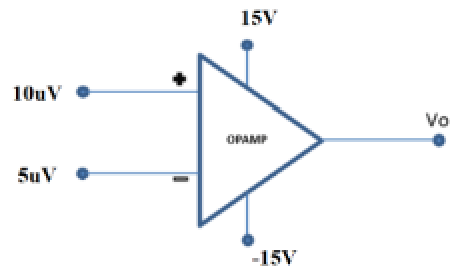
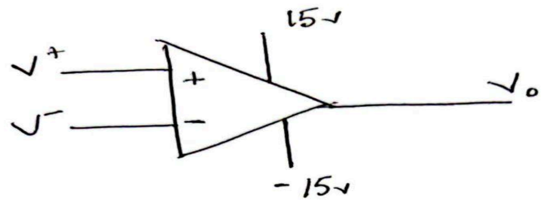
Op-Amp

1. Observe the following circuit.



Calculate the value of Vo. Repeat the problem with V+=1 mV and V-=0.2 mV. Consider A=2105.

(1)



$A = 2105$

(i) $V^+ = 10 \times 10^{-6}$ v , $V^- = 5 \times 10^{-6}$

$$V_o = A\left(V^+ - V^-\right) = 2105 \times (10-5) \times 10^{-6}$$

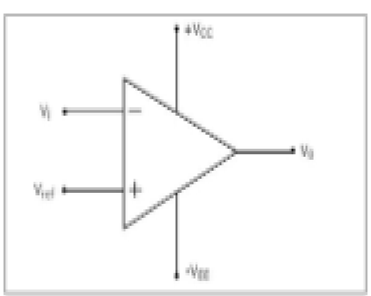
$$V_o = 0.0105 \text{ V}$$

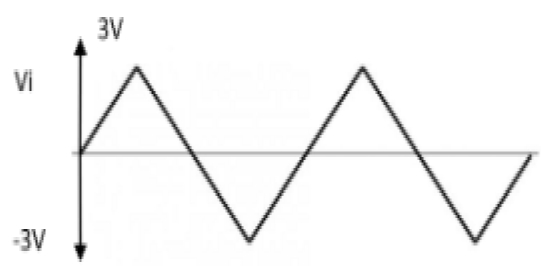
(ii) $V^+ = 1 \times 10^{-3}$ v , $V^- = 0.2 \times 10^{-3}$ V

$$V_o = A\left(V^+ - V^-\right) = 2105 \times (1 - 0.2) \times 10^{-3}$$

$$V_o = 1.684 \text{ v}$$

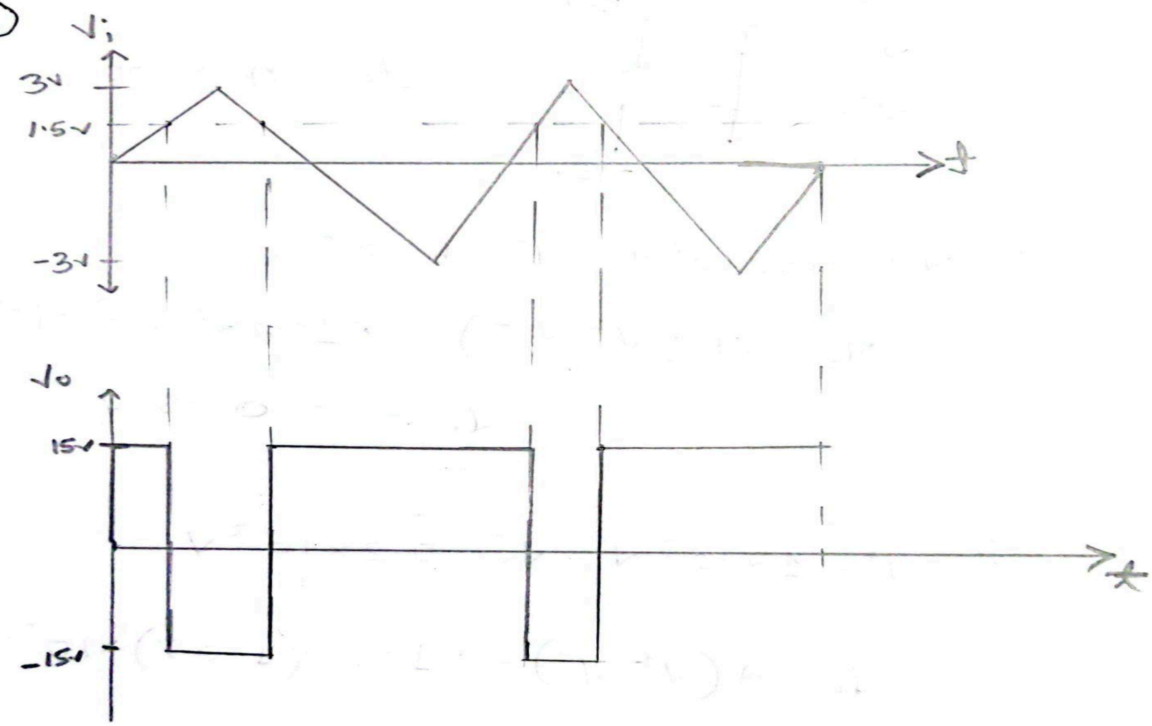
2. Draw output Vo for the following op-amp circuit.



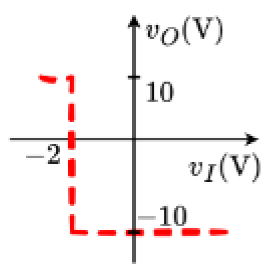


VCC = 15V= -VEE , Vref = 1.5V, Vi is a 6V p-p triangular signal as shown below.

2



3. Design a circuit using **op-amp** that has the voltage transfer characteristics as shown in the figure below. $v_O(V)$ is the **output voltage** and $v_I(V)$ is the **input voltage**.



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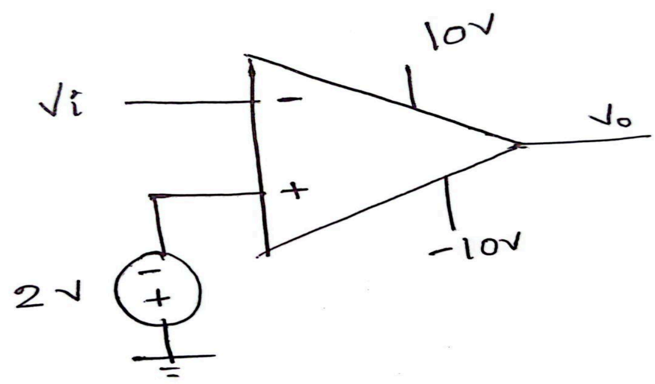
③ Ans:



5.

A valve is used to release (when valve is OPEN,) or maintain (when valve is CLOSED,) water pressure in a water tank. The valve operates on **ACTIVE LOW** logic. (i.e., the valve is OPENED when given a LOW voltage of 1 V, but remains CLOSED when provided a HIGH voltage of 6 V.)

A pressure sensor is installed in the water tank that outputs a voltage linearly proportional to pressure, as shown in the table below.

At **0.5 atm** pressure	At **1 atm** pressure	At **1.5 atm** pressure
$v_{0.5\,atm} = 0.5\,V$	$v_{1\,atm} = 3\,V$	$v_{1.5\,atm} = 5.5\,V$

The pressure in the water tank can be measured by the formula $P = h\rho g$, where P, (in **Pascals (Pa)** unit) is the water pressure, h is the height of water in the tank (in $metres$), $\rho(= 1000\ kgm^{-3})$ is the density of water and g is the acceleration due to gravity (in ms^{-2}).

[1 atm = 101325 Pa]

i. **Design** a circuit using Op-Amp comparator to automatically turn OPEN the valve if water level exceeds **10 m**.

ii. **Draw** the voltage transfer characteristics (VTC) of the designed Op-Amp.

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5 (i)

Given, $P = h\rho g$ | $h = 10m$, $\rho = 1000\ kgm^{-3}$, $g = 9.8$

$= 10 \times 1000 \times 9.8$

$= 98000\ Pa$

Converting to atm $= \dfrac{98000}{101325}$ [$\because 1atm = 101325\ Pa$]

$= 0.967$

Now,

Pressure change

For $(1-0.5) = 0.5$ atm, voltage change in $(3-0.5) = 2.5V$

1 " " " " " $\dfrac{2.5}{0.5}V$

$(0.967-0.5) = 0.467$ " " " " " $\dfrac{2.5 \times 0.467}{0.5}V$

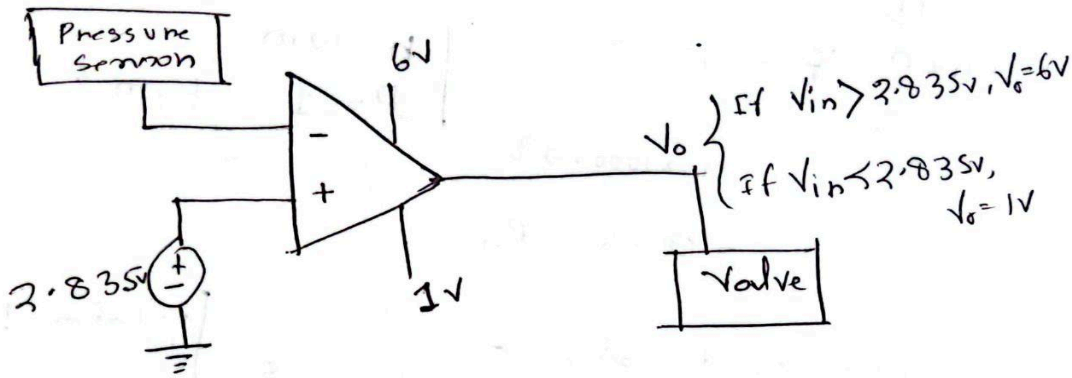
$= 2.335$

so, for 0.967 atm pressure

voltage in $= (0.5 + 2.335)$

$= 2.835V$

·OP-Amp Circuit →



(ii)

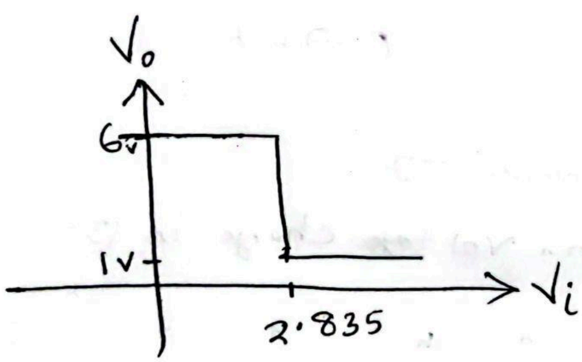


Fig: VTC of the OP-AMP (i)

0.1μF ; **determine** the output voltage at t = 1 ms. [1]

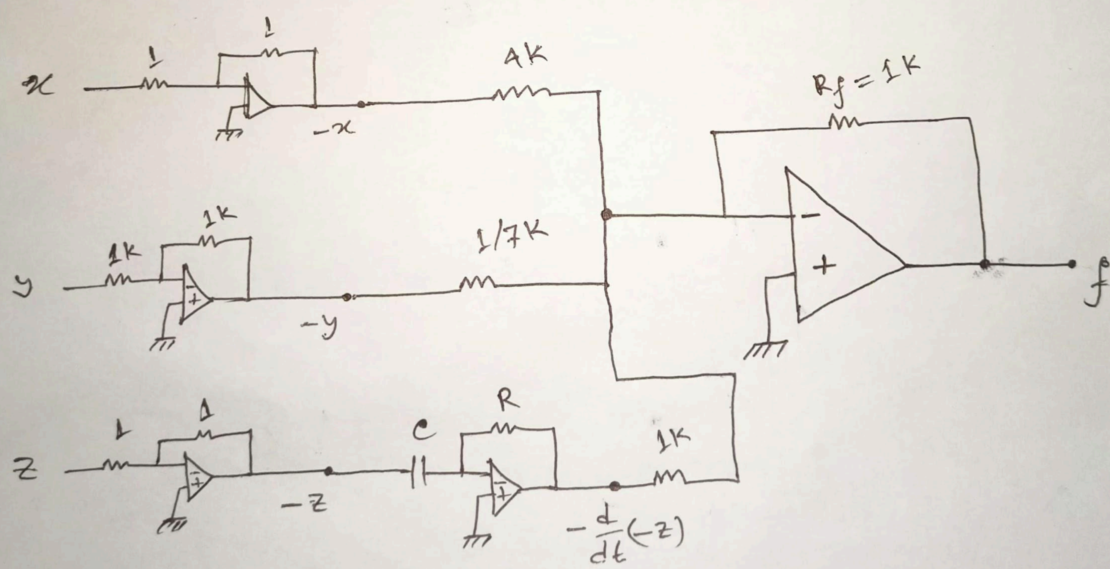
(e) **Design** a circuit using Op-Amps to implement the following expression: [4]

$f = \frac{1}{4}x + 7y - \frac{d}{dt}z$

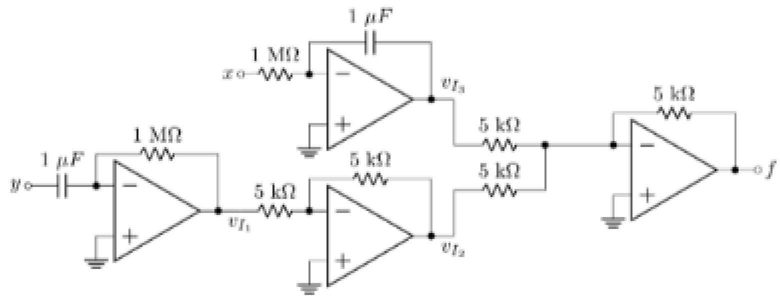
$$\# \; f = \frac{1}{4}x + 7y - \frac{d}{dt}(z)$$

$$= -\left[-\frac{1}{4}x - 7y + \frac{d}{dt}(z)\right]$$

$$= -\left[\frac{1}{4}(-x) + 7(-y) + \left\{-\frac{d}{dt}(-z)\right\}\right]$$



8.



(a) **Analyze** the circuit above to find an expression of f in terms of inputs x and y. Also, **determine** the intermediate outputs v_{I_1}, v_{I_2}, and v_{I_3} as denoted in the circuit. [4]

(b) Draw the circuit of an inverting amplifier and **design** it in such a way that the voltage gain, $k = -4$. (*i.e.*, find the values of R_1 and R_2). [3]

(c) **Show** the input and output waveforms of the inverting amplifier of part (b) assuming a sinusoidal input of 0.5 V amplitude. **Calculate** the amplitude of the output. [2]

(d) Consider the inverting amplifier of part (b) again. Assume the input voltage can provide a maximum current of 0.5 μA. **Determine** the design changes required, if any, for the circuit to work. [1]

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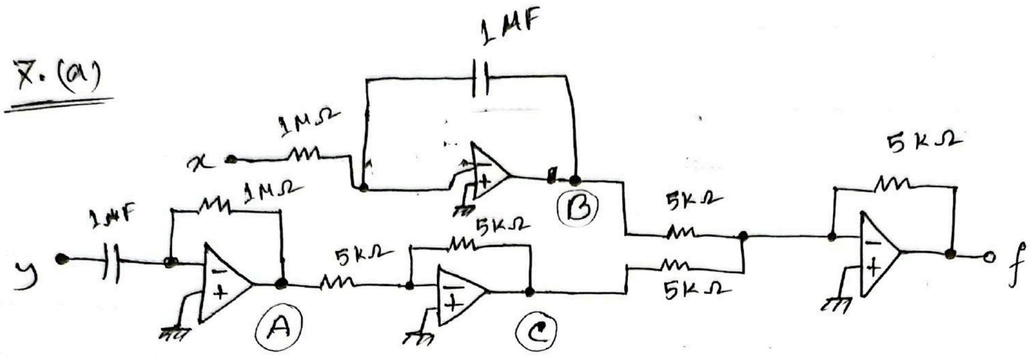
7. (a)



$$A = -RC\left[\frac{d}{dt}(y)\right] = -(1M\Omega \times 1MF)\left[\frac{d}{dt}(y)\right]$$
$$= -\frac{d}{dt}(y)$$

$$B = -\frac{1}{RC}\left[\int x\,dt\right]$$
$$= -\int x\,dt$$

$$C = -\frac{5}{5}\left(-\frac{d}{dt}(y)\right)$$
$$= \frac{d}{dt}(y)$$

$$f = -\left[\frac{R_f}{R_1}(B) + \frac{R_f}{R_2}(C)\right]$$
$$= -\left[\frac{5}{5}\left(-\int x\,dt\right) + \frac{5}{5}\,\frac{d}{dt}(y)\right]$$
$$= \int x\,dt - \frac{d}{dt}(y)$$

(Ans.)

7.(b) Given,

$$k = -4$$

for inverting,

$$V_{out} = -\frac{R_2}{R_1}(V_{in})$$

here,

$$\therefore -\frac{R_2}{R_1} = -4$$

$$\Rightarrow \frac{R_2}{R_1} = \frac{4}{1}$$

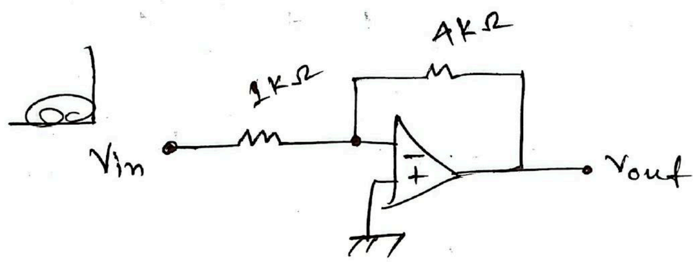
$$\Rightarrow 4R_1 = R_2$$

$$\therefore R_1 : R_2 = 1 : 4$$

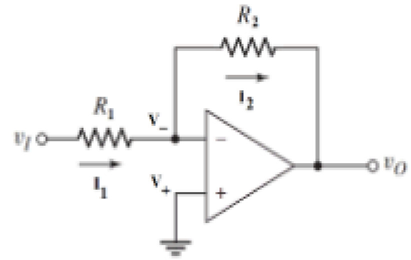
let,

$R_1 = 1\,k\Omega$

$R_2 = 4\,k\Omega$



12.



(a) **Design** an inverting amplifier (i.e., find the values of R_1 and R_2 of the circuit shown in the Figure above) in such a way that the voltage gain is **−5**.

(b) Consider the circuit you drew in (a) again. Assume the input $v_i = 0.1 \sin\omega t$ (V) has a maximum current rating of 5 μA. What design changes, if any, are required for this input, if the voltage gain remains the same?

(c) **Draw** the input and output waveforms of the circuit you designed in (c).

- **Analyze** the following circuit and derive the expression for the output voltage (V_{out}) in terms of the inputs. If V_1=1 V, V_2 = 2V, and V_3 = 1.5 V, and all the resistors have equal values, calculate V_{out}.

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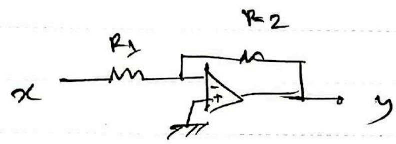
11. (a) Given,

gain = −5



we know,

$$y = -\frac{R_2}{R_1}(x)$$

here,

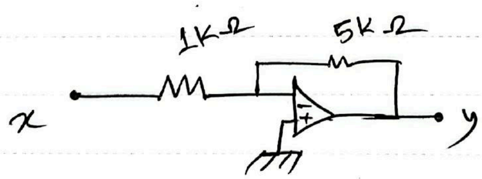
$$-\frac{R_2}{R_1} = -5$$

$$\Rightarrow 5R_1 = R_2$$

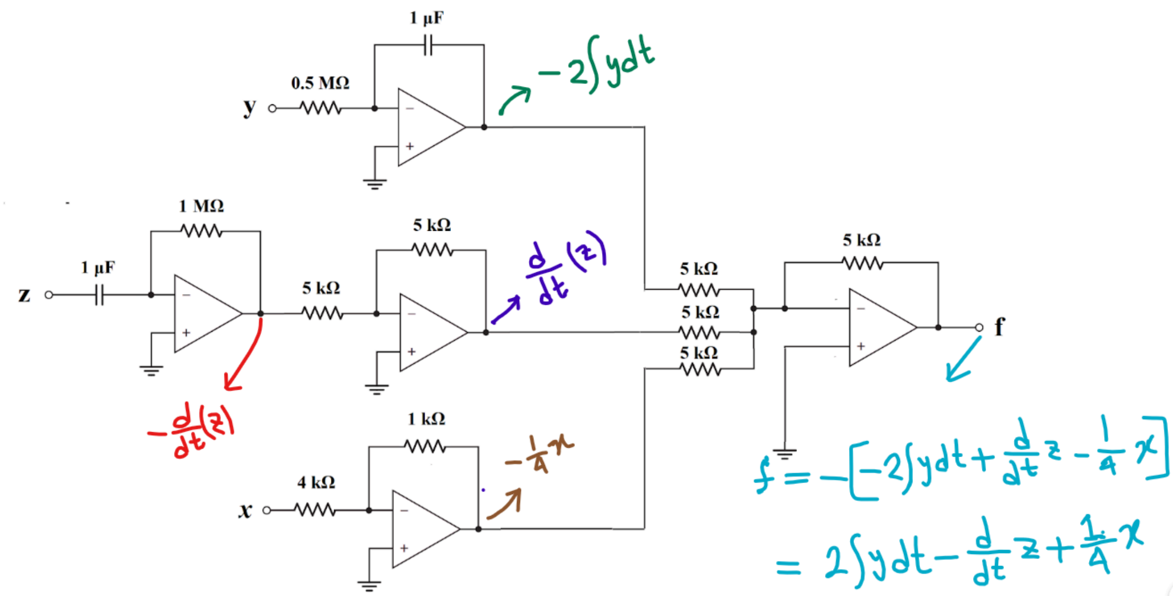
let,

$R_1 = 1K\Omega$

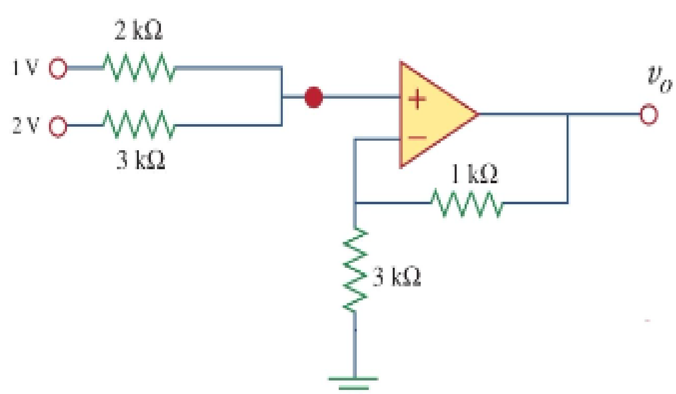
$R_2 = 5K\Omega$



12. **Analyze** the following circuit to find an expression of f in terms of x, y, and z.



14. Consider the Ideal Op-Amp and find the value of Vo.



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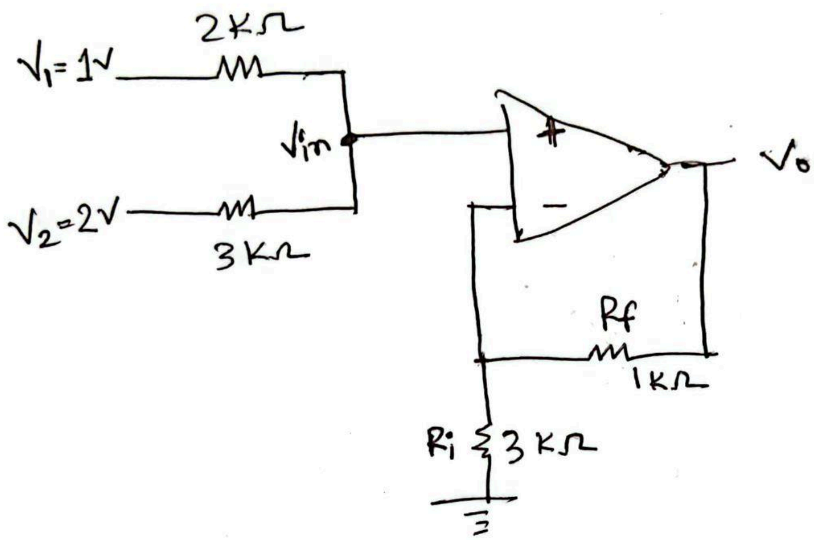
(13)



<u>At V_{in},</u>

$$\frac{V_1 - V_{in}}{2} + \frac{V_2 - V_{in}}{3} = 0$$

$$\Rightarrow \frac{1 - V_{in}}{2} + \frac{2 - V_{in}}{3} = 0$$

$$\Rightarrow \frac{3 - 3V_{in} + 4 - 2V_{in}}{6} = 0$$

$$\Rightarrow 5V_{in} = 7$$

$$\Rightarrow V_{in} = 1.4$$

We know for non-inverting OP-Amp,

$$V_o = \left(1 + \frac{R_f}{R_i}\right) V_{in}$$

$$= \left(1 + \frac{1}{3}\right) 1.4$$

$$= 1.867\ V$$

Diode Logic Gates

- Implement the following expressions using ideal diodes:

  i. xy+ yz

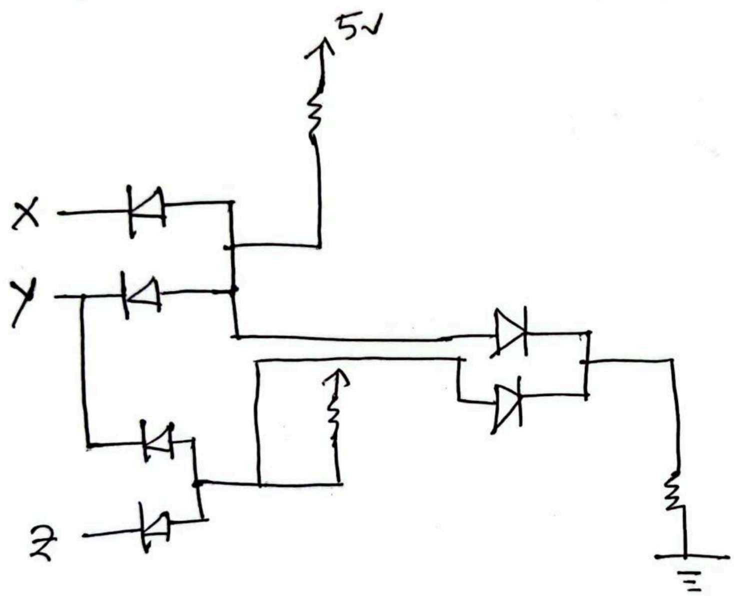
  ii. XOR

  iii. XNOR

  iv. (A+B)XY

• Implement expression using ideal diodes →

(i.) $xy + yz$



(ii and iii) → You can only implement OR/And gates with diode. NOT, XOR, XNOR, NAND Gates can be implemented using diode.

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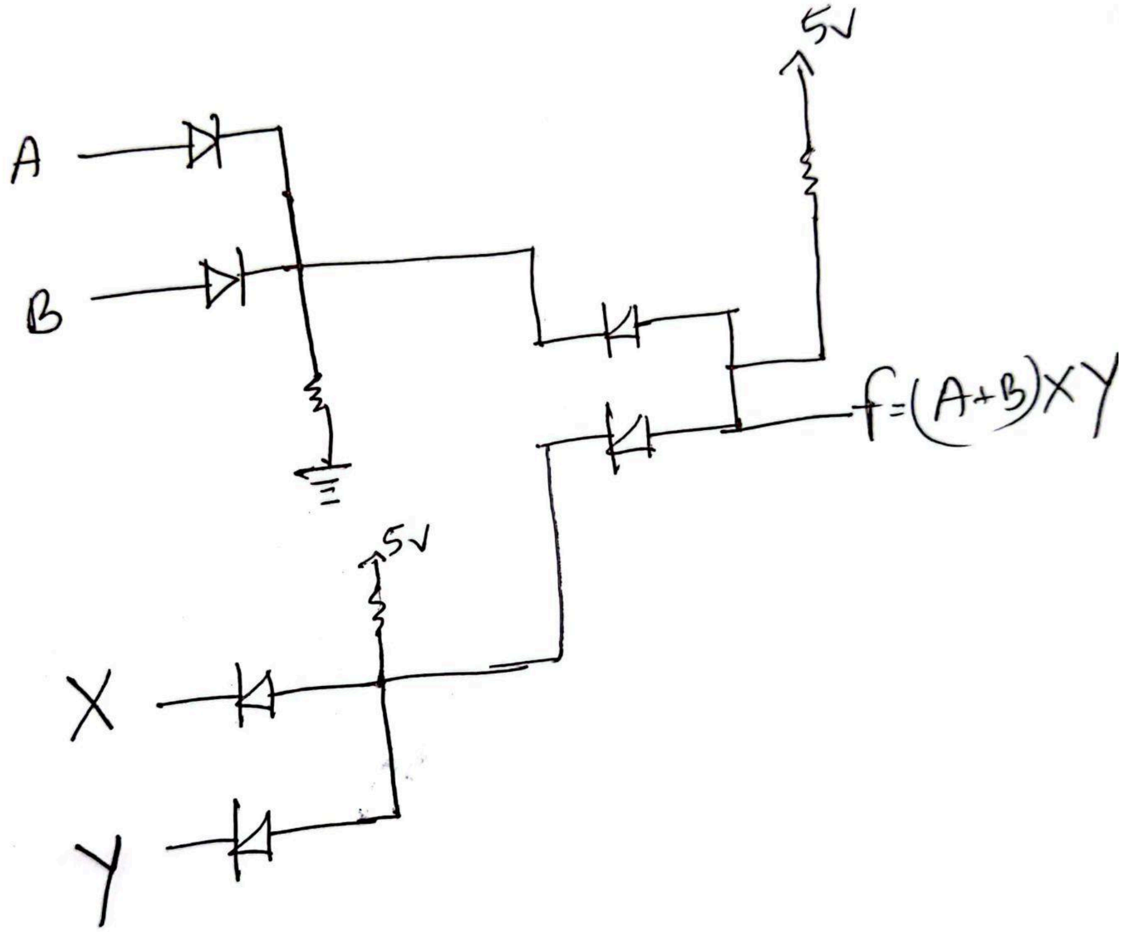
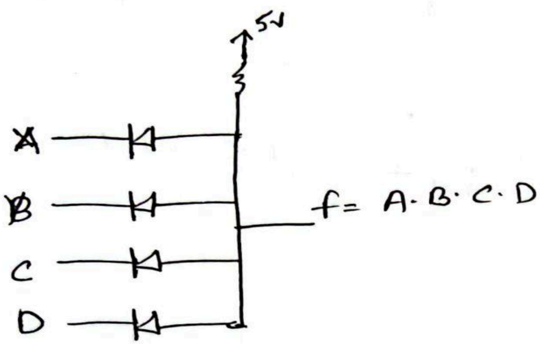
iv.



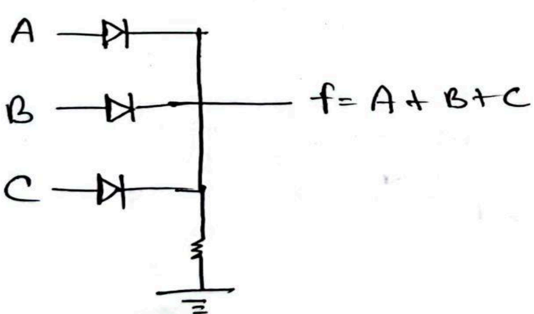
- Design a 4 input AND gate using ideal diodes

- Design a 3 input OR gate using ideal diodes

• 4 input And Gate →



• 3 input OR Gate →



• Five Question problem →

Ans: $A \cdot B \cdot C \cdot (D \oplus E)$

You cannot use diodes for implementing XOR functions.

- For this question, assume all the diodes are ideal.

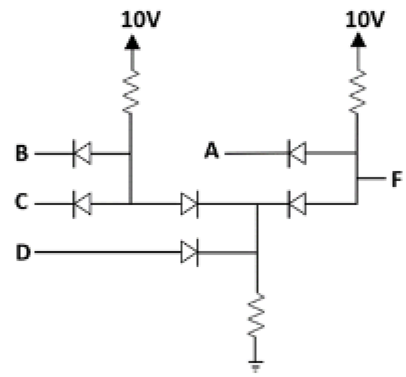


Figure 1

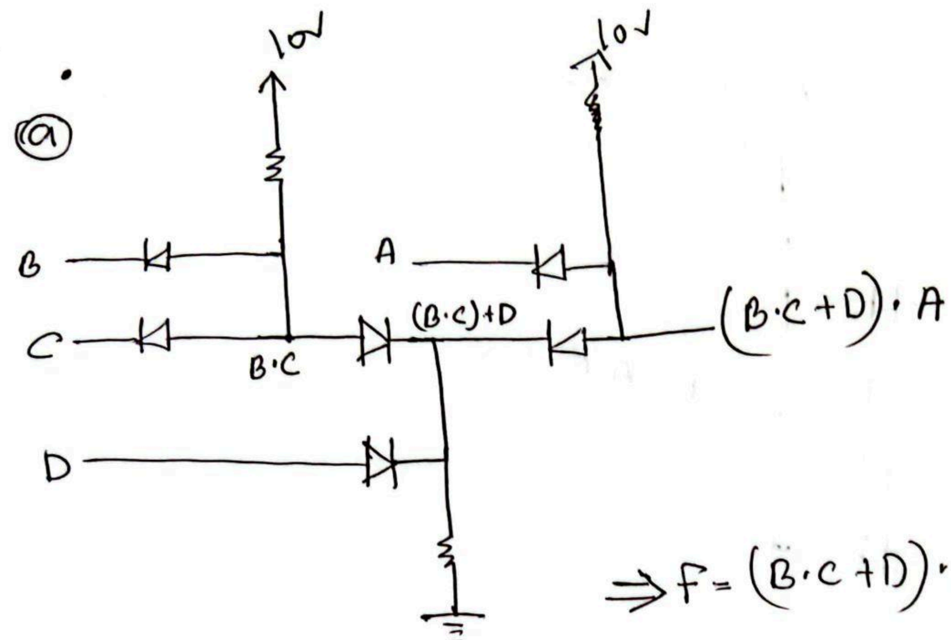
(a) Assuming A, B, C, D are boolean variables, analyze the circuit of Figure 1 to find an expression of F in terms of A, B, C and D.

(b) Analyze the circuit in Figure 1 to find the output voltage(s) F and complete the table in Figure 2, assuming A, B, C and D are voltage signals

A	B	C	D	F
4V	3V	4V	6V	
5V	3V	4V	2V	
13V	3V	4V	15V	

Figure 2

(a)



$$\Rightarrow F = (B\cdot C + D)\cdot A$$

(B)

A	B	C	D	F
4	3	4	6	4
5	3	4	2	3
13	3	4	15	10

Row 1: $\overset{3}{B}\cdot\overset{4}{C} \xrightarrow{\text{min}} = 3 \Rightarrow \overset{3}{(B\cdot C)}+\overset{6}{D} \xrightarrow{\text{max}} \Rightarrow 6 \Rightarrow \underbrace{((B\cdot C)+D)}_{6}\cdot \overset{4}{A} \xrightarrow{\text{min}} \Rightarrow 4$

Row 3: $B\cdot C = 3 \Rightarrow \overset{3}{(B\cdot C)}+\overset{15}{D} \xrightarrow{\text{max}} \Rightarrow 15$

$\underbrace{(B\cdot C+D)}_{15}\cdot \underset{13}{A} \xrightarrow{\text{min}} \Rightarrow 13$

But our saturation/Power supply in 10V.

So, Ans = 10V

- Maisha is designing a game where she needs to determine an algorithm for level upgrades. The quests in level-1 are expressed using Boolean variables A, B, C, D, and E. For upgrading from level-1 to level-2 she will need to fulfill the following conditions-

  i. Quest "A" and "B" must be completed
  ii. At Least one quest has to be completed from "C", "D" and "E"

  (a) **Deduce** the logic function, F, using Boolean variables A, B, C, D, and E to implement Maisha's algorithm. [3]

  (b) **Determine** the values of "F" in the following table using the logic function from (a). [2]

A	B	C	D	E	F
0	0	1	0	1	?
0	1	1	1	0	?
1	0	0	0	0	?
1	1	1	0	0	?

  (c) **Draw** the circuit diagram implementing the logic function from (a). [3]

  (d) **Discuss** whether you can design a NAND gate with Si diodes. [2]

• Maisha's Designing Game →

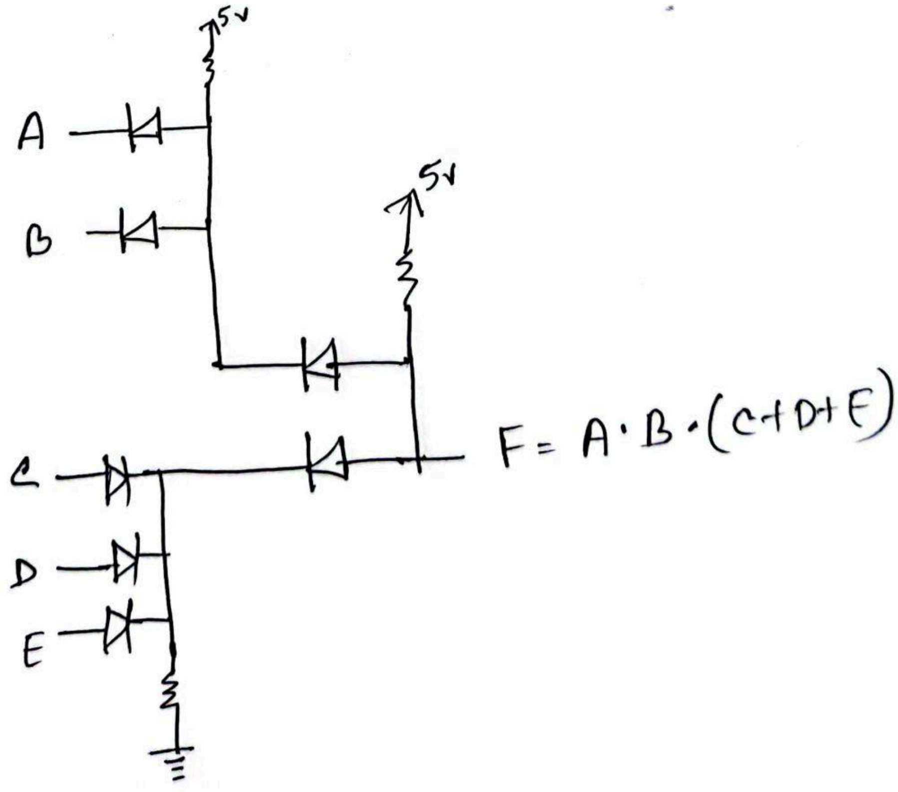
(a)

$$F = A \cdot B \cdot (C + D + E)$$

(b)

A	B	C	D	E	F
0	0	1	0	1	0
0	1	1	1	0	0
1	0	0	0	0	0
1	1	1	0	0	1

(c)



(d) Ans:

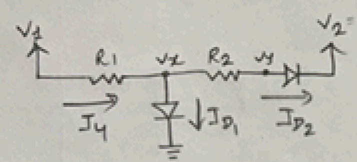
You can not design NANA, NOR, XOR. Gates using diodes. Because they need Not Gate, which can not be implemented by diodes.

Diode: Method of assumed states

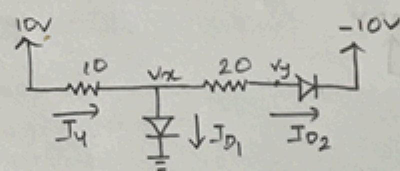
Diode : Method of Assumed State

$V_{D_0} = 0.3V$

1) $I_{D_1}, I_{D_2}, V_x, V_y$?

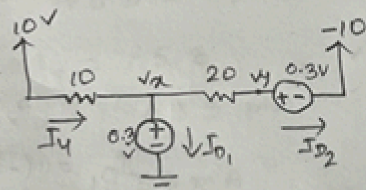


(i) when, $V_1 = 10V$, $V_2 = -10V$, $R_1 = 10k\Omega$, $R_2 = 20k\Omega$



(i) $D_1 \rightarrow ON$, $D_2 \rightarrow ON$

(ii)



$\underline{V_x}$

$V_x - 0 = 0.3$

$\Rightarrow V_x = 0.3V$

$\underline{V_y}$

$V_y - (-10) = 0.3$

$\Rightarrow V_y = 0.3 - 10$

$= -9.7V$

$\underline{I_4}$

$$I_4 = \frac{10 - V_x}{10} = \frac{10 - 0.3}{10} = 0.97mA$$

$\underline{I_{D_2}}$

$$I_{D_2} = \frac{V_x - V_y}{20} = \frac{0.3 - (-9.7)}{20} = 0.5mA$$

$I_4 = I_{D_1} + I_{D_2}$

$\Rightarrow I_{D_1} = I_4 - I_{D_2}$

$= 0.97 - 0.5$

$= 0.47mA$

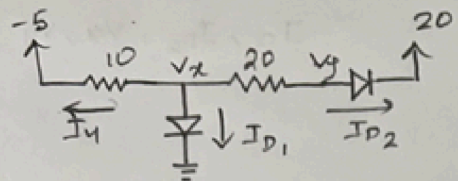
(iii) Verifying

$I_{D_1} > 0$

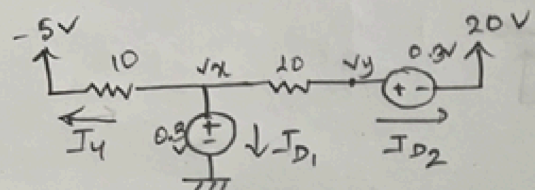
$I_{D_2} > 0$

$\therefore$ assumption correct

(ii) When $V_1 = -5V$, $V_2 = 20V$, $R_1 = 10k\Omega$, $R_2 = 20k\Omega$



(1) $D_1 \to ON$, $D_2 \to ON$



V_x

$V_x - 0 = 0.3$

$\Rightarrow V_x = 0.3V$

V_y

$V_y - 20 = 0.3$

$\Rightarrow V_x = 20.3V$

I_y

$$I_4 = \frac{0.3-(-5)}{10}$$

$$= 0.53mA$$

I_{D_2}

$$I_{D_2} = \frac{V_x - V_y}{20}$$

$$= \frac{0.3 - 20.3}{20}$$

$$= -1 \, mA \; (\ngtr 0)$$

$$I_{D_1} = (-I_4) + (-I_{D_2})$$

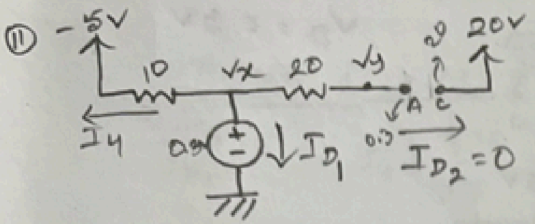
$$= -0.53 + 1$$

$$= 0.47 \, mA$$

Therefore, assumption not correct.

(I) $D_1 \rightarrow ON$, $D_2 \rightarrow OFF$

(II)



$I_4 = I_{D_1}$

$V_x = 0.3V$

$V_x = V_y = 0.3V$

<u>KVL</u>

$-10 I_4 + 0.3 = -5 - 0$

$\Rightarrow \cancel{+}10 I_4 = \cancel{+}5.3$

$\Rightarrow I_4 = 0.53\ mA$

$I_{D_1} = 0.53\ mA$

$V_D = V_A - V_C$

$= 0.3 - 20$

$= -19.7V$

(III) <u>Verifying</u>

$I_{D_1} > 0$

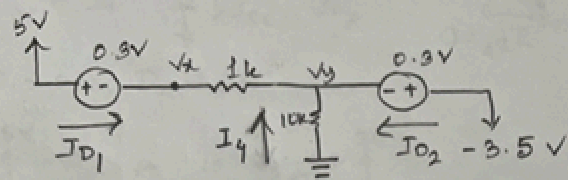
$V_D < V_{D0}$

$\therefore$ Assumption correct

2) D When $v_1 = 5V$, $v_2 = -3.5V$, $R_1 = 1k\Omega$, $R_2 = 10k\Omega$

$V_{D_0} = 0.3V$

① $D_1 \rightarrow ON$, $D_2 \rightarrow ON$



V_x

$5 - V_x = 0.3$

$\Rightarrow V_x = 4.7V$

V_y

$-3.5 - V_y = 0.3$

$\Rightarrow V_y = -3.8V$

$$I_{D_1} = \frac{V_x - V_y}{1}$$

$= 4.7 - (-3.8)$

$= 8.5\ mA \quad (>0)$

$$I_4 = \frac{0 - (-3.8)}{10}$$

$= 0.38\ mA$

$I_{D_1} = I_4 + I_{D_2}$

$\Rightarrow I_{D_1} = -I_4 - I_{D_2}$

$\Rightarrow -I_{D_2} = I_{D_1} + I_4$

$\Rightarrow -I_{D_2} = 8.5 + 0.38$

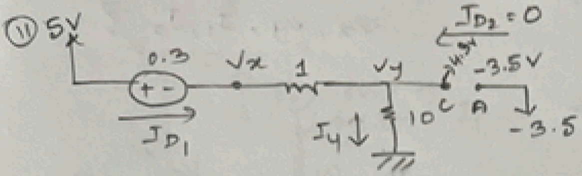
$\Rightarrow I_{D_2} = -8.88\ mA \quad (\not> 0)$

I_{D_2} isn't greater than zero

$\therefore$ Therefore, assumption not correct

(i) $D_1 \rightarrow ON$, $D_2 \Rightarrow OFF$

(ii)



$\underline{V_x}$

$5 - V_x = 0.3$

$\Rightarrow V_x = 4.7V$

$I_{D_1} = I_y$

$0.3 + I_{D_1} + 10 I_y = 5 - 0$

$\Rightarrow 0.3 + I_{D_1} + 10 I_{D_1} = 5$

$\Rightarrow 11 I_{D_1} = 4.7$

$\Rightarrow I_{D_1} = 0.43 \; mA$

$I_y = 0.43 \; mA$

$I_y = \frac{V_y - 0}{10}$

$\Rightarrow V_y = 10 \times 0.43$

$= 4.3V$

$V_D = V_A - V_C$

$= -3.5 - (4.3)$

$= -7.8 V.$

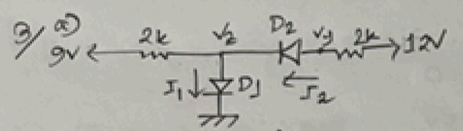
(iii) $\underline{\text{Verifying}}$

$I_{D_1} > 0$

$V_D < V_{D_0}$

$\therefore$ Assumption correct

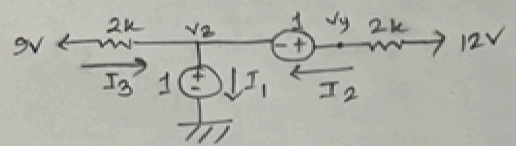
3/ a)



$V_{D_0} = 1\ V$

V_x, V_y, I_1, I_2 ?

b) $D_1 \to ON$, $D_2 \to ON$ → given



V_2

$V_2 - 0 = 1$

$\Rightarrow V_2 = 1V$

V_y

$V_y - 1 = 1$

$\Rightarrow V_y = 2$

I_3

$$I_3 = \frac{9 - V_2}{2} = \frac{9-1}{2} = 4\ mA$$

I_2

$$I_2 = \frac{12-2}{2} = 5\ mA$$

I_1

$$I_1 = I_3 + I_2 = 4 + 5 = 9\ mA$$

Verifying

$I_1 > 0$
$I_2 > 0$ ∴ Assumption correct

c) $P = I_1 \times V$

$= 9 \times 1$

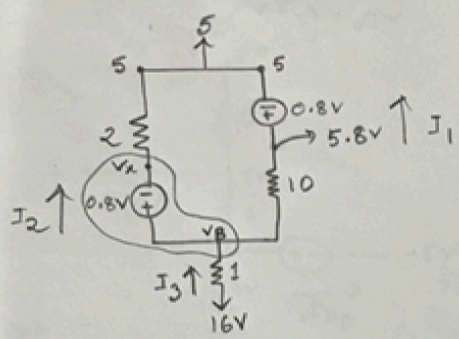
$= 9\ mW \to +ve$

∴ D_1 is consuming power

4/ $D_1 \to ON$, $D_2 \to ON$

$V_{D0} = 0.8V$

J_1, J_2, J_3 ?



$V_B - V_x$ supernode,

$$V_B\left(\frac{1}{1}+\frac{1}{10}\right) + V_x\left(\frac{1}{2}\right) - \frac{16}{1} - \frac{5}{2} = 0$$

$$\Rightarrow 1.1V_B + (2^{-1})V_x = 18.5 \quad \text{— (i)}$$

$V_B - V_x$ constraint $\Rightarrow$

$$V_B - V_x = 0.8$$

$$\Rightarrow V_B + (-1)V_x = 0.8 \quad \text{— (ii)}$$

Solving (i) & (ii)

$V_B = 11.8\ V$

$V_x = 11.01V$

Now,

$$J_3 = \frac{16-11.8}{1} = 4.2\ mA$$

$$J_2 = \frac{V_x - 5}{2} = \frac{11.01-5}{2} = 3\ mA$$

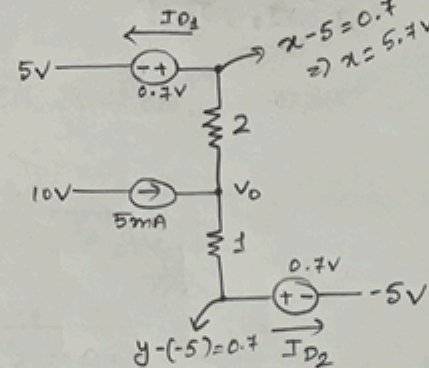
$$J_1 = \frac{V_B - 5.8}{10} = \frac{11.8-5.8}{10} = 0.6\ mA$$

Verifying

$J_2 > 0$ $\therefore$ Assumption correct

$J_1 > 0$

5/ $D_1 \rightarrow ON$, $D_2 \rightarrow ON$ $\qquad V_{D_0} = 0.7V$



$x - 5 = 0.7$
$\Rightarrow x = 5.7V$

$y - (-5) = 0.7$
$\Rightarrow y = -4.3V$

KCl at V_0

$$V_0\left(\frac{1}{2} + \frac{1}{1}\right) - \frac{5.7}{2} - (-4.3) - 5 = 0$$

$$\Rightarrow \frac{3}{2} V_0 = 3.55$$

$$\Rightarrow V_0 = 2.37V$$

$$I_{D_1} = \frac{V_0 - 5.7}{2} = \frac{2.37 - 5.7}{2} = -1.67\,mA \ (\not> 0)$$

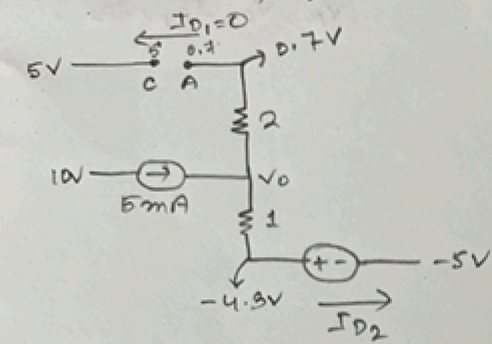
$$I_{D_2} = \frac{V_0 - (-4.3)}{1} = 2.37 + 4.3 = 6.67\,mA \ (> 0)$$

As I_{D_1} isn't greater than zero

$\therefore$ Therefore, assumption not correct

$D_1 \rightarrow OFF$, $D_2 \rightarrow ON$

$V_{D_2} = 0.7V$



$I_{D_2} = 5mA$

$$I_{D_2} = \frac{V_0 + 4.3}{1}$$

$$\Rightarrow V_0 = 5 - 4.3$$
$$= 0.7V$$

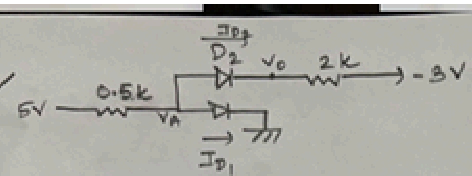
$$V_D = V_A - V_C$$
$$= 0.7 - 5$$
$$= -4.3V$$

Verifying

$I_{D_2} > 0$

$V_D < V_{D_0}$

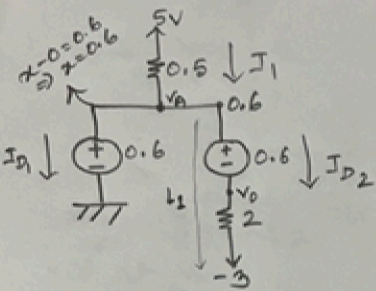
6/



$V_{D0} = 0.6$

$V_A, V_0, I_{D_1}, I_{D_2}$?

$D_1 \to ON$, $D_2 \to ON$



$V_A = 0.6$

$0.6 - V_0 = 0.6$

$\Rightarrow V_0 = 0$

$$I_1 = \frac{5-0.6}{0.5}$$

$= 8.8$ mA

$L_1 \to$

$0.6 + 2I_{D_2} = 0.6 - (-3)$

$\Rightarrow 2I_{D_2} = 3.6 - 0.6$

$\Rightarrow I_{D_2} = 1.5$ mA

$I_1 = I_{D_1} + I_{D_2}$

$\Rightarrow I_{D_1} = I_1 - I_{D_2}$

$= 8.8 - 1.5$

$= 7.3$ mA

Verifying

$I_{D_1} > 0$

$I_{D_2} > 0$

$\therefore$ Assumption correct

Rectifiers

1.

The input of a full-wave rectifier is a cosine voltage with peak V_M = 5 V and frequency 60 Hz, and output load resistance is R = 2 kΩ. Silicon diodes are used in this circuit for which the forward drop is V_{D0} = 0.7 V.

(a) Briefly explain the purpose of a rectifier and describe its operation.
(b) Show the input and output waveforms.
(c) Calculate the DC value of the output voltage.

Now after connecting a capacitor in parallel with the load, the output becomes a ripple voltage **Vout =** V_{DC} **±0.2 V**

(d) Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor.
(e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in ‘c’ and comment on the difference between these two.

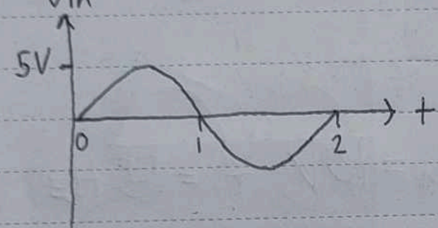
Practice Sheet
Rectifiers

DD MM YYYY

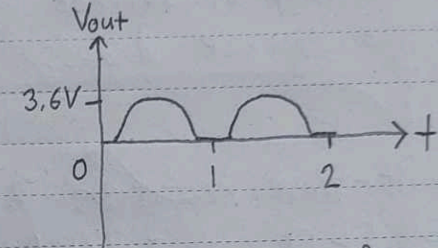
1. Full-Wave Rectifier, $V_M = 5V$, $f_i = 60\,Hz$, $R = 2\,k\Omega$
$V_{D0} = 0.7\,V$

a) The purpose of a rectifier is to convert AC to DC. The rectifier does this operation by allowing current to flow in 1 direction only.

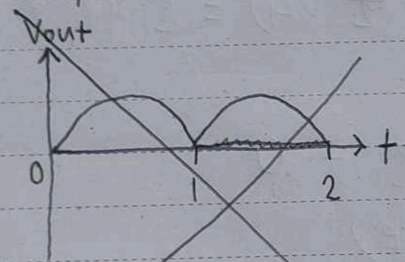
b)



Input Waveform



Output Waveform



~~Output Waveform~~

c) $V_{DC} = \frac{2}{\pi} V_M - 2V_{D0} = \frac{2}{\pi}(5) - 2(0.7) = 1.78\,V$

d) $\cancel{V_{DC} = 0}$ $V_r(p-p) = 0.2 + 0.2 = 0.4\,V$

$V_r(p-p) = \frac{V_p}{F_r \times RC} = 0.4$

$\Rightarrow \frac{5 - 0.7 \times 2}{120 \times 2 \times C} = 0.4$

$\Rightarrow C = 0.0375$ mF

1.e) $V_{DC} = V_P - \frac{1}{2} V_{r(p-p)} = 3.6 - \frac{1}{2}(0.4) = 3.4\,V$

After connecting the capacitor the DC value increased compared to when capacitor was not connected. This is because of the smoothing effect of the capacitor, which discharges when output of the voltage source is not maximum, and this stops drastic drop of voltage when the voltage of the voltage source drops.

2.

The input of a **Half-wave rectifie**r is a sine voltage with peak VM = 10 V and frequency 55 Hz, and output load resistance is R = 2.5 kΩ. Silicon diodes are used in this circuit for which the forward drop is V_{D0} = 0.4 V.

(a) Calculate the DC value of the output voltage.

Now after connecting a capacitor in parallel with the load, the output becomes a ripple voltage **Vout =** V_{DC} **±0 V.**

(d) Calculate the **peak-to-peak ripple voltage**, and from that, the value of the capacitor.

(e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in ‘c’ and comment on the difference between these two.

(f) Draw the **Voltage Transfer Characteristic (VTC) curve**

2. Half-Wave rectifier, $V_M = 10V$, $f_i = 55\,Hz$,
$R = 2.5\,k\Omega$, $V_{Do} = 0.4V$

a) $V_{DC} = \frac{V_M}{\pi} - \frac{1}{2} V_{Do} = \frac{10}{\pi} - \frac{1}{2}(0.4) = 2.98\,V$

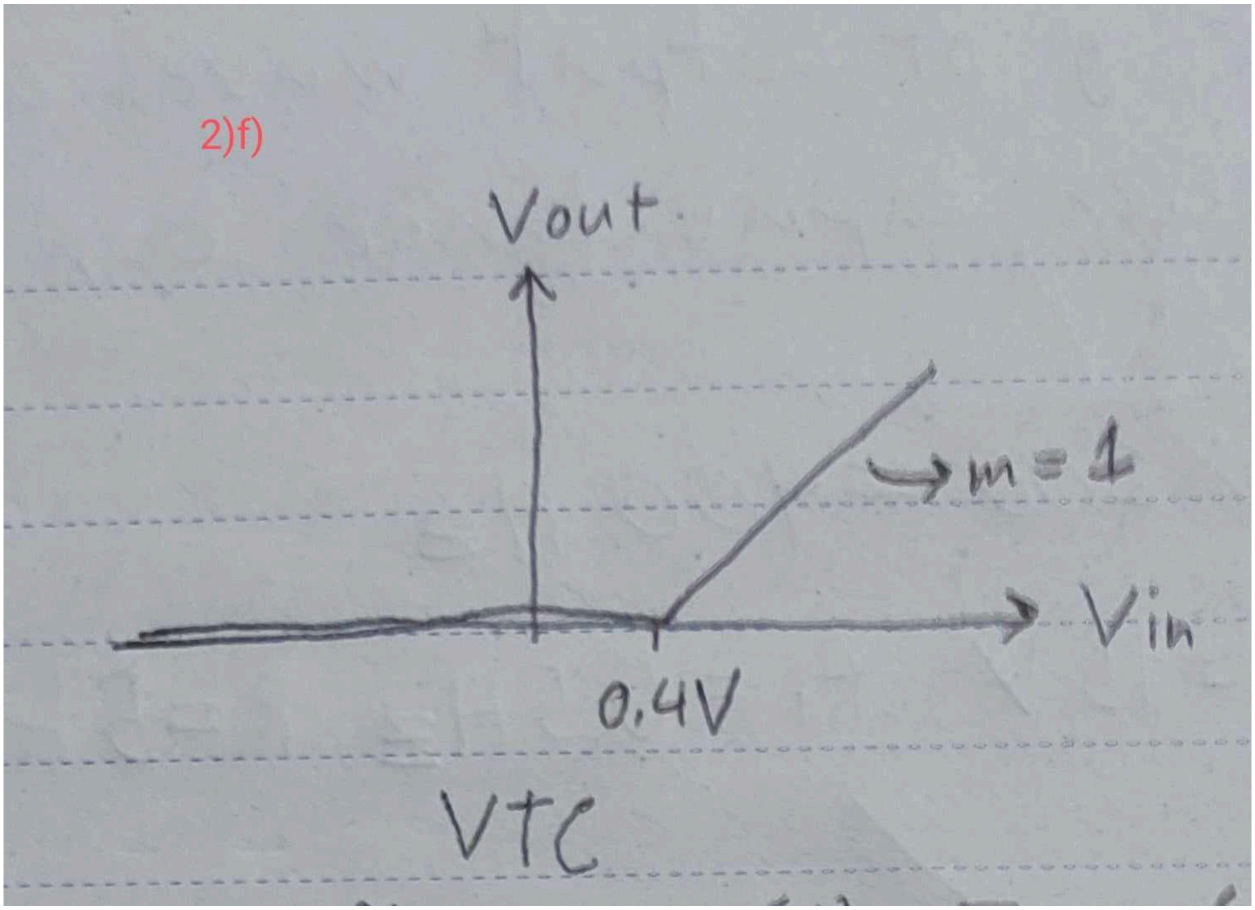
d) $V_{r(p-p)} = 0\,V$

$$V_{r(p-p)} = \cancel{V_p - \tfrac{1}{2} V_r} \; \frac{V_p}{f_r \times R \times C} = 0$$

$$\Rightarrow C = \infty \text{ (infinite)}$$

e) $V_{DC} = V_p - \frac{1}{2} V_{r(p-p)} = (10 - 0.4) - \frac{1}{2}(0) = 9.6\,V$.

After connecting the capacitor the DC value increased compared to when capacitor was not connected. This is because of the smoothing effect of the capacitor, which discharges when output of the voltage source is not max, and this stops drastic drop of voltage when output of the voltage source drops.



3.

The input of a full-wave rectifier is expressed by, Vs(t)= 7sin(400πt), and output load resistance is R = 5 kΩ. Silicon diodes are used in this circuit for which the forward drop is V_{D0} = 0.3 V.

(a) Calculate the input and output wave frequency.
(b) Show the input and output waveforms.
(c) Calculate the DC value of the output voltage.

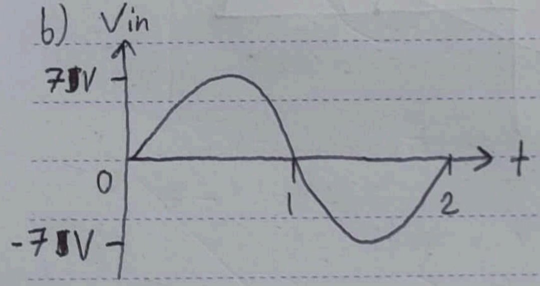
Now after connecting a capacitor, C= 100 μF in parallel with the load.

(d) Calculate the peak-to-peak ripple voltage,
(e) Calculate the average of the output voltage V_{DC} after connecting the capacitor. Compare this with the DC value determined in 'c' and comment on the difference between these two.
(f) How can you provide better filtering for the output waves?
(g) What is the frequency of the Ripple voltage?

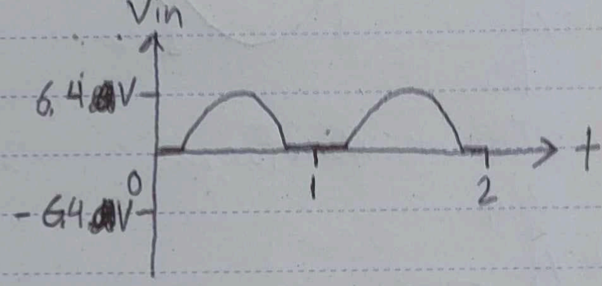
3. FW Rectifier, $V_s(t) = 7\sin(400\pi t)$, $R = 5k\Omega$,
$V_{Do} = 0.3V$, $V_M = 7$, $f_i = \frac{400}{2} = 200\,Hz$, $V_p = 6.4V$

a) $f_i = 200\,Hz$, $f_o = 2f_i = 400\,Hz$

b)



Input waveform



Output waveform

c) $V_{DC} = \frac{2}{\pi}V_M - 2V_{Do} = \frac{2}{\pi}(7) - 2(0.3) = 3.86\,V$

d) $C = 100\mu F$, $V_r = \frac{V_P}{f_r \times RC} = \cancel{\frac{6.4}{400\times5\times100}}$

$= \frac{6.4}{400\times5\times10^3\times100\times10^{-6}} = 0.032\,V$

e) $V_{DC} = V_P - \frac{1}{2}V_r = 6.4 - \frac{1}{2}(0.032) = 6.38\,V$

The V_{DC} value is higher and close to the peak voltage after connecting the capacitor due to the capacitor's smoothing effect.

f) For better filtering of output waves a capacitor of higher capacitance can be used.

g) $f_r = 2f_i = 2\times200 = 400\,Hz$

4.

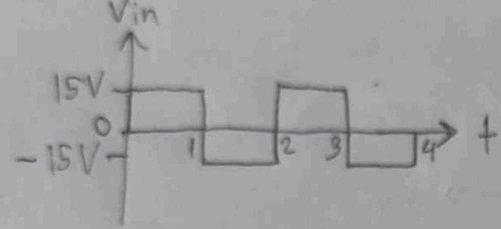
The input of a **Half-wave rectifier** is a **Square** wave voltage with peak V_M = 15 V and frequency 0.5 Hz, and output load resistance is R = 5 kΩ. Silicon diodes are used in this circuit for which the forward drop is V_{D0} = 0.7 V.

i. Show the input and output waveforms.

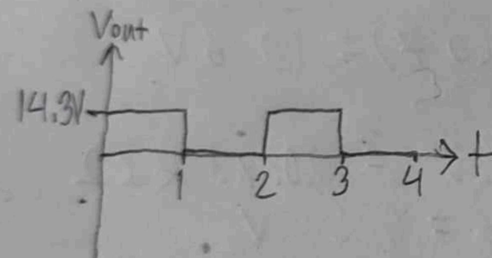
ii. Draw the VTC curve

4. HW rectifier, $V_M = 15V$, $f_i = \cancel{50}\ 0.5\,\text{Hz}$, $R = 5k\Omega$, $V_{D0} = 0.7V$

i)

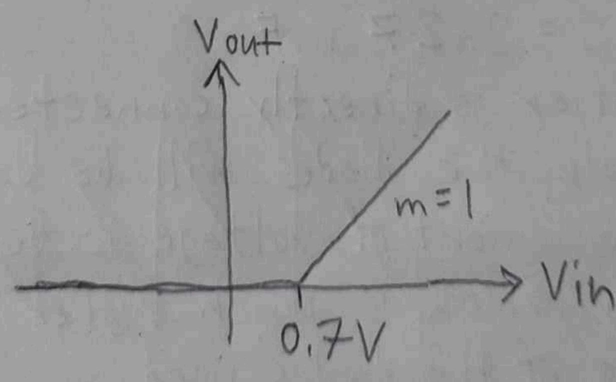


Input Waveform



Output Waveform

ii)



VTC

5.

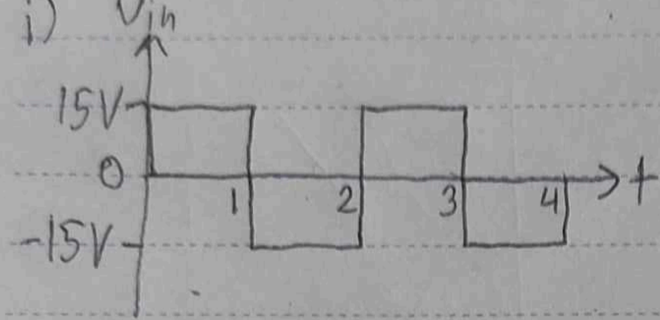
The input of a **full-wave rectifier** is a **Square** wave voltage with peak V_M = 15 V and frequency 0.5 Hz, and output load resistance is R = 5 kΩ. Silicon diodes are used in this circuit for which the forward drop is V_{D0} = 0.7 V.

i. Show the input and output waveforms.

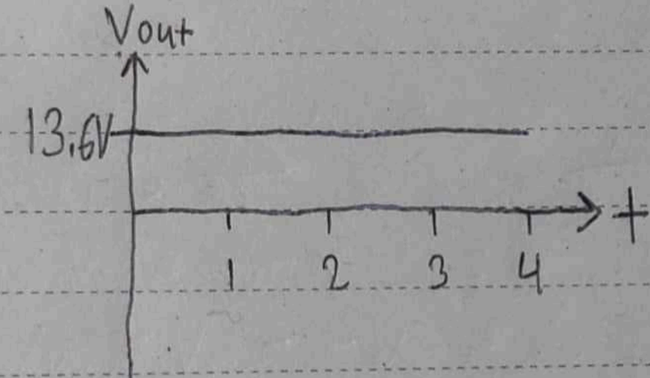
ii. Draw the VTC curve

5. FW, $V_M = 15V$, $V_{D0} = 0.7V$

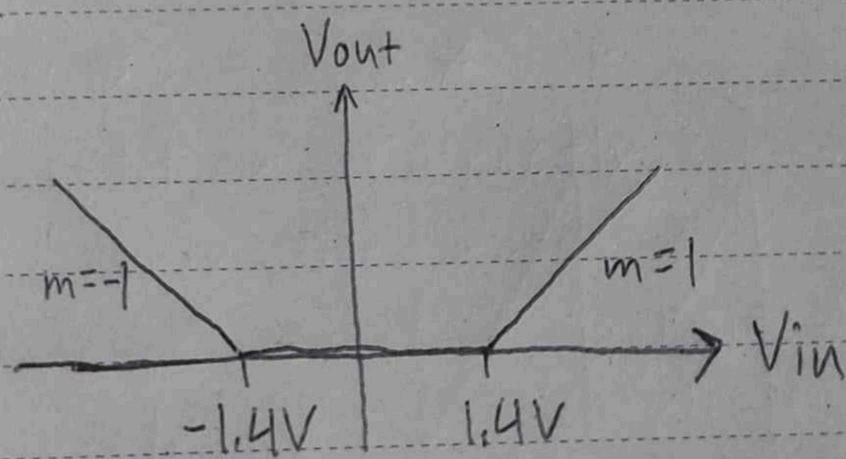
i)



Input Waveform

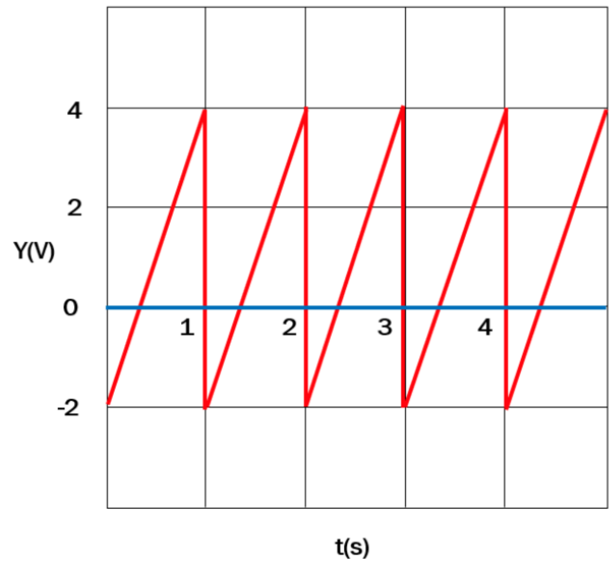


ii)



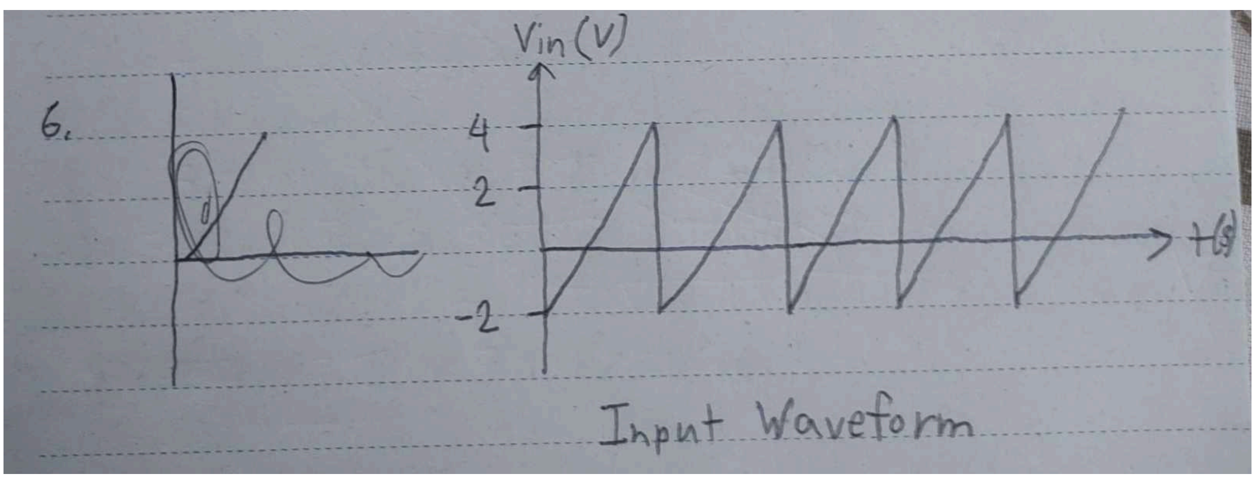
VTC

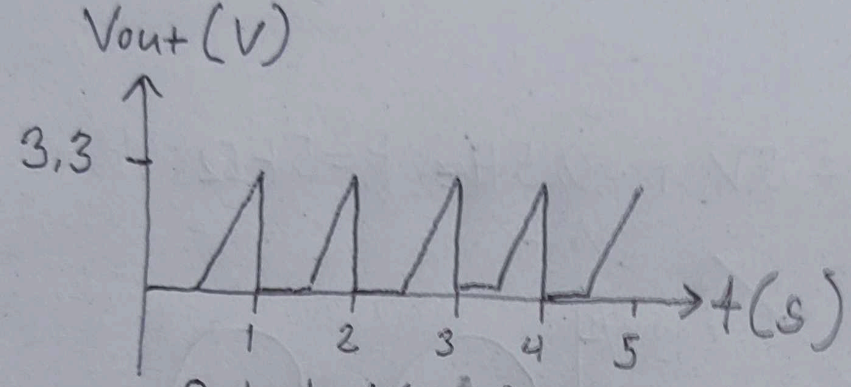
6.



The input of a Half-wave rectifier is exhibited in the Figure above and output load resistance is R = 5 kΩ. Silicon diodes are used in this circuit for which the forward drop is $V_{D0} = 0.7$ V.

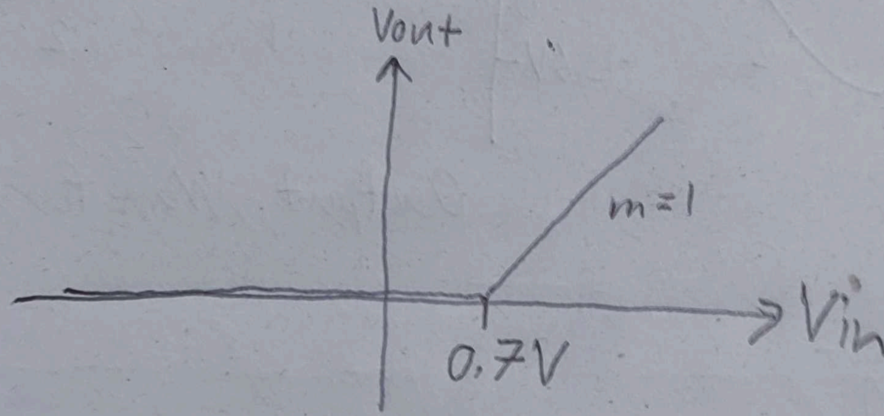
i. Show the input and output waveforms.
ii. Draw the VTC curve





Output waveform

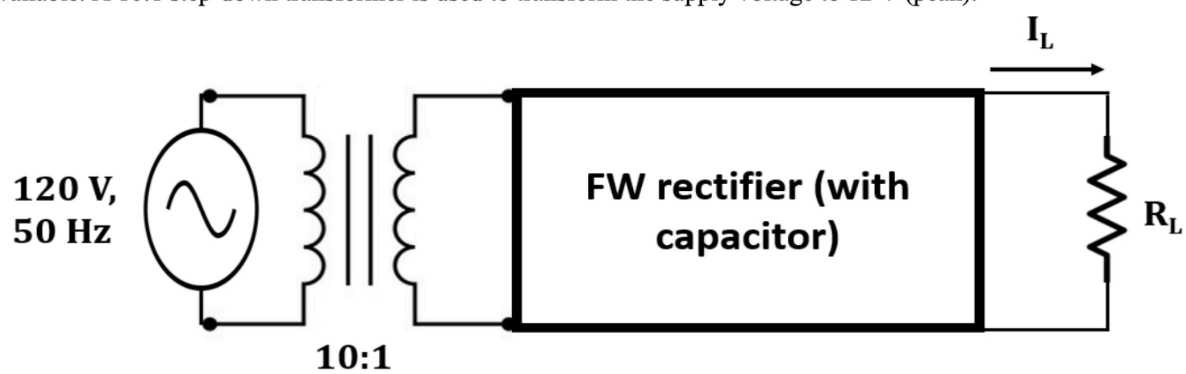
ii)



VTC

7.

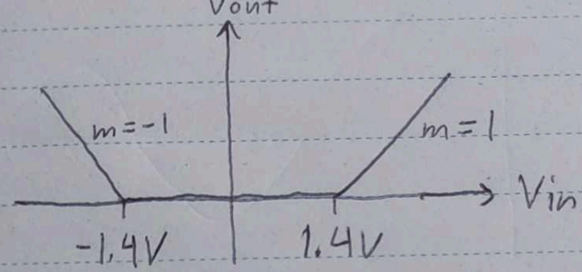
A full-wave rectifier is designed to deliver a maximum current $I_L = 120$ mA to the load. The rectifier produces an output with a ripple of 5% of the peak output voltage. An input line voltage of 120 V (peak), 50 Hz is available. A 10:1 step-down transformer is used to transform the supply voltage to 12 V (peak).



(a) Draw the Voltage Transfer Characteristics of the full-wave rectifier. [2]
(b) Calculate the peak output voltage. [1]
(c) Determine the value of the Load Resistor to deliver a maximum load current of 120mA. [2]
(d) Deduce the value of the Capacitor and the DC average value. [1]
(e) Assume the transformer is removed and the rectifier is directly connected to the AC power supply line. Discuss the state of the diodes. [Hint: use the Peak Input Value of the rectifier input] [3]

7. FW Rectifier, $V_M = 12V$, $f_i = 50Hz$, $V_{Do} = 0.7V$ (Assumed)

a)



VTC

b) $V_P = V_M - 2V_{Do} = 12 - 2(0.7) = 10.6V$

c) $I_L = 120\,mA$

$I_L = \frac{V_P}{R_L} \Rightarrow R_L = \frac{V_P}{I_L} = \frac{10.6}{120} = 0.0883\,k\Omega$

d) $V_r = \frac{5}{100} \times V_P = 0.05 \times 10.6 = 0.53V$.

$V_{DC} = V_P - \frac{1}{2}V_r = 10.6 - \frac{1}{2}(0.53) = 10.335V$

$V_r = \frac{V_P}{f_r RC} \Rightarrow 0.53 = \frac{10.6}{100 \times 0.0883 \times C}$

$\Rightarrow C = 2.27\,mF$

e) If the rectifier is directly connected to the AC power supply the diodes will be damaged because a huge amount of voltage is being supplied by the AC supply which is much higher than the voltage ratings of the diodes used.