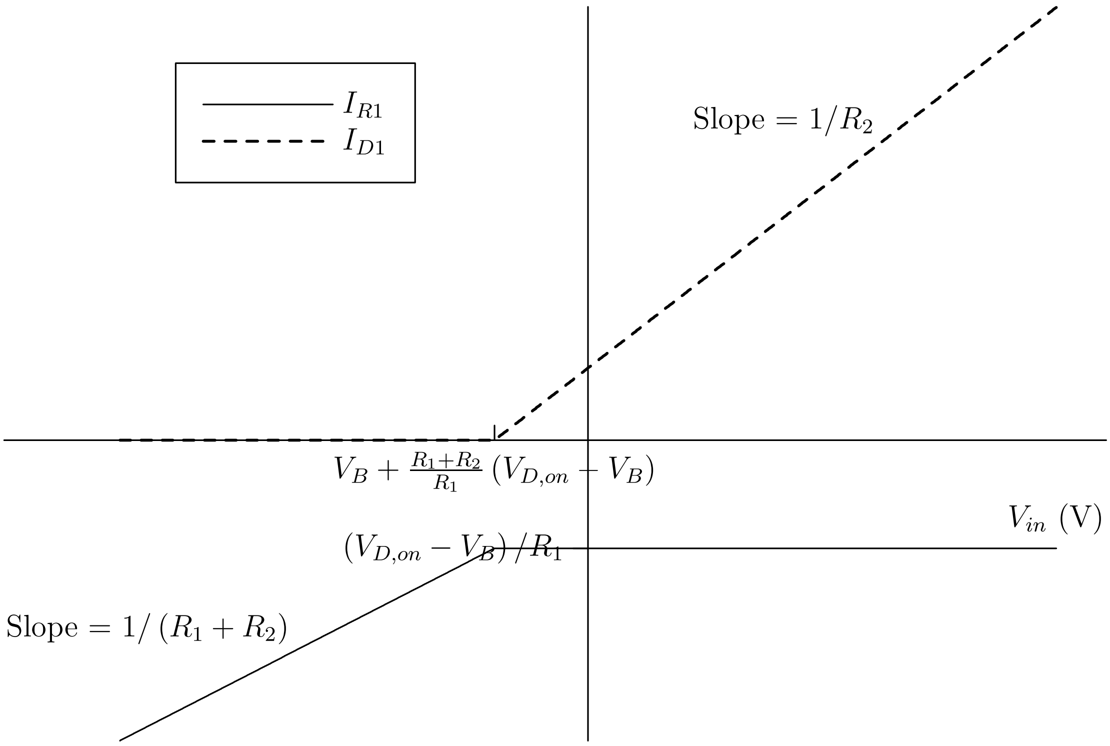
$$I_{D1}=\begin{cases}0 & V_{in}>V_B-\frac{R_1+R_2}{R_1}V_{D,on}\\ -\frac{V_{in}+V_{D,on}+V_B}{R_2}-\frac{V_{D,on}}{R_1} & V_{in}<V_B-\frac{R_1+R_2}{R_1}V_{D,on}\end{cases}$$



(d)

$$I_{R1} = \begin{cases} \frac{V_{in}-V_B}{R_1+R_2} & V_{in} < V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on}-V_B\right) \\ \frac{V_{D,on}-V_B}{R_1} & V_{in} > V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on}-V_B\right) \end{cases}$$

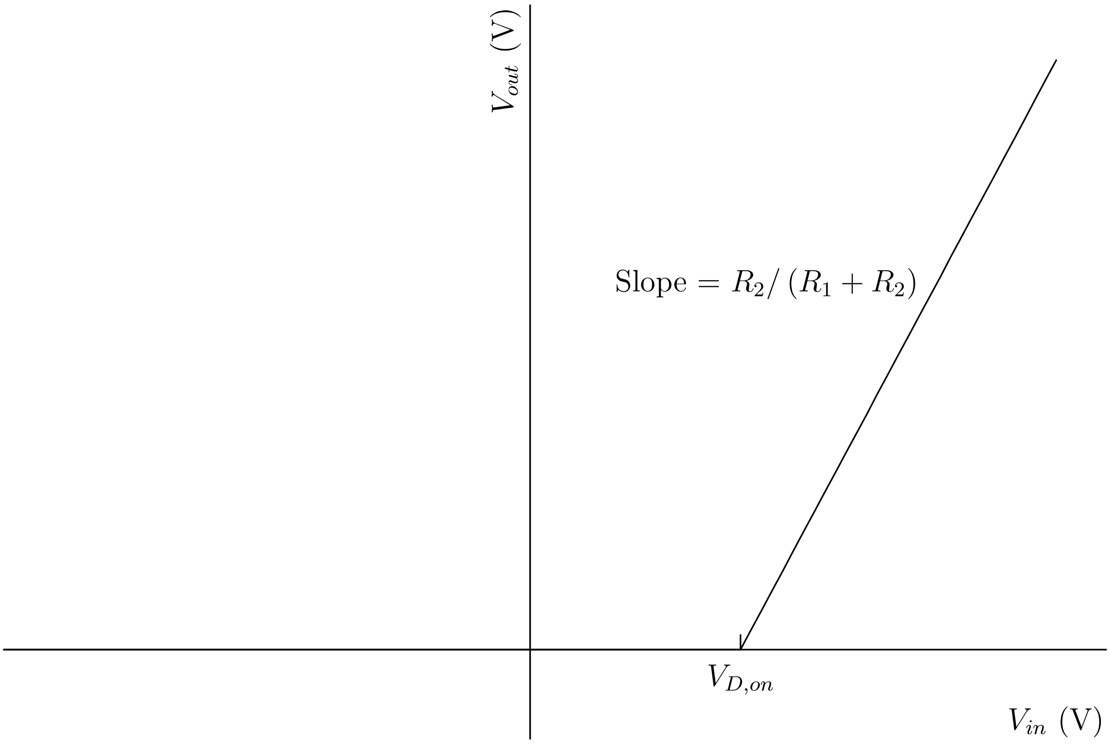
$$I_{D1} = \begin{cases} 0 & V_{in} < V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on}-V_B\right) \\ \frac{V_{in}-V_{D,on}}{R_2} - \frac{V_{D,on}-V_B}{R_1} & V_{in} > V_B + \frac{R_1+R_2}{R_1}\left(V_{D,on}-V_B\right) \end{cases}$$



I_{R1}
I_{D1}
Slope $= 1/R_2$
$V_B + \frac{R_1+R_2}{R_1}(V_{D,on} - V_B)$
V_{in} (V)
$(V_{D,on} - V_B)/R_1$
Slope $= 1/(R_1 + R_2)$

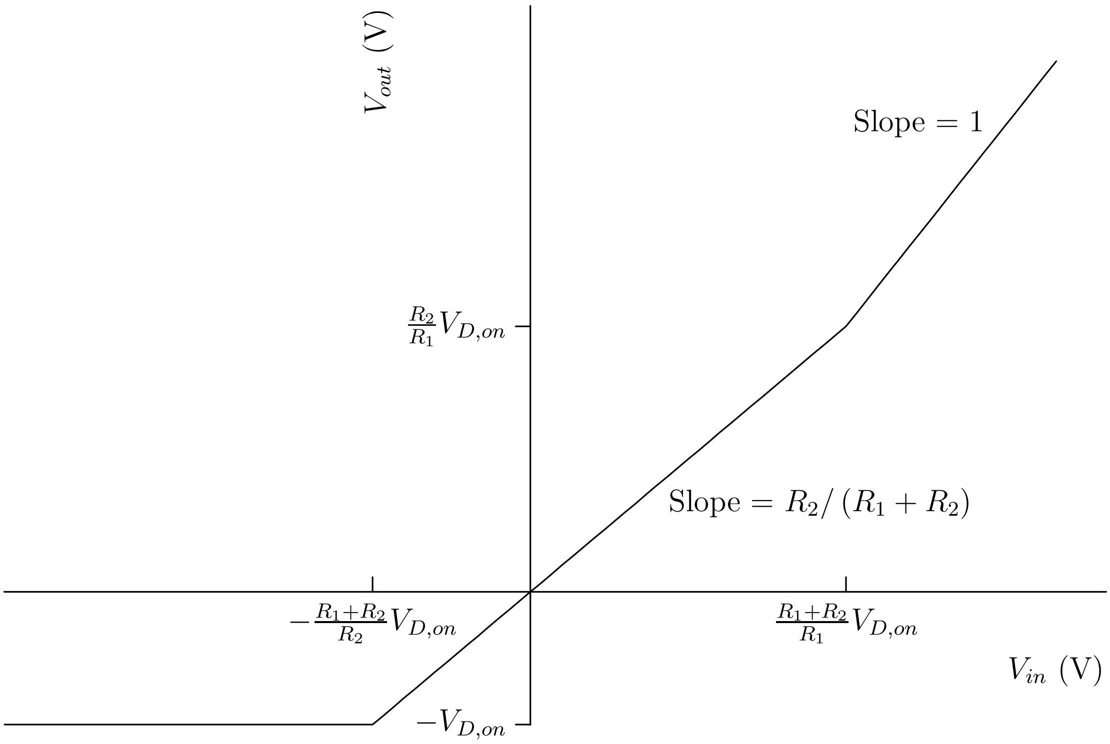
3.27 (a)

$$V_{out} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{R_2}{R_1+R_2}\left(V_{in} - V_{D,on}\right) & V_{in} > V_{D,on} \end{cases}$$



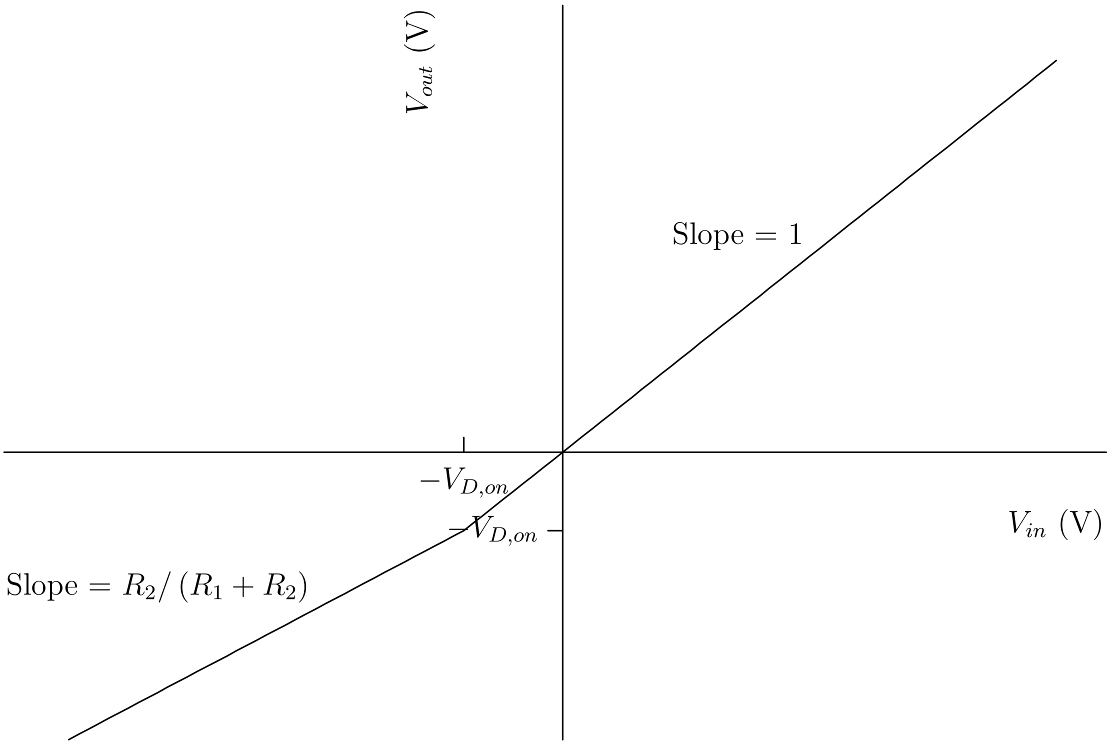
(b)

$$V_{out} = \begin{cases} -V_{D,on} & V_{in} < -\frac{R_1+R_2}{R_2}V_{D,on} \\ \frac{R_2}{R_1+R_2}V_{in} & -\frac{R_1+R_2}{R_2}V_{D,on} < V_{in} < \frac{R_1+R_2}{R_1}V_{D,on} \\ V_{in} - V_{D,on} & V_{in} > \frac{R_1+R_2}{R_1}V_{D,on} \end{cases}$$



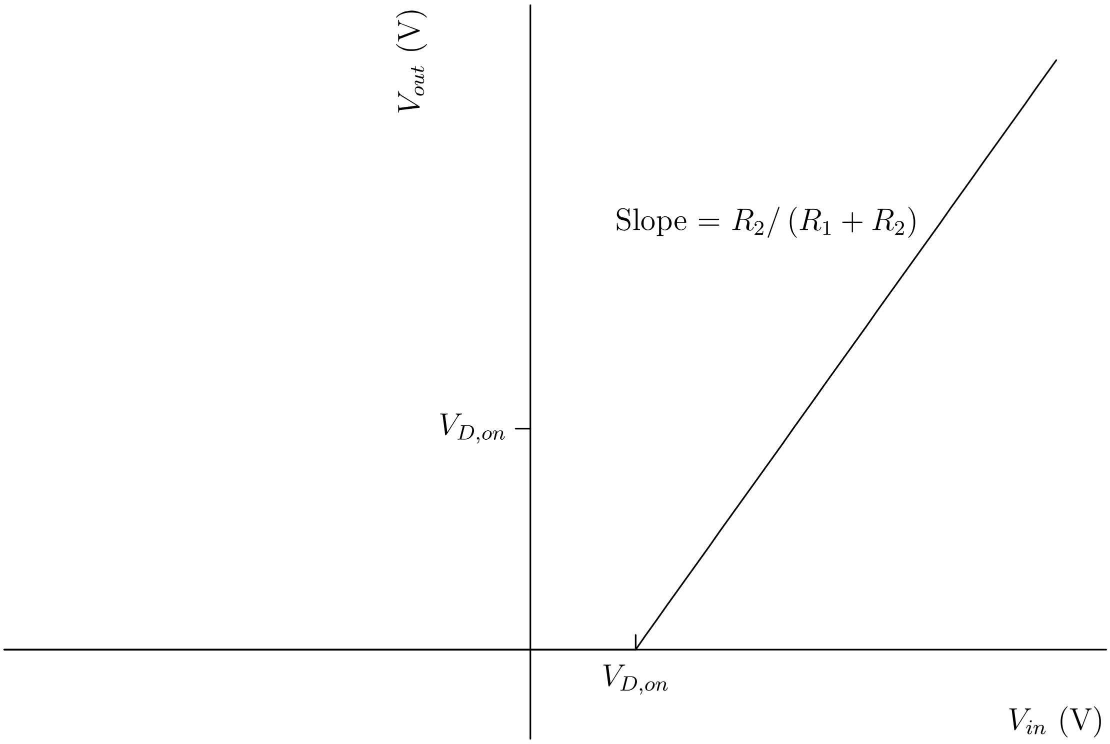
(c)

$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2}\left(V_{in}+V_{D,on}\right)-V_{D,on} & V_{in} < -V_{D,on} \\ V_{in} & V_{in} > -V_{D,on} \end{cases}$$



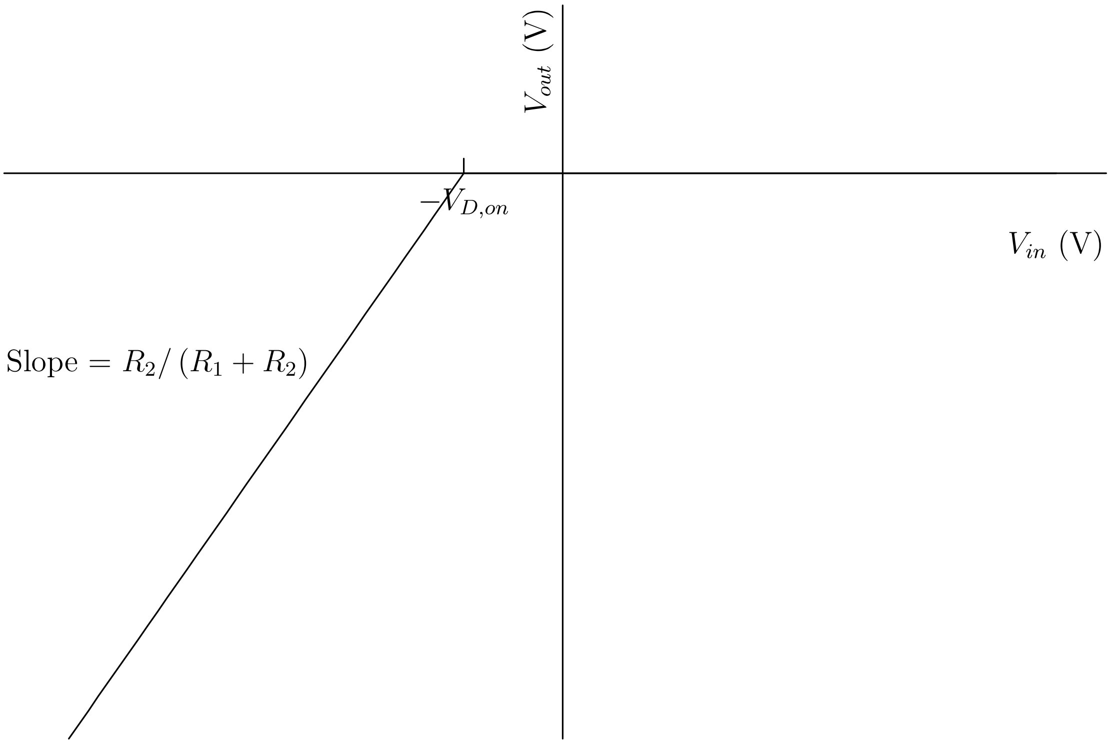
(d)

$$V_{out} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{R_2}{R_1+R_2}\left(V_{in} - V_{D,on}\right) & V_{in} > V_{D,on} \end{cases}$$



(e)

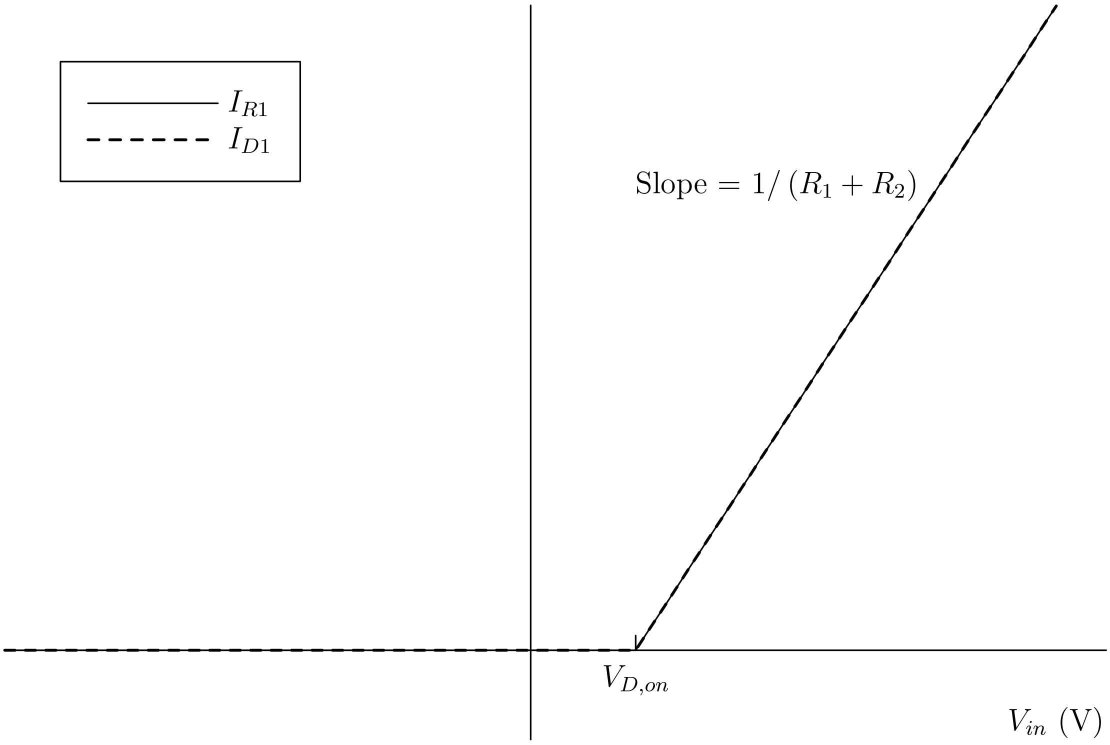
$$V_{out} = \begin{cases} \frac{R_2}{R_1+R_2}\left(V_{in} + V_{D,on}\right) & V_{in} < -V_{D,on} \\ 0 & V_{in} > -V_{D,on} \end{cases}$$


V_{out} (V)
$-V_{D,on}$
V_{in} (V)
Slope $= R_2/(R_1+R_2)$

3.28 (a)

$$I_{R1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{in} > V_{D,on} \end{cases}$$

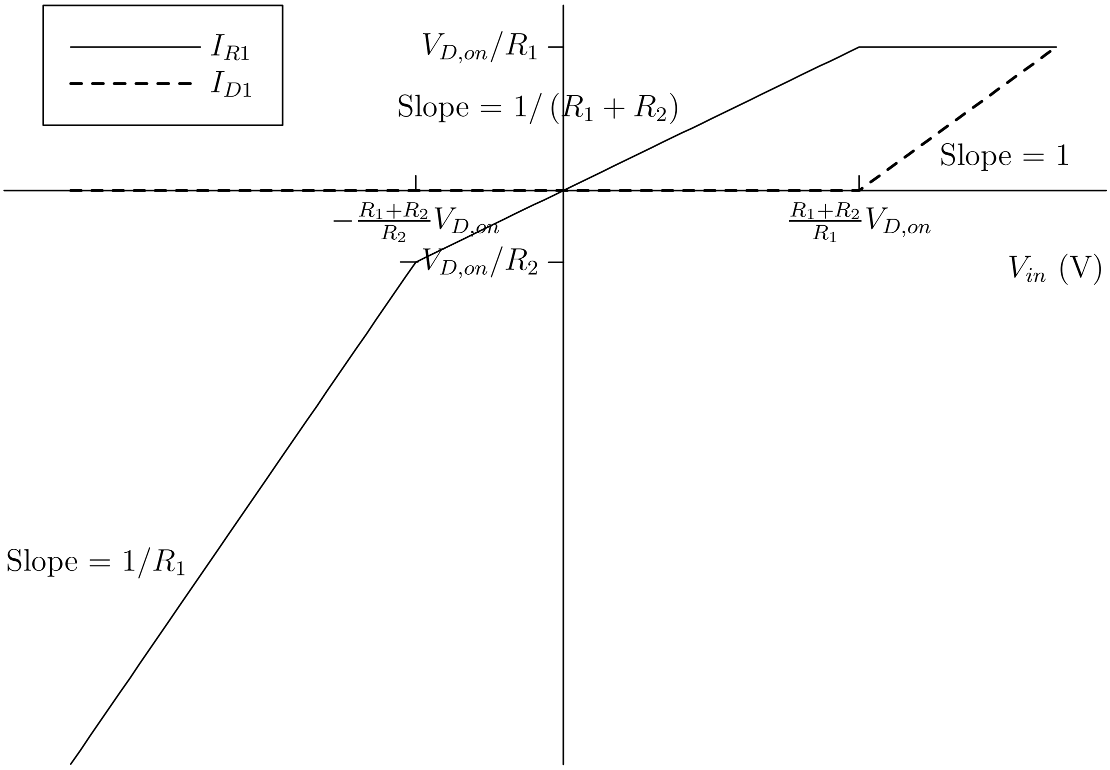
$$I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{in} > V_{D,on} \end{cases}$$



(b)

$$I_{R1} = \begin{cases} \frac{V_{in} + V_{D,on}}{R_1} & V_{in} < -\frac{R_1 + R_2}{R_2} V_{D,on} \\ \frac{V_{in}}{R_1 + R_2} & -\frac{R_1 + R_2}{R_2} V_{D,on} < V_{in} < \frac{R_1 + R_2}{R_1} V_{D,on} \\ \frac{V_{D,on}}{R_1} & V_{in} > \frac{R_1 + R_2}{R_1} V_{D,on} \end{cases}$$

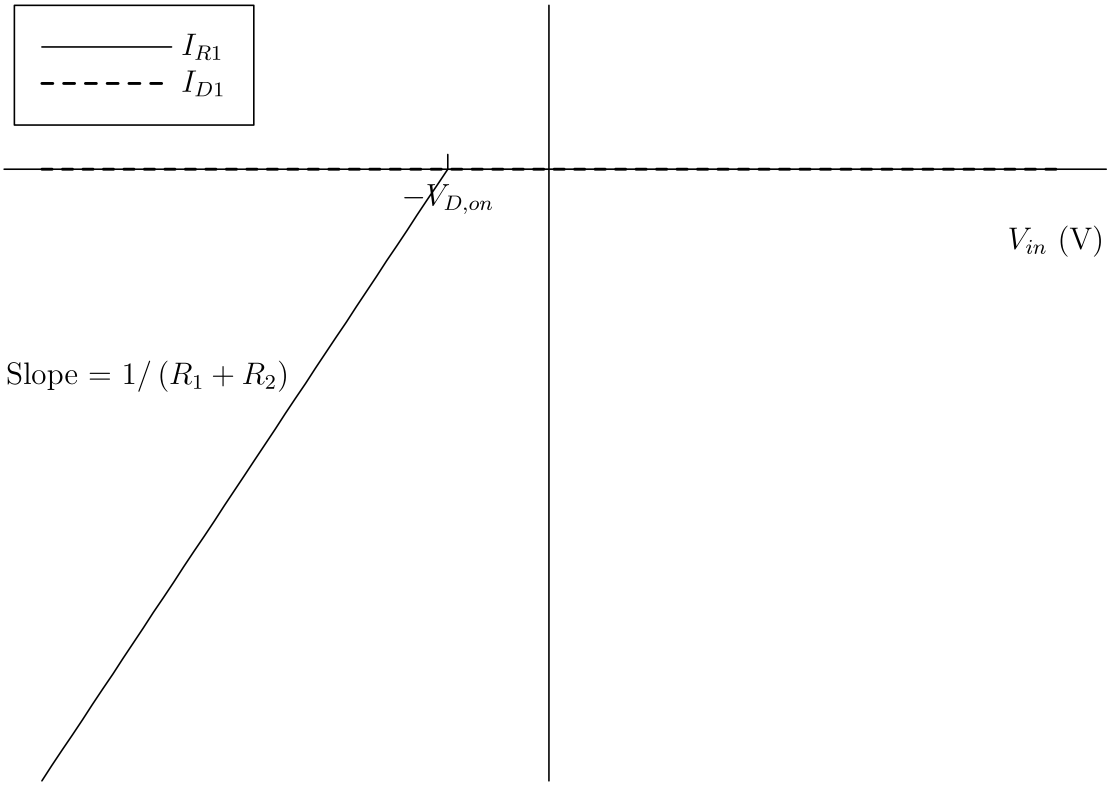
$$I_{D1} = \begin{cases} 0 & V_{in} < -\frac{R_1 + R_2}{R_2} V_{D,on} \\ 0 & -\frac{R_1 + R_2}{R_2} V_{D,on} < V_{in} < \frac{R_1 + R_2}{R_1} V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_2} - \frac{V_{D,on}}{R_1} & V_{in} > \frac{R_1 + R_2}{R_1} V_{D,on} \end{cases}$$



(c)

$$I_{R1} = \begin{cases} \frac{V_{in}+V_{D,on}}{R_1+R_2} & V_{in} < -V_{D,on} \\ 0 & V_{in} > -V_{D,on} \end{cases}$$

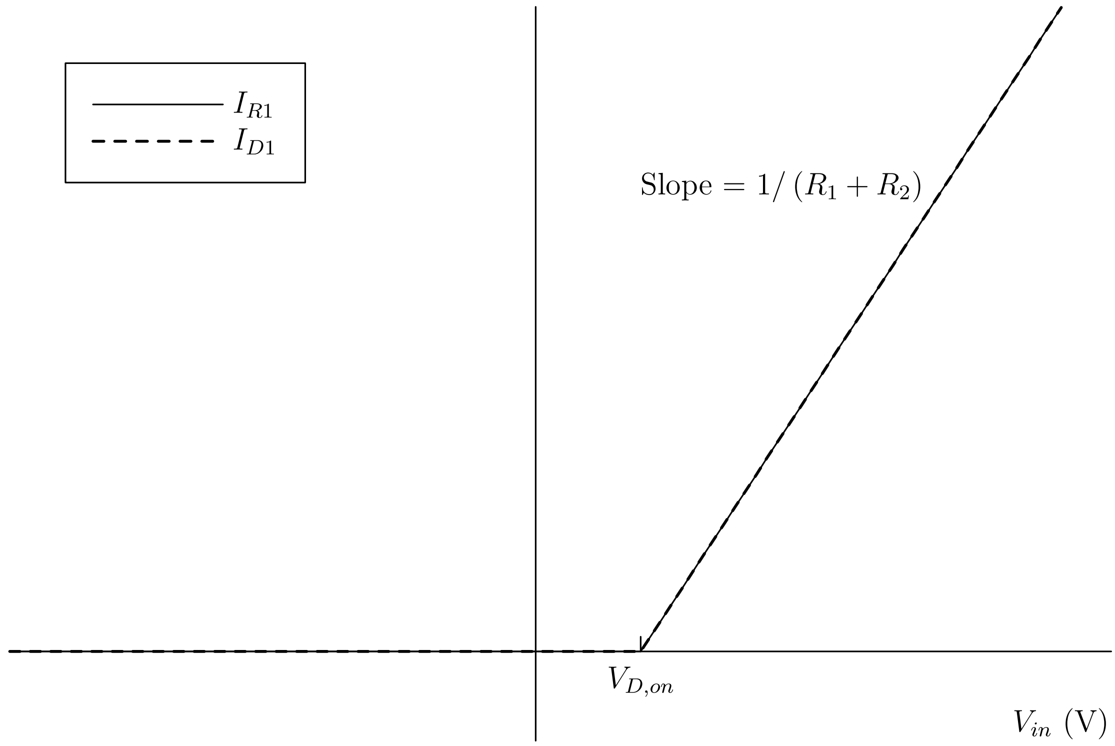
$$I_{D1} = \begin{cases} 0 & V_{in} < -V_{D,on} \\ 0 & V_{in} > -V_{D,on} \end{cases}$$



(d)

$$I_{R1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{in} > V_{D,on} \end{cases}$$

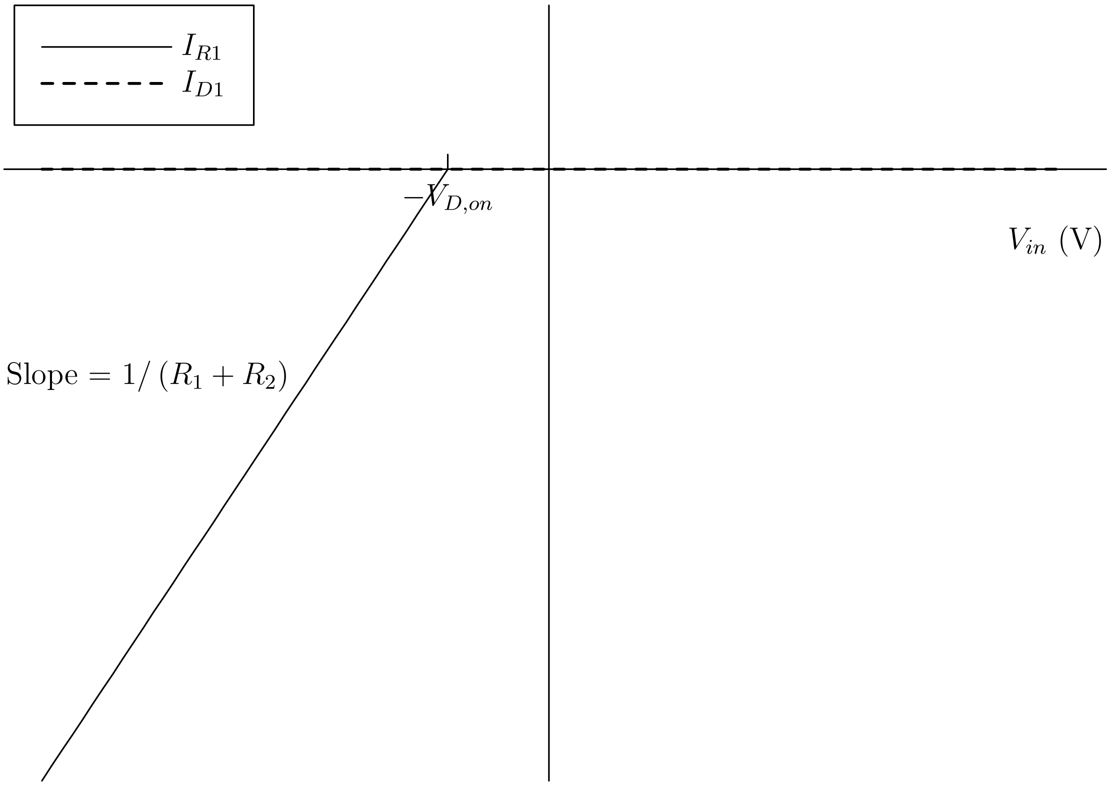
$$I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{in} > V_{D,on} \end{cases}$$



(e)

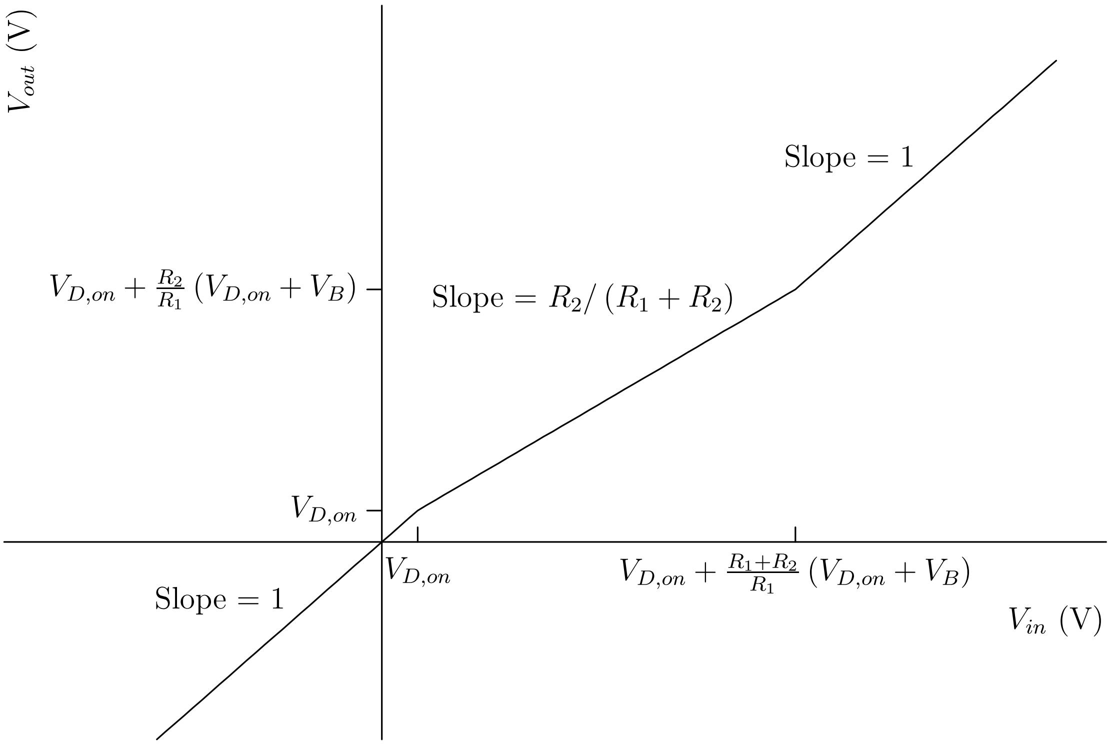
$$I_{R1} = \begin{cases} \frac{V_{in}+V_{D,on}}{R_1+R_2} & V_{in} < -V_{D,on} \\ 0 & V_{in} > -V_{D,on} \end{cases}$$

$$I_{D1} = \begin{cases} 0 & V_{in} < -V_{D,on} \\ 0 & V_{in} > -V_{D,on} \end{cases}$$


I_{R1}
I_{D1}
$-V_{D,on}$
V_{in} (V)
Slope $= 1/(R_1 + R_2)$

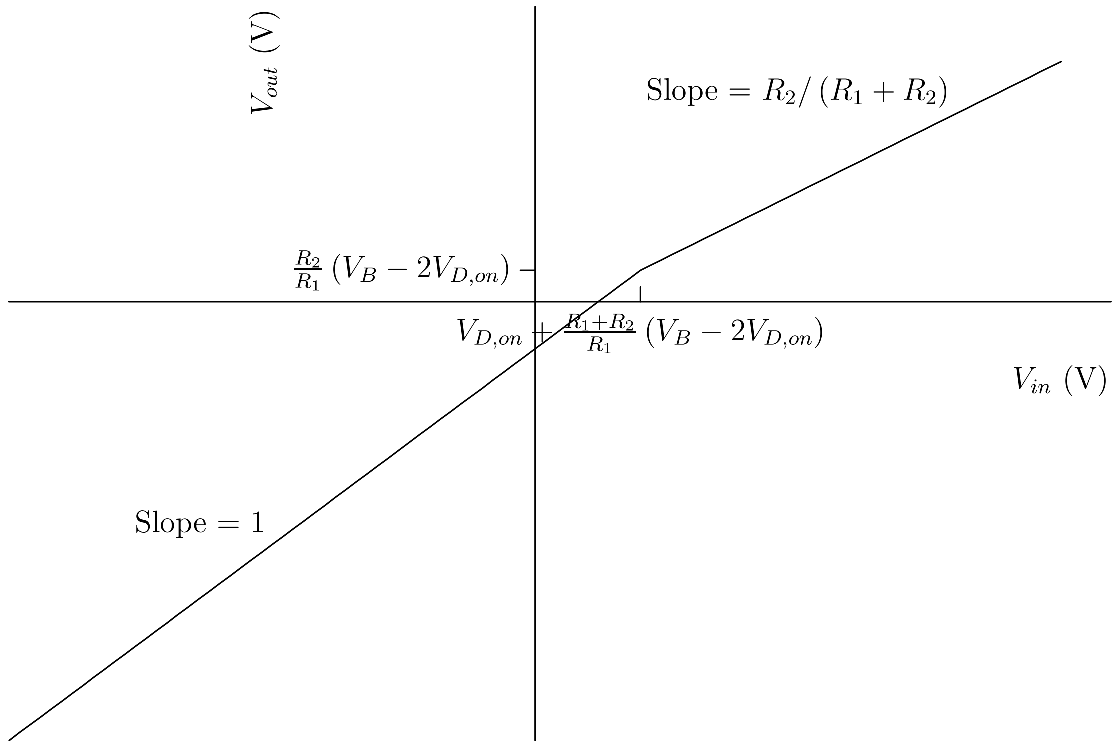
3.29 (a)

$$V_{out} = \begin{cases} V_{in} & V_{in} < V_{D,on} \\ V_{D,on} + \frac{R_2}{R_1+R_2}\left(V_{in} - V_{D,on}\right) & V_{D,on} < V_{in} < V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on} + V_B\right) \\ V_{in} - V_{D,on} - V_B & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on} + V_B\right) \end{cases}$$



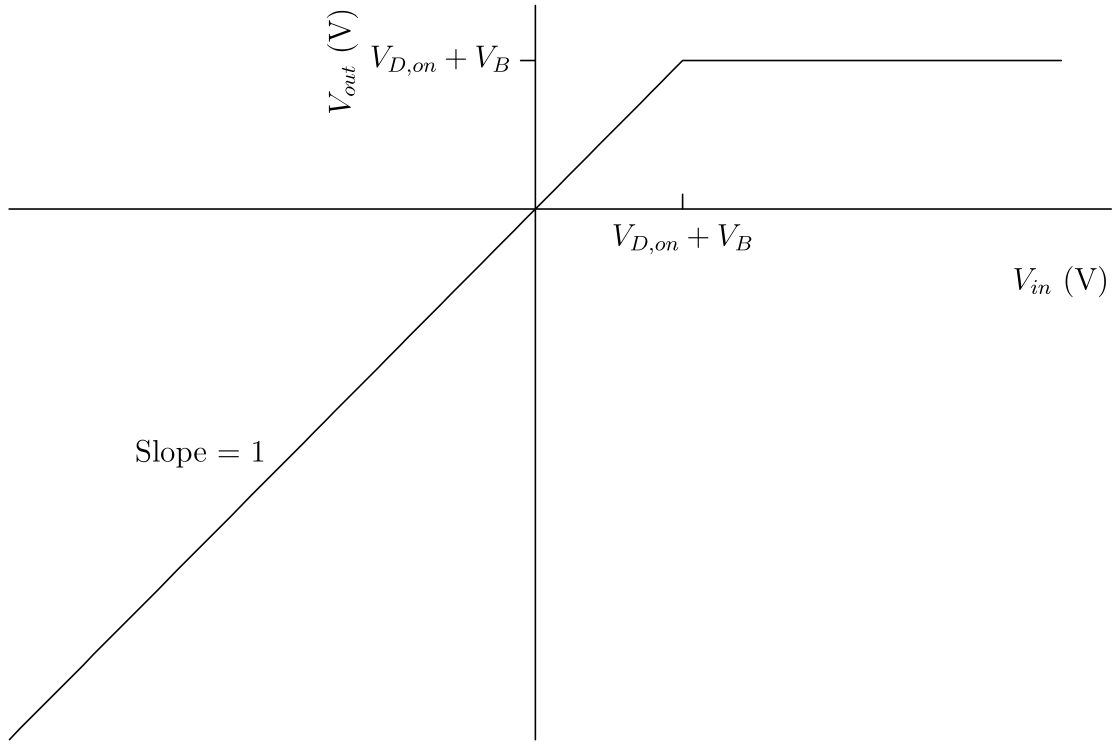
(b)

$$V_{out} = \begin{cases} V_{in} + V_{D,on} - V_B & V_{in} < V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_B - 2V_{D,on}\right) \\ \frac{R_2}{R_1+R_2}\left(V_{in} - V_{D,on}\right) & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_B - 2V_{D,on}\right) \end{cases}$$



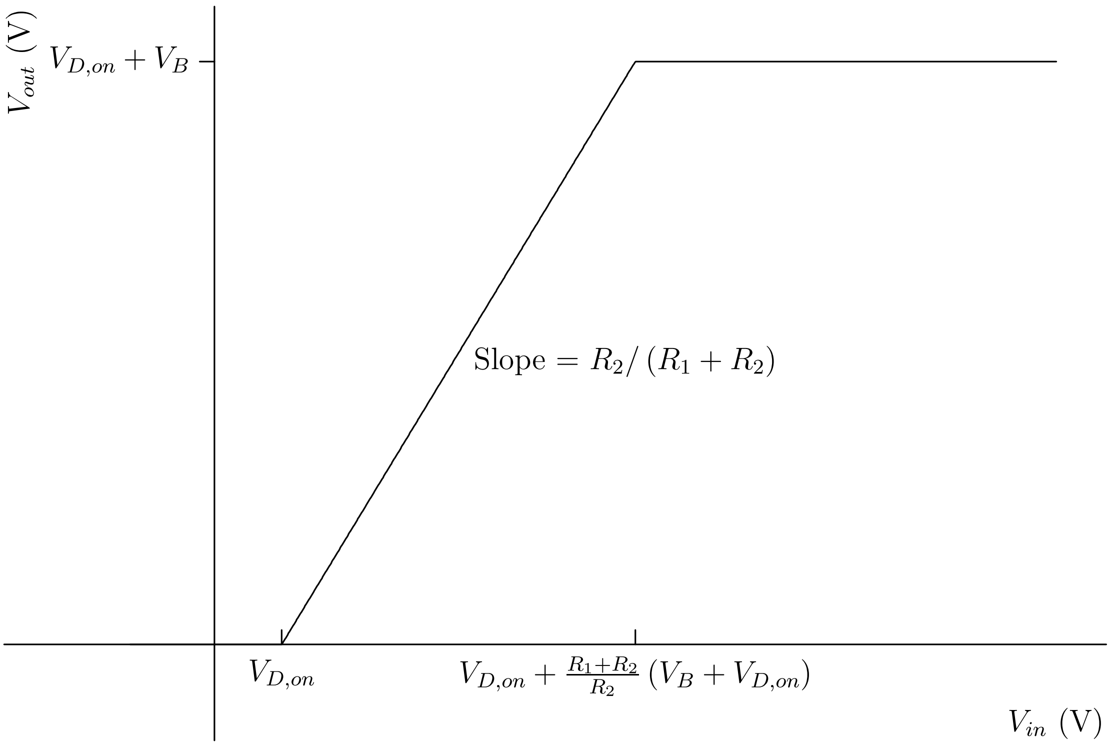
(c)

$$V_{out} = \begin{cases} V_{in} & V_{in} < V_{D,on} + V_B \\ V_{D,on} + V_B & V_{in} > V_{D,on} + V_B \end{cases}$$



(d)

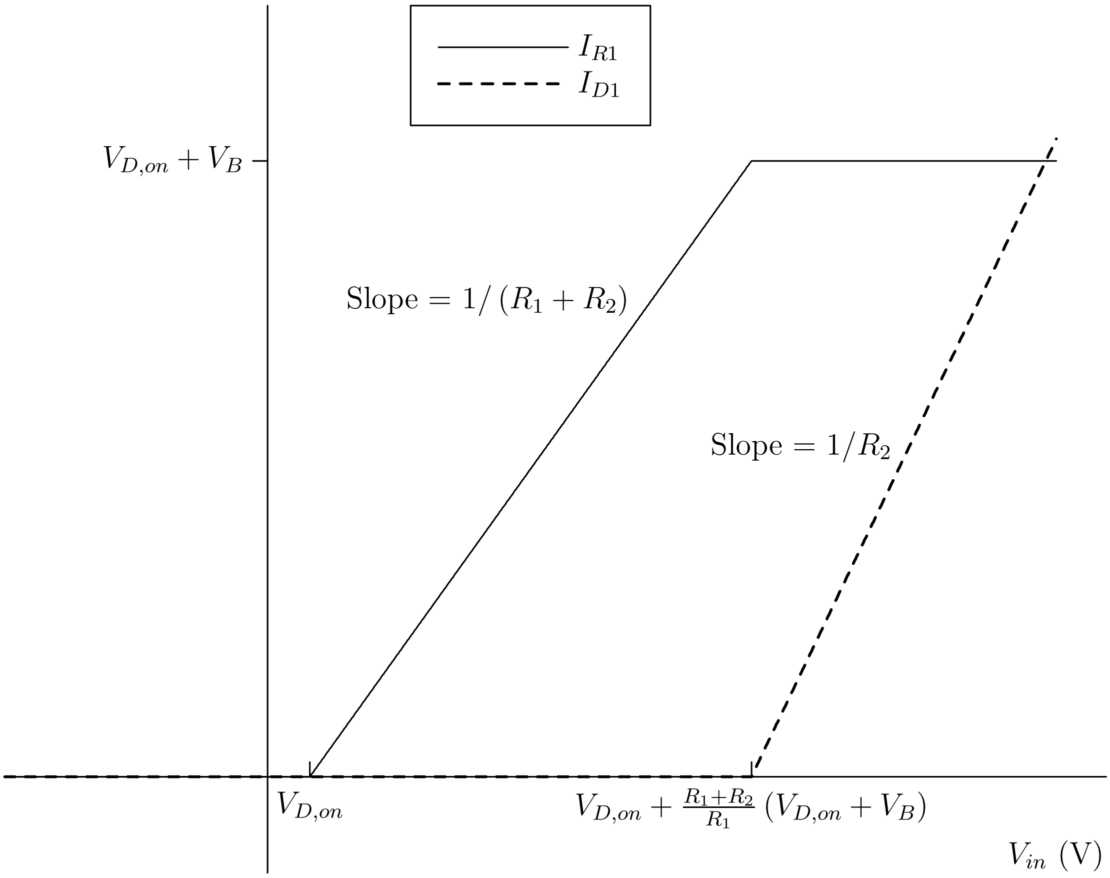
$$V_{out} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{R_2}{R_1+R_2}\left(V_{in} - V_{D,on}\right) & V_{D,on} < V_{in} < V_{D,on} + \frac{R_1+R_2}{R_2}\left(V_B + V_{D,on}\right) \\ V_{D,on} + V_B & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_2}\left(V_B + V_{D,on}\right) \end{cases}$$



3.30 (a)

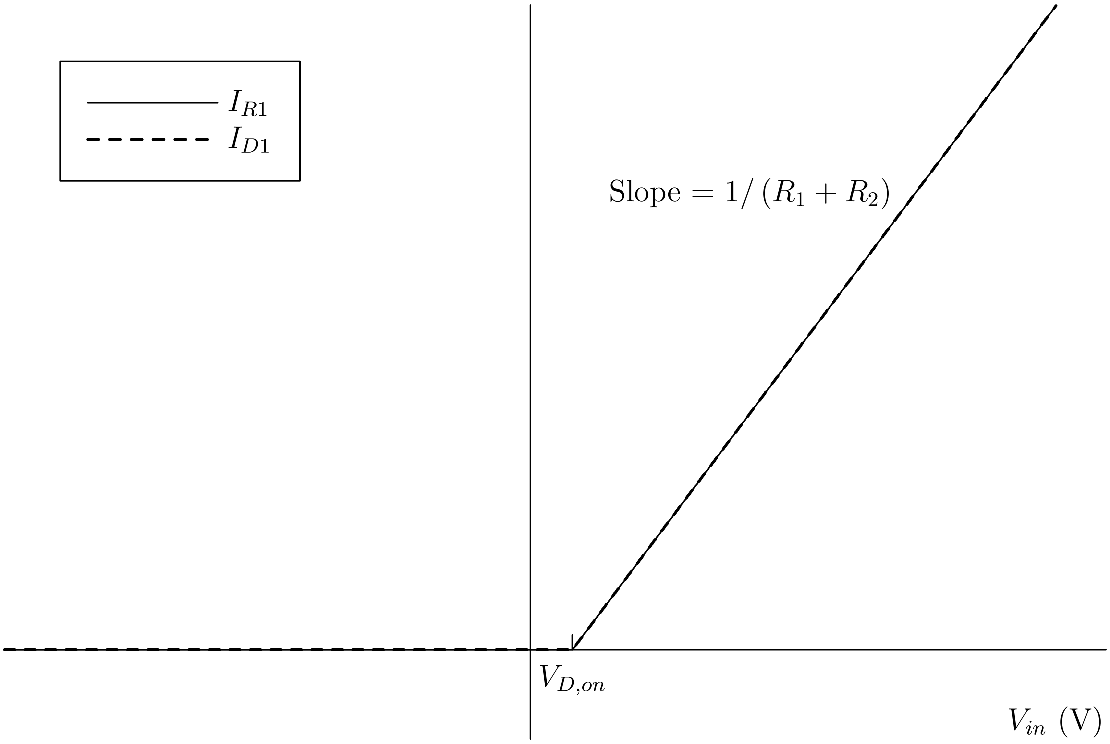
$$I_{R1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in}-V_{D,on}}{R_1+R_2} & V_{D,on} < V_{in} < V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on}+V_B\right) \\ \frac{V_{D,on}+V_B}{R_1} & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on}+V_B\right) \end{cases}$$

$$I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on}+V_B\right) \\ \frac{V_{in}-2V_{D,on}-V_B}{R_2} - \frac{V_{D,on}+V_B}{R_1} & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_{D,on}+V_B\right) \end{cases}$$



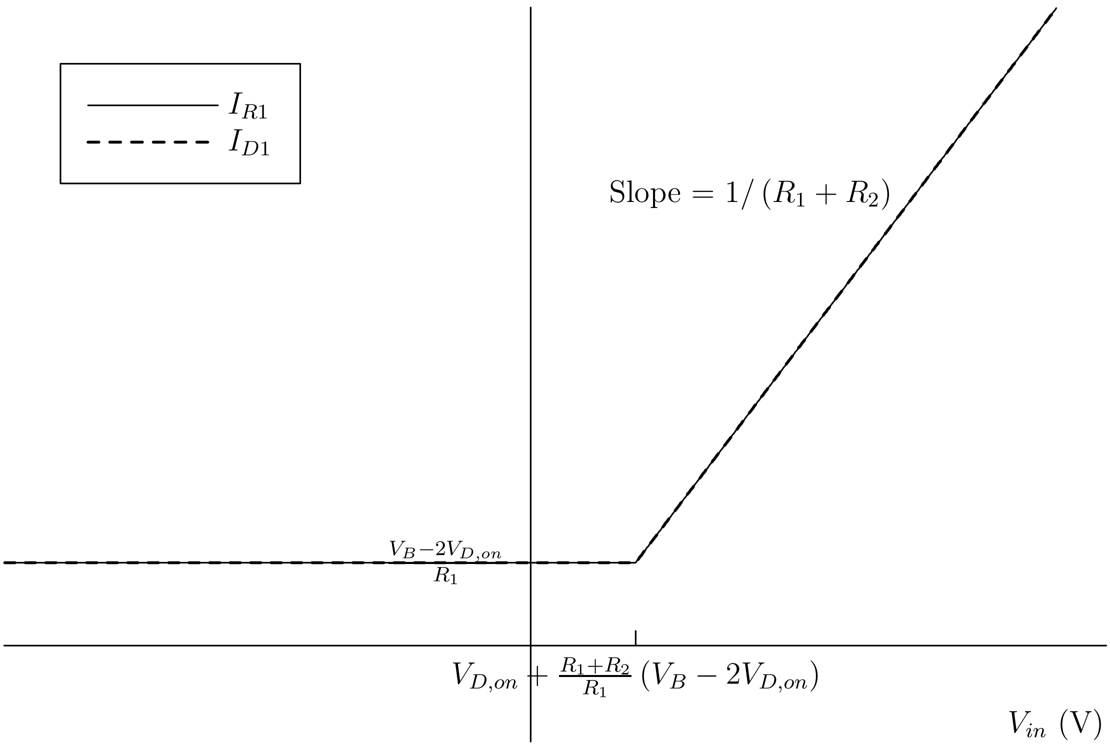
(b) If $V_B < 2V_{D,on}$:

$$I_{R1} = I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in}-V_{D,on}}{R_1+R_2} & V_{in} > V_{D,on} \end{cases}$$



If $V_B > 2V_{D,on}$:

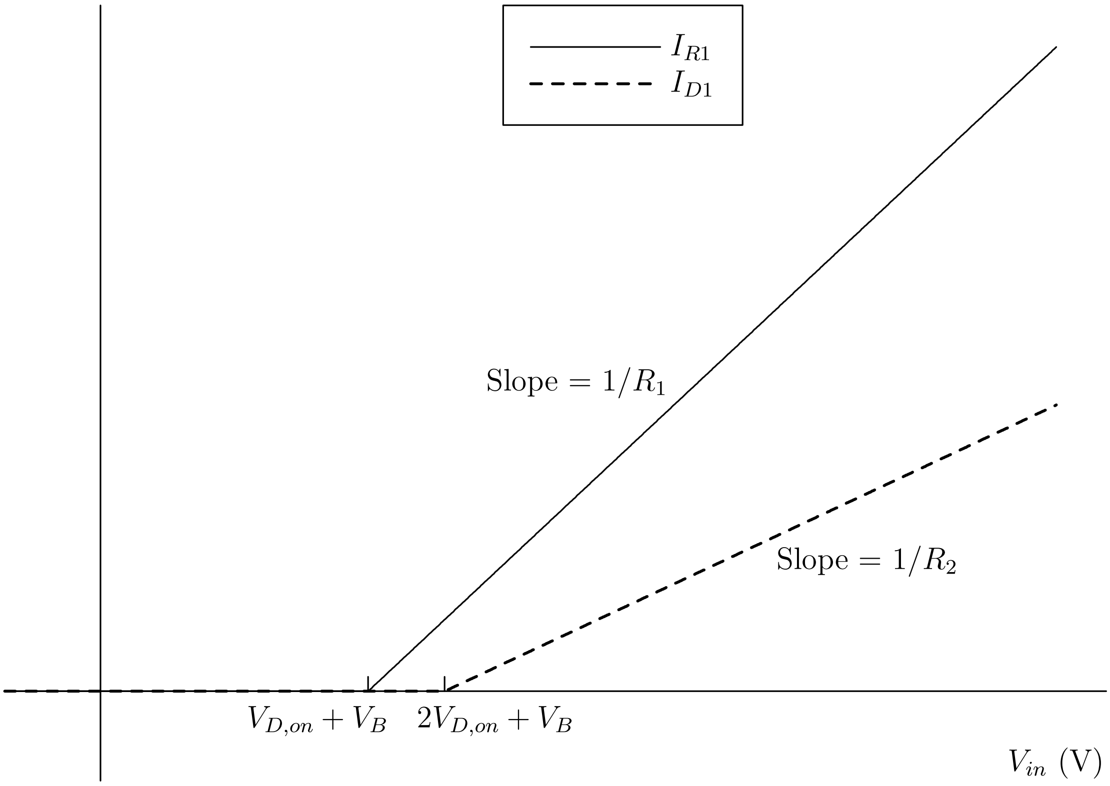
$$I_{R1} = I_{D1} = \begin{cases} \frac{V_B - 2V_{D,on}}{R_1} & V_{in} < V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_B - 2V_{D,on}\right) \\ \frac{V_{in} - V_{D,on}}{R_1+R_2} & V_{in} > V_{D,on} + \frac{R_1+R_2}{R_1}\left(V_B - 2V_{D,on}\right) \end{cases}$$



(c)

$$I_{R1} = \begin{cases} 0 & V_{in} < V_{D,on} + V_B \\ \frac{V_{in} - V_{D,on} - V_B}{R_1} & V_{in} > V_{D,on} + V_B \end{cases}$$

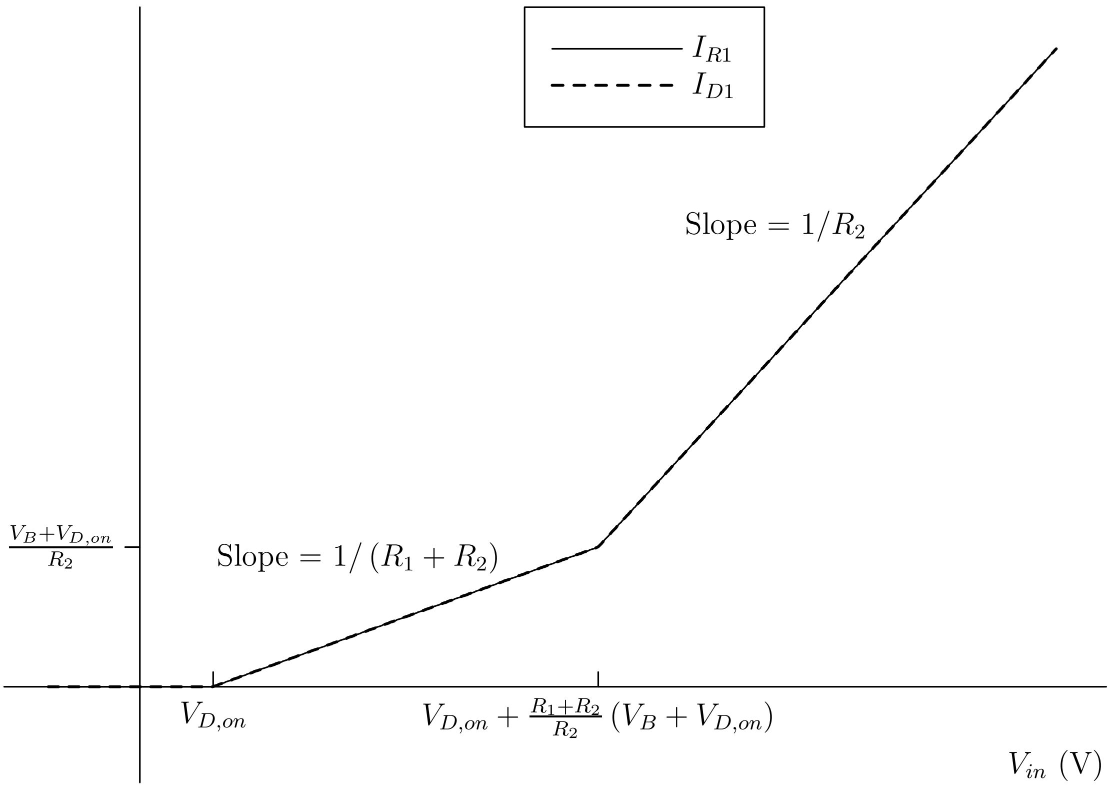
$$I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} + V_B \\ 0 & V_{D,on} + V_B < V_{in} < 2V_{D,on} + V_B \\ \frac{V_{in} - 2V_{D,on} - V_B}{R_2} & V_{in} > 2V_{D,on} + V_B \end{cases}$$



(d)

$$I_{R1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{D,on} < V_{in} < V_{D,on} + \frac{R_1 + R_2}{R_2}(V_B + V_{D,on}) \\ \frac{V_{in} - 2V_{D,on} - V_B}{R_1} & V_{in} > V_{D,on} + \frac{R_1 + R_2}{R_2}(V_B + V_{D,on}) \end{cases}$$

$$I_{D1} = \begin{cases} 0 & V_{in} < V_{D,on} \\ \frac{V_{in} - V_{D,on}}{R_1 + R_2} & V_{D,on} < V_{in} < V_{D,on} + \frac{R_1 + R_2}{R_2}(V_B + V_{D,on}) \\ \frac{V_{in} - 2V_{D,on} - V_B}{R_1} & V_{in} > V_{D,on} + \frac{R_1 + R_2}{R_2}(V_B + V_{D,on}) \end{cases}$$


I_{R1}
I_{D1}
Slope = $1/R_2$
Slope = $1/\left(R_1+R_2\right)$
$\frac{V_B+V_{D,on}}{R_2}$
$V_{D,on}$
$V_{D,on}+\frac{R_1+R_2}{R_2}\left(V_B+V_{D,on}\right)$
V_{in} (V)

3.31 (a)

$$I_{D1} = \frac{V_{in} - V_{D,on}}{R_1} = 1.6 \text{ mA}$$
$$r_{d1} = \frac{V_T}{I_{D1}} = 16.25\ \Omega$$
$$\Delta V_{out} = \frac{R_1}{r_d + R_1}\Delta V_{in} = \boxed{98.40 \text{ mV}}$$

(b)

$$I_{D1} = I_{D2} = \frac{V_{in} - 2V_{D,on}}{R_1} = 0.8 \text{ mA}$$
$$r_{d1} = r_{d2} = \frac{V_T}{I_{D1}} = 32.5\ \Omega$$
$$\Delta V_{out} = \frac{R_1 + r_{d2}}{R_1 + r_{d1} + r_{d2}}\Delta V_{in} = \boxed{96.95 \text{ mV}}$$

(c)

$$I_{D1} = I_{D2} = \frac{V_{in} - 2V_{D,on}}{R_1} = 0.8 \text{ mA}$$
$$r_{d1} = r_{d2} = \frac{V_T}{I_{D1}} = 32.5\ \Omega$$
$$\Delta V_{out} = \frac{r_{d2}}{r_{d1} + R_1 + r_{d2}}\Delta V_{in} = \boxed{3.05 \text{ mV}}$$

(d)

$$I_{D2} = \frac{V_{in} - V_{D,on}}{R_1} - \frac{V_{D,on}}{R_2} = 1.2 \text{ mA}$$
$$r_{d2} = \frac{V_T}{I_{D2}} = 21.67\ \Omega$$
$$\Delta V_{out} = \frac{R_2 \parallel r_{d2}}{R_1 + R_2 \parallel r_{d2}}\Delta V_{in} = \boxed{2.10 \text{ mV}}$$

3.32 (a)

$$\Delta V_{out} = \Delta I_{in} R_1 = \boxed{100 \text{ mV}}$$

(b)

$$I_{D1} = I_{D2} = I_{in} = 3 \text{ mA}$$
$$r_{d1} = r_{d2} = \frac{V_T}{I_{D1}} = 8.67 \ \Omega$$
$$\Delta V_{out} = \Delta I_{in} \left(R_1 + r_{d2}\right) = \boxed{100.867 \text{ mV}}$$

(c)

$$I_{D1} = I_{D2} = I_{in} = 3 \text{ mA}$$
$$r_{d1} = r_{d2} = \frac{V_T}{I_{D1}} = 8.67 \ \Omega$$
$$\Delta V_{out} = \Delta I_{in} r_{d2} = \boxed{0.867 \text{ mV}}$$

(d)

$$I_{D2} = I_{in} - \frac{V_{D,on}}{R_2} = 2.6 \text{ mA}$$
$$r_{d2} = \frac{V_T}{I_{D2}} = 10 \ \Omega$$
$$\Delta V_{out} = \Delta I_{in} \left(R_2 \parallel r_{d2}\right) = \boxed{0.995 \text{ mV}}$$

33 a) $i_{1} = i_{in}$

$= 0.1\,mA$

b) $i_{r_1} = i_{in}$

$= 0.1\,mA$

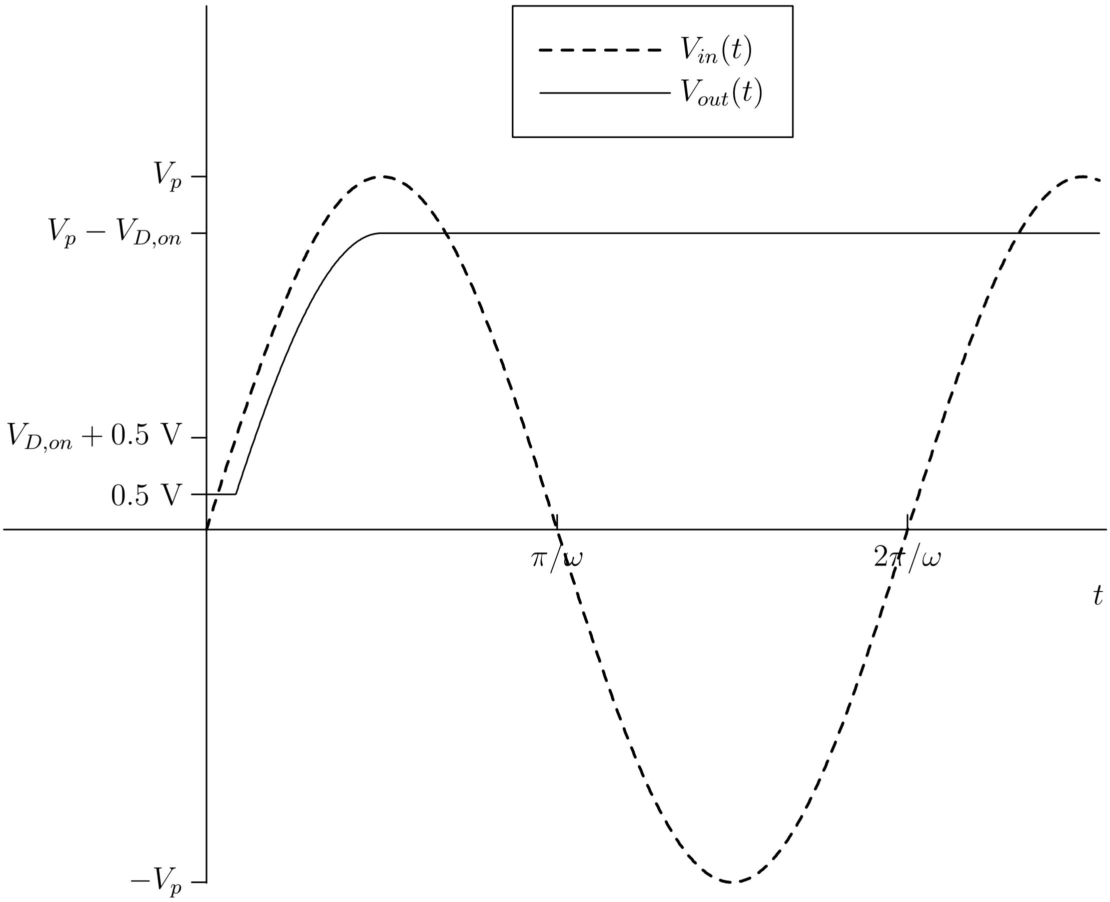
c) $i_{r_1} = i_{in}$

$= 0.1\,mA$

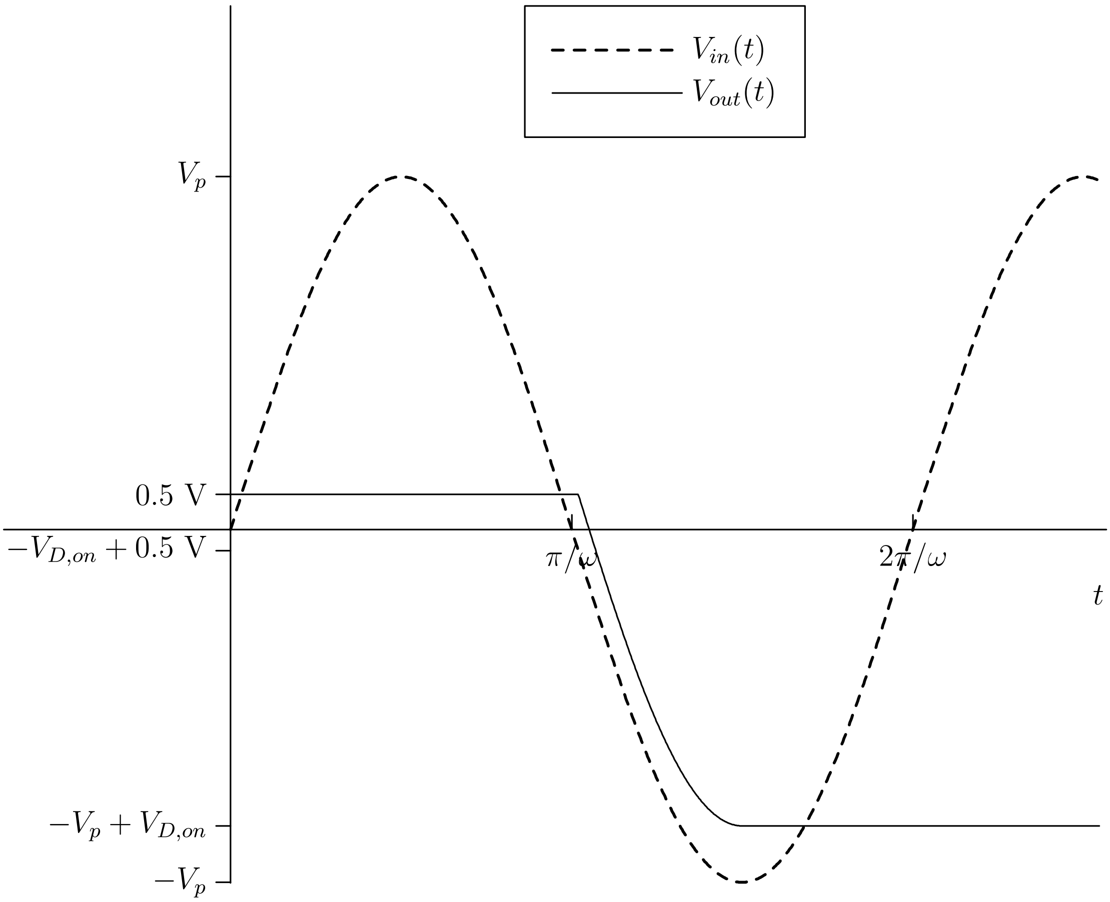
d) $i_{r_1} = i_{in}$

$= 0.1\,mA.$

3.34



3.35



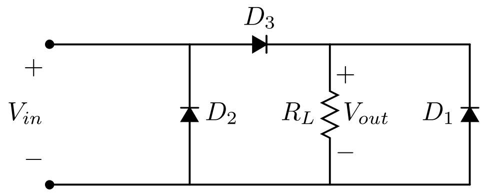
3.36

$$
\begin{aligned}
V_R &\approx \frac{V_p - V_{D,on}}{R_L C_1 f_{in}} \\
V_p &= 3.5\ \mathrm{V} \\
R_L &= 100\ \Omega \\
C_1 &= 1000\ \mu\mathrm{F} \\
f_{in} &= 60\ \mathrm{Hz} \\
V_R &= \boxed{0.45\ \mathrm{V}}
\end{aligned}
$$

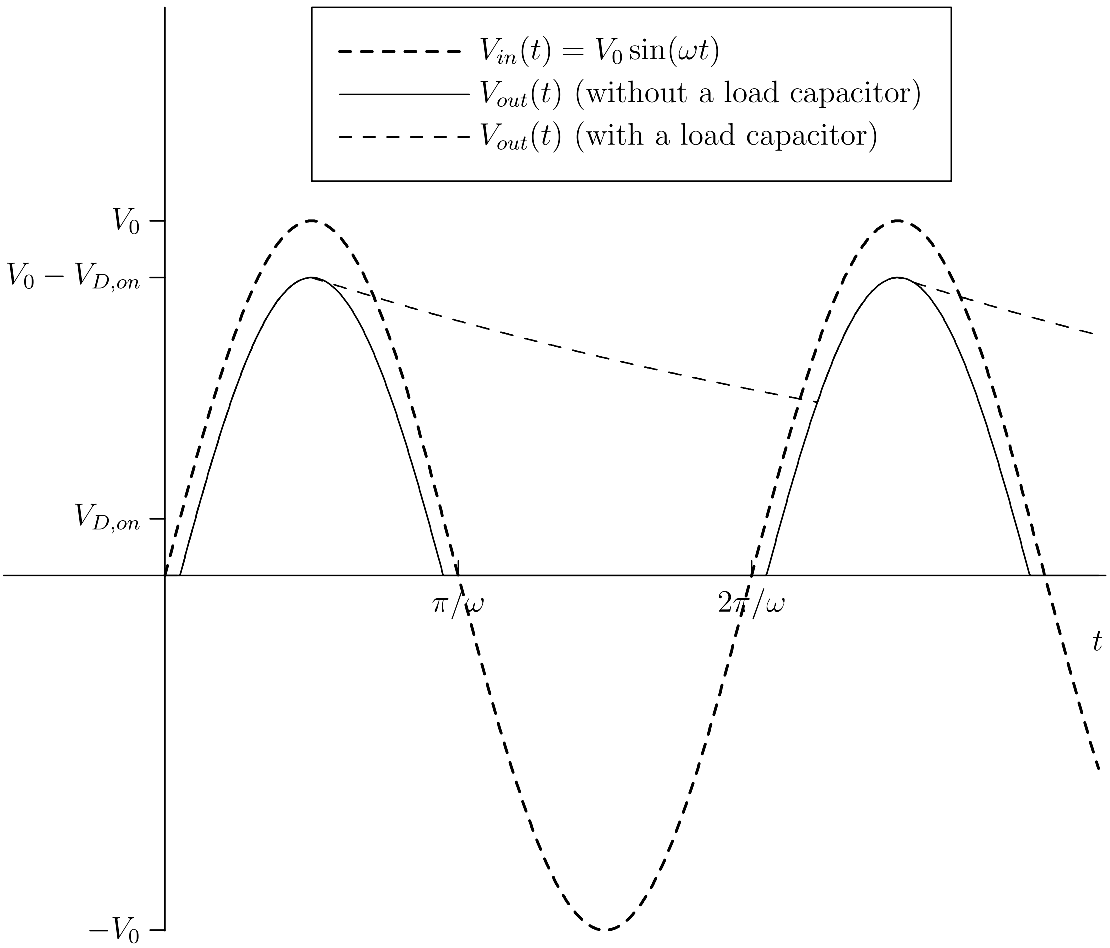
3.37

$$
\begin{aligned}
V_R &= \frac{I_L}{C_1 f_{in}} \le 300\text{ mV} \\
f_{in} &= 60\text{ Hz} \\
I_L &= 0.5\text{ A} \\
C_1 &\ge \frac{I_L}{(300\text{ mV})\, f_{in}} = \boxed{27.78\text{ mF}}
\end{aligned}
$$

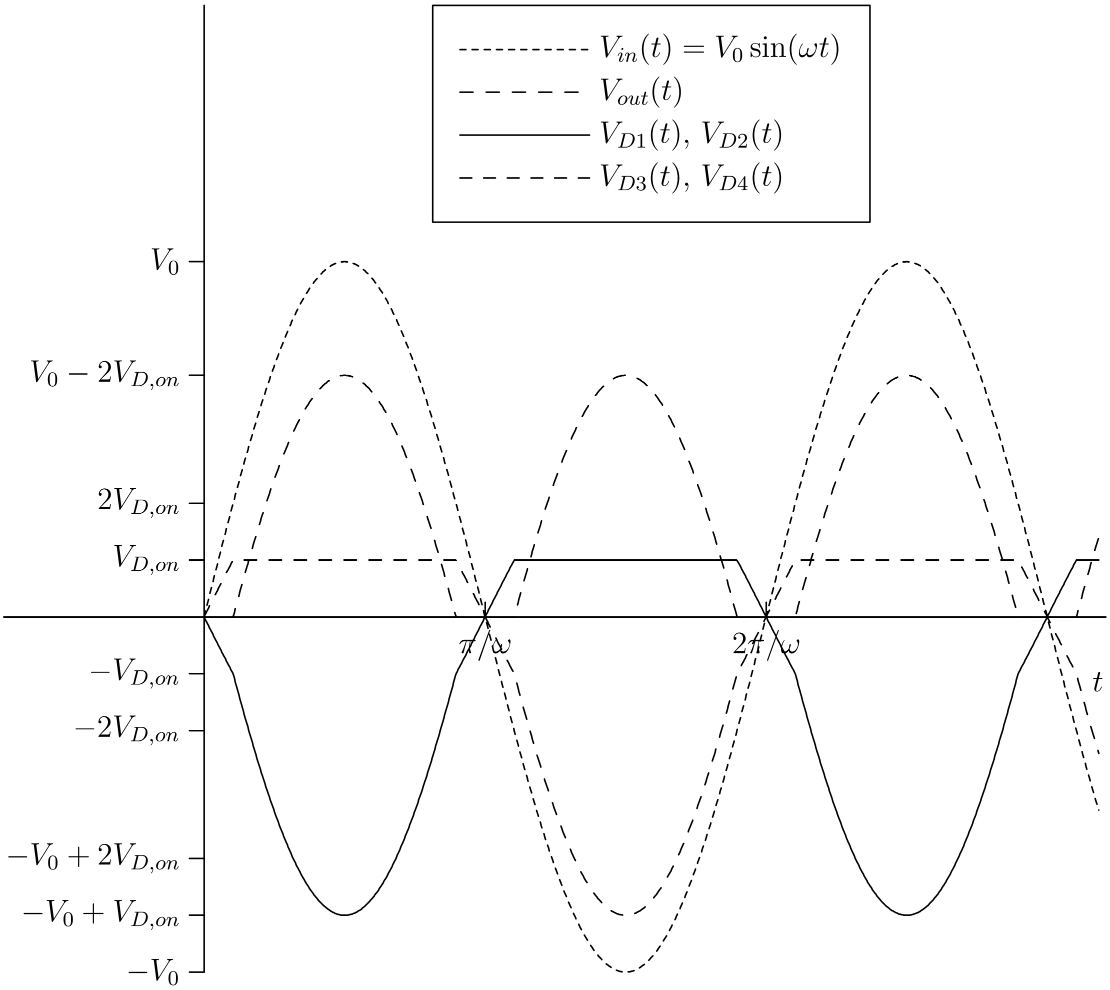
3.38 Shorting the input and output grounds of a full-wave rectifier shorts out the diode D_4 from Fig. 3.38(b). Redrawing the modified circuit, we have:



On the positive half-cycle, D_3 turns on and forms a half-wave rectifier along with R_L (and C_L, if included). On the negative half-cycle, D_2 shorts the input (which could cause a dangerously large current to flow) and the output remains at zero. Thus, the circuit behaves like a half-wave recifier. The plots of $V_{out}(t)$ are shown below.



3.39 Note that the waveforms for V_{D1} and V_{D2} are identical, as are the waveforms for V_{D3} and V_{D4}.



3.40 During the positive half-cycle, D_2 and D_3 will remain reverse-biased, causing V_{out} to be zero as no current will flow through R_L. During the negative half-cycle, D_1 and D_3 will short the input (potentially causing damage to the devices), and once again, no current will flow through R_L (even though D_2 will turn on, there will be no voltage drop across R_L). Thus, V_{out} always remains at zero, and the circuit fails to act as a rectifier.