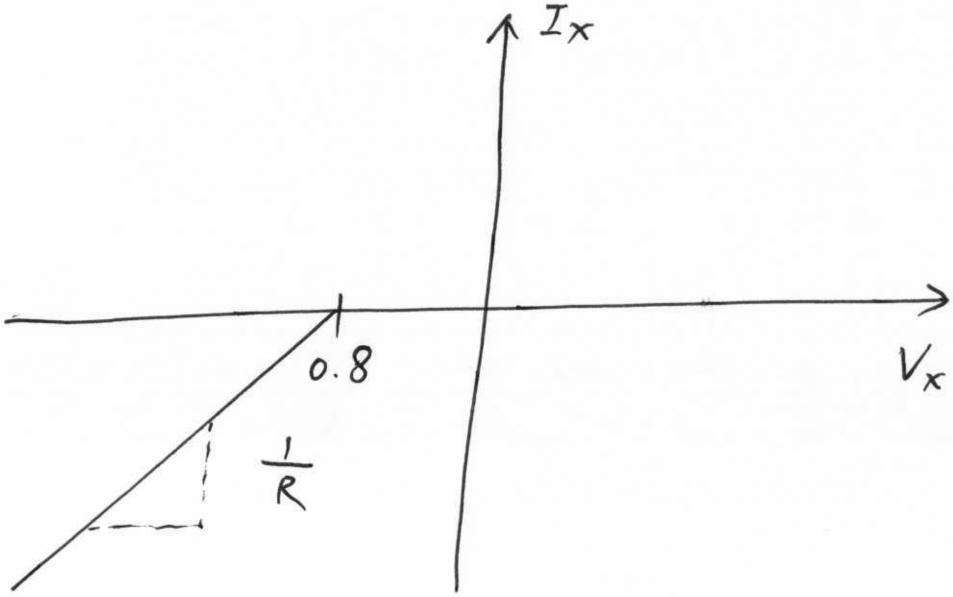
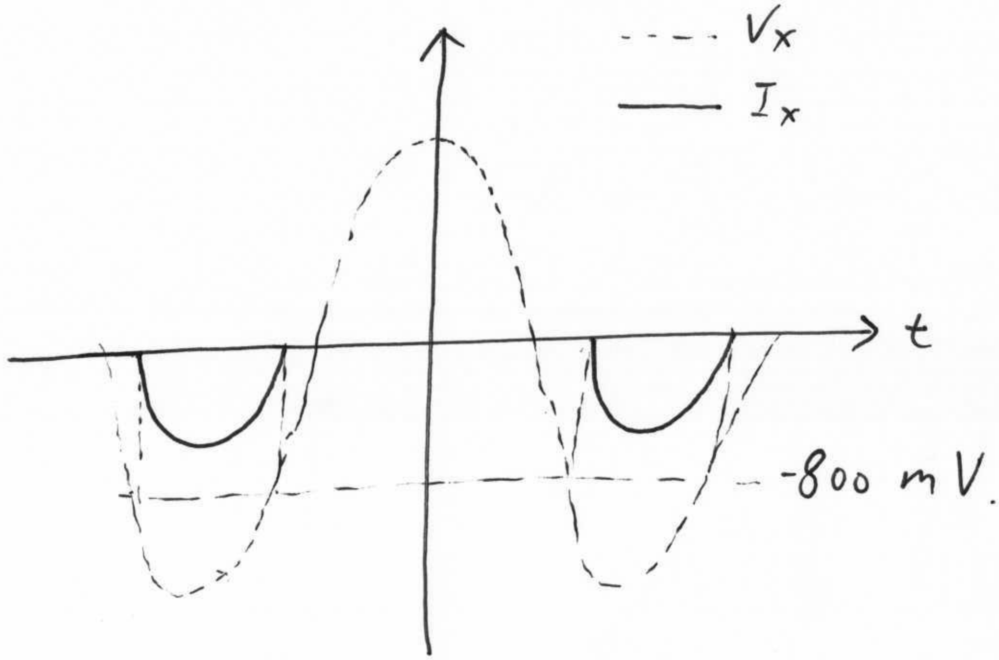
(1)

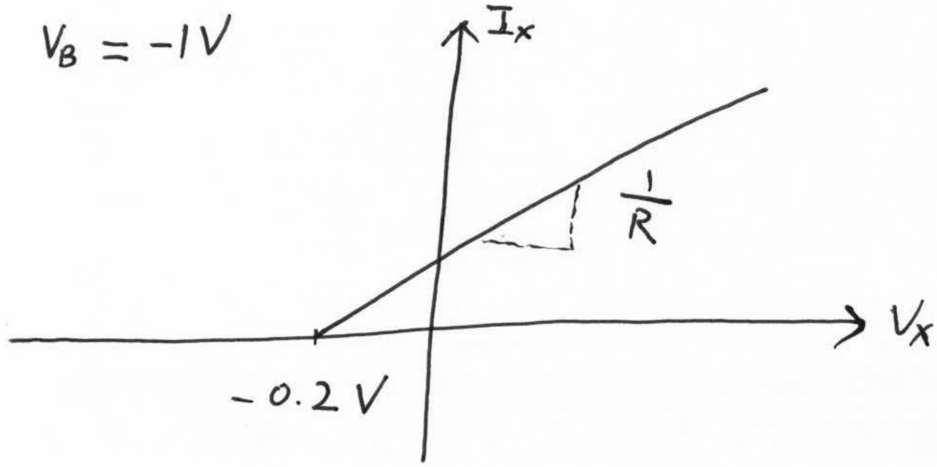


(2)

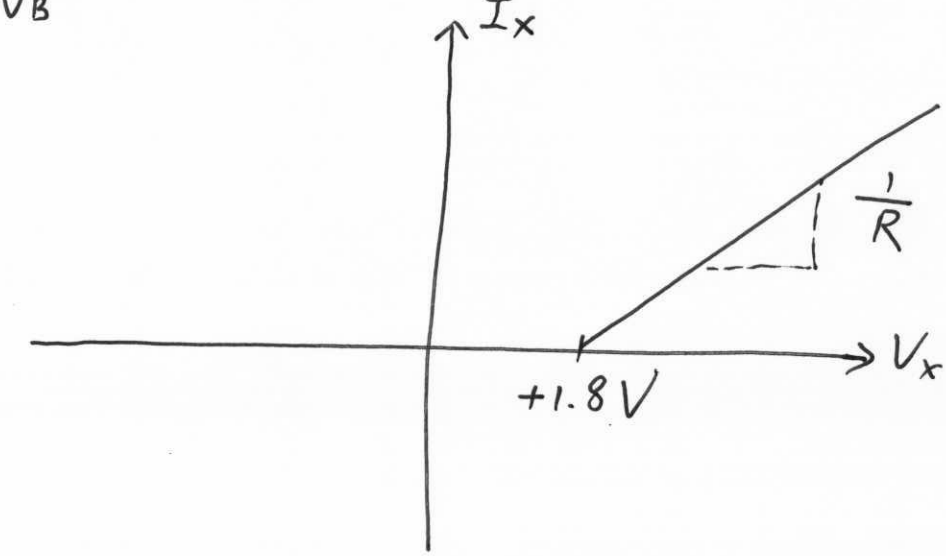


③

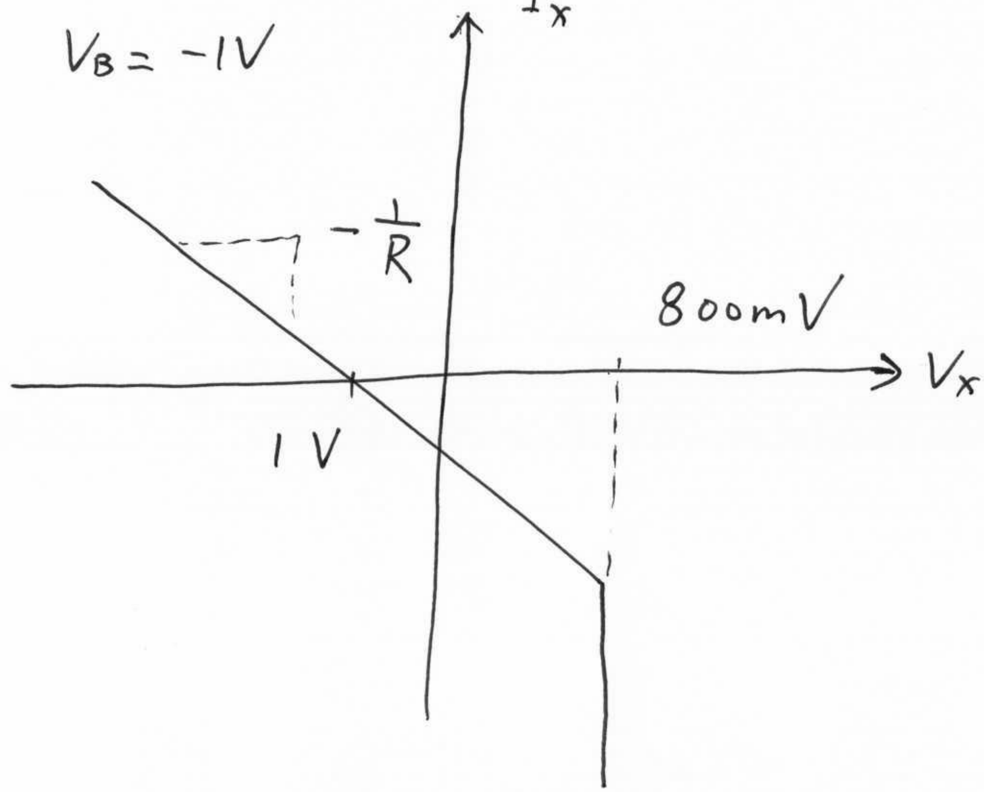
$V_B = -1V$

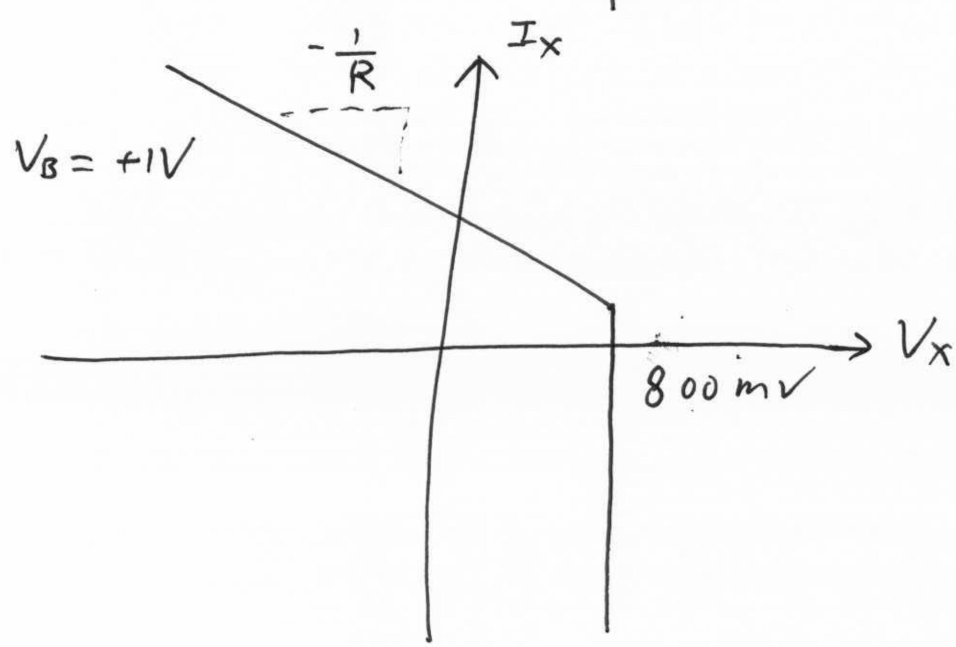


V_B

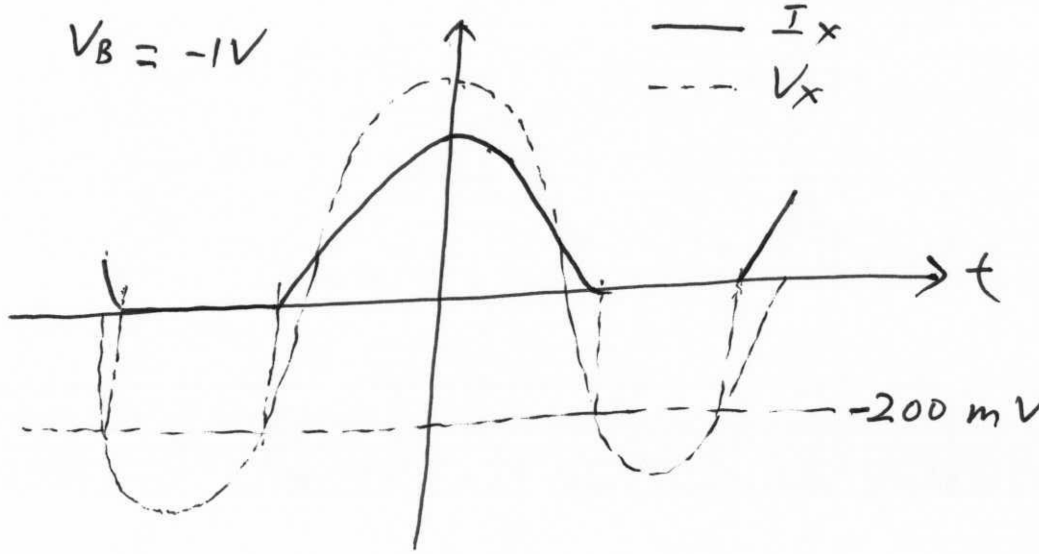


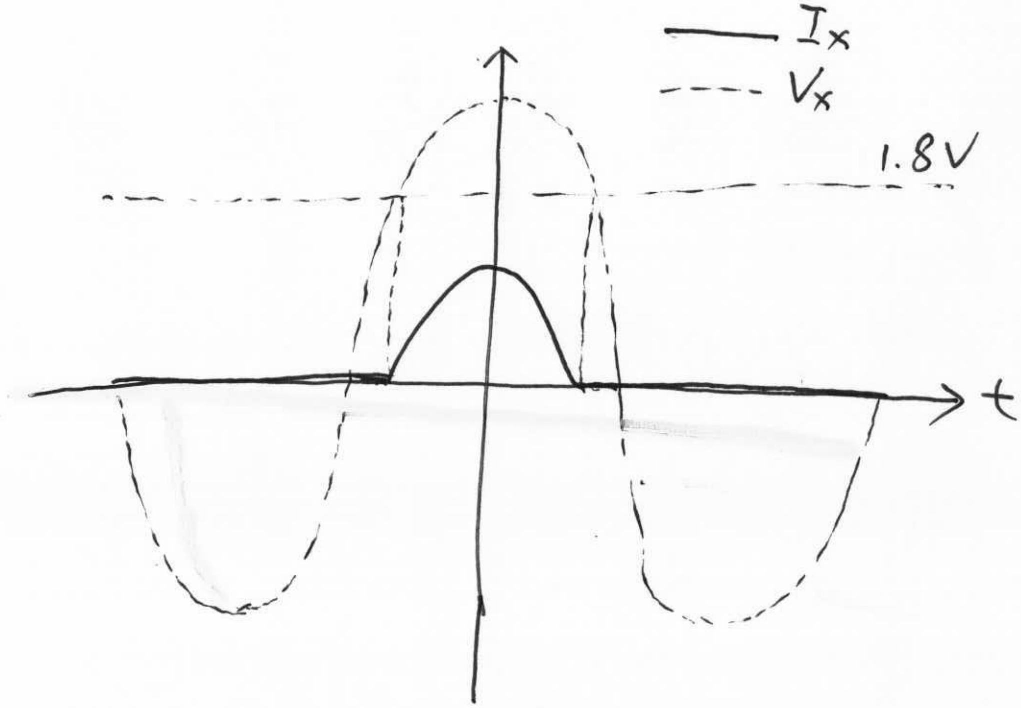
(4)



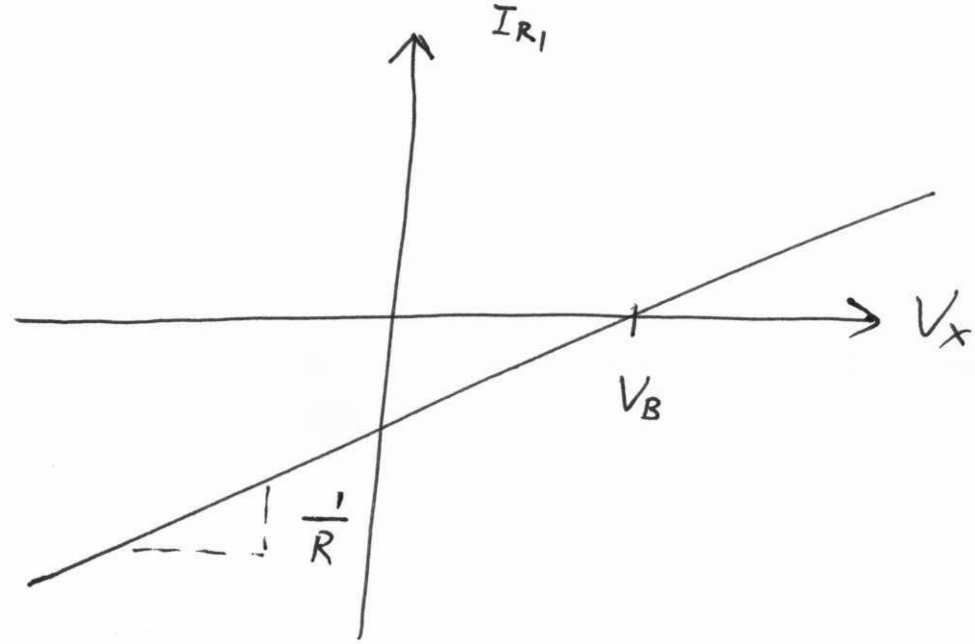


(5)





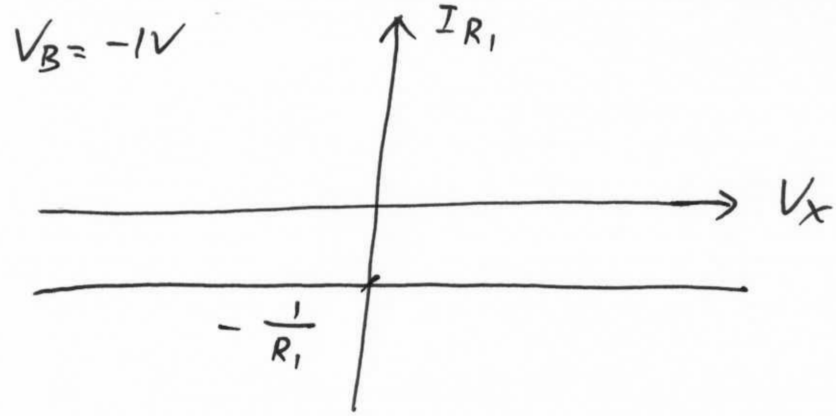
(6)



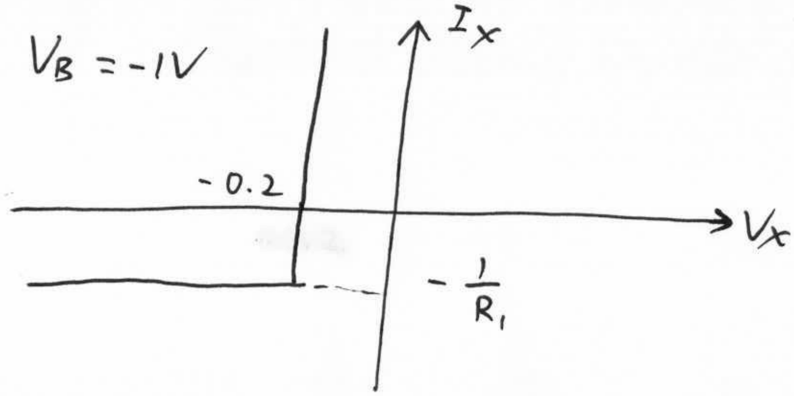
$I_{D_1} = 0$ for all V_X

($\because$ $V_B > 0$, D_1 is reverse-biased)

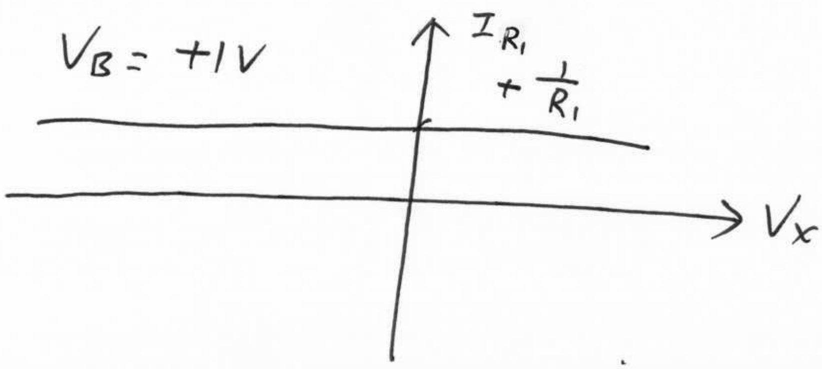
(7)



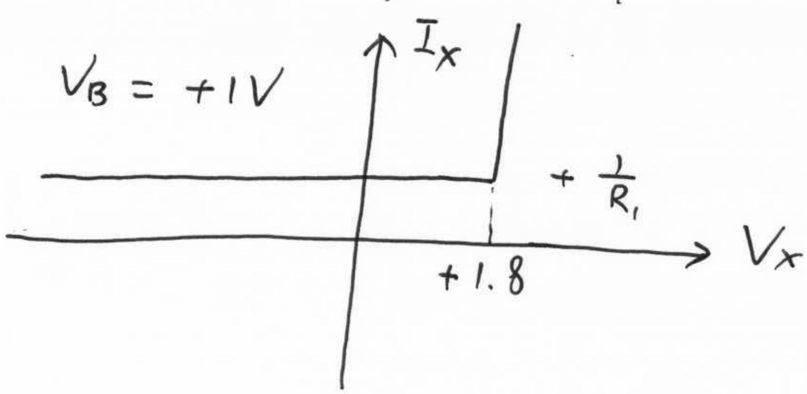
$V_B = -1V$
I_{R_1}
V_x
$-\frac{1}{R_1}$



$V_B = -1V$
I_x
-0.2
V_x
$-\frac{1}{R_1}$

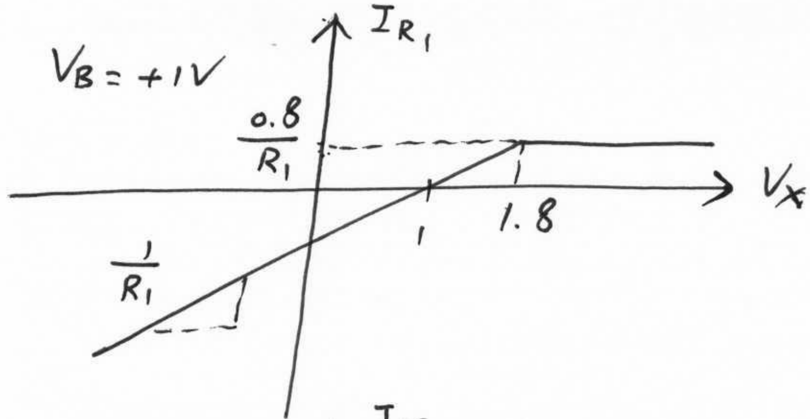


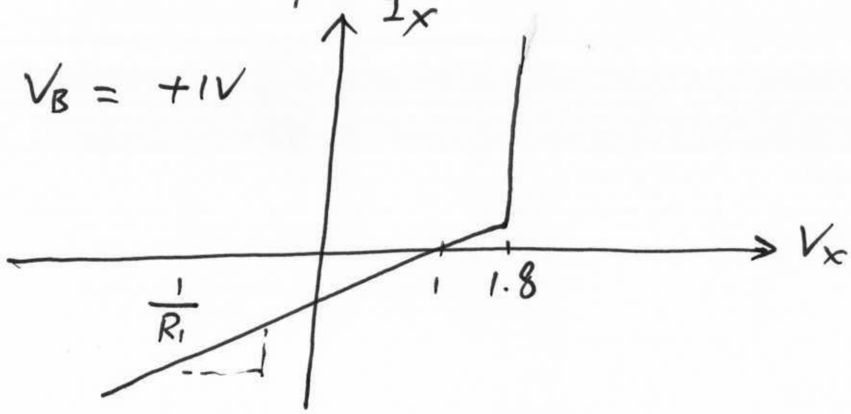
$V_B = +1V$
I_{R_1}
$+\frac{1}{R_1}$
V_x

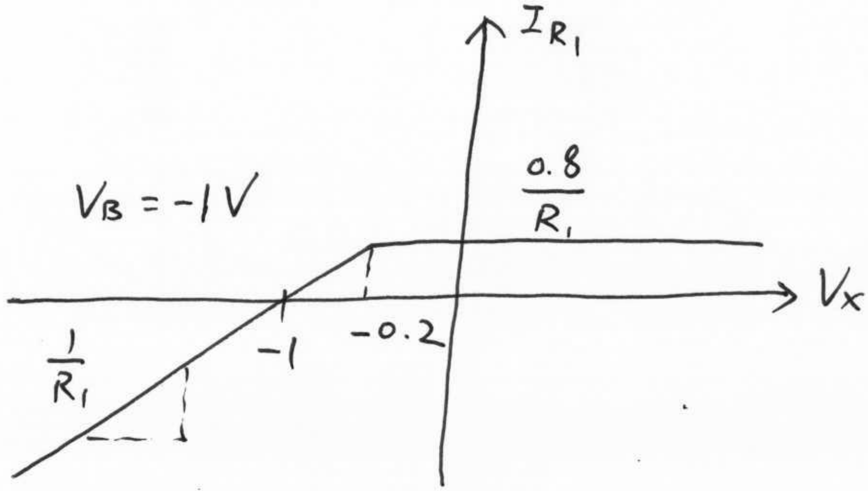


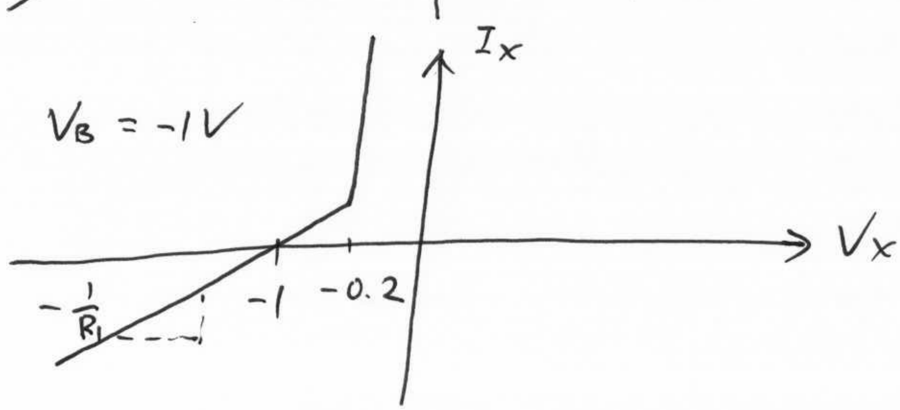
$V_B = +1V$
I_x
$+\frac{1}{R_1}$
V_x
$+1.8$

(8)


$V_B = +1V$
I_{R_1}
$\frac{0.8}{R_1}$
V_x
1
1.8
$\frac{1}{R_1}$

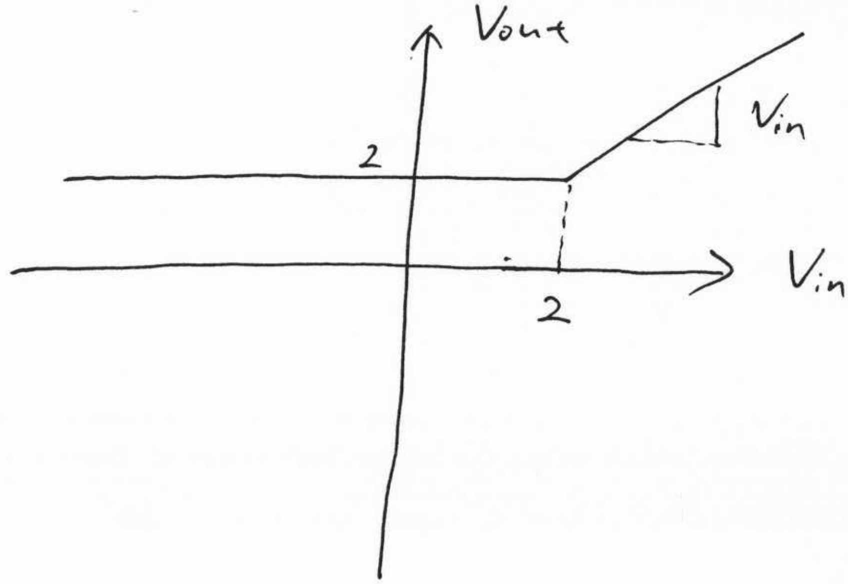

$V_B = +1V$
I_x
V_x
1
1.8
$\frac{1}{R_1}$


$V_B = -1V$
I_{R_1}
$\frac{0.8}{R_1}$
V_x
-1
-0.2
$\frac{1}{R_1}$

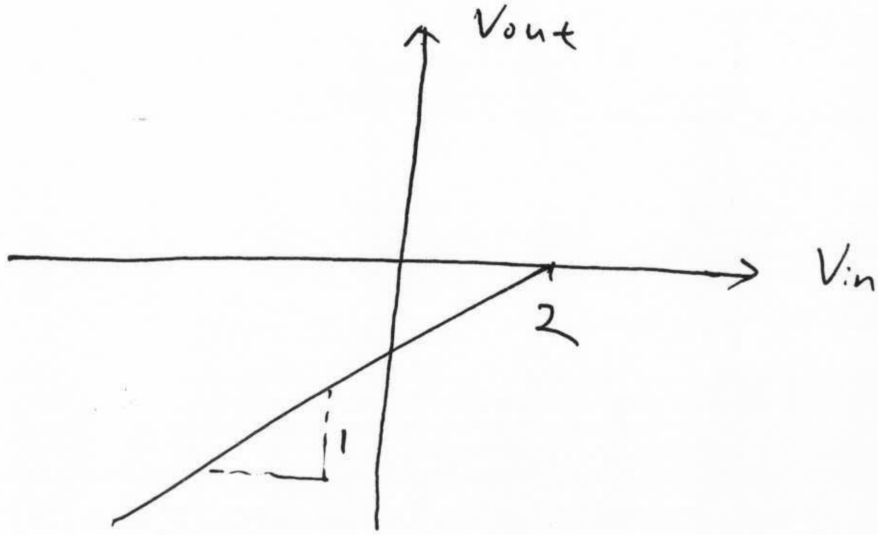

$V_B = -1V$
I_x
V_x
-1
-0.2
$-\frac{1}{R_1}$

(9)

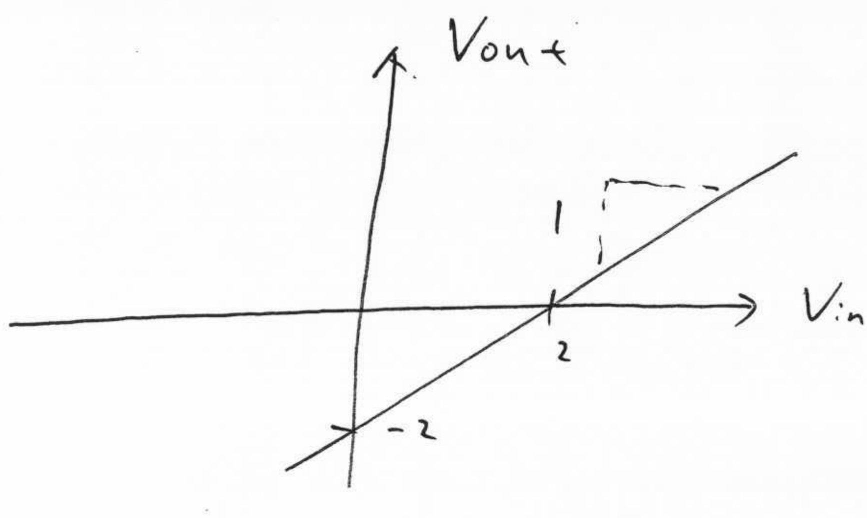
a)



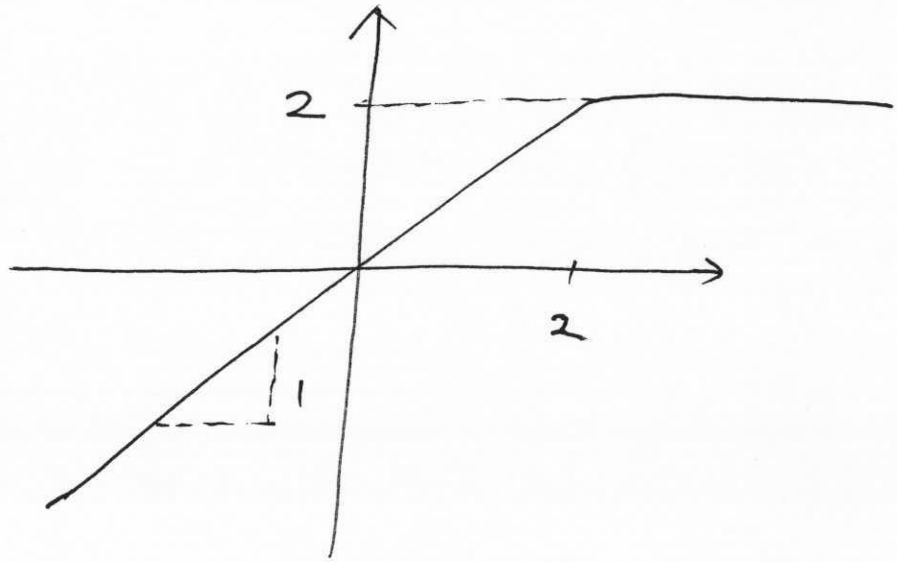
b)



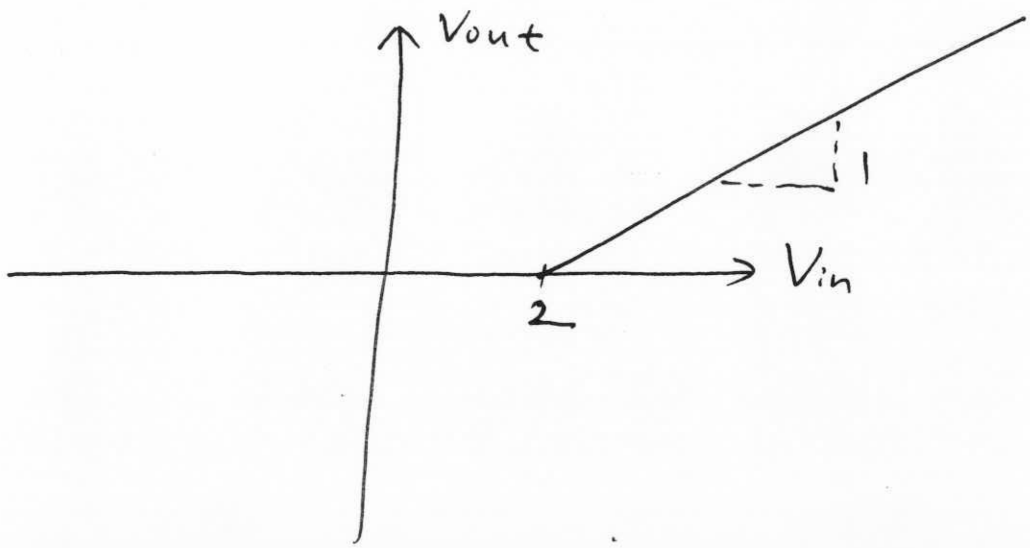
c)



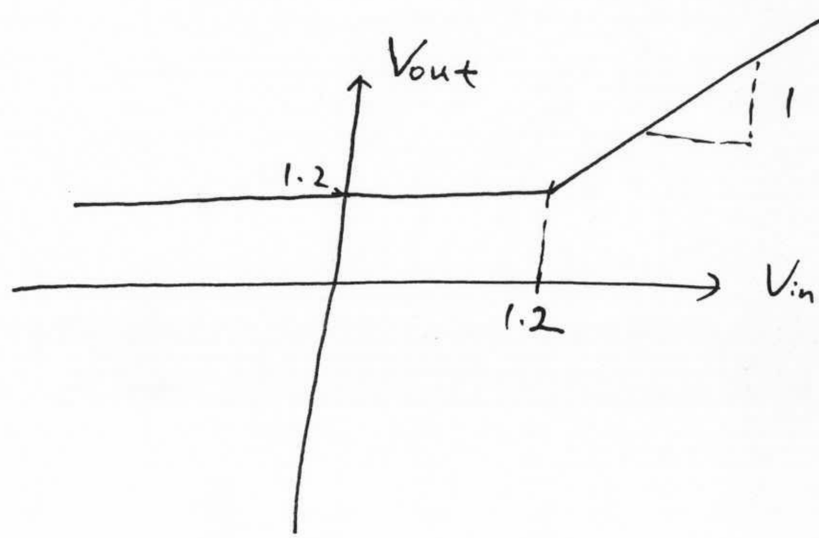
d)



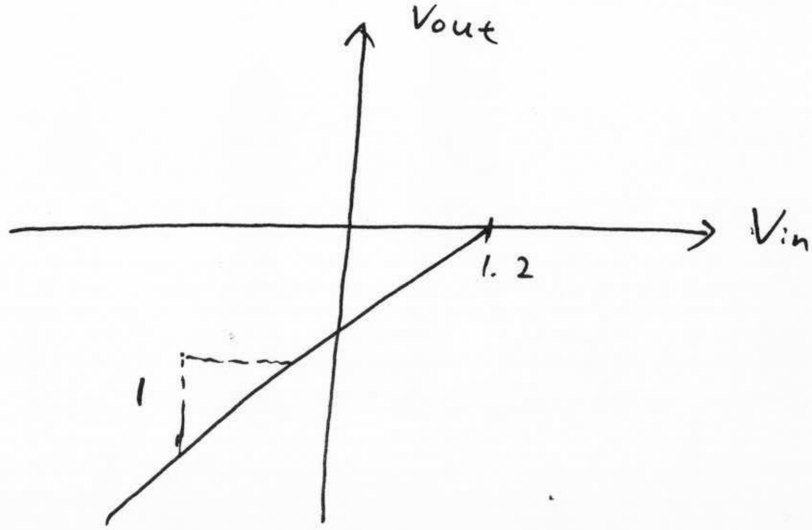
e)



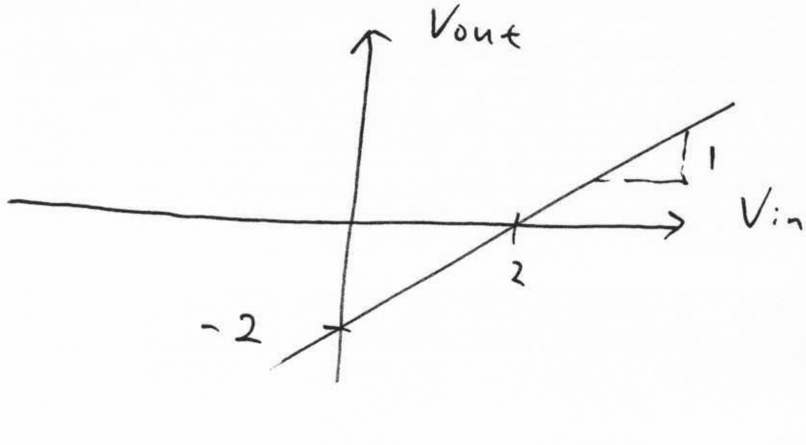
(10) a)



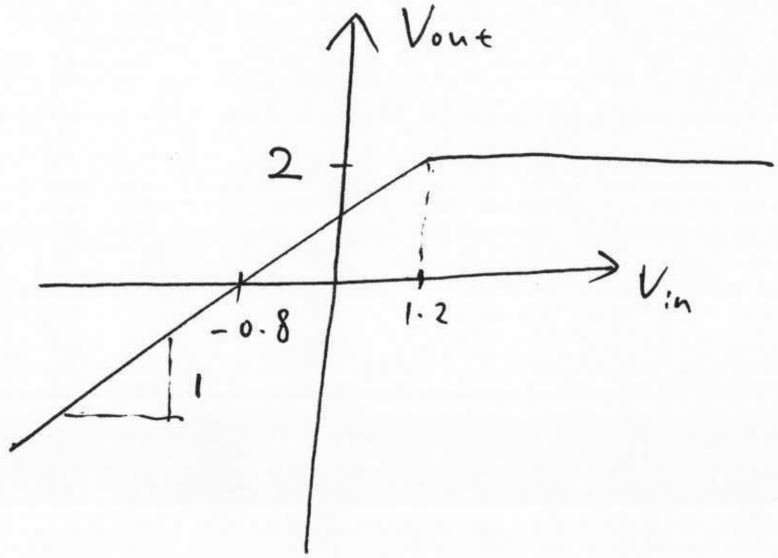
b)



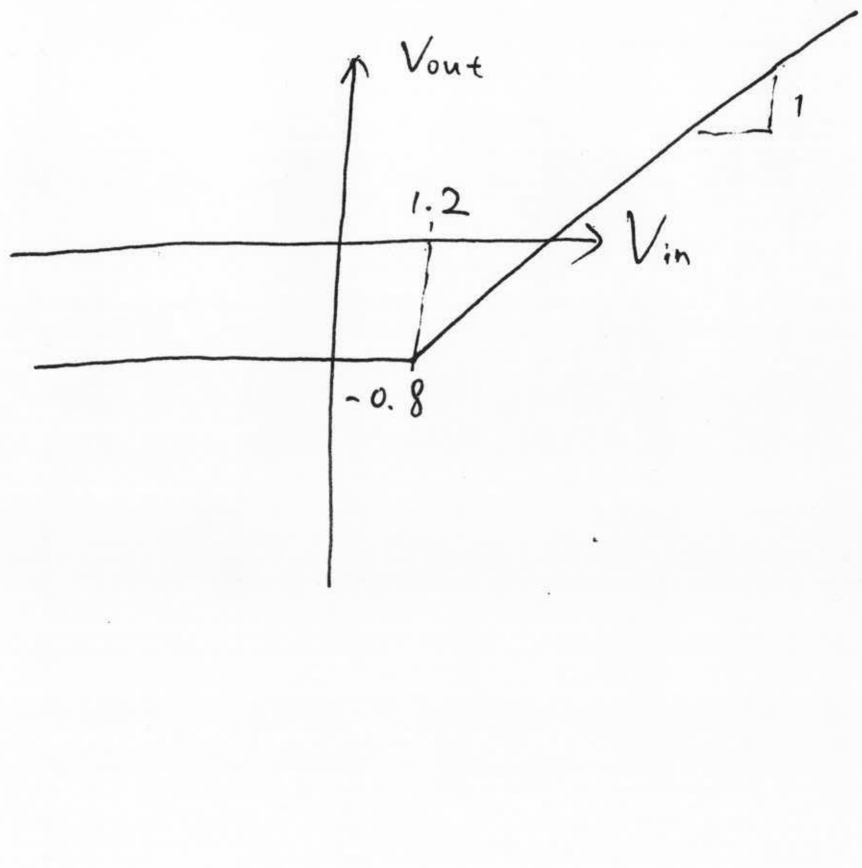
c)



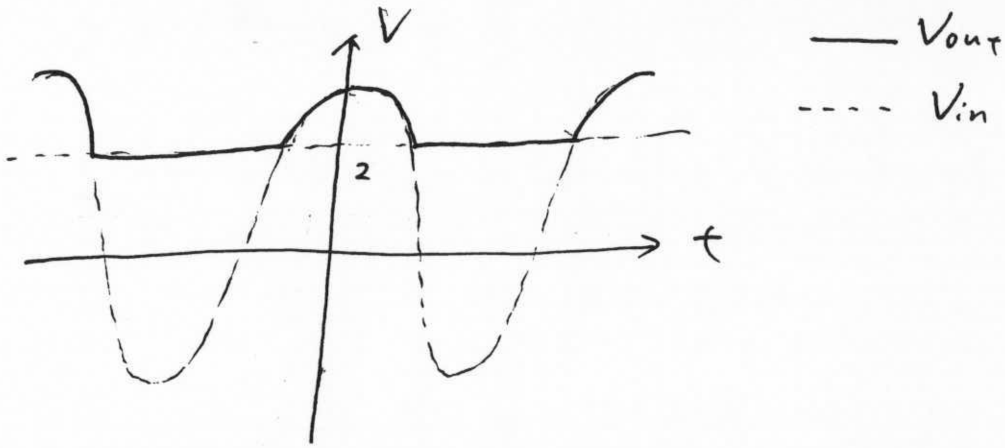
d)



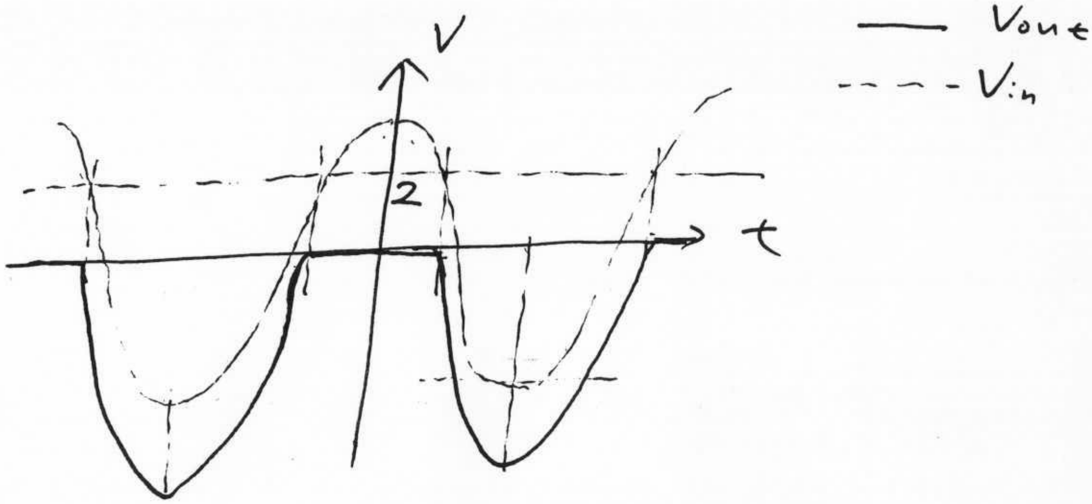
e)



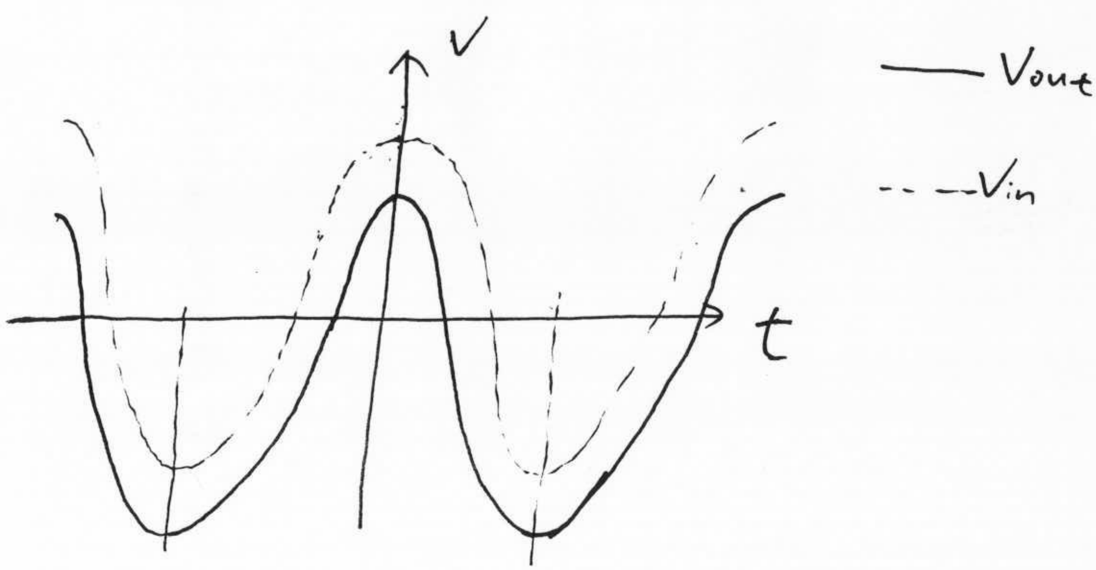
(11) a)



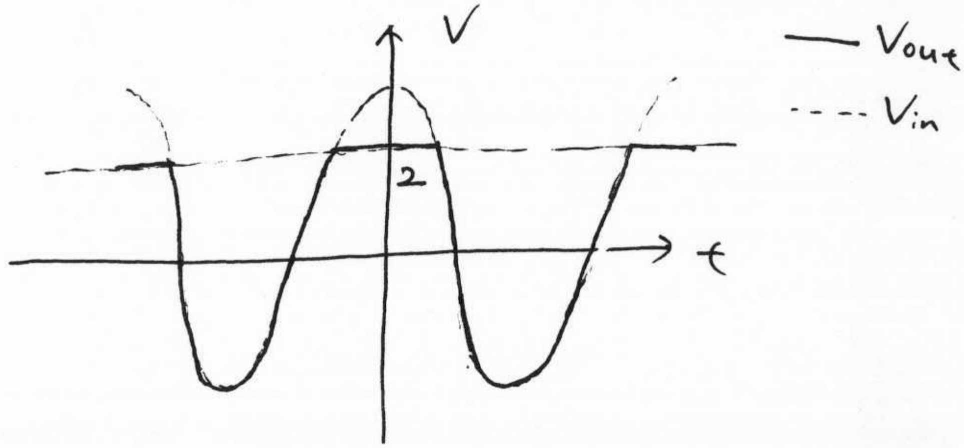
b)



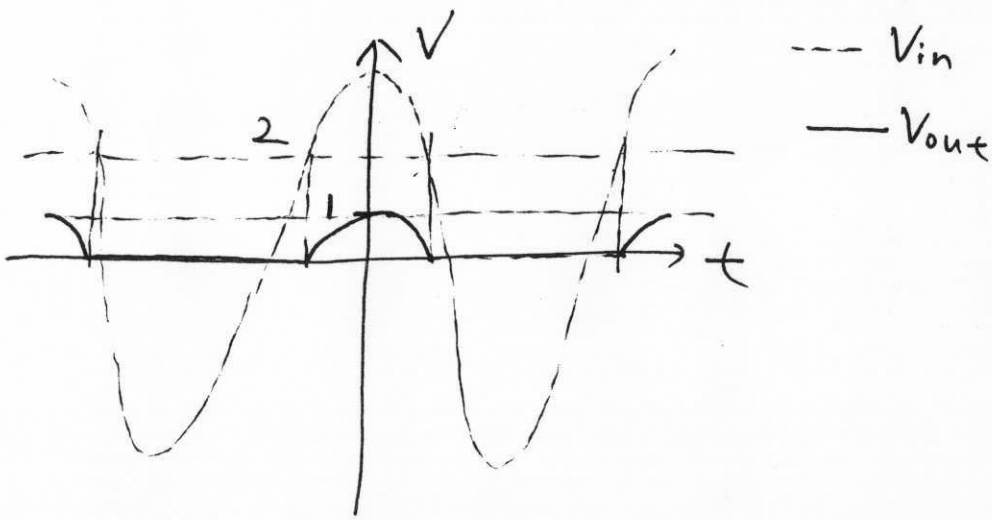
c)



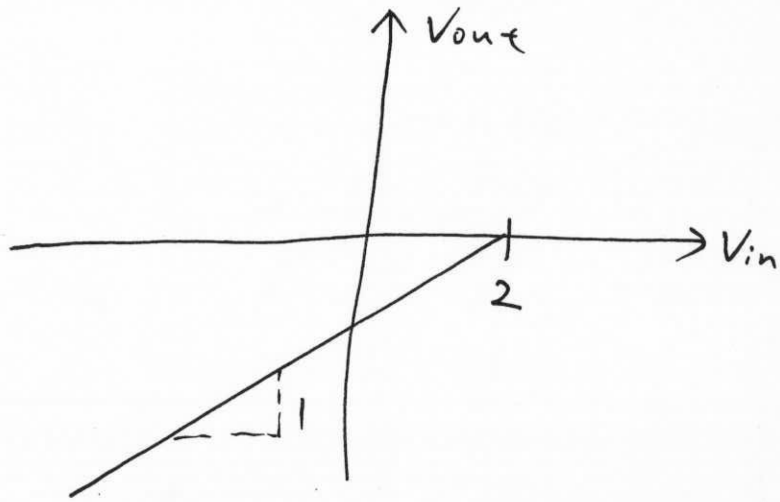
d)



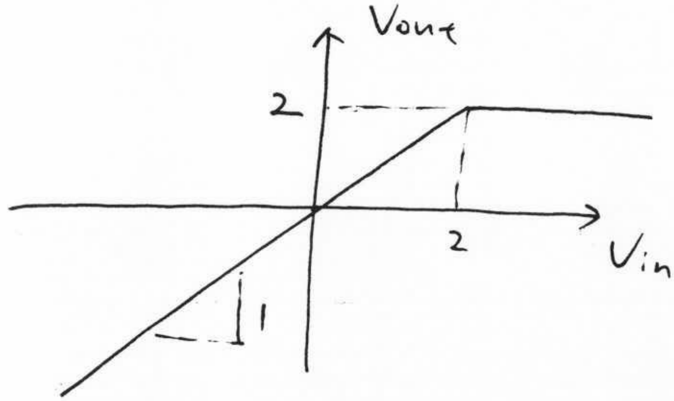
e)



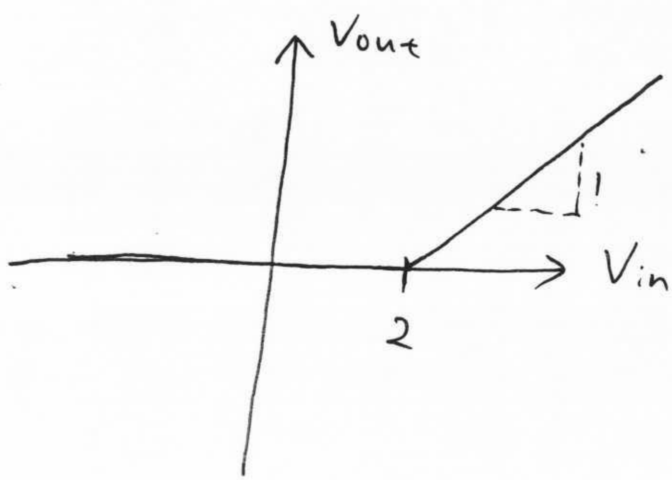
⑫ a)



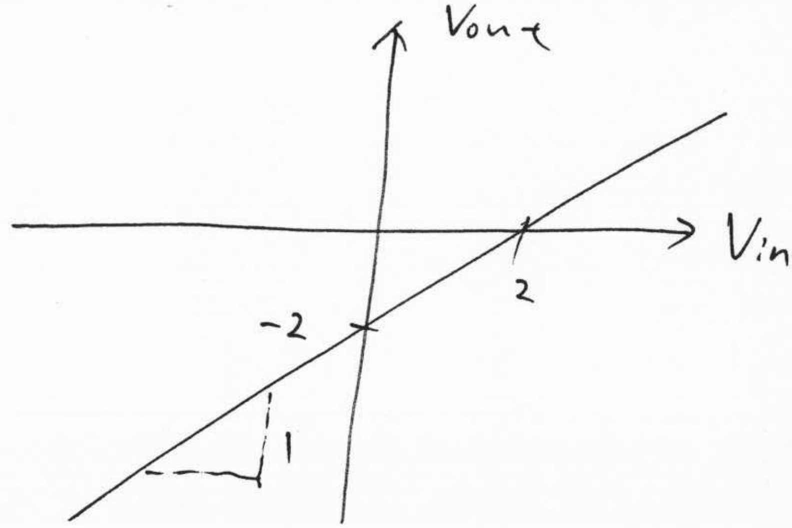
b)



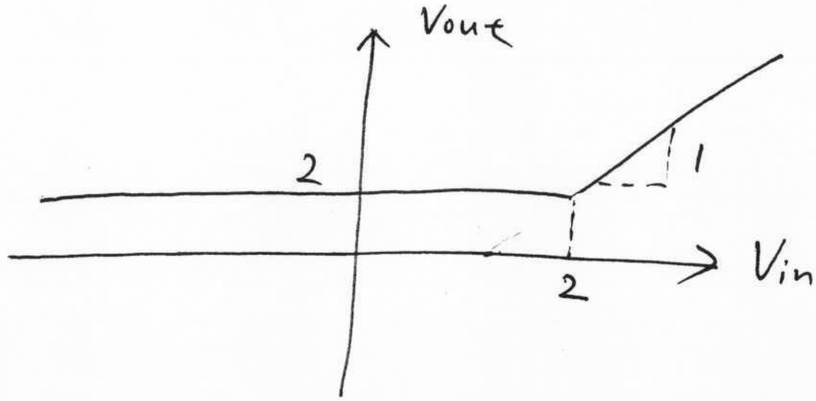
c)



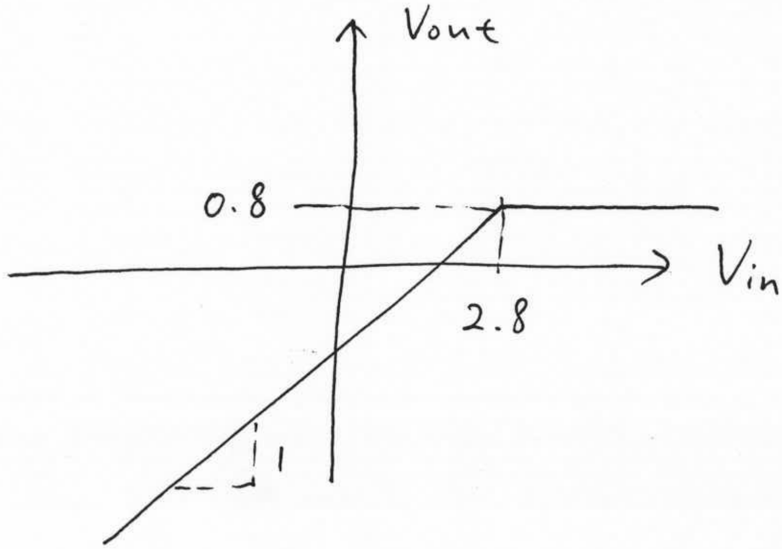
d)



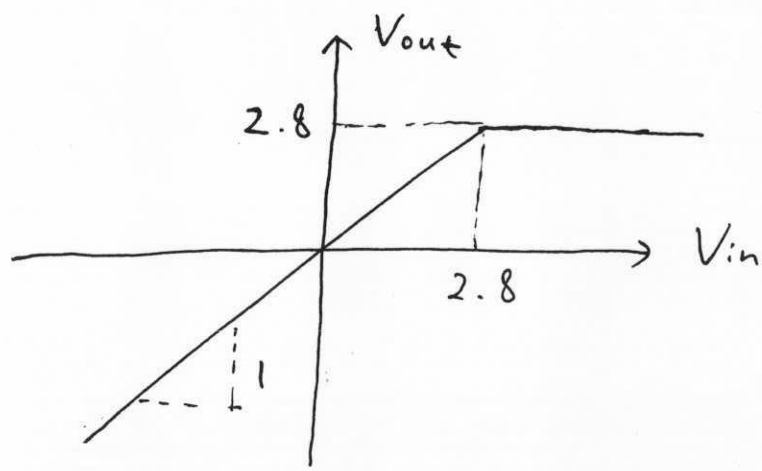
e)



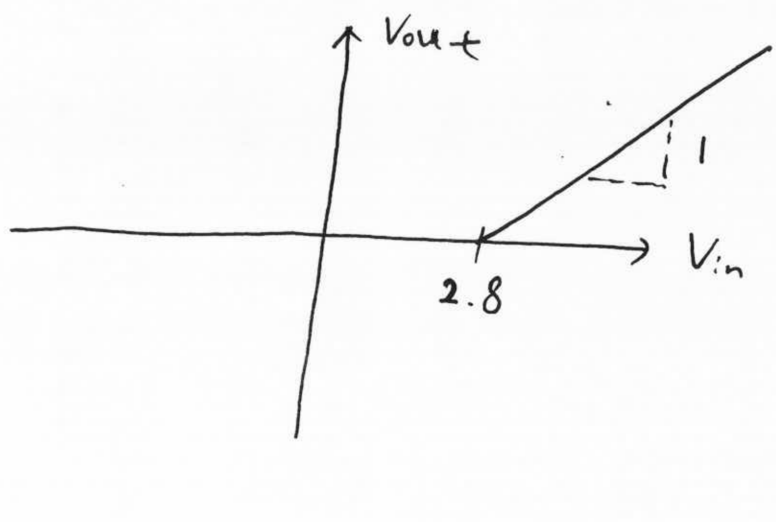
⑬ a)



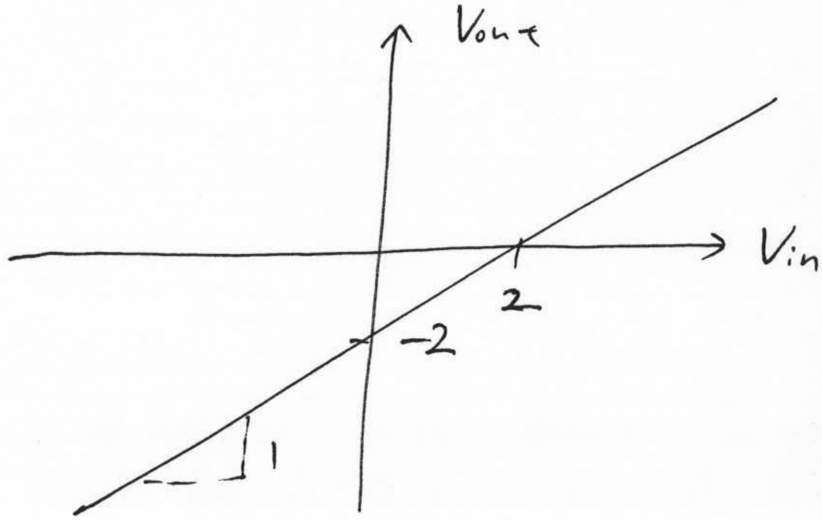
b)



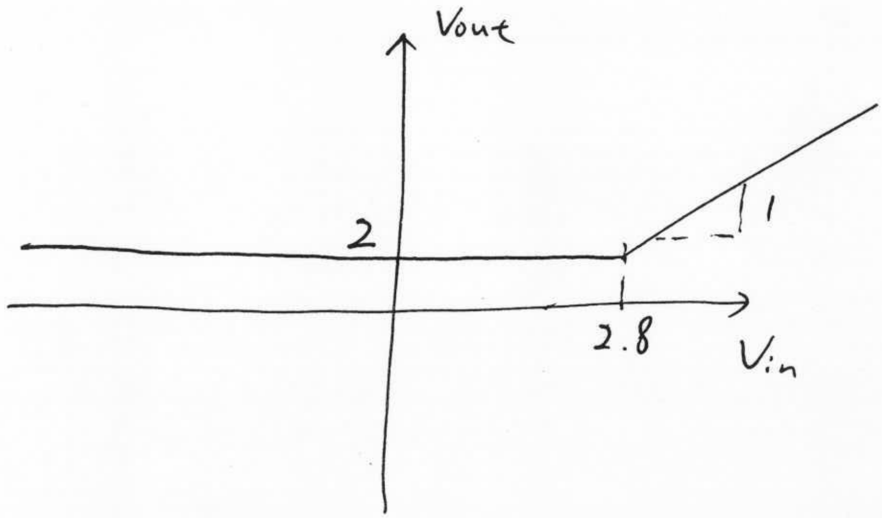
c)



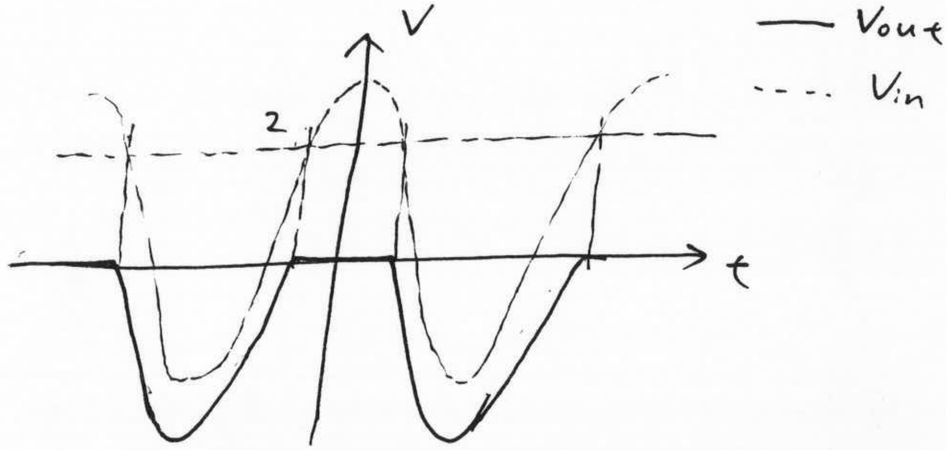
d)



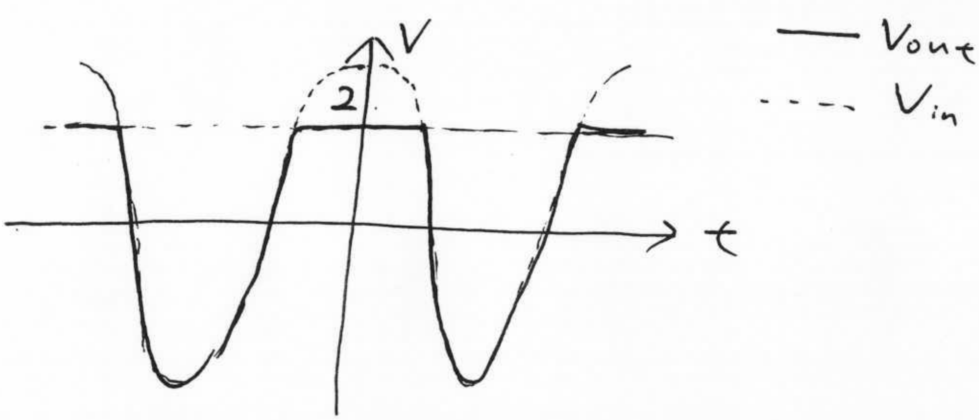
e)



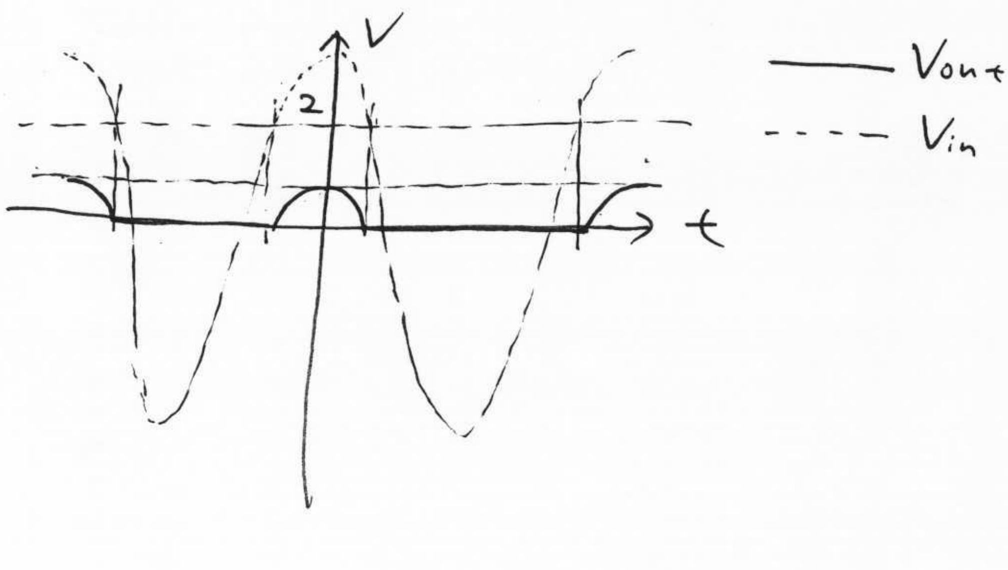
(14) a)



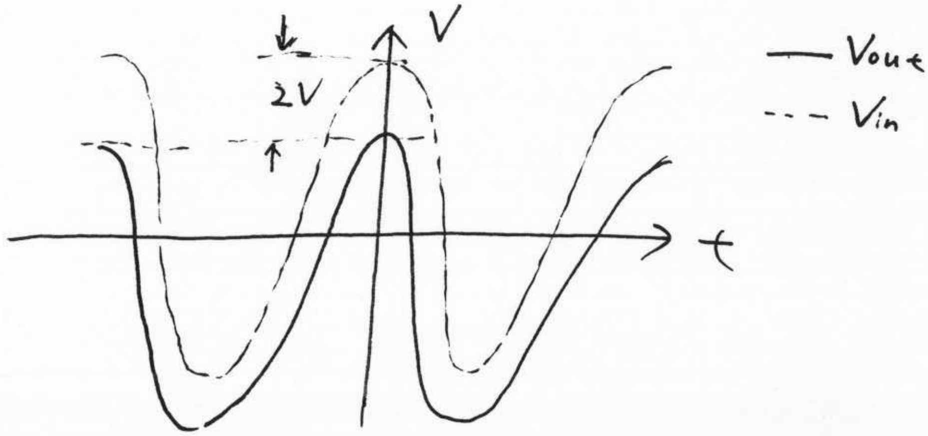
b)



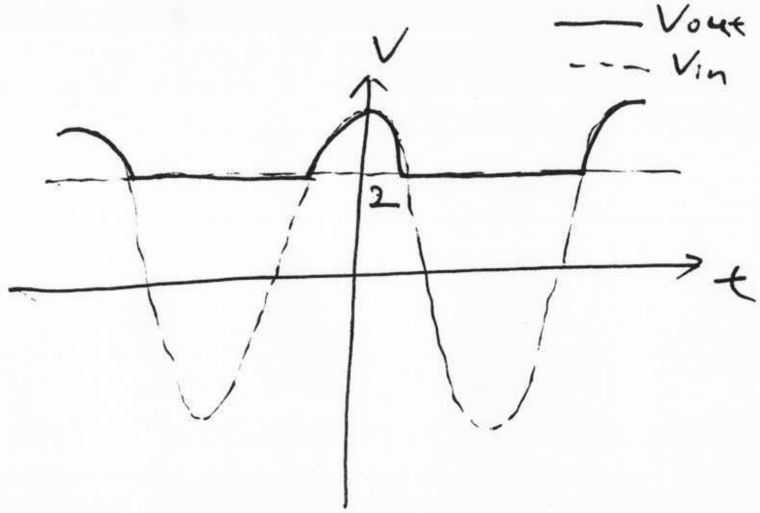
c)



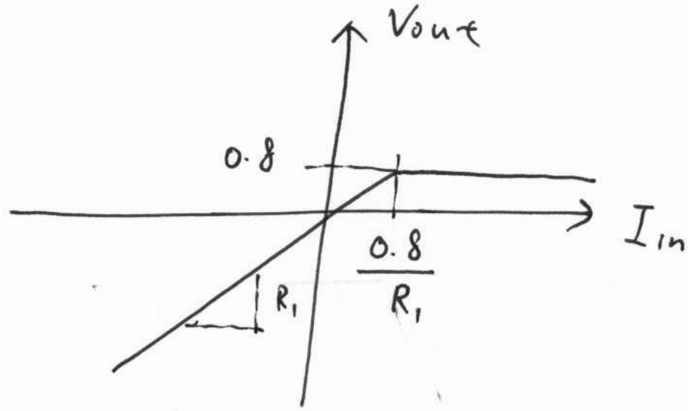
d)



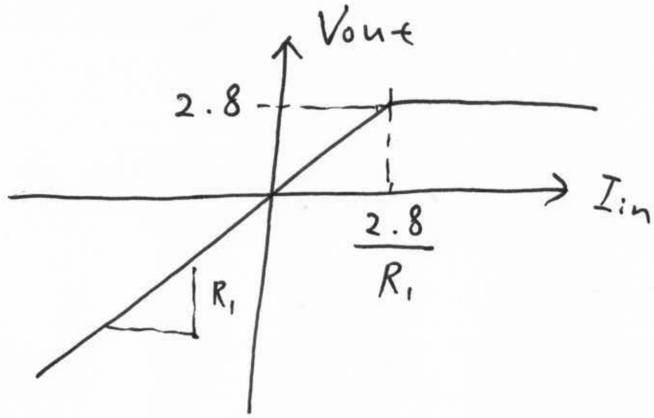
e).



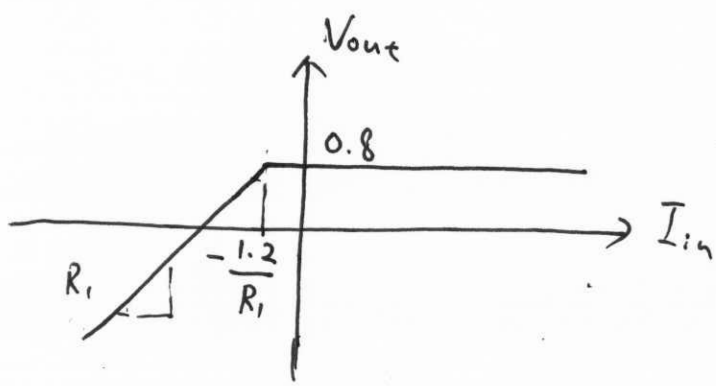
(15) a)


Vout
0.8
Iin
0.8
R1
R1

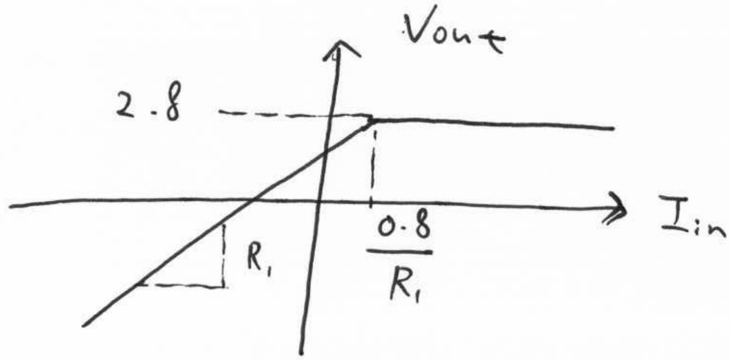
b)


Vout
2.8
Iin
2.8
R1
R1

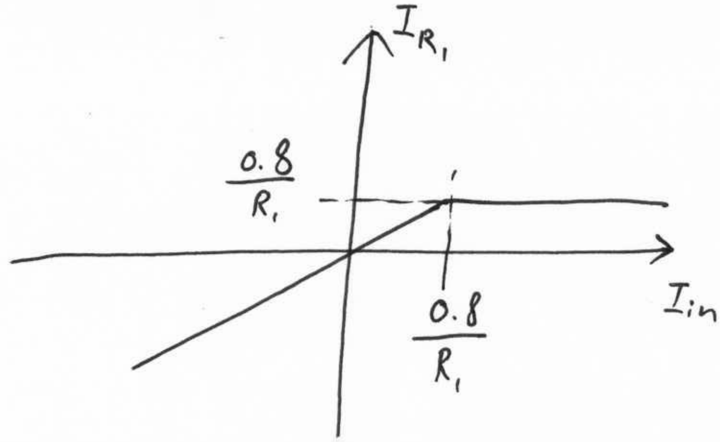
c)


Vout
0.8
Iin
-1.2
R1
R1

d)

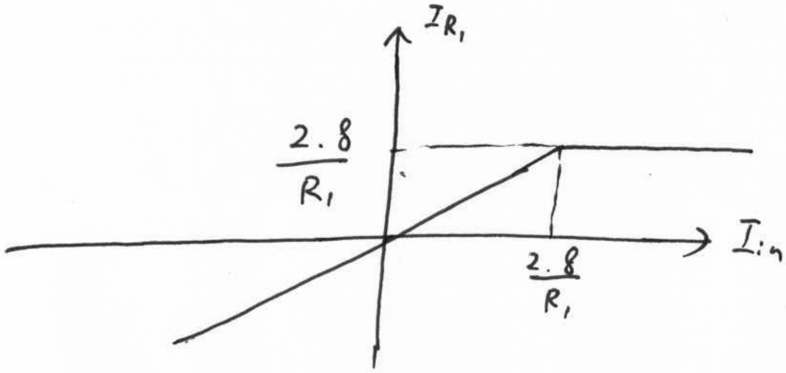

Vout
2.8
Iin
0.8
R1
R1

(16) a)



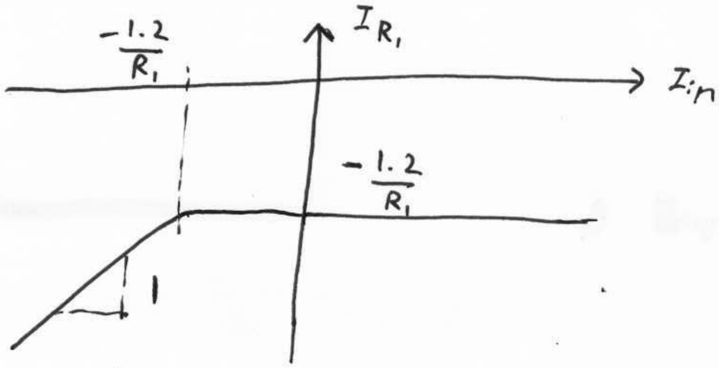
I_{R_1}
$\frac{0.8}{R_1}$
$\frac{0.8}{R_1}$
I_{in}

b)



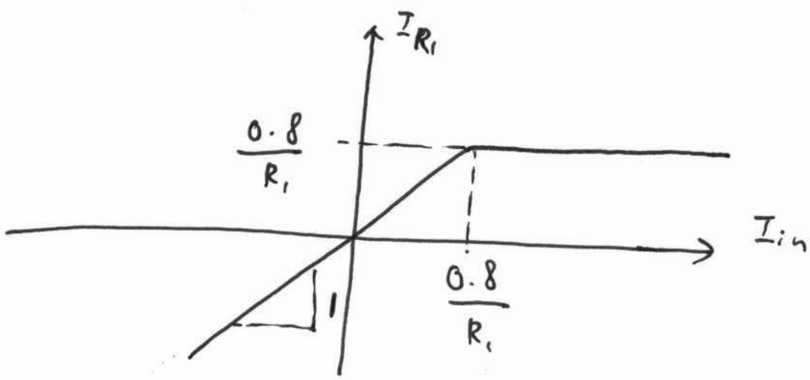
I_{R_1}
$\frac{2.8}{R_1}$
I_{in}
$\frac{2.8}{R_1}$

c)



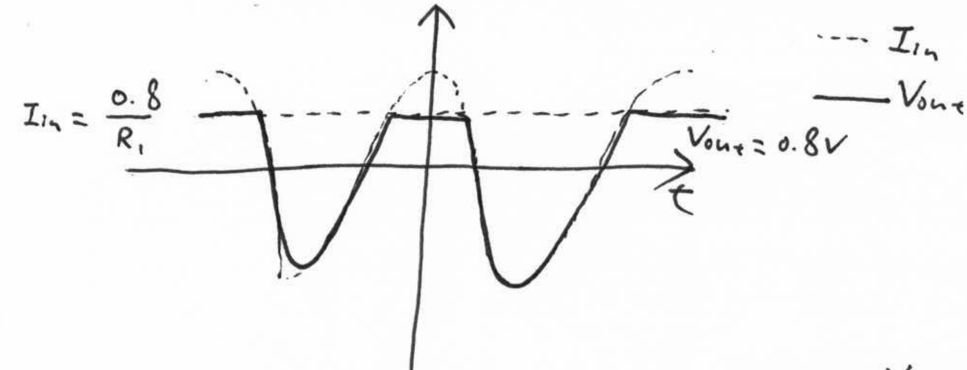
$-\frac{1.2}{R_1}$
I_{R_1}
I_{in}
$-\frac{1.2}{R_1}$
1

d)

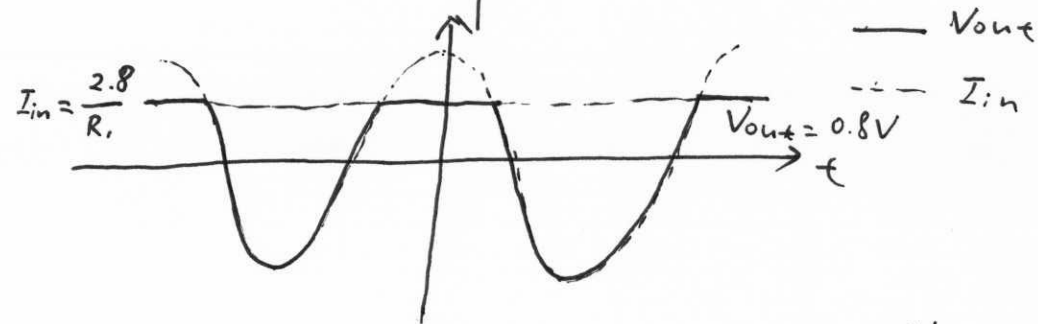


I_{R_1}
$\frac{0.8}{R_1}$
I_{in}
$\frac{0.8}{R_1}$
1

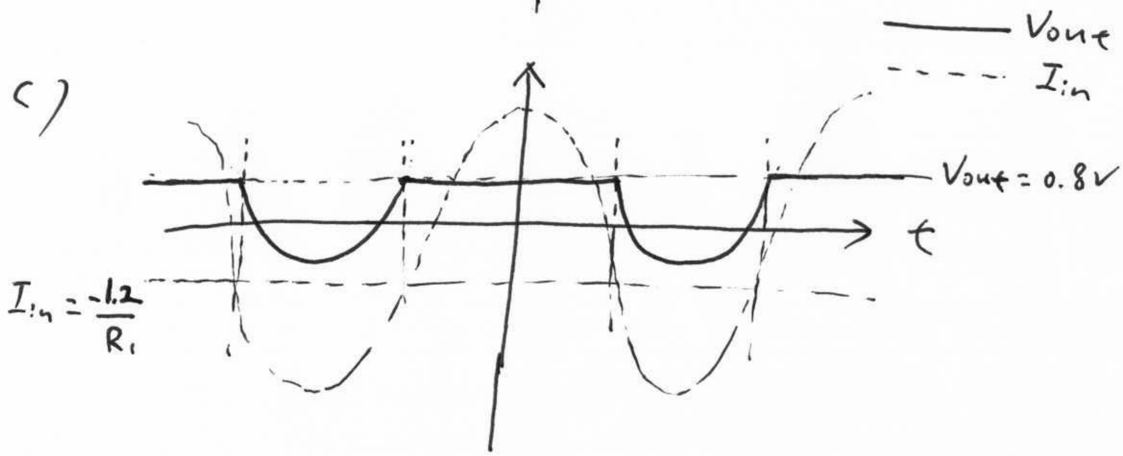
(17) a)


$I_{in} = \frac{0.8}{R_1}$
$V_{out} = 0.8V$
t
--- I_{in}
— V_{out}

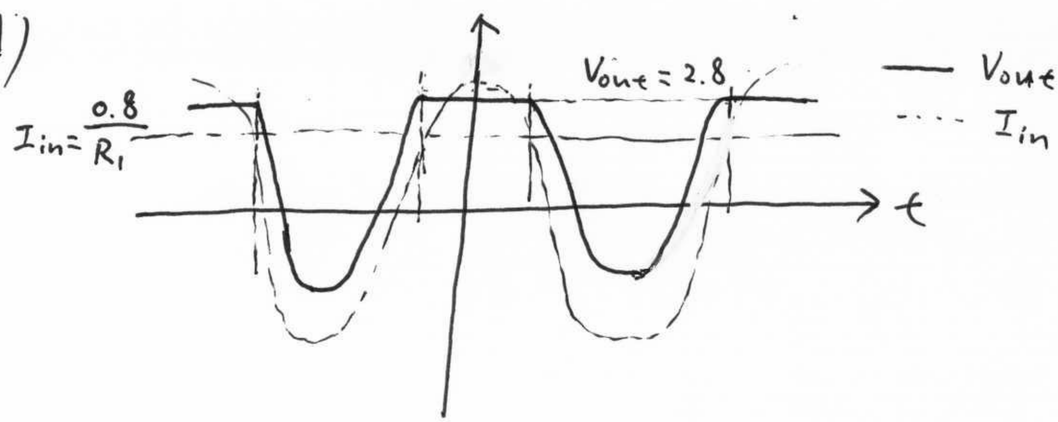
b)


$I_{in} = \frac{2.8}{R_1}$
$V_{out} = 0.8V$
t
— V_{out}
--- I_{in}

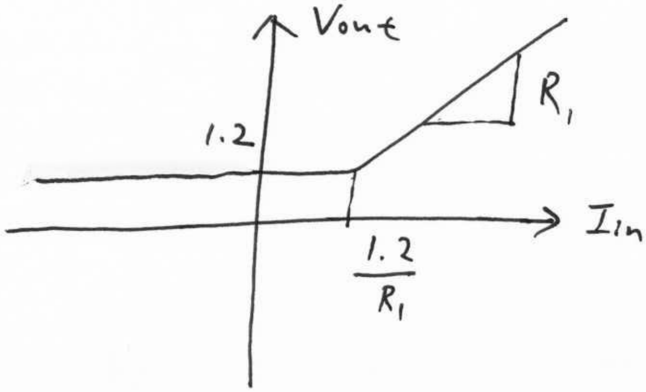
c)


$V_{out} = 0.8V$
t
$I_{in} = \frac{-1.2}{R_1}$
— V_{out}
--- I_{in}

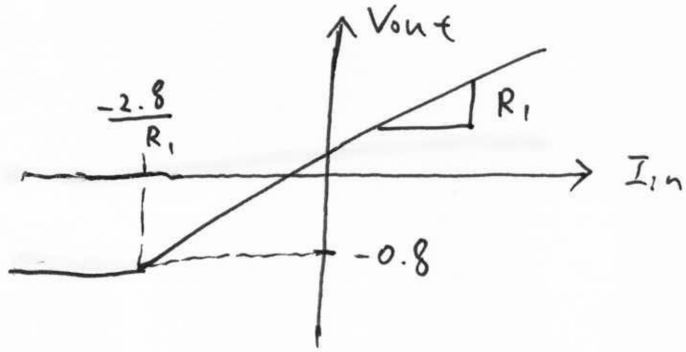
d)


$V_{out} = 2.8$
$I_{in} = \frac{0.8}{R_1}$
t
— V_{out}
--- I_{in}

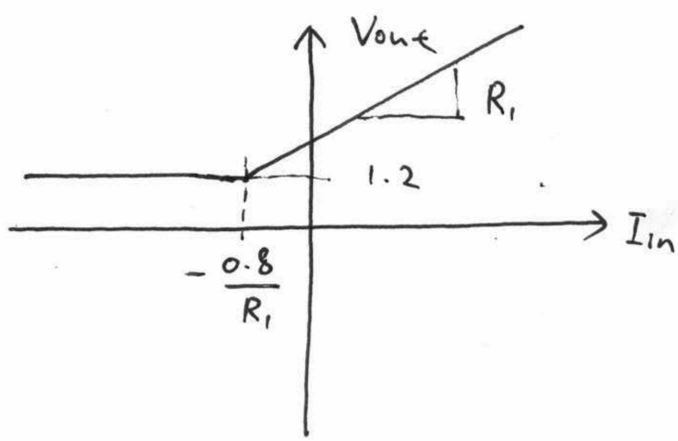
(18) a)



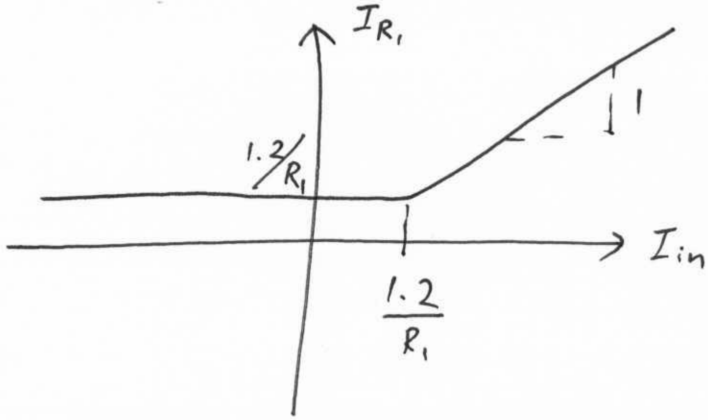
b)



c)

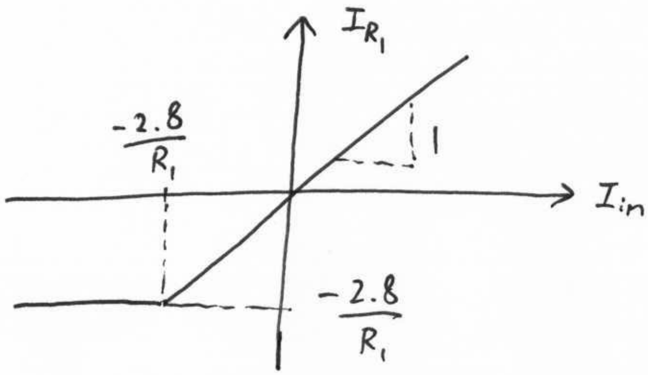


(19) a)



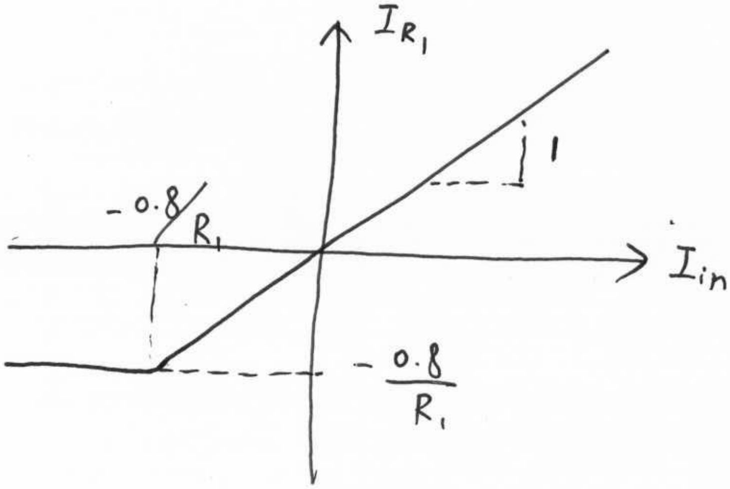
I_{R_1}
1.2/R_1
1
I_{in}
$\frac{1.2}{R_1}$

b)



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

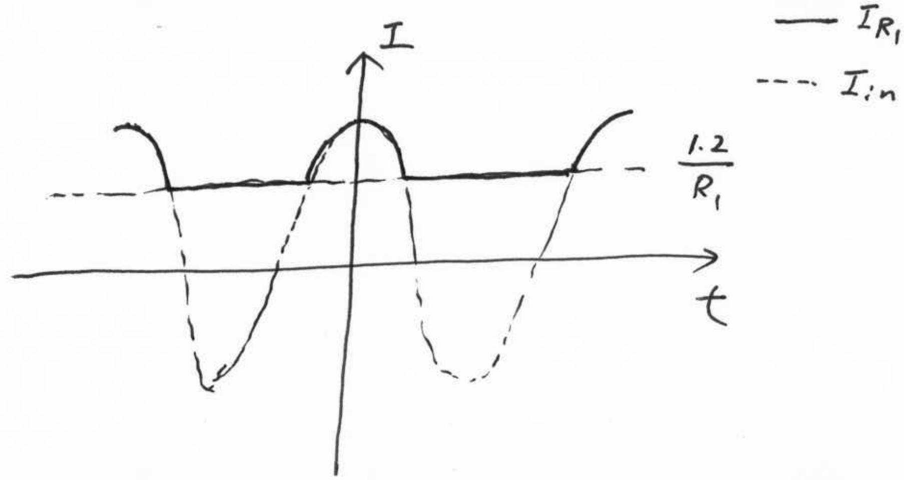
c)



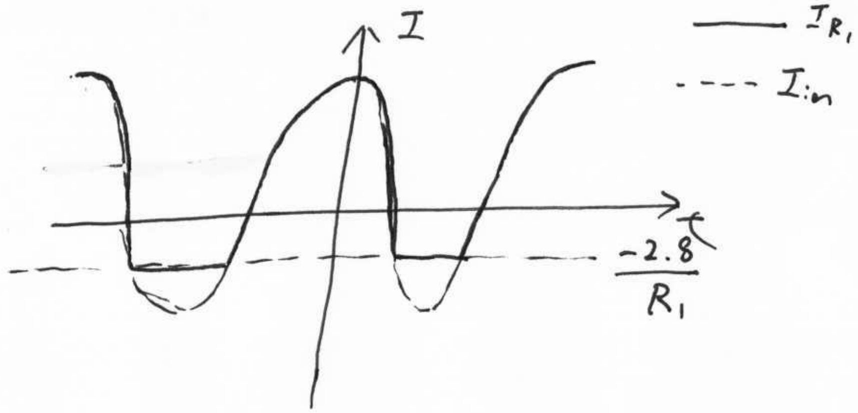
I_{R_1}
1
$-0.8/R_1$
I_{in}
$-\frac{0.8}{R_1}$

(20)

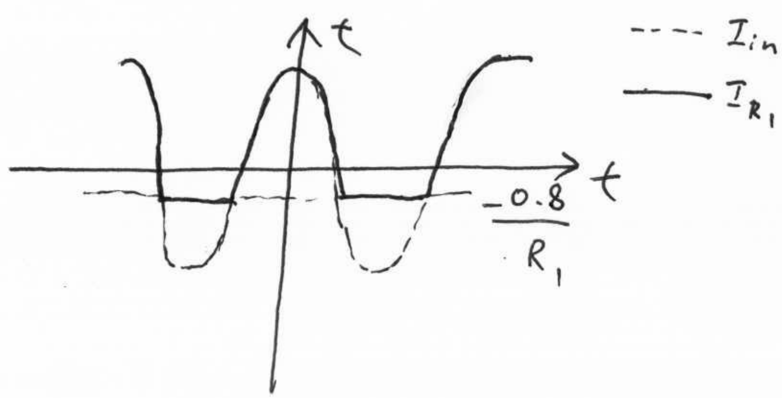
a)



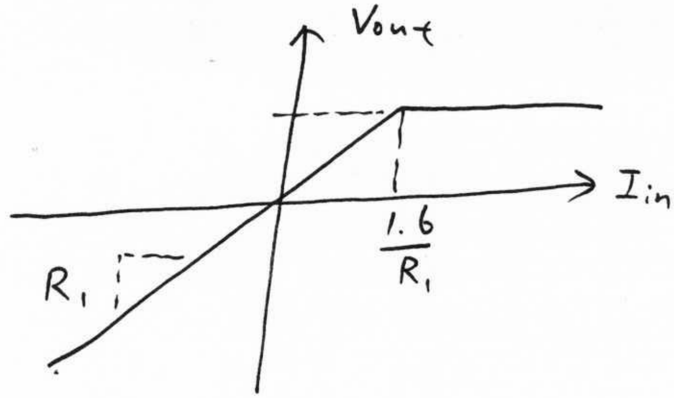
b)



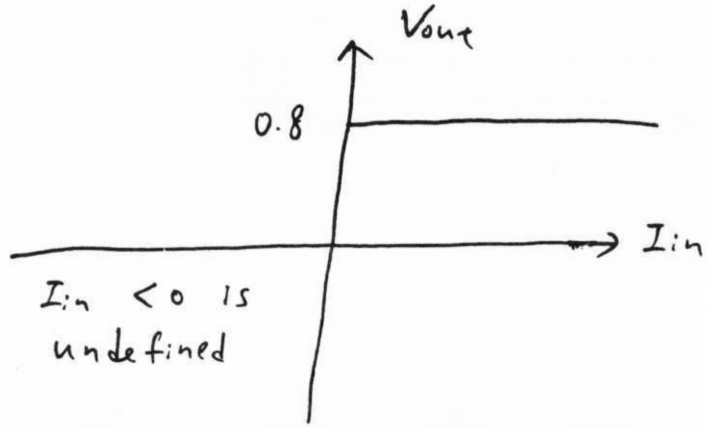
c)



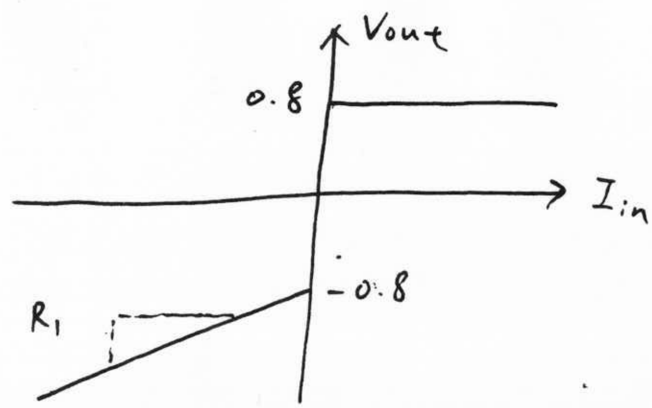
(21) a)


Vout
Iin
1.6
R1
R1

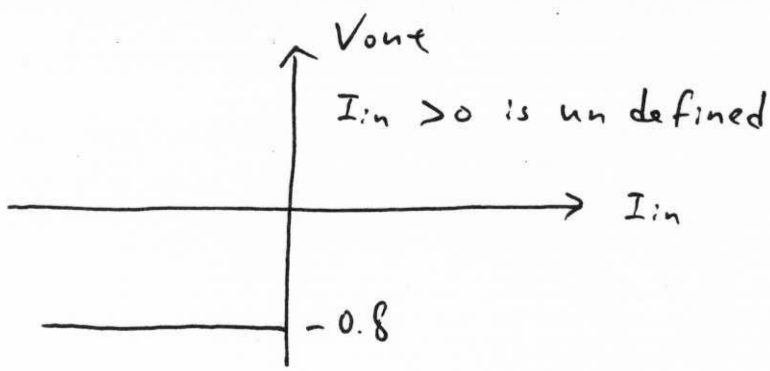
b)


Vout
0.8
Iin
Iin <0 is undefined

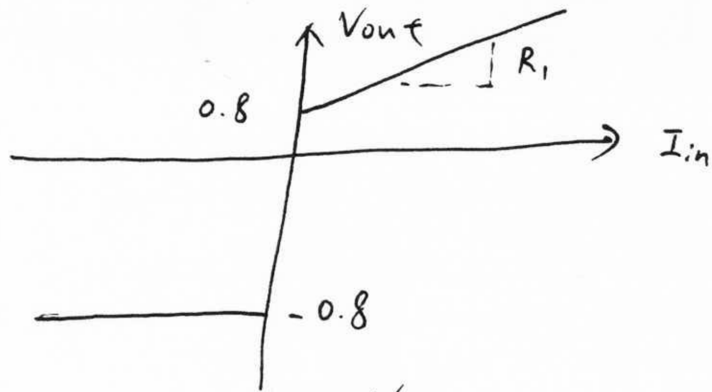
c)


Vout
0.8
Iin
-0.8
R1

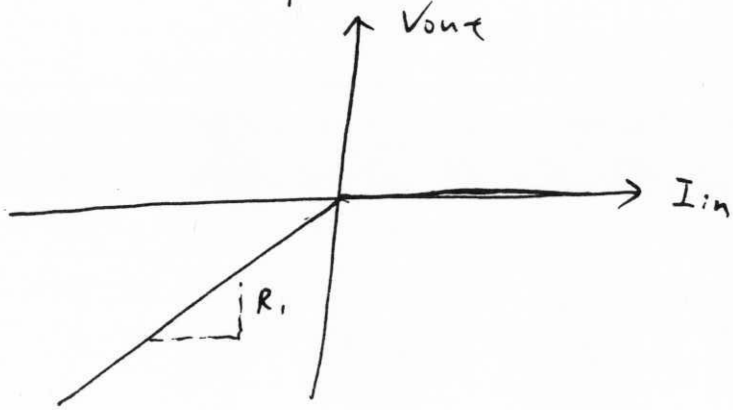
d)


Vout
Iin >0 is undefined
Iin
-0.8

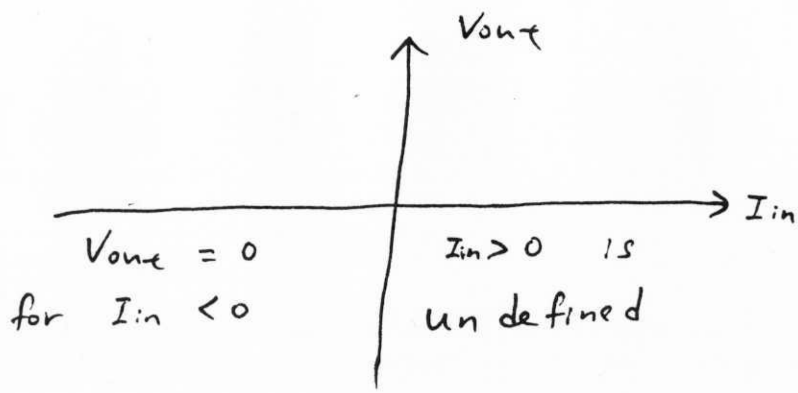
e)


Vout
R1
0.8
Iin
-0.8

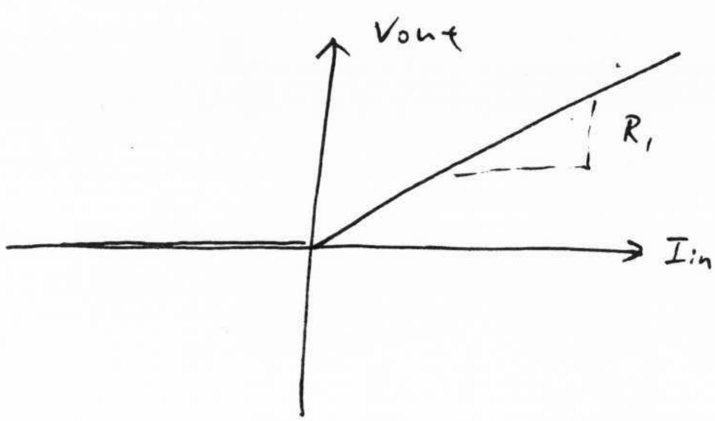
f)


Vout
Iin
R1

g)

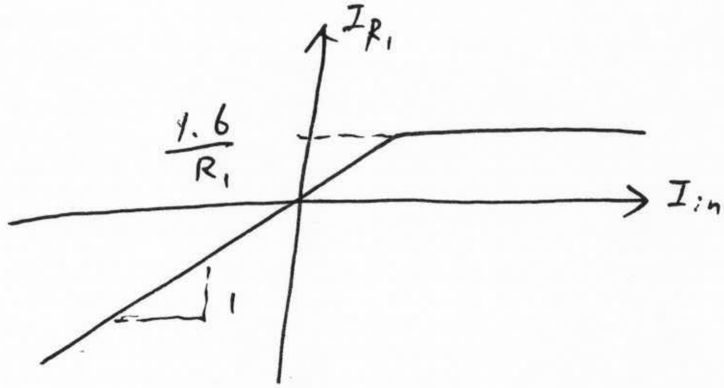

Vout
Iin
Vout = 0
for Iin < 0
Iin > 0 is
undefined

h)


Vout
R1
Iin

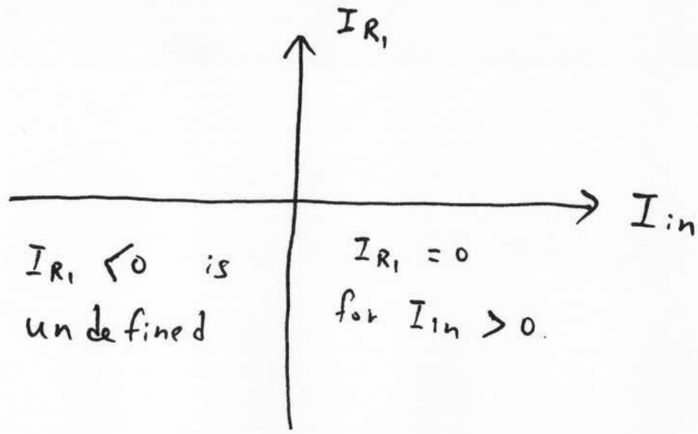
(22)

a)



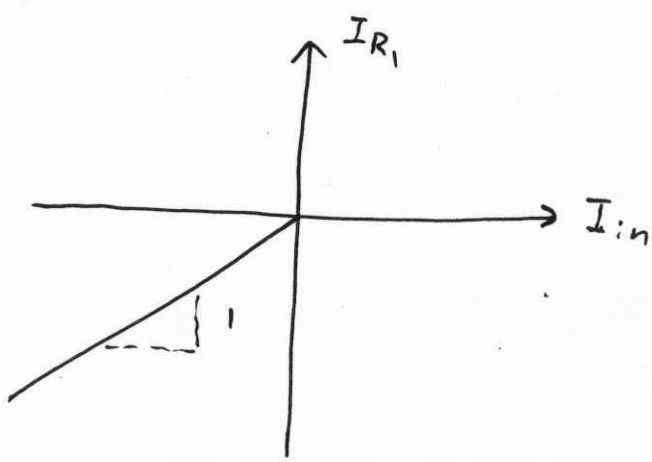
I_{R_1}
$\frac{4.6}{R_1}$
I_{in}
1

b)



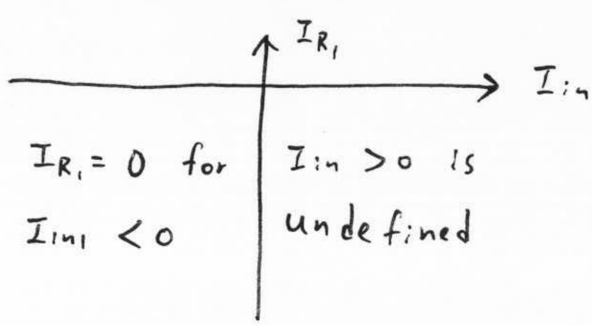
I_{R_1}
I_{in}
$I_{R_1} < 0$ is undefined
$I_{R_1} = 0$ for $I_{in} > 0$.

c)



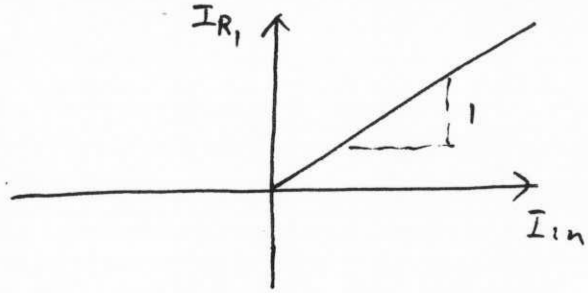
I_{R_1}
I_{in}
1

d)

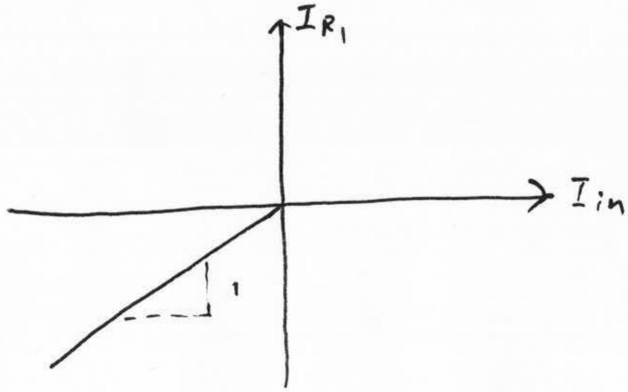


I_{R_1}
I_{in}
$I_{R_1} = 0$ for $I_{in} < 0$
$I_{in} > 0$ is undefined

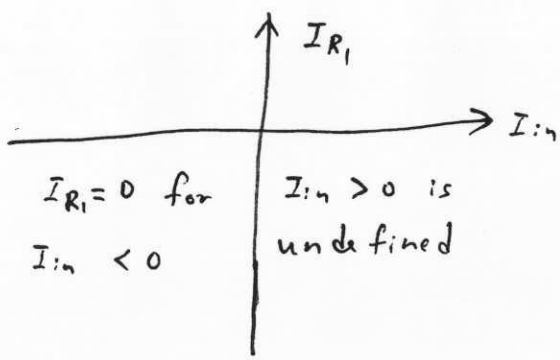
e)


I_{R_1}
1
I_{in}

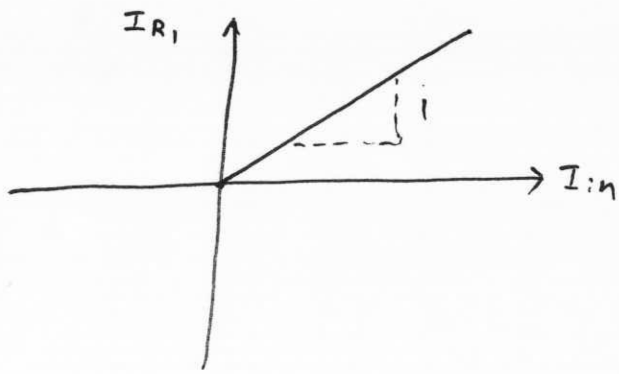
f)


I_{R_1}
I_{in}
1

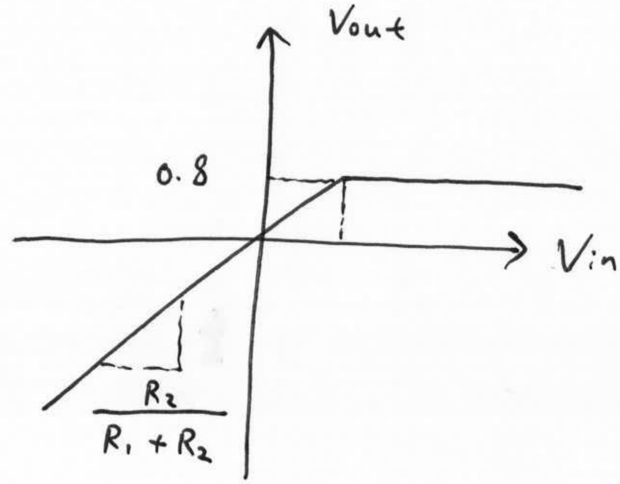
g)


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

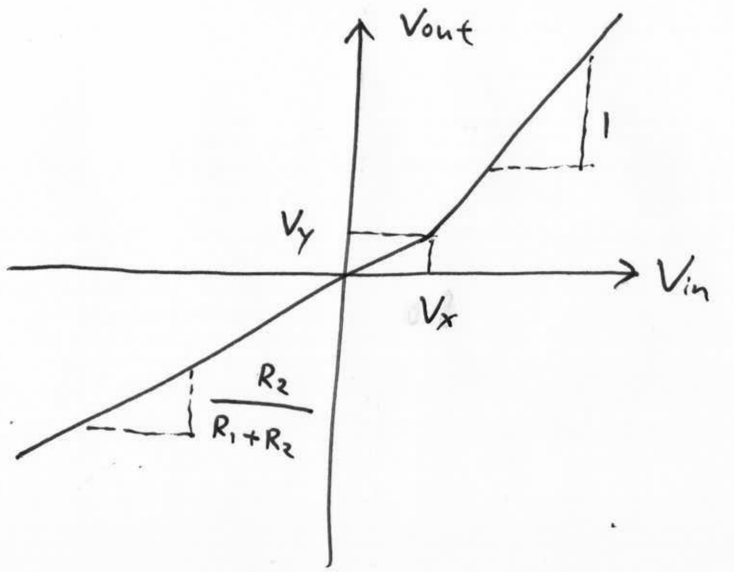
h)


I_{R_1}
1
I_{in}

(23) a)



b)

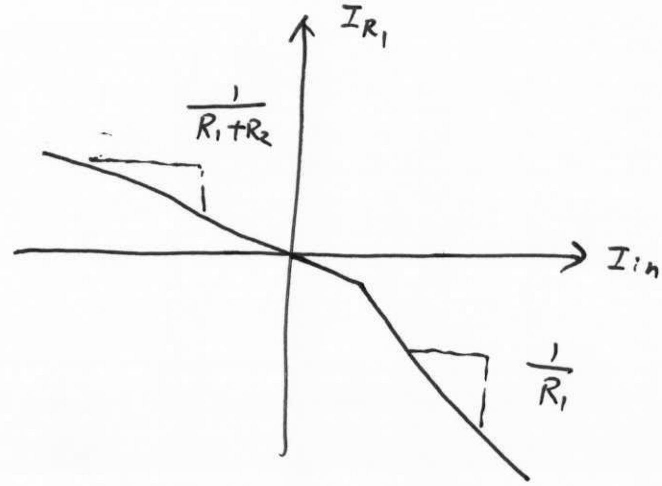


<u>Note</u>: at the turning point when D_1 starts to conduct, V_x, V_y need to satisfy 2 conditions:

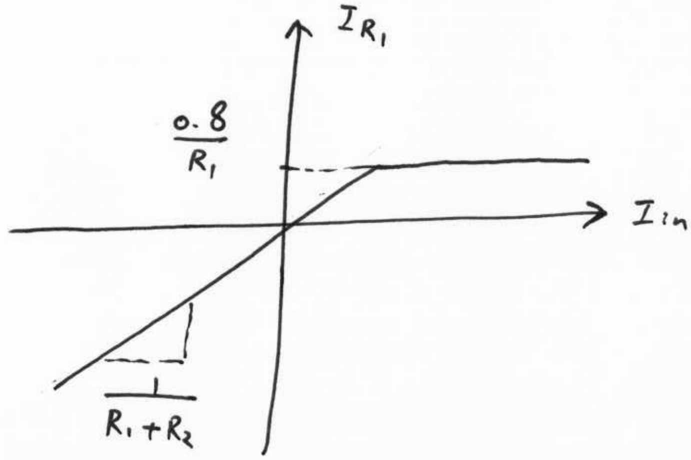
$$V_x - V_y = 0.8 \quad \text{——} \quad (1)$$

$$V_y = \frac{R_2}{R_1 + R_2} V_x \quad \text{——} \quad (2)$$

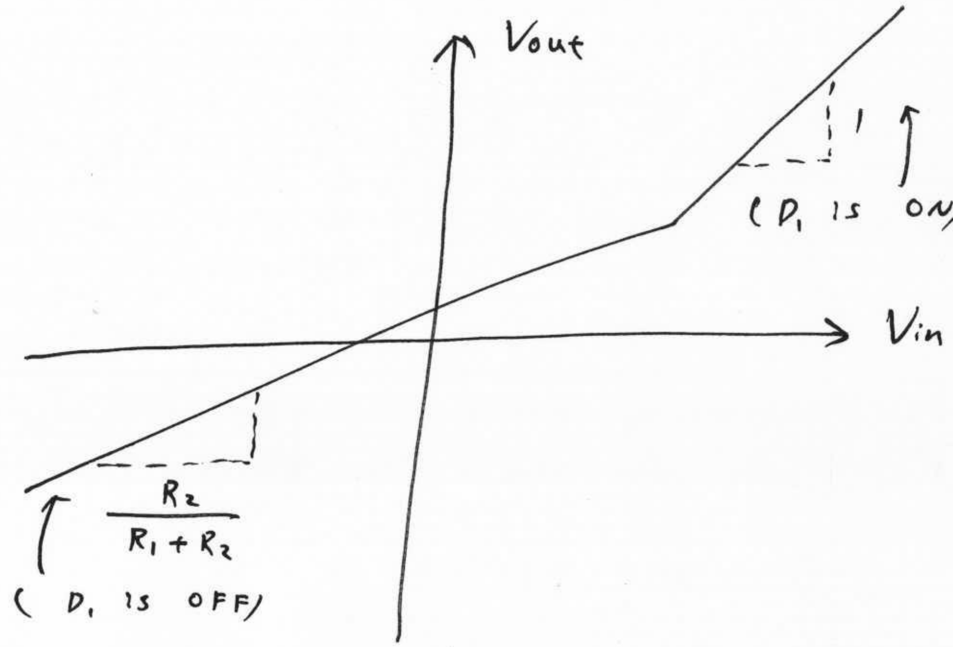
(24) a)



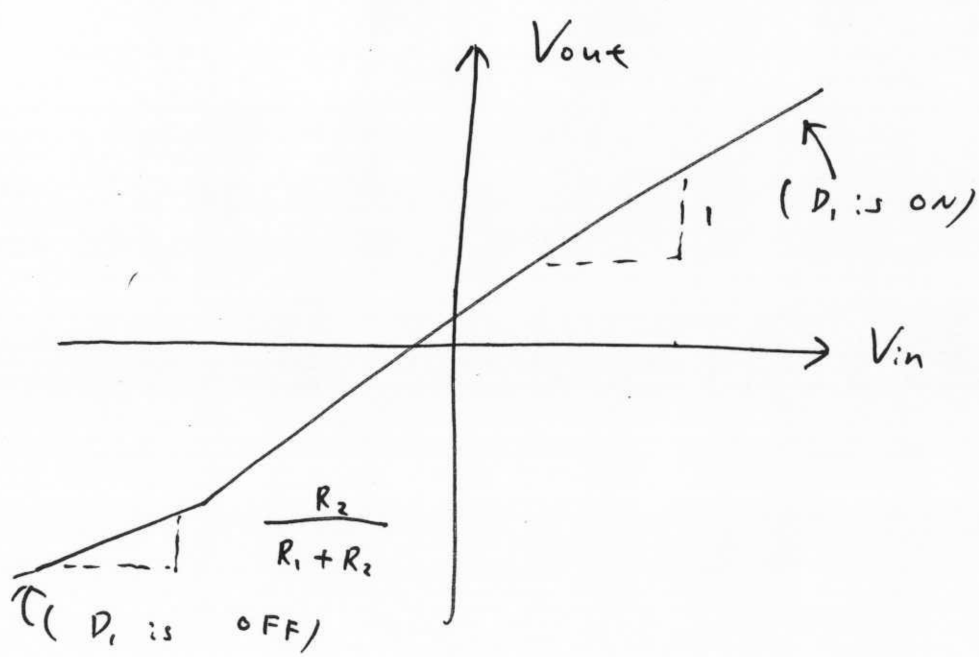
b)



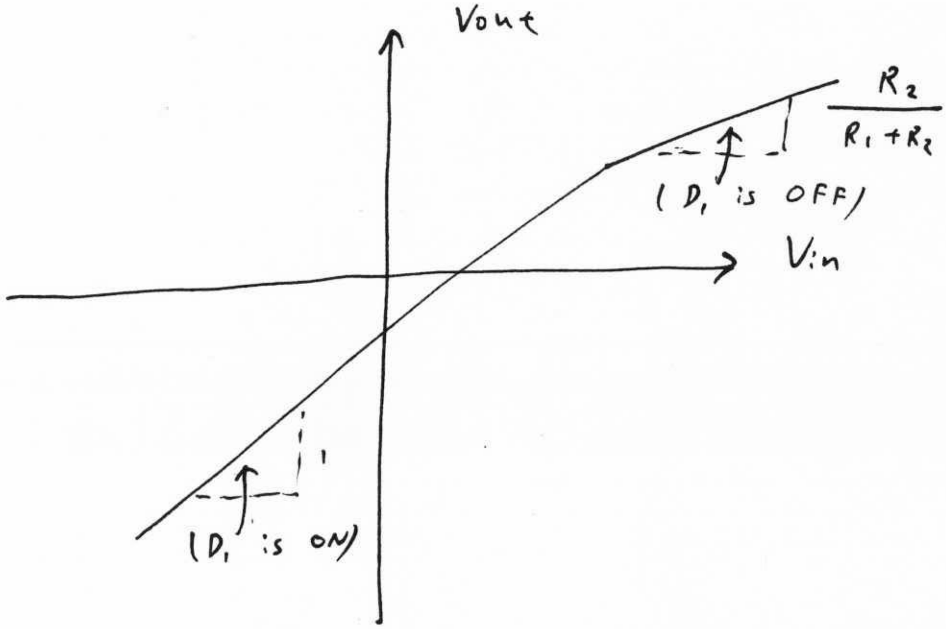
(25) a)


Vout
Vin
1
(D1 is ON)
R2 / R1 + R2
(D1 is OFF)

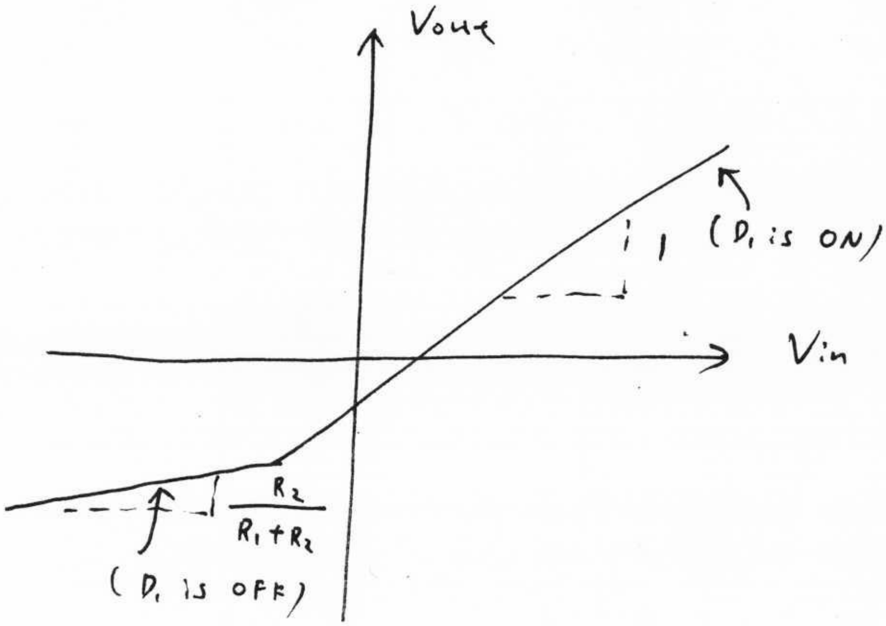
b)


Vout
Vin
1
(D1 is ON)
R2 / R1 + R2
(D1 is OFF)

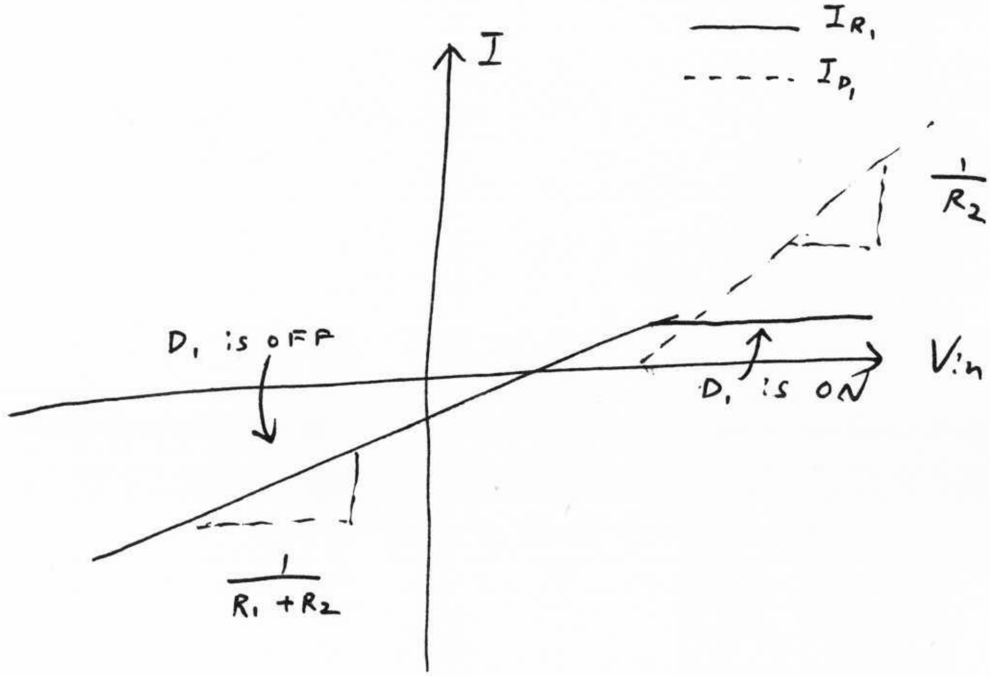
c)


Vout
Vin
$\frac{R_2}{R_1+R_2}$
(D1 is OFF)
1
(D1 is ON)

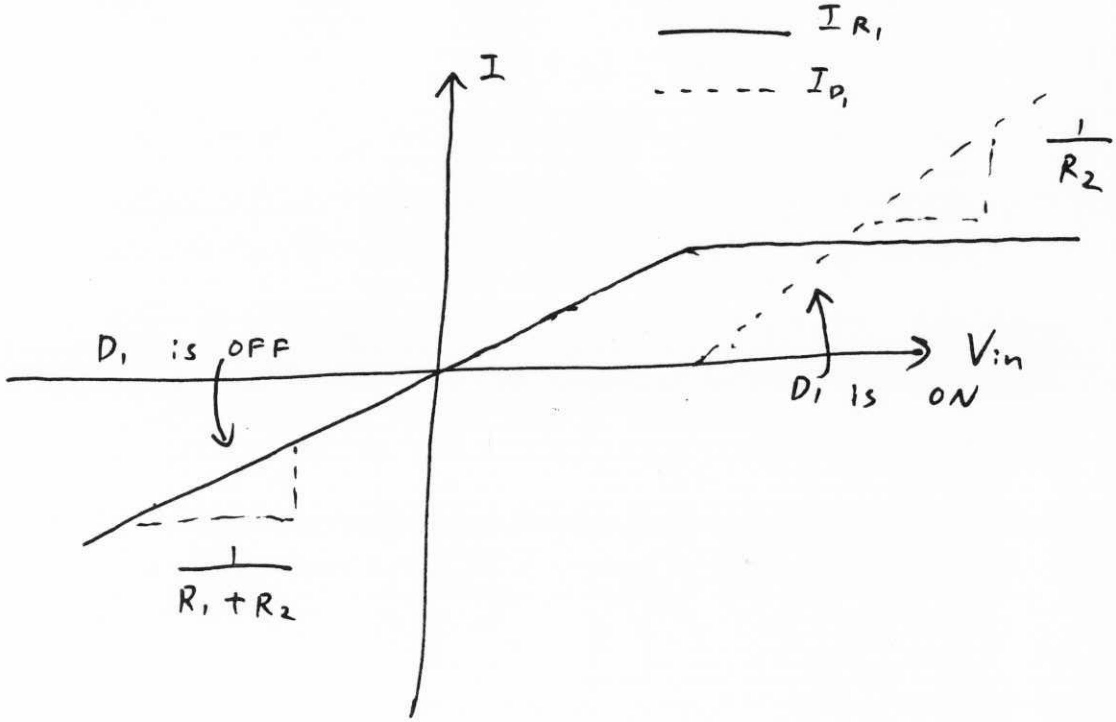
d)


Vout
Vin
1
(D1 is ON)
$\frac{R_2}{R_1+R_2}$
(D1 is OFF)

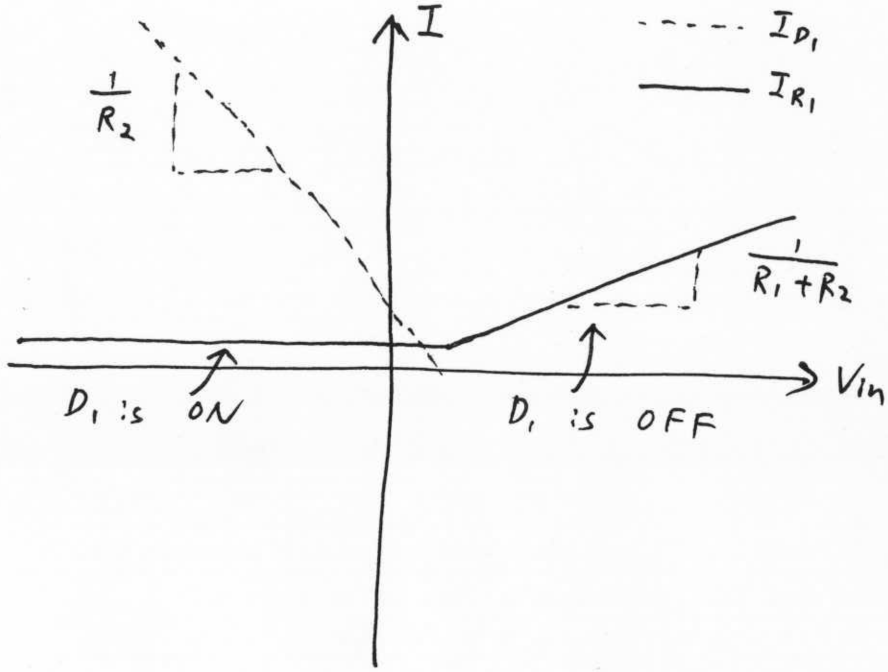
(2b) a)


I
I_{R_1}
I_{D_1}
$\frac{1}{R_2}$
D_1 is OFF
V_{in}
D_1 is ON
$\frac{1}{R_1+R_2}$

b)

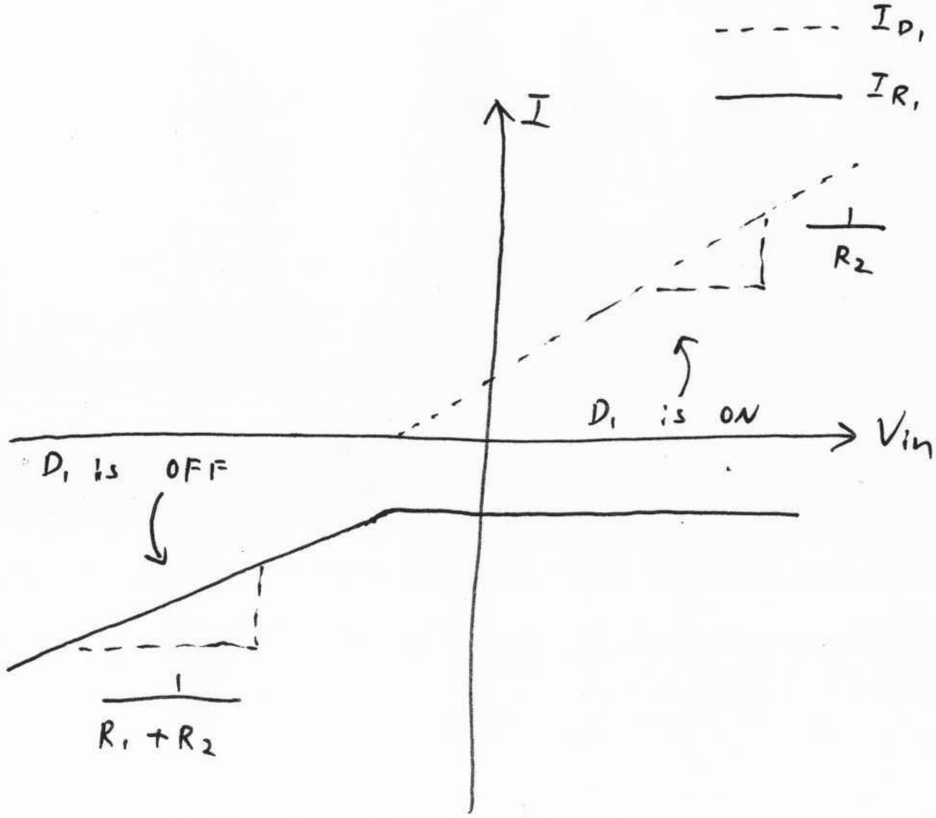

I
I_{R_1}
I_{D_1}
$\frac{1}{R_2}$
D_1 is OFF
V_{in}
D_1 is ON
$\frac{1}{R_1+R_2}$

c/



I
I_{D_1}
I_{R_1}
$\frac{1}{R_2}$
$\frac{1}{R_1+R_2}$
V_{in}
D_1 is ON
D_1 is OFF

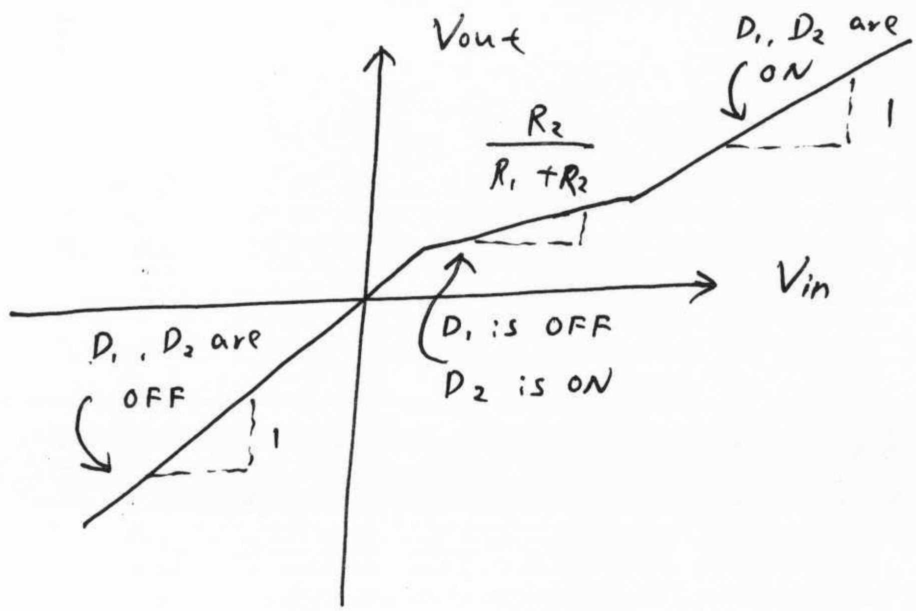
d/



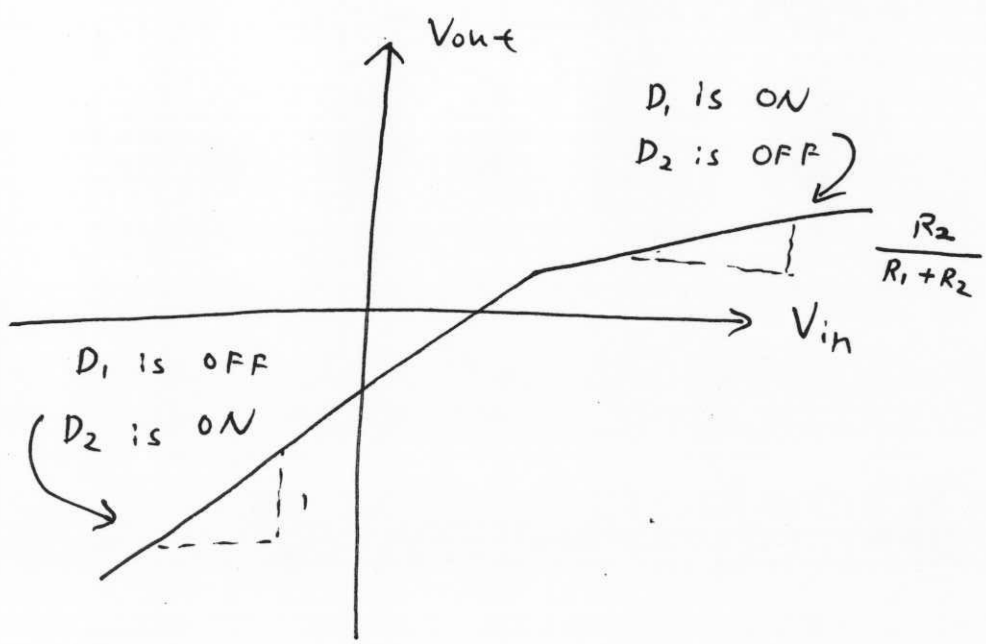
I_{D_1}
I_{R_1}
I
$\frac{1}{R_2}$
D_1 is ON
V_{in}
D_1 is OFF
$\frac{1}{R_1+R_2}$

(27)

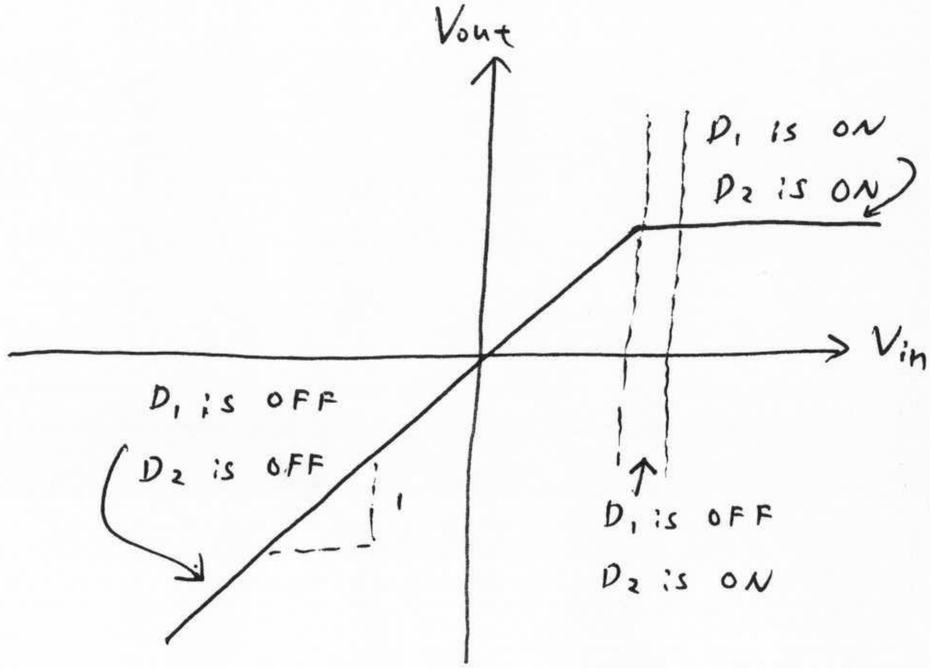
a)


Vout
Vin
D1, D2 are ON
1
R2 / R1 + R2
D1 is OFF
D2 is ON
D1, D2 are OFF
1

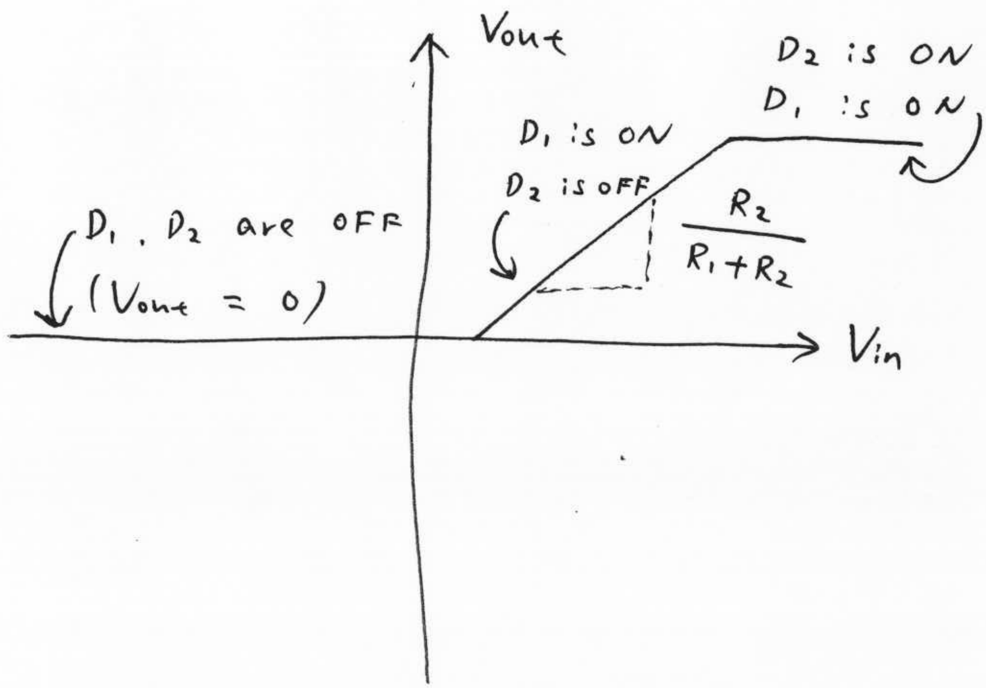
b)


Vout
Vin
D1 is ON
D2 is OFF
R2 / R1 + R2
D1 is OFF
D2 is ON
1

c)

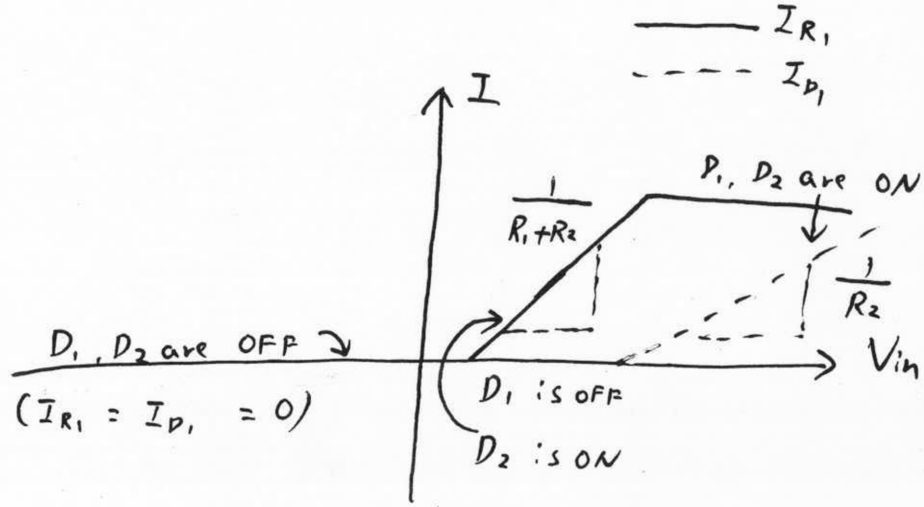

Vout
D1 is ON
D2 is ON
Vin
D1 is OFF
D2 is OFF
1
D1 is OFF
D2 is ON

d)


Vout
D2 is ON
D1 is ON
D1 is ON
D2 is OFF
D1, D2 are OFF
(Vout = 0)
R2
R1+R2
Vin

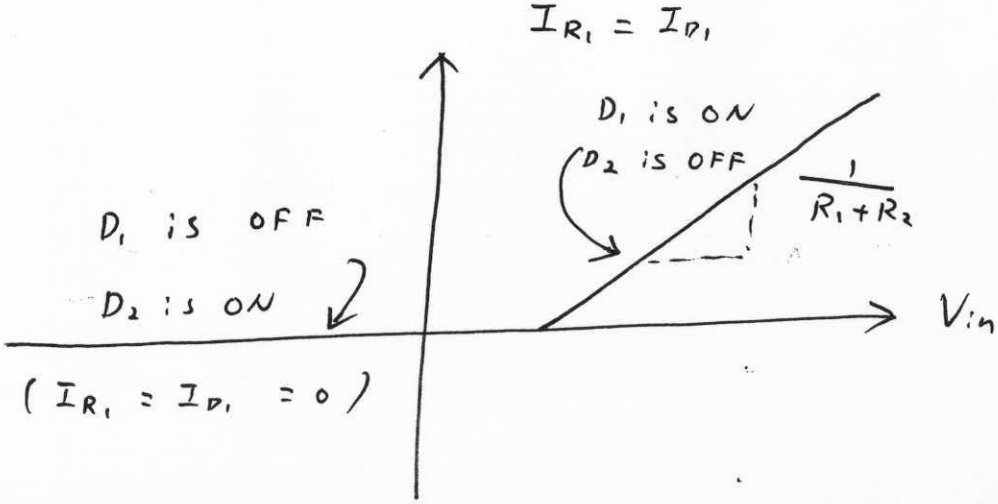
(28)

a)



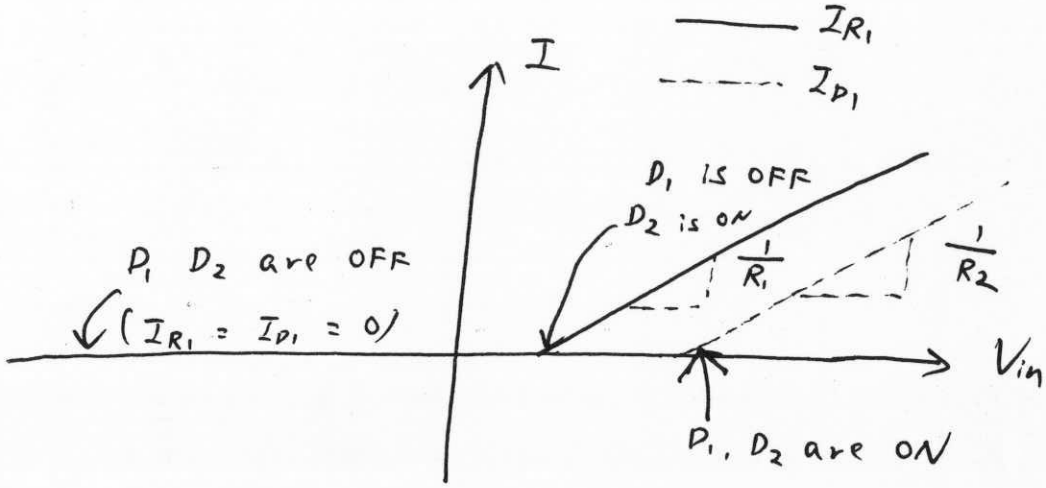
I
I_{R_1}
I_{D_1}
D_1, D_2 are ON
$\frac{1}{R_1+R_2}$
$\frac{1}{R_2}$
D_1, D_2 are OFF
($I_{R_1} = I_{D_1} = 0$)
D_1 is OFF
D_2 is ON
V_{in}

b)

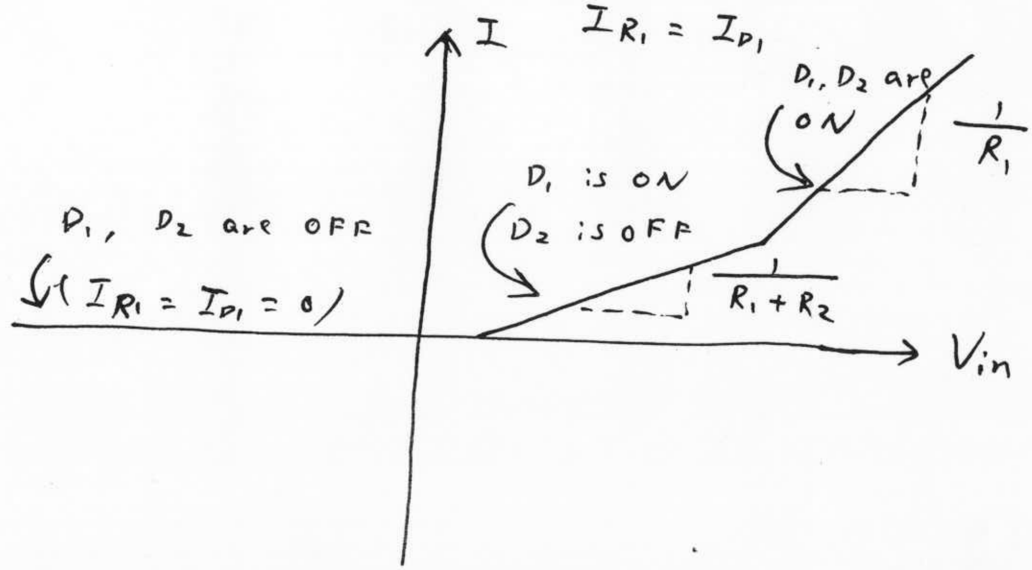


$I_{R_1} = I_{D_1}$
D_1 is ON
D_2 is OFF
$\frac{1}{R_1+R_2}$
D_1 is OFF
D_2 is ON
($I_{R_1} = I_{D_1} = 0$)
V_{in}

c)

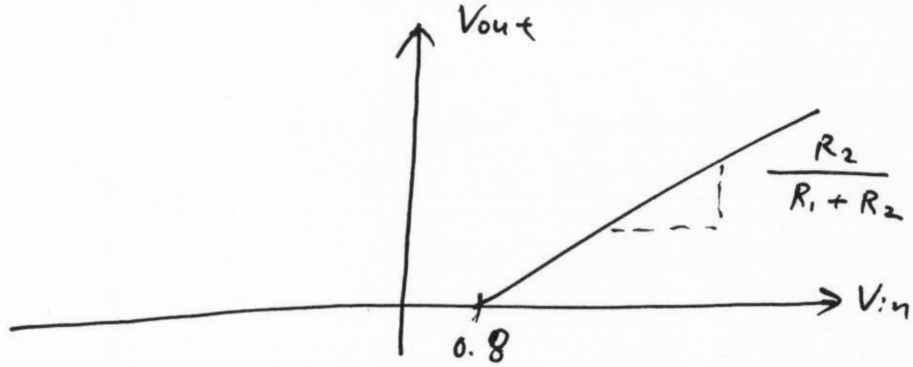

I
I_{R_1}
I_{D_1}
D_1 IS OFF
D_2 is ON
$\frac{1}{R_1}$
$\frac{1}{R_2}$
D_1 D_2 are OFF
$(I_{R_1} = I_{D_1} = 0)$
V_{in}
D_1, D_2 are ON

d)

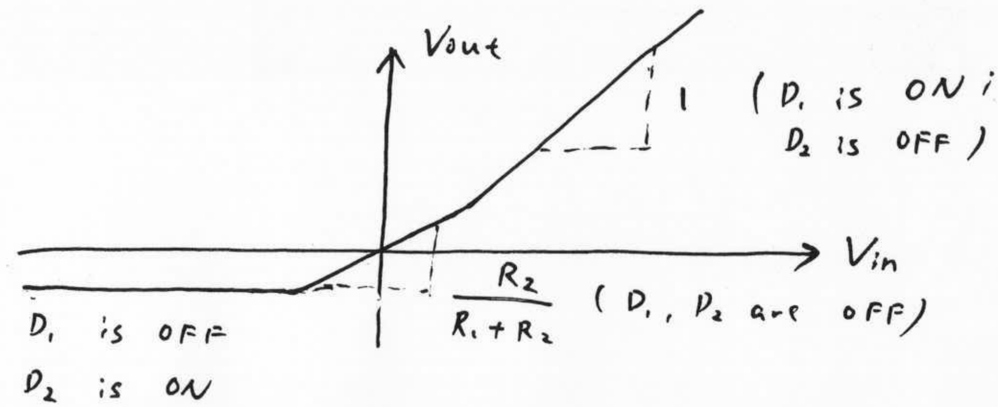

I
$I_{R_1} = I_{D_1}$
D_1, D_2 are ON
$\frac{1}{R_1}$
D_1 is ON
D_2 is OFF
D_1, D_2 are OFF
$(I_{R_1} = I_{D_1} = 0)$
$\frac{1}{R_1 + R_2}$
V_{in}

(29)

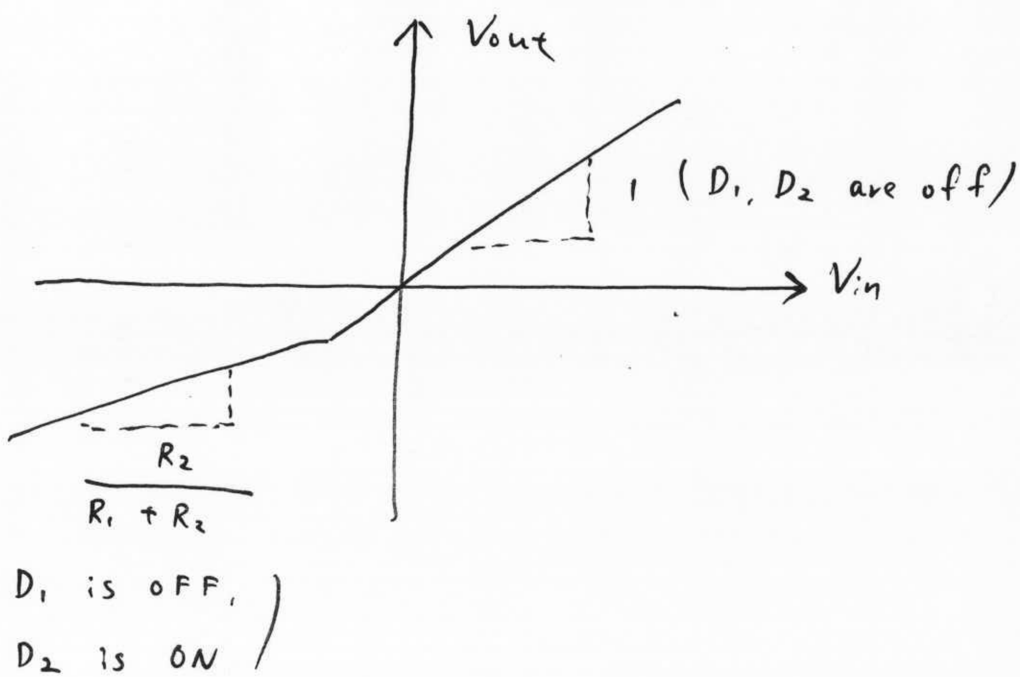
a)


Vout
R2
R1 + R2
Vin
0.8

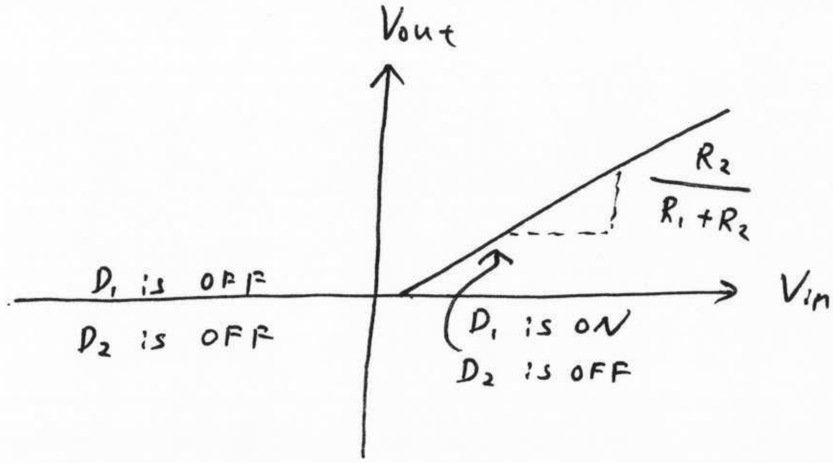
b)


Vout
1 (D1 is ON ; D2 is OFF)
Vin
R2
R1 + R2
(D1, D2 are OFF)
D1 is OFF
D2 is ON

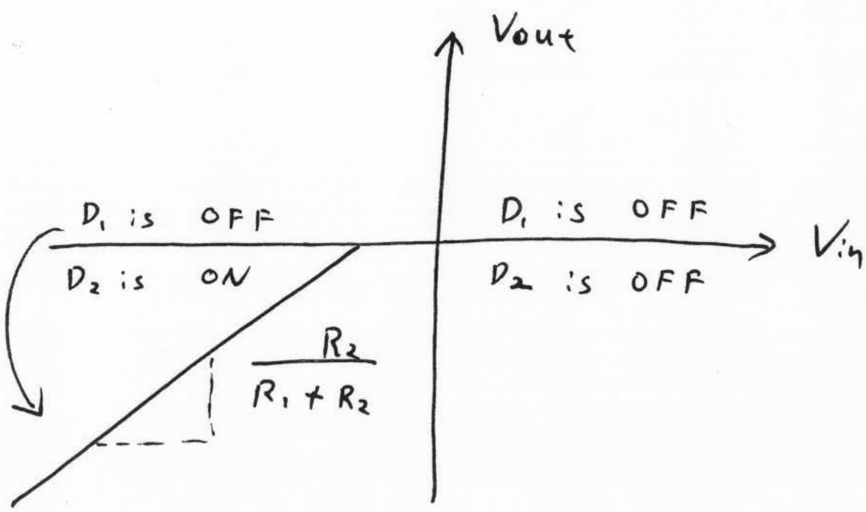
c)


Vout
1 (D1, D2 are off)
Vin
R2
R1 + R2
(D1 is OFF, D2 is ON)

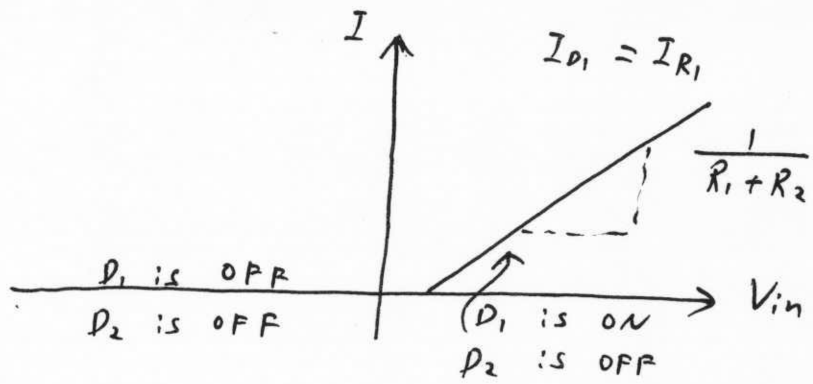
d)


Vout
Vin
D1 is OFF
D2 is OFF
R2
R1 + R2
D1 is ON
D2 is OFF

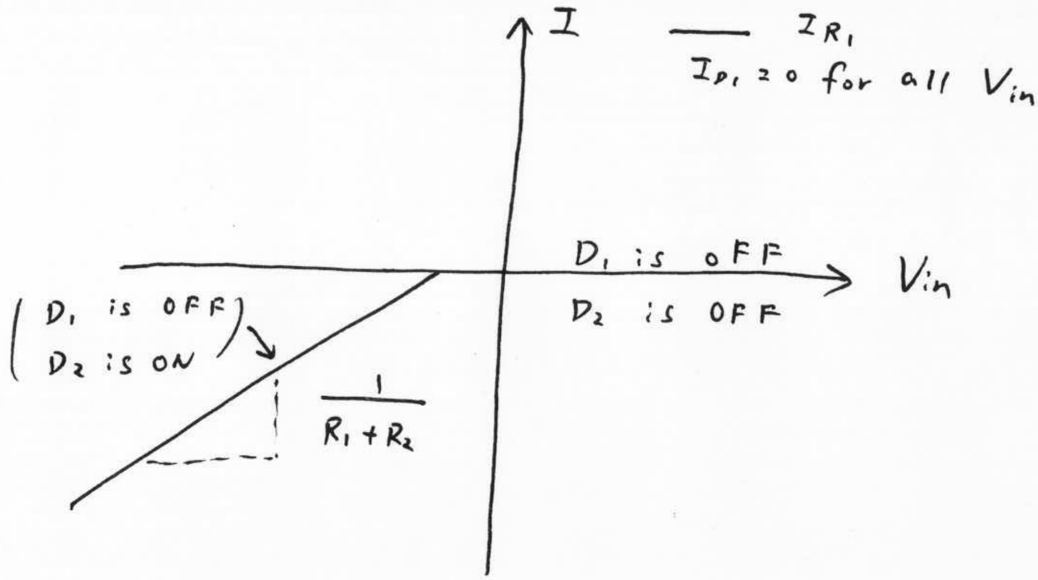
e)


Vout
Vin
D1 is OFF
D2 is ON
D1 is OFF
D2 is OFF
R2
R1 + R2

d)

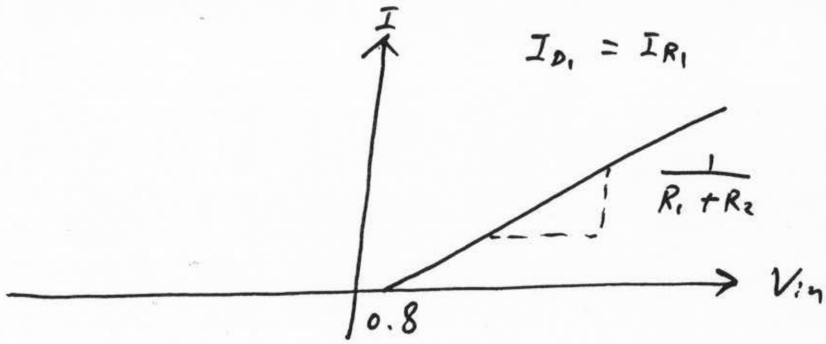

I
$I_{D_1} = I_{R_1}$
$\frac{1}{R_1 + R_2}$
D_1 is OFF
D_2 is OFF
V_{in}
D_1 is ON
D_2 is OFF

e)


I
I_{R_1}
$I_{D_1} = 0$ for all V_{in}
D_1 is OFF
D_2 is OFF
V_{in}
D_1 is OFF
D_2 is ON
$\frac{1}{R_1 + R_2}$

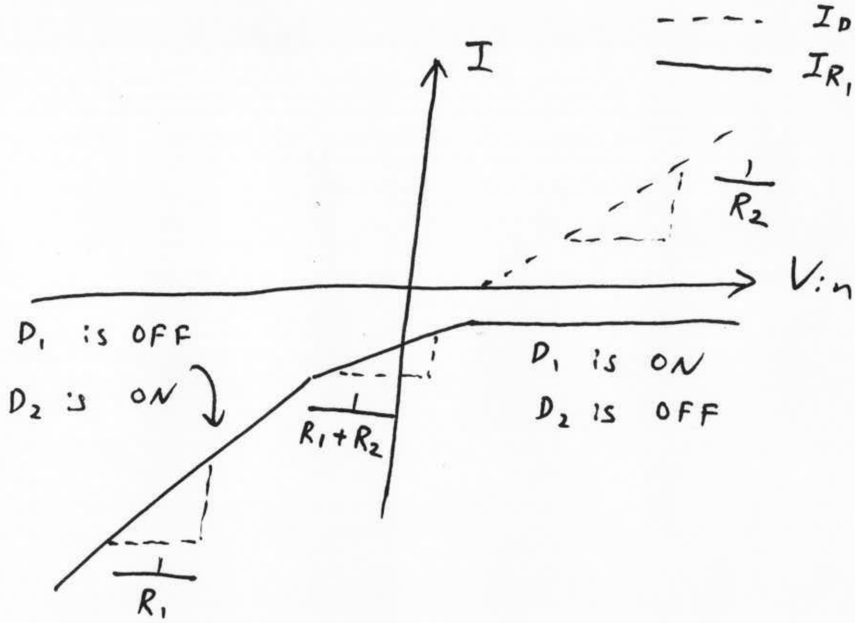
(30)

a)



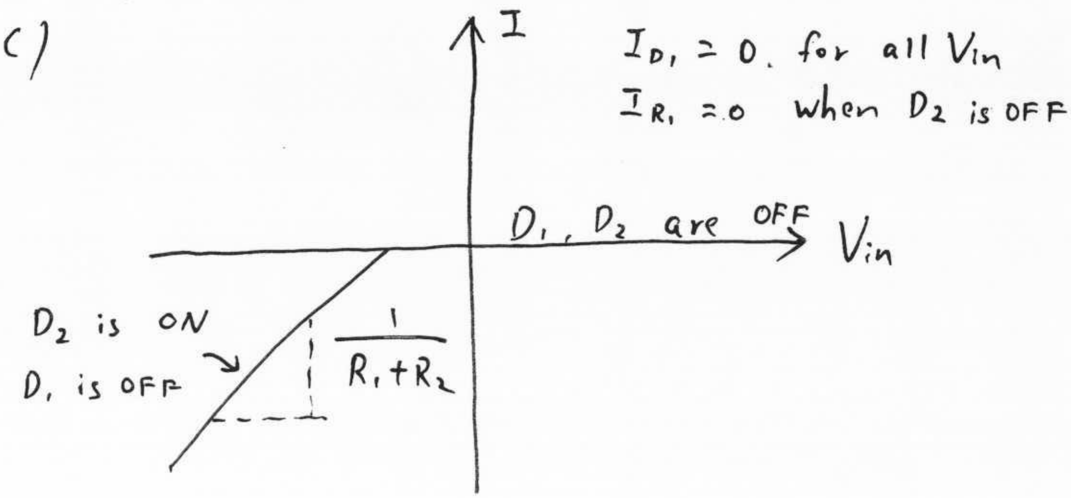
I
I_D1 = I_R1
1 / (R1 + R2)
Vin
0.8

b)



- - - - I_D1
——— I_R1
I
1 / R2
Vin
D1 is OFF
D2 is ON
1 / (R1 + R2)
D1 is ON
D2 is OFF
1 / R1

c)



I
I_D1 = 0. for all Vin
I_R1 = 0 when D2 is OFF
D1, D2 are OFF
Vin
D2 is ON
D1 is OFF
1 / (R1 + R2)

(31) a) when V_{in} changes from $+2.4V$ to $+2.5V$,

D_1 is ON throughout the change.

$$\therefore \quad V_{out} \approx V_{in} - 0.8V,$$

i.e., V_{out} changes from $+1.6V$ to $+1.7V$.

b) when V_{in} changes from $+2.4V$ to $+2.5V$,

D_1 and D_2 are both ON.

$$\therefore \quad V_{out} = V_{in} - V_{ON,D1},$$

i.e., V_{out} changes from $+1.6V$ to $+1.7V$.

c) when V_{in} changes from $+2.4V$ to $+2.5V$,

D_1 and D_2 are both ON.

$$V_{out} \approx V_{ON,D2},$$

i.e., V_{out} stays at $+0.8V$.

d) when V_{in} changes from $+2.4V$ to $+2.5V$,

D_2 is ON.

$$\therefore \quad V_{out} \approx V_{ON,D2},$$

i.e., V_{out} stays at $+0.8V$

(32) a) $V_{out} = i \times R_1$

$= 0.1 mA \times 1k\Omega$

$= 0.1 V$

b) $r_{d1} = r_{d2} = \frac{26 mV}{3 mA.}$ (Eq. 3.58)

$\simeq 8.67 \Omega.$

$V_{out} = i \times (R_1 + r_{d2})$

$= 0.1 mA (1.00867 k\Omega)$

$\simeq 1.009 \times 10^{-1} V$

c) $V_{out} = i \times r_{d2}$

$= 0.1 mA \times 8.67$ (from (b))

$= 0.867 mV$

d) $V_{out} = i \times (R_2 // r_{d2})$

$\approx i \times r_{d2}$ ($\because R_2 >> r_{d2}$)

$= 0.867 mV$

(33) a) $i_{r_1} = i_{in}$

$= 0.1\ mA$

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

$= 0.1\ mA$

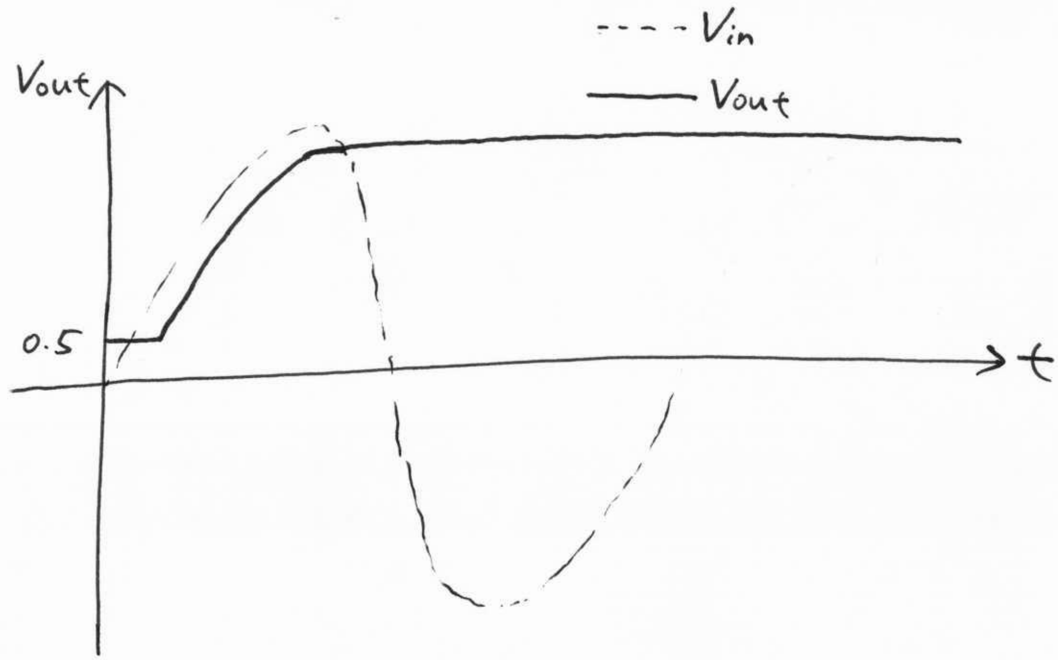
c) $i_{r_1} = i_{in}$

$= 0.1\ mA$

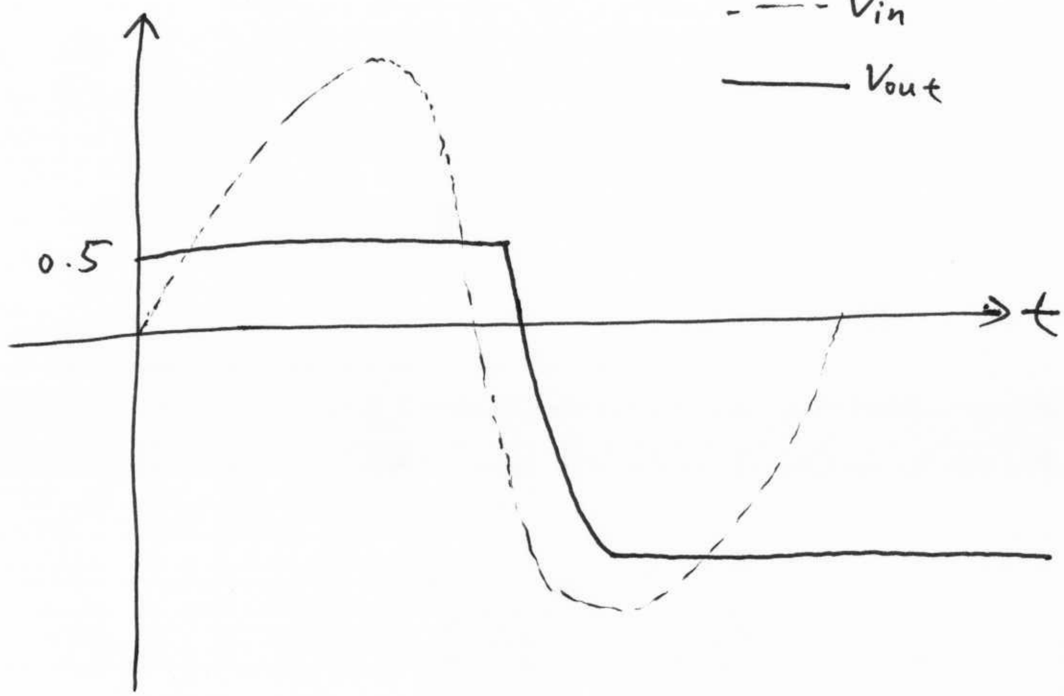
d) $i_{r_1} = i_{in}$

$= 0.1\ mA.$

(34).



35



(36) From eq. (3.80),

$$\text{Ripple amplitude}, V_R \approx \frac{V_P - V_{D,on}}{R_L C f_{in}}$$

$$= \frac{3.5 - 0.8}{10 \quad 1000 \times 10^{-6} \times 60}$$

$$= 0.45 V$$

(37)

From Eq. (3.83),

$$V_R = \frac{I_L}{C f_{in}}$$

$$\because \quad V_R \leq 300 \text{ mV}$$

$$\frac{I_L}{C f_{in}} \leq 300 \text{ mV}$$

$$\therefore \quad C \geq \frac{I_L}{f_{in} \times 0.3}$$

$$C \geq \frac{0.5}{60 \times 0.3},$$

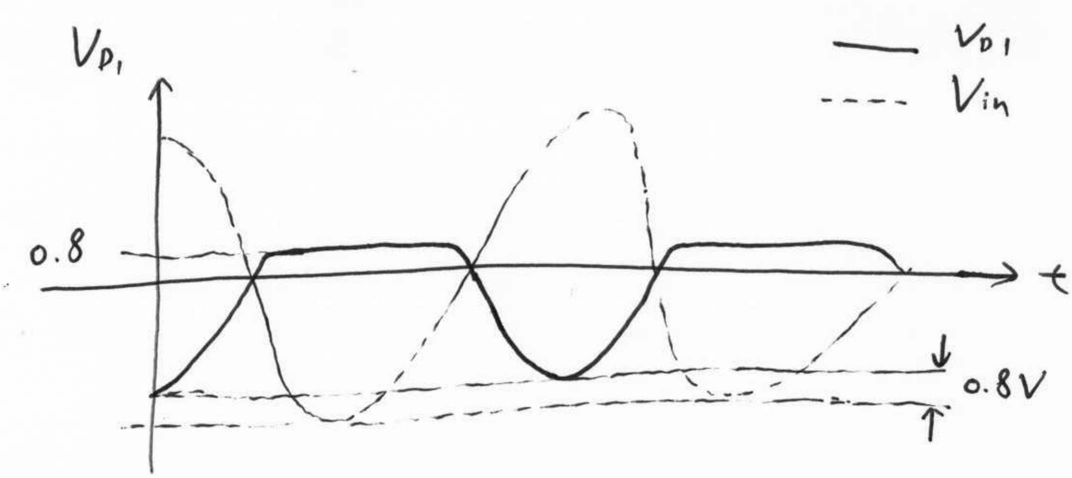
$$\text{i.e. } C \geq 0.278 \text{ F}$$

(38) - This circuit would fail to function as a full-wave rectifier.

- It only rectifies for $V_{in-} > V_{in+}$ (Current flows through D_1 and D_2)
- But for $V_{in+} > V_{in-}$, there is no conduction path through the load.
- Thus, this circuit behave like a half-wave rectifier

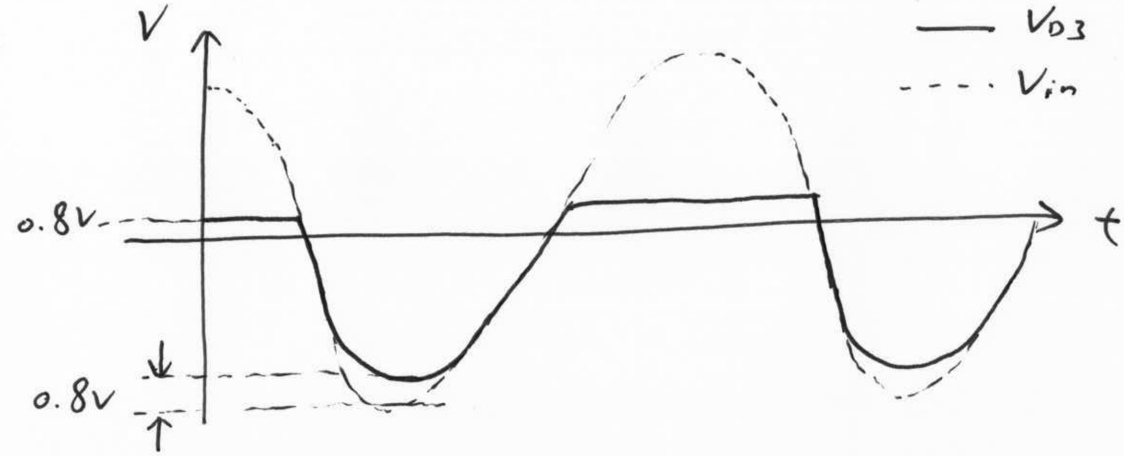
(39)

(i)

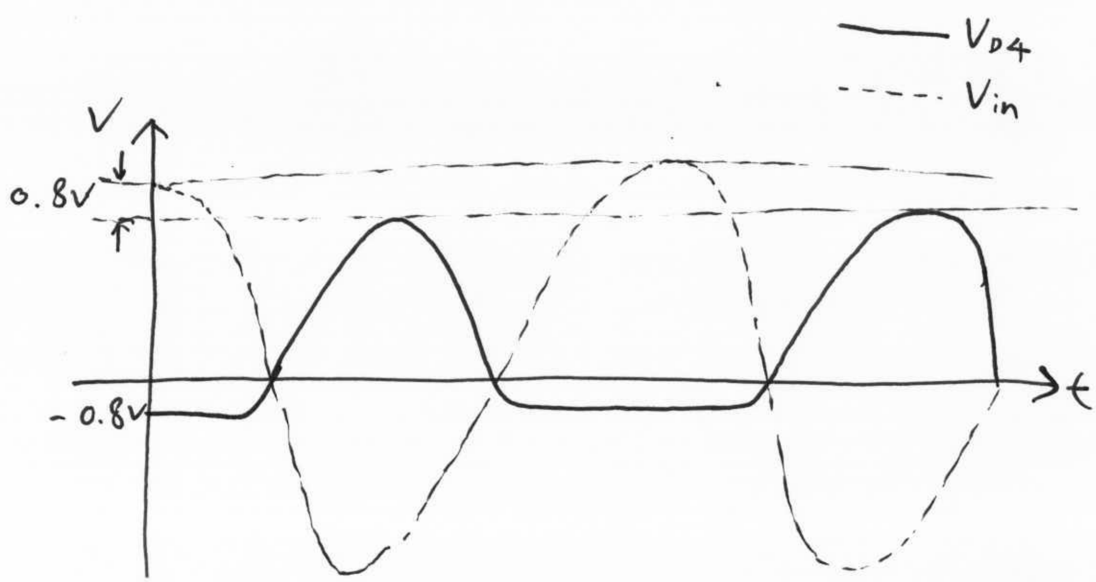


(ii) V_{D2} is same as V_{D1} (above)

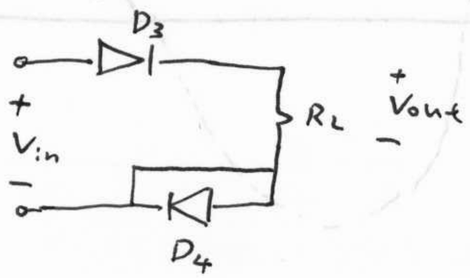
(iii)



(iv)

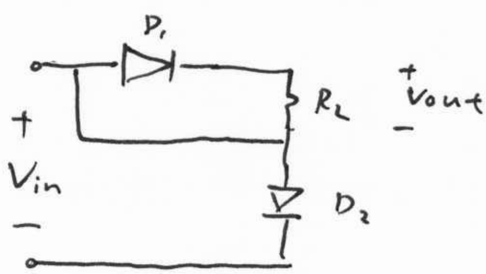


(40) In the positive half of the cycle, when $V_{in+} > V_{in-}$, the circuit is operating as:



D_4 is shunted, and $D_3 - R_L$ forms a half-wave rectifier.

In the negative half of the cycle, when $V_{in-} > V_{in+}$, the circuit becomes:



D_1 is shunted and is off.
Thus, $V_{out} = 0$.

Shunting the resistor load with a capacitor has no effect in the above two cases.

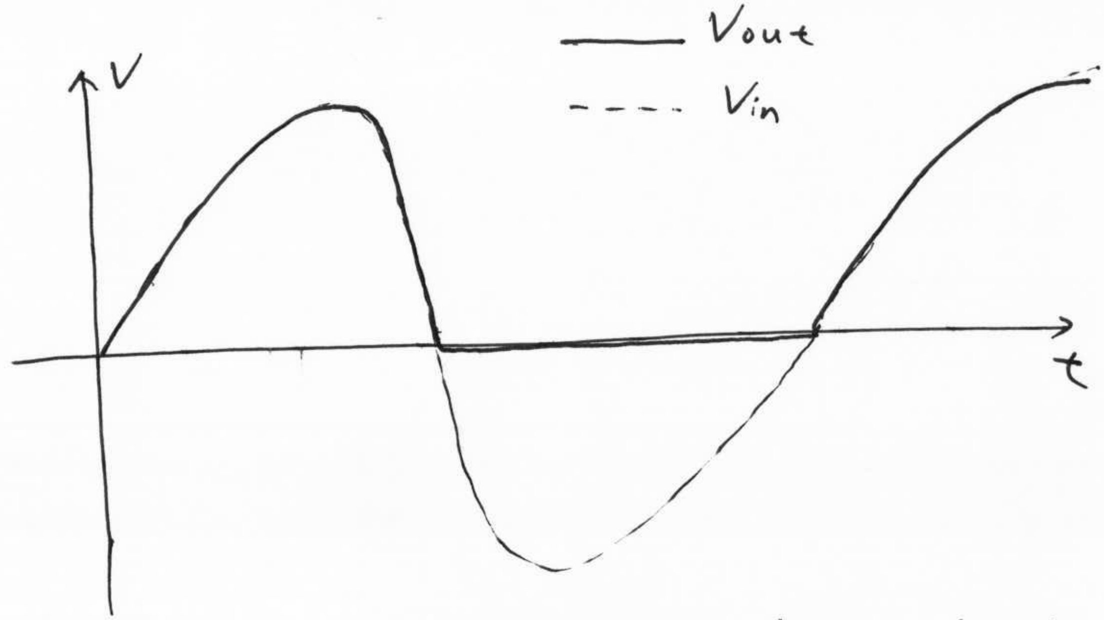
(41) Using Eq. (3.94),

$$V_R \approx \frac{1}{2} \cdot \frac{V_P - 2V_{P,ON}}{R_L C_1 f_{in}}$$

$$= \frac{1}{2} \cdot \frac{3 - 2 \times 0.8}{30 \times 1000 \times 10^{-6} \times 60}$$

$$= 0.389V$$

(42)



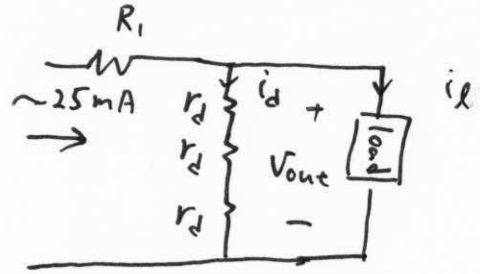
- With the two negative terminals shorted together, the circuit behaves like a half-wave rectifier.

- When $V_{in+} > V_{in-}$, D_3 and D_4 conduct as usual. There will be an additional path that bypasses D_4, since V_{in-} and V_{out-} are shorted. But this additional path causes no change to the Vout waveform.

- When $V_{in-} > V_{in+}$, both V_{out+} and V_{out-} track V_{in-}. V_{out+} connects to V_{in-} through D_1; V_{out-} connect to V_{in-} through the additional shorted path.

- Thus $(V_{out+}) - (V_{out-}) = 0$, ie. $V_{out} = 0$

(43) The circuit can be simplified as:



First, find r_d:

$$r_d = \frac{V_T}{I_D} \quad \text{(from eq. 3.60)}$$

$$= \frac{26\,mV}{5\,mA}$$

$$= 5.2\,\Omega$$

since $i_\ell = +1\,mA$.

$i_d = -1\,mA$.

∴ change in V_{out},

i.e. $V_{out} = (-1\,mA)(3 \times 5.2)$

$$= -15.6\,mV$$

(44) a) From Eq. (3.94),

the ripple amplitude, $V_R = \frac{1}{2} \cdot \frac{V_p - 2V_{D,on}}{R_L C_1 f_{in}}$

$$= \frac{1}{2} \cdot \frac{5 - 2 \times 0.8}{1000 \times 100 \times 10^{-6} \times 60}$$

$$= 0.283\ V$$

b) The ripple across the load,

$$v_\ell = i \times 3 r_d,$$

where i is the change in current flowing through R_1, in series with the 3 diodes.

$$\because r_d = \frac{V_T}{I_D}$$

$$\approx \frac{26\,mV}{5/R_1} = 5.2\ \Omega$$

$$i \approx \frac{V_R}{R_1 + 3 r_d}$$

$$= 0.279\ mA$$

$$\therefore v_\ell = 0.279\,mA \times 3 \times 5.2$$

$$= 4.35\ mV$$

(45) With positive theshold = + 2.2V,

$$V_{B1} = 2.2 - 0.8$$

$$= +1.4V$$

with negative thres hold = −1.9V,

$$-V_{B2} = -1.9 + 0.8$$

$$= -1.1V.$$

$$V_{B2} = 1.1V$$

To meet the maximum current criterion,

Since $I_{R1} = I_{D1}$ or I_{D2}.,

I_{D1} or I_{D2} is at max when

I_{R1} is at max.

I_{R1} is at max when $|V_R|$ is max,

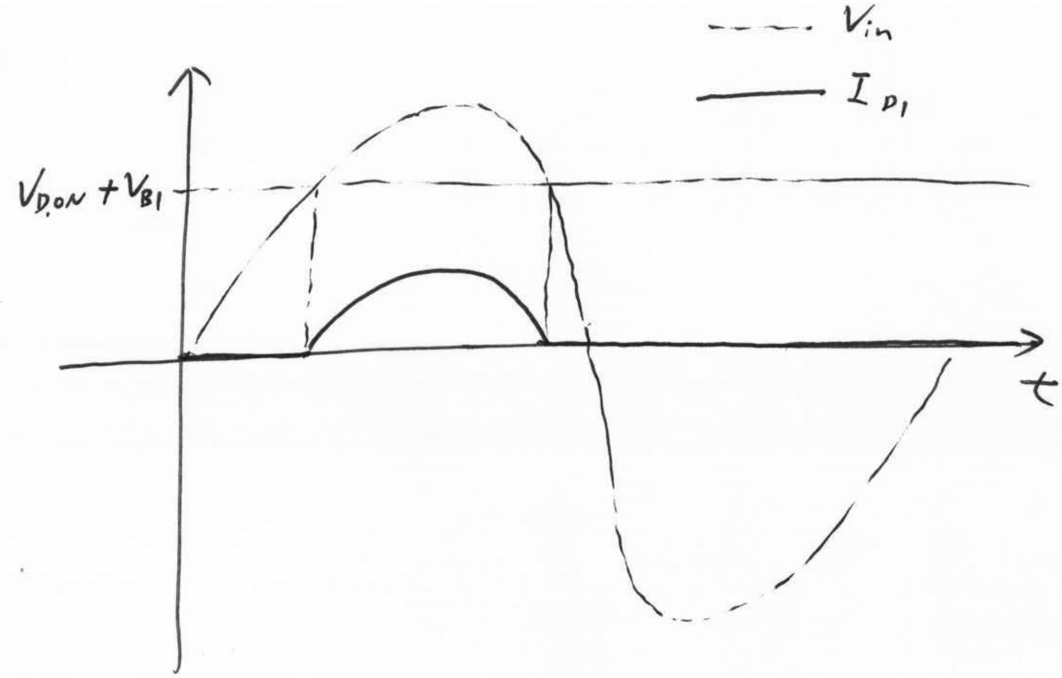
ie. $|V_R| = 5 - 1.9$

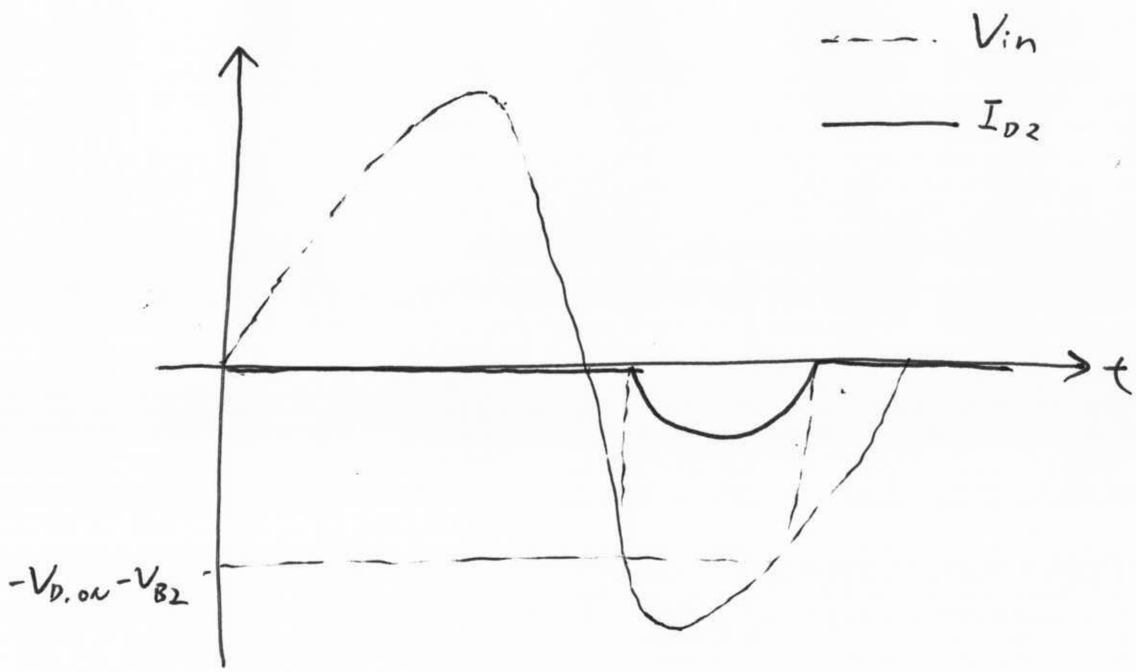
$$= 3.1V.$$

Since $I_{R1} \leq 2$ mA.

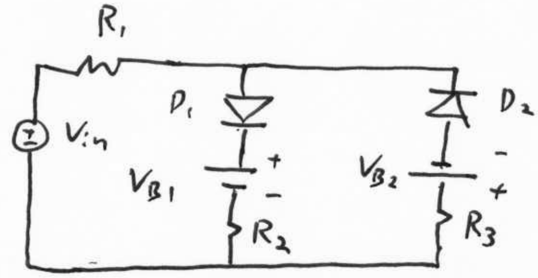
$R_1 \geq \frac{3.1}{2mA}$, ie. $R_1 \geq 1550\Omega$

(46)





(47) The required circuit is:



Similar to Example 3.34,

$$V_{B1} = V_{B2} = (2 - 0.8)V$$
$$= 1.2V$$

To find R_2,

For $V_{in} > 2V$, $\frac{V_{out}}{V_{in}}$ has a slope of 0.5.

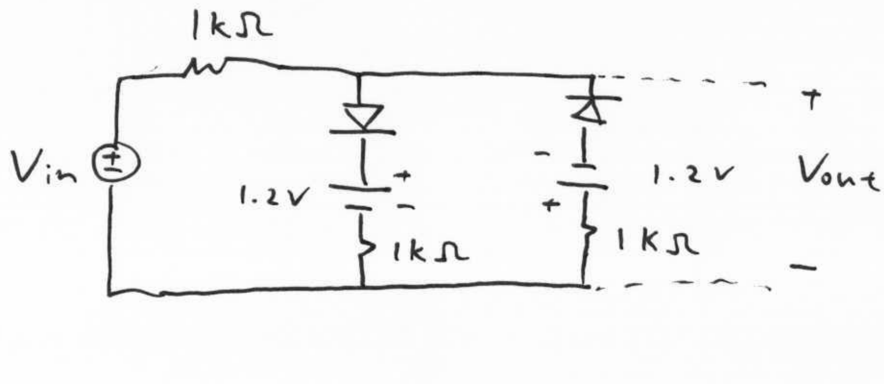
This implies $R_2 = R_1$

(R_1 and R_2 forms a volt. divider).

Similarly, $R_3 = R_1$

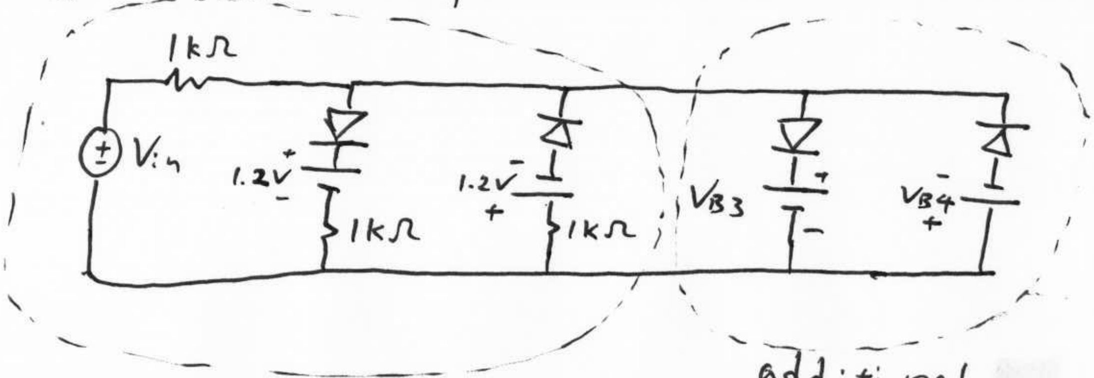
Thus, set $R_1 = R_2 = R_3 = 1\,k\Omega$.

The resulting circuit is:



(48) For $|V_{in}| < 4V$, the $V_{out} - V_{in}$ characteristic is similar to prob. (47).

To get voltage limiting characteristic for $V_{in} > 4V$, and $V_{in} < -4V$, we can shunt the circuit used in prob(47) with two antiparallel diodes as below:



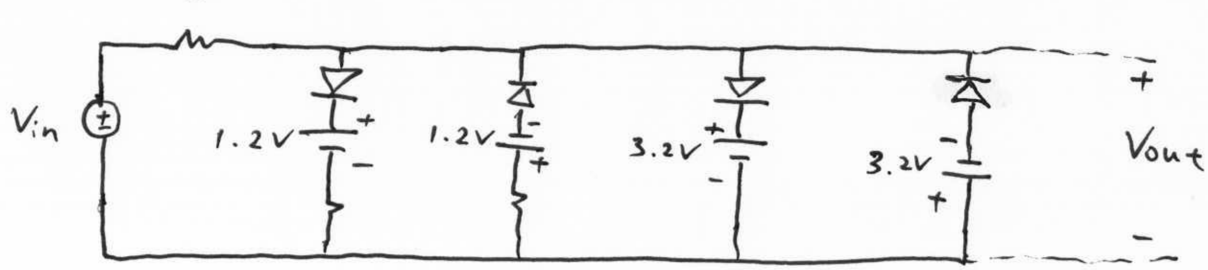
ckt used in prob. 47

additional antiparallel diodes

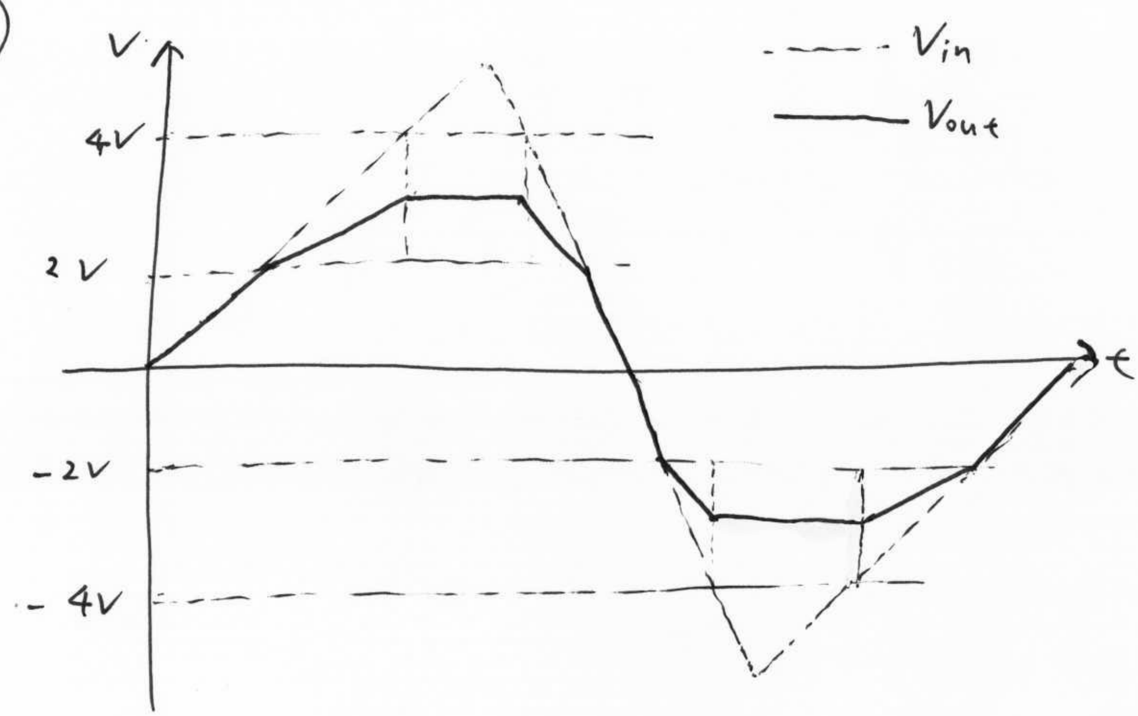
$$V_{B3} = V_{B4} = 4 - 0.8$$

$$= 3.2V$$

Resulting circuit is:



(49)



To get a better approximate of a sinusoid, the slope of the input-output characteristic should decrease more gradually from 1 to 0 through more sections.

eg: