6. Diode equivalent circuits

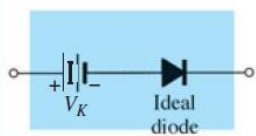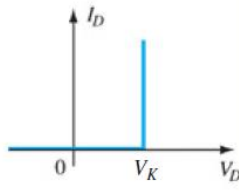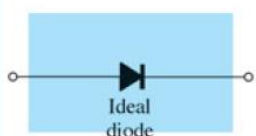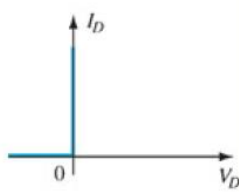An equivalent circuit is a combination of elements properly chosen to best represent the actual terminal characteristics of a device, system, or such in a particular operating region.

The **ideal diode** is included to establish that there is only one direction of conduction through the device, and a reverse-bias condition will result in the open-circuit state for the device, see the figure below.

Since a silicon semiconductor diode (**simplified model**) does not reach the conduction state until V_D reaches 0.7 V with a forward bias, a battery V_K opposing the conduction direction must appear in the equivalent circuit as in the figure below.

For more representation of the diode (**piecewise-linear model**), we can represent the internal resistance of the diode at forward bias, by representing a series resistance connected in series with the diode and replacing the exponential curve for the real diode with a liner curve, as in the figure below.

Type	Conditions	Model	Characteristics
Piecewise-linear model			
Simplified model	$R_{network} \gg r_{av}$		
Ideal device	$R_{network} \gg r_{av}$ $E_{network} \gg V_K$		

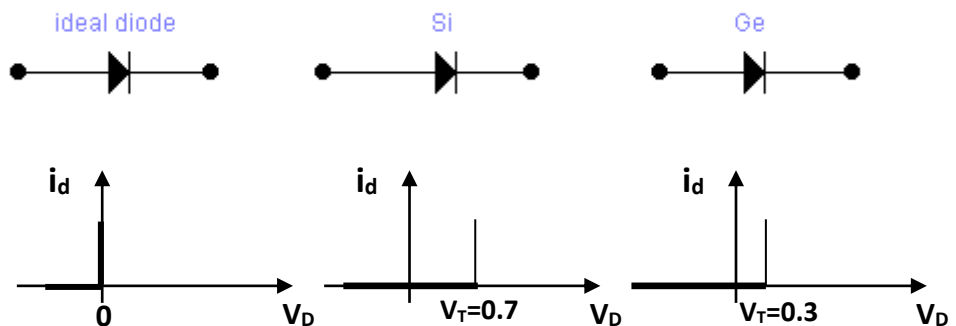**Example:** Calculate the resulting current and voltage for the resistor R.
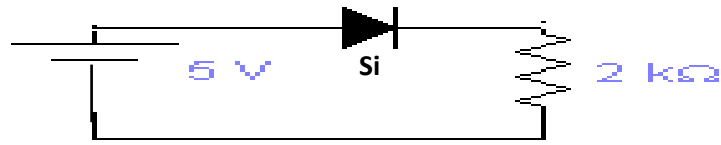
Solution:
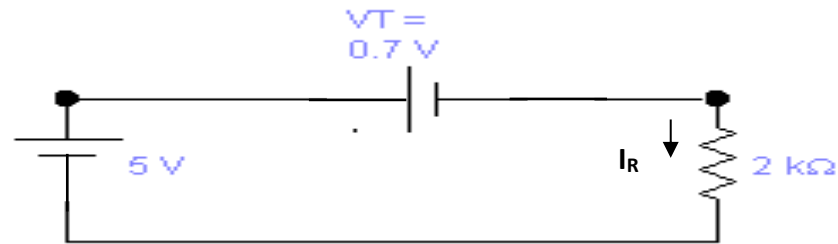
$$\therefore V_R = 5 - 0.7 = 4.3V$$

$$I_d = I_R \quad = \quad \frac{V_R}{R} = \frac{4.3}{2 \times K\Omega} = 2.15mA$$

7. Diode Application

### ❖ Series diode configurations with DC inputs.

The simplified models for the diode will be employed as shown below.

Ideal and simplified for the diode

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For the simplified models voltages less than 0.7V for Si and 0.3V for Ge will also result in an open cct and for voltage greater than the above values will result in the equivalent cct short cct as shown below.

OFF state for ideal, S_i ,G_e   **ON state for ideal, S_i, G_e**
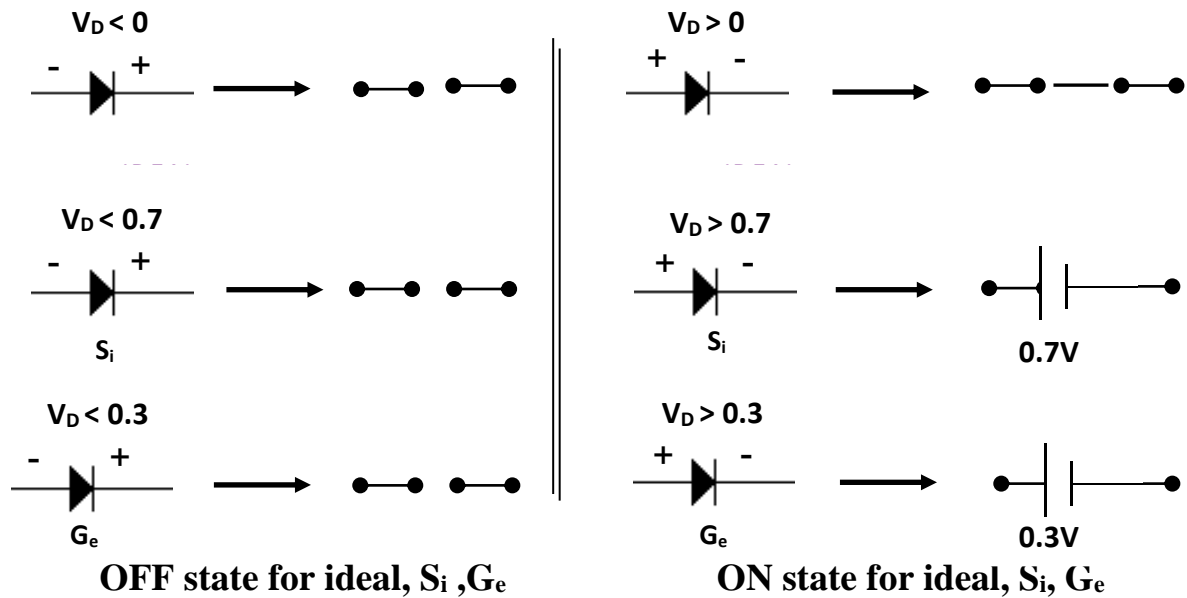
Let us begin by determining the various voltages and the current level for the series DC configuration of Fig. 1.7. The first question is the state of the diode (short cct.) or (open cct.) for most situations, removing the diode from the picture and determining the direction of the resulting current will provide the diode states short cct. or open cct. as shown in Fig. 1.8.
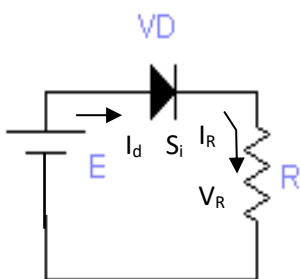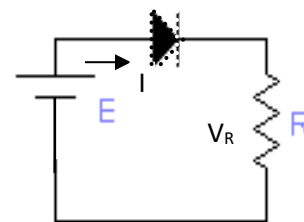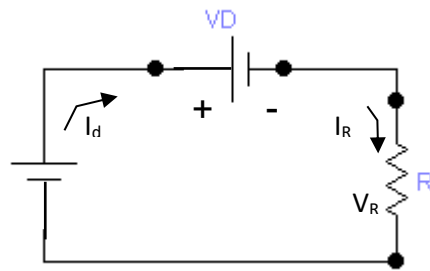

Fig. 1.7. Series diode configure   **Fig. 1.8** determining the state of Diode

Assuming E>V_T, the diode is in the ON state and the equivalent cct is shown in below.

V_D=V_T

V_R=E-V_T

I_D=I_R=$\dfrac{V_R}{R}$

Example: For the series diode configuration of Fig. 1.9, determine V_D, V_R, and I_D?
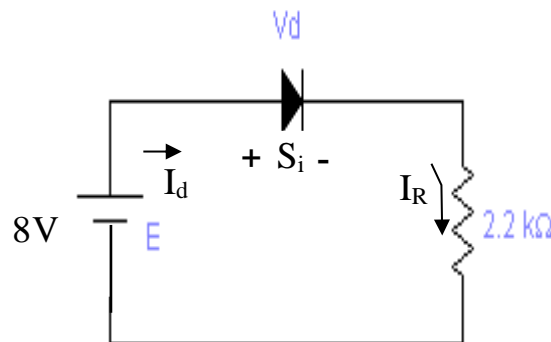

Fig. 1.9

Solution:

The diode is in the on state because the applied voltage establishes a current in the clockwise direction to match the arrow of the symbol.

V_T=V_D=0.7V

V_R=E-V_T=E-V_D=8-0.7=7.3V

$\therefore I_D$=I_R=$\dfrac{V_R}{R}$ = $\dfrac{7.8}{2.2\times10^3}$ = 3.32mA
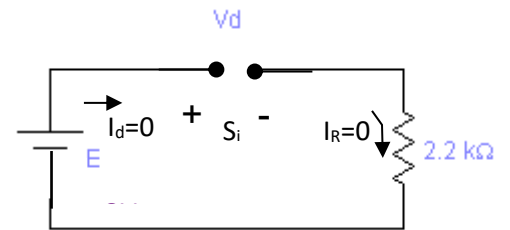
If the example above is repeated with the diode reversed, then removing the diode, we find that the direction of I in Fig. 1.9 as shown above is opposite to the arrow in the diode: -

The diode is in the open circuit (off state)

$$\therefore I_D = 0 \text{ A}$$

$$V_R = I_R R = 0 \text{ (R)} = 0 \text{ V}$$

$$V_D = E - V_R = E - 0 = E = 8V$$

Example: Determine Vo and I_D for the series cct. in Fig. 1.10?
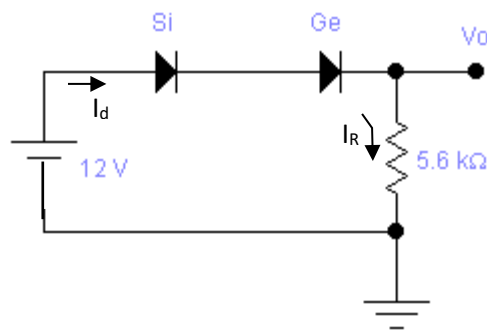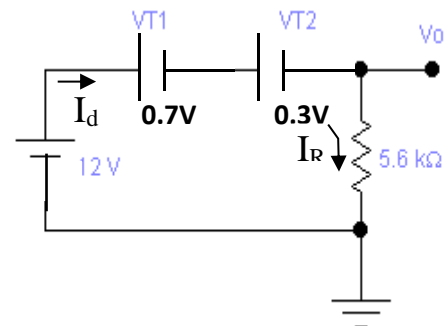

Fig. 1.10

Solution:

The resulting current, established by voltage source, has the same direction as the arrowhead of the symbols of both diodes

$$E > (0.7 + 0.3) \text{ V}$$

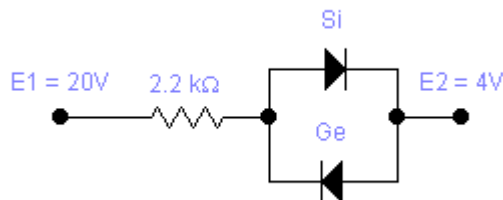$$\therefore V_0 = E - V_{T1} - V_{T2}$$

$$= 12 - 0.7 - 0.3 = 11V$$

$$I_D = I_R = \frac{V_R}{R} = \frac{V_o}{R} = \frac{11}{5.6k\Omega} = 1.96 \quad \text{mA}$$

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❖ Parallel and series-parallel configuration

The methods applied in series configuration can be extended to the analysis of parallel and series-parallel.
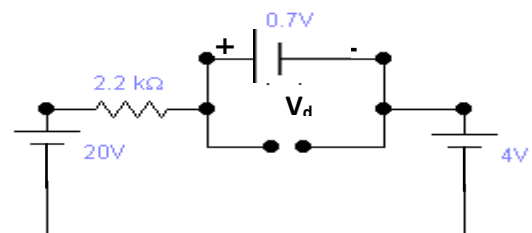

Example: Determine the current I for the network below?

Solution:

The resulting current direction is such as to turn ON the silicon diode and turnoff the Germanium diode

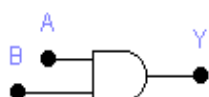$$\therefore I = \frac{E_1 - E_2 - V_D}{R} = \frac{20 - 4 - 0.7}{2.2 \times 10^3} = 6.95 \text{mA}$$
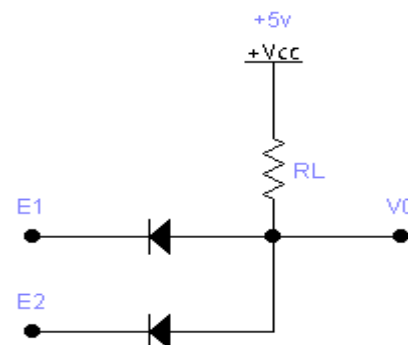

❖ Diode logic gates

Diode can be used to form logic gates, which perform some of the logical operations required in digital computers.

1-AND Gate

Truth table

E_2	E_1	V_0
0 V	0 V	0 V
0V	+5V	0V
+5V	0V	0V

Y=A.B

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The output of AND gate becomes 5V only when all input are equal to 5 V.

2-OR Gate

Truth table

E$_2$	E$_1$	V$_0$
0 V	0 V	0 V
0V	+5V	+5V
+5V	0V	+5V
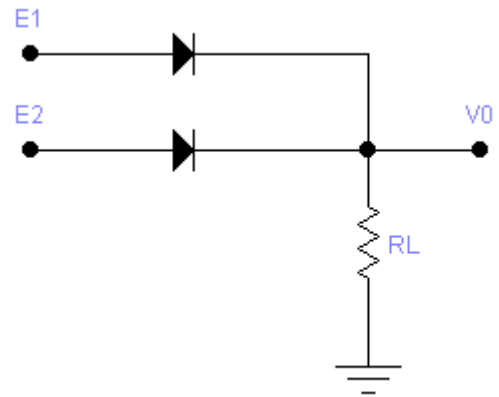
+ve logic OR gate
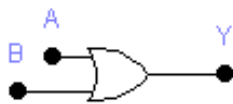
Y=A+B

The output of OR gate becomes 5V if one or both inputs are 5 V.

Ex:-

$E_1 = 10V$, R_1 4.7k-Ω, Si, I, V_0, R_2 2.2K, $E_2 = -5V$

Fig 1
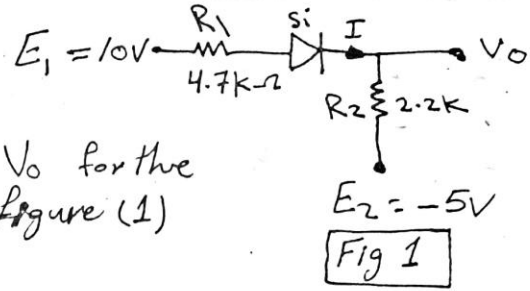
Determine I, V_1, V_2 and V_0 for the series dc Configuration of figure (1)

Sol:-

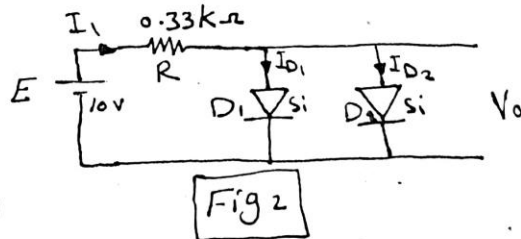$$I = \frac{E_1 + E_2 - 0.7}{R_1 + R_2} = \frac{14.3}{6.9k} \cong 2.07 \ mA$$

$$V_1 = I * R_1 = 2.07 * 4.7 = 9.73 \ V$$

$$V_2 = I * R_2 = 2.07 * 2.2 = 4.55 \ V$$

$$V_0 - V_2 + E_2 = 0 \implies V_0 = V_2 - E_2 = -0.45 \ V$$

Ex:-

Determine V_0, I_1, I_{D_1} and I_{D_2} for the parallel diode Configuration of Fig(2)

I_1, 0.33k-Ω, R, I_{D_1}, I_{D_2}, E 10V, D_1 Si, D_2 Si, V_0

Fig 2

Sol:-

$$I_1 = \frac{E - 0.7}{0.33 \ k} = \frac{9.3}{0.33k} = 28.18 \ mA$$

$$I_{D_1} = I_{D_2} = \frac{28.18}{2} = 14.09 \ mA$$

وذلك لأن D_1 و D_2

هما مربوطان على التوازي ولهم نفس النوع

$$V_0 = 0.7$$

EX:-.

Determine the currents $I_1, I_2,$ and I_{D_2} for the network of fig (3).

Fig 3
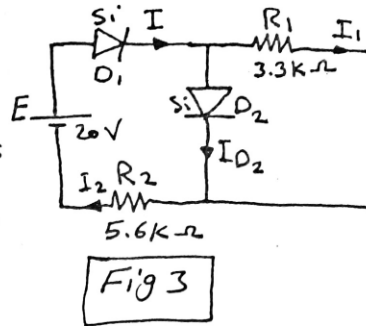
SoL:-

$$I_1 = \frac{0.7}{R_1} = \frac{0.7}{3.3k} = 0.212 \text{ mA}$$

$$E - 0.7 - 0.7 - I_2 \times R_2 = 0$$

$$I_2 = \frac{20 - 1.4}{R_2} = \frac{18.6}{5.6k} = 3.32 \text{ mA}$$

$$I_2 = I_{D_2} + I_1 \implies I_{D_2} = I_2 - I_1$$

$$\therefore I_{D_2} = 3.32 - 0.212 \simeq 3.11 \text{ mA}$$

I مادة قمية

❖ Half – Wave Rectifier

Half – wave rectifier: It is the process of removing one half the input signal to establish a dc level. The term rectification comes from the use of the term rectifier for diode employed in power supply for ac to dc conversion process

The circuit of Fig. 1.11 called a half wave rectifier will generate a wave from V_0 that will have an average value of particular use in the ac – to – dc conversion process.
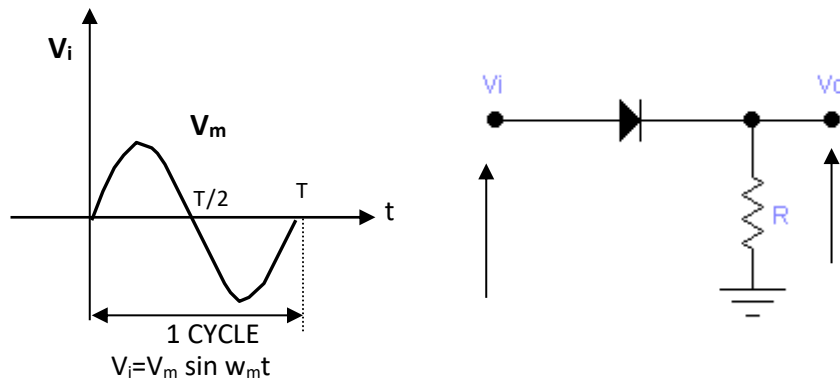
Ideal model for diode will be used for simplicity.

Fig. 1.11

During the interval $t = 0 \rightarrow T/2$ in Fig. 1.11, the polarity of the input voltage V_i is shown in Fig. 1.12. The output voltage is contacted directly to the input, with the result that for period $0 \rightarrow T/2$, $V_0 = V_i$.

For period $T/2 \rightarrow T$, the polarity of the input voltage V_i is shown in Fig. 1.13 and the ideal diode produces in off state, $V_0 = 0V$.the input voltage V_i and output voltage is shown in Fig. 1.14.
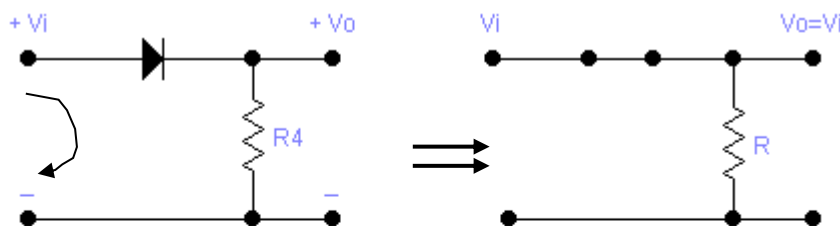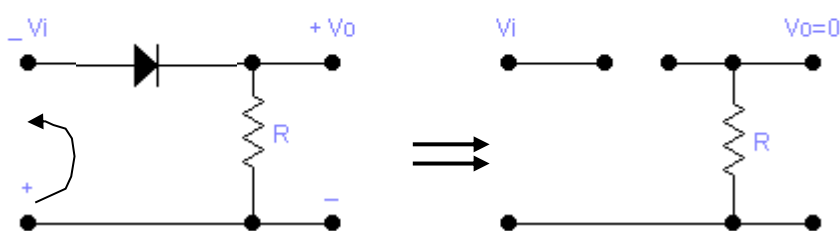

Fig. 1.12

Conducting
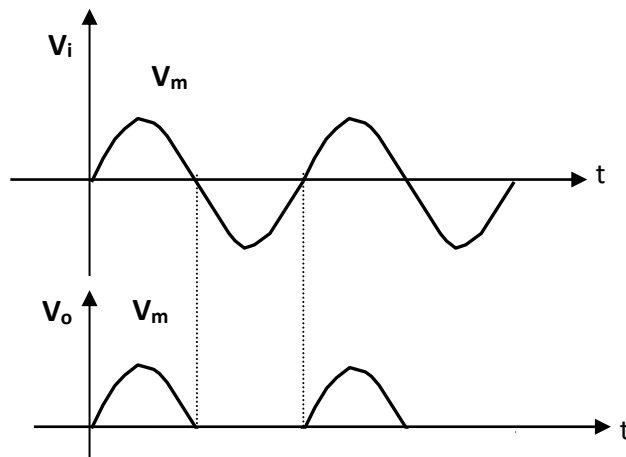
Fig. 1.13

Non-Conducting region

Fig. 1.14 half wave Rectifier

The output signal V_0 now has a net positive area above the axis over a full period and an average value determined by:

average (V_{dc} value) $= 0.318 V_m$.

The effect of using a silicon a idea with $V_T = 0.7V$ is shown by Fig. 1.15 for the forward bias. The input must now be at least 0.7V before the diode

conducts. When conducting $V_0 = V_i - V_T$.

$V_{dc} = 0.318 (V_m - V_T)$.

If $V_m \gg V_T$

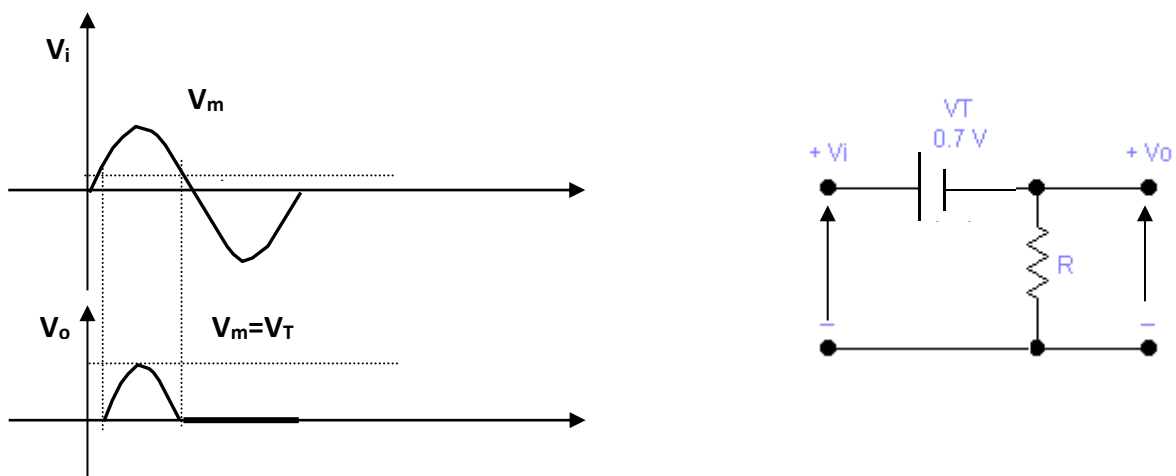$\therefore V_{dc} = 0.318\ V_m \Big|_{V_m \gg V_T}$

Fig. 1.15

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Example:

A-Sketch the output V_0 and determine the dc level of the output for the network of Fig. 1.16.

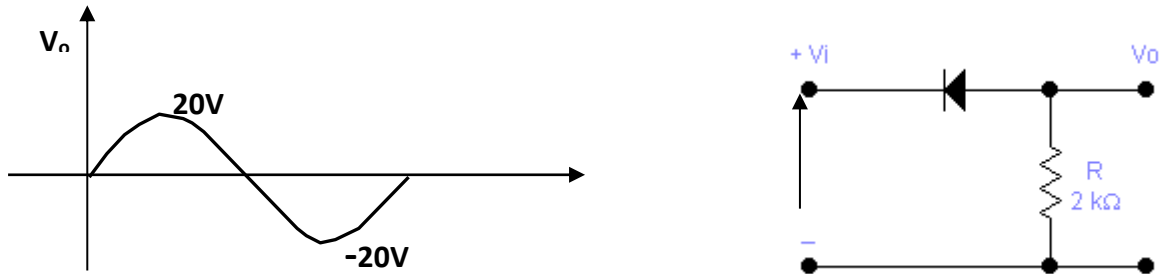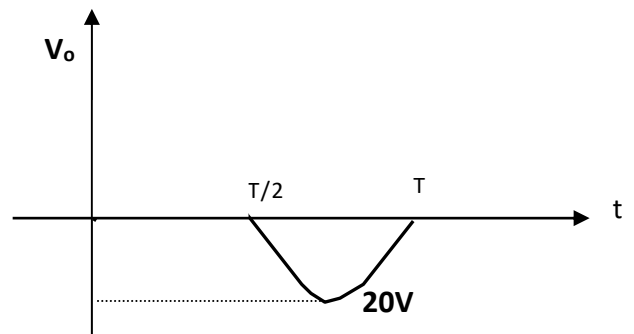B-repeat part (A) if the ideal diode is replaced by a silicon diode.

Fig. 1.16

Solution:

In this situation the diode will conduct during the negative part of the input as shown in the Fig below

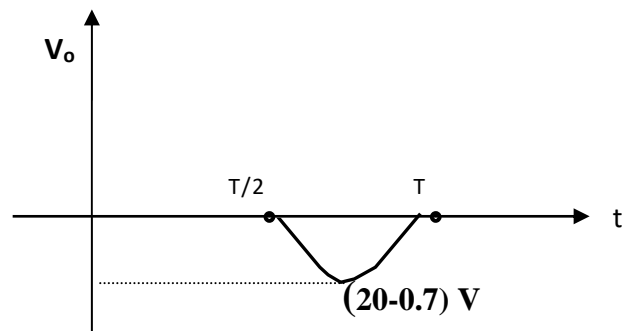$$V_{dc} = -0.318V_m$$

$$= -0.318(20) = -6.36V$$

B-using A silicon diode, the output shown in fig below

$$\therefore V_{dc} = -0.318(V_m - V_T)$$

$$= -0.318(20-0.7)$$

$$= -6.1374V$$

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The peak – inverse voltage (PIV) rating of diode is voltage rating that must not be exceeded in the reverse bias region, or the diode will enter the Zener breakdown region. The required PIV rating for the half wave receiver can be shown below, it is obvious PIV rating of the diode must equally or exceed the peat value of the input voltage.

$$PIV_{rating} = V_m \text{ rating for half wave rectifier}$$