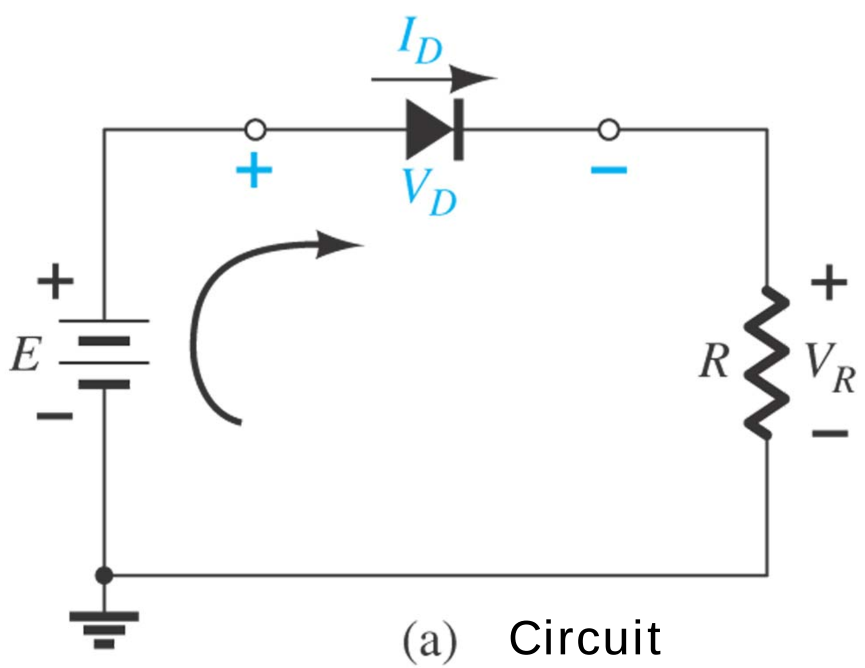
# Diode Application

WED DK2 9-10am

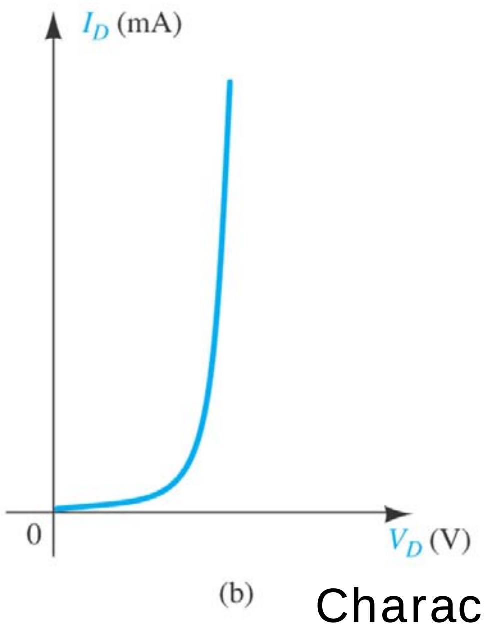
THURS DK6 2-4pm

# Simple Diode circuit

## Series diode configuration



(a) Circuit

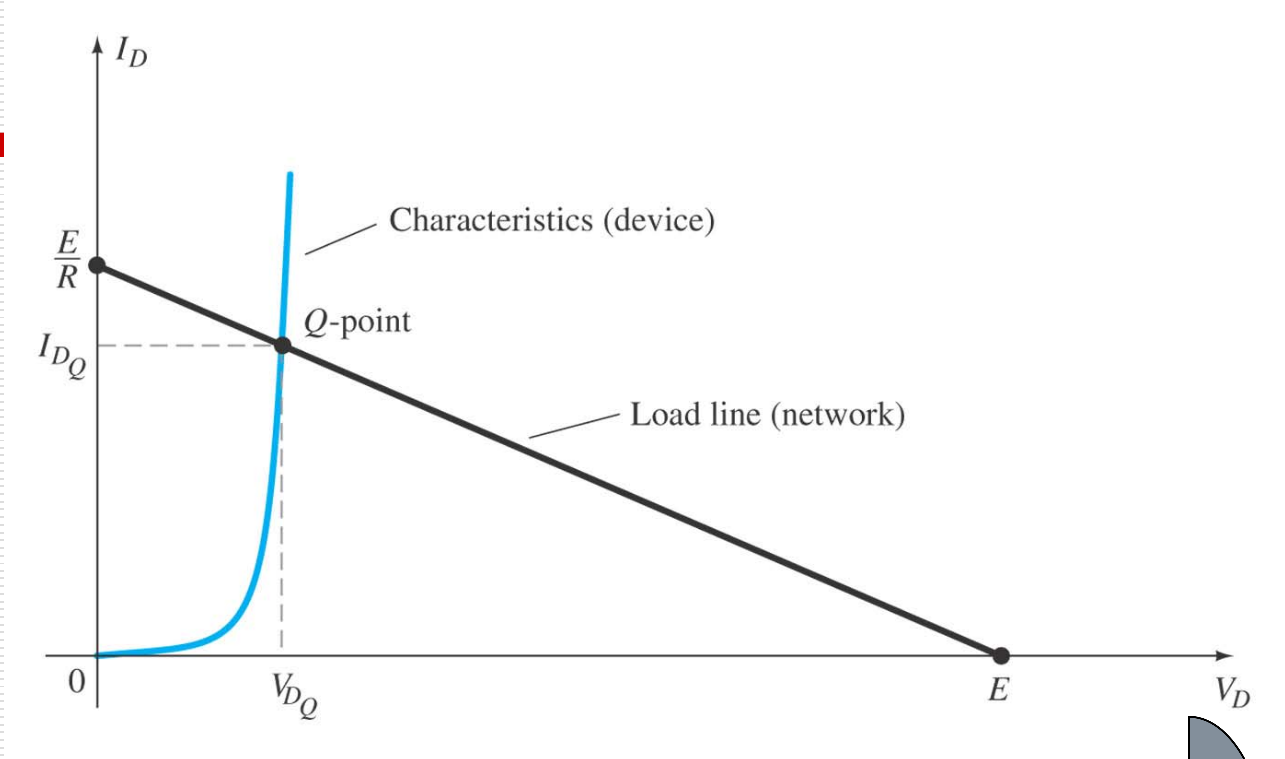


(b) Characteristics

From Kirchoff's Voltage Law $E = V_D + I_D R$

From previous lecture $I_D = I_S\left(e^{V_D/nV_T} - 1\right)$

# Load line analysis



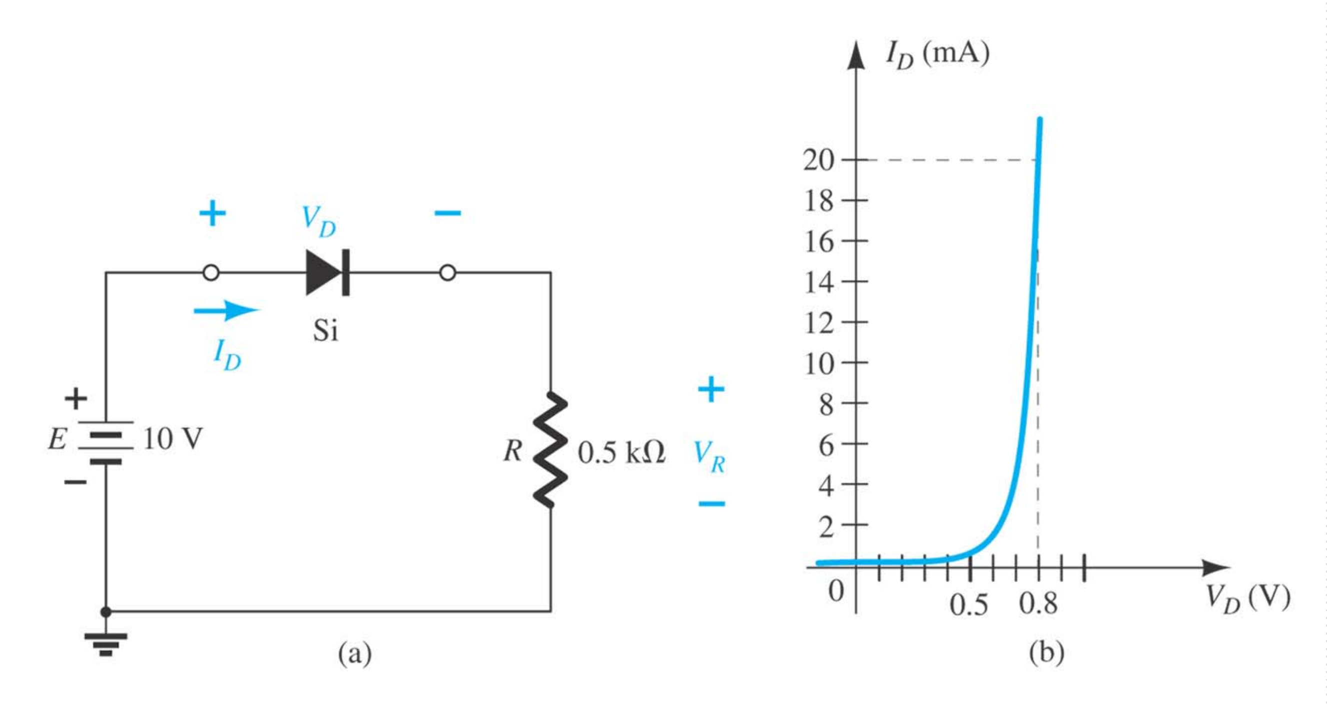

When $V_D = 0$ V then

$$I_D = \frac{E}{R}\bigg|_{V_D = 0V}$$

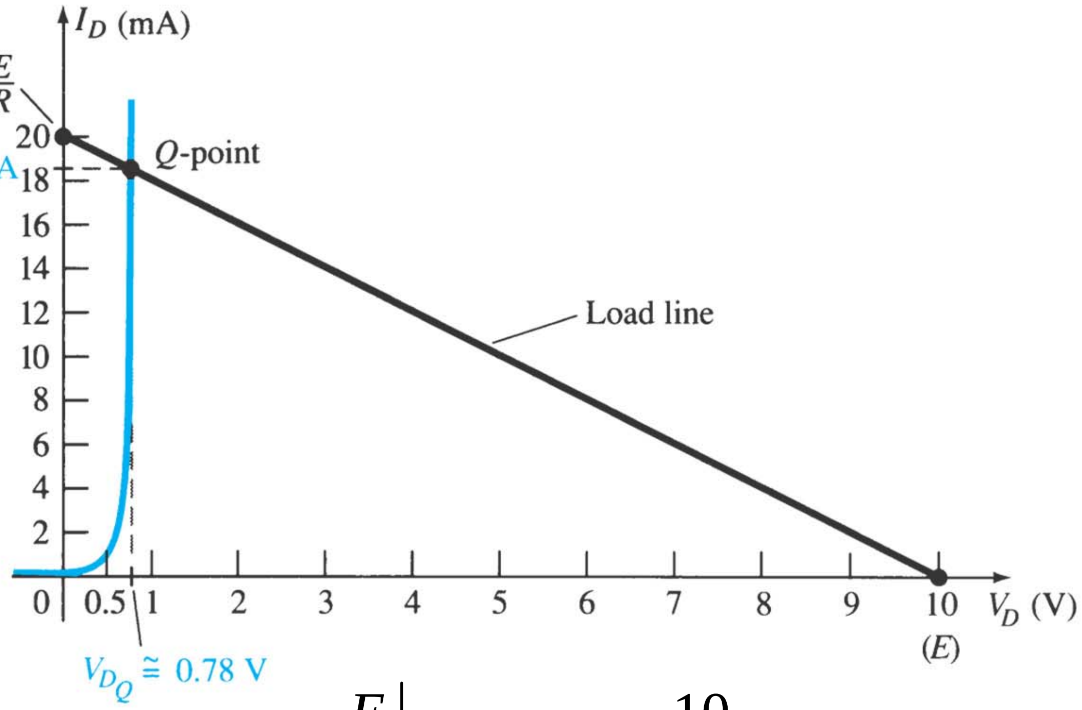
When $I_D = 0$ A then

$$V_D = E\Big|_{I_D = 0A}$$

**Example** For the series diode below employing the diode characteristic beside it, determine $V_{DQ}$ , $I_{DQ}$ and $V_R$,




**Robert L. Boylestad**
*Electronic Devices and Circuit Theory, 9e*



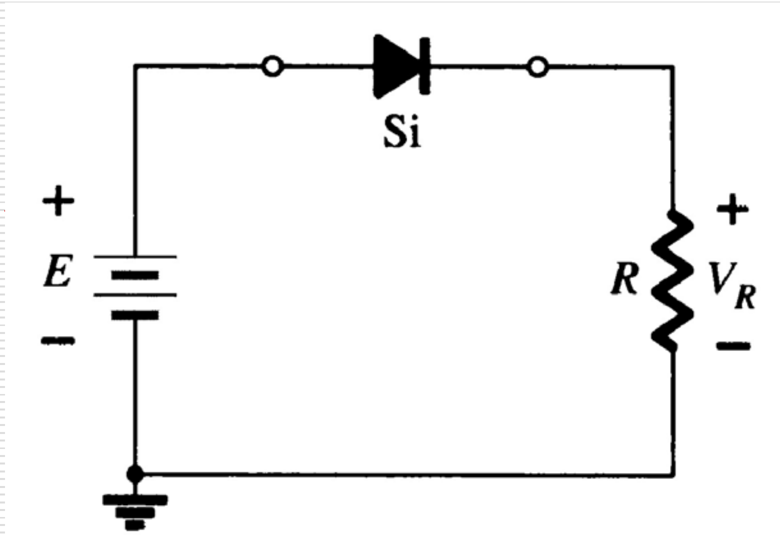

For load line

$$I_D = \frac{E}{R}\bigg|_{V_D=0V} = \frac{10}{0.5k\Omega} = 20\,mA$$

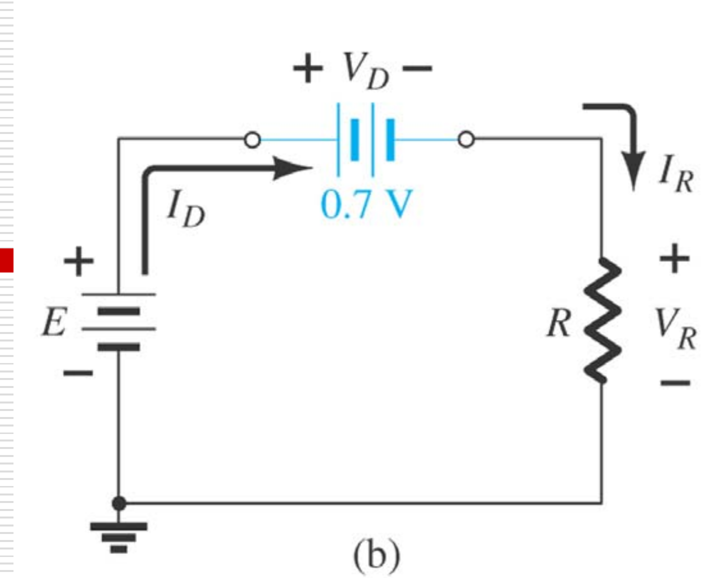
$$V_D = E\big|_{I_D=0A} = 10V$$

By drawing the load line on the diode characteristic we obtained the $V_{DQ} = 0.78V$ $I_{DQ} = 18.5mA$

$V_R = I_R R = I_{DQ} R = 18.5mA \times 1\ k\Omega = 18.5V$

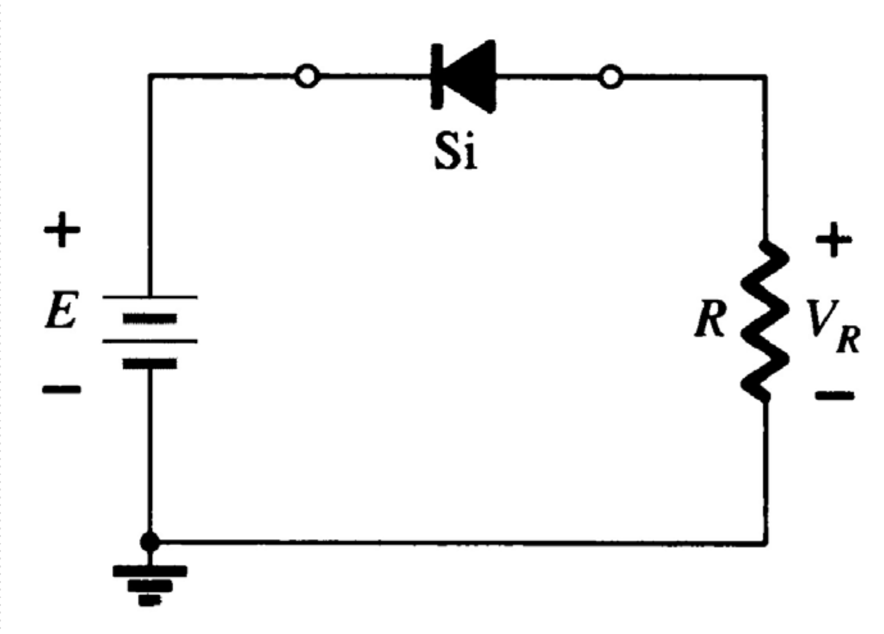



Diode circuit

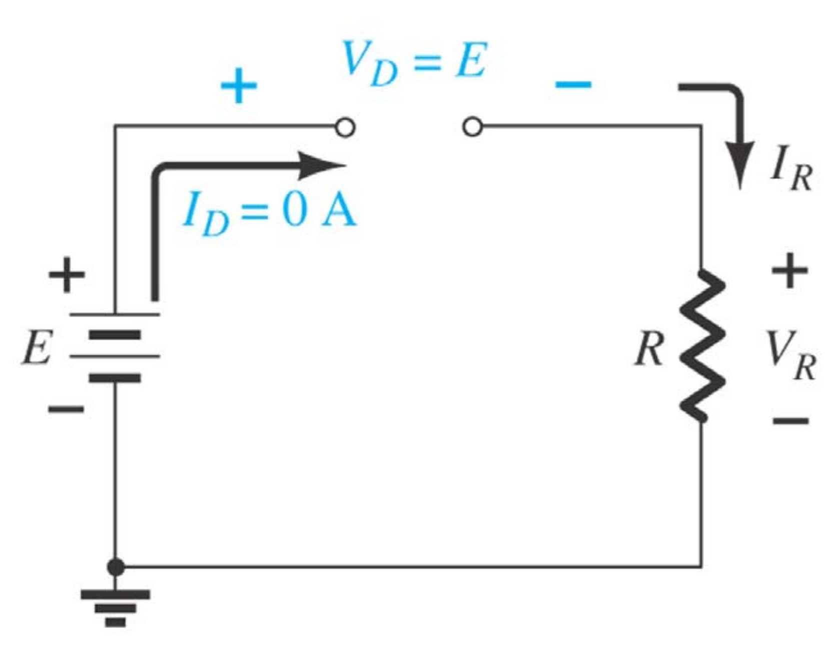



Equivalent circuit

A diode is “ON” state if the current established by the applied sources is such that its direction matches that of the arrow in the diode symbol and $V_D \geq 0.7V$ for Si, $V_D \geq 0.3V$ for Ge , $V_D \geq 1.2V$ for GaAs



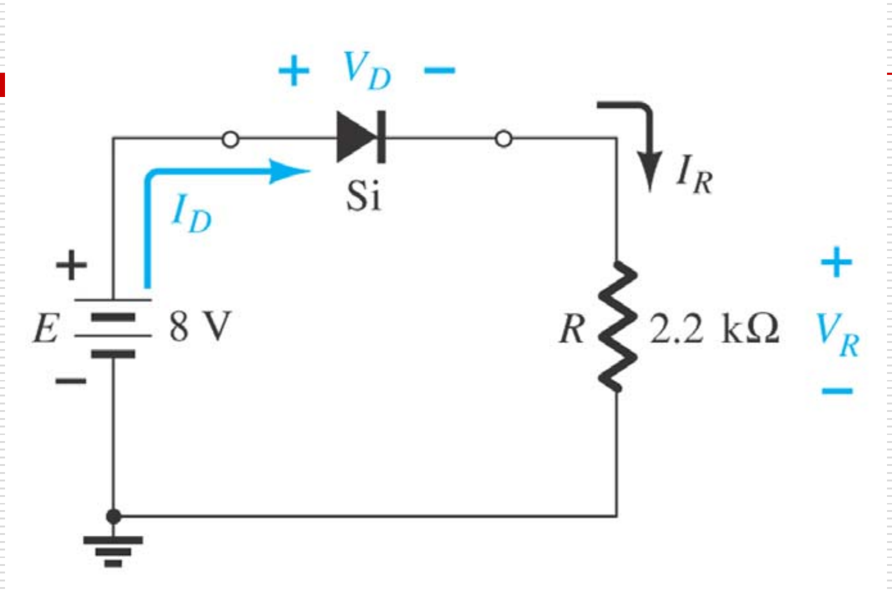

Diode circuit




Equivalent circuit

A diode is “OFF” state if the current established by the applied sources is reversed  the direction of the arrow in the diode symbol. Then $I_D=0$

For the diode below determine $V_D$, $V_R$ and $I_D$



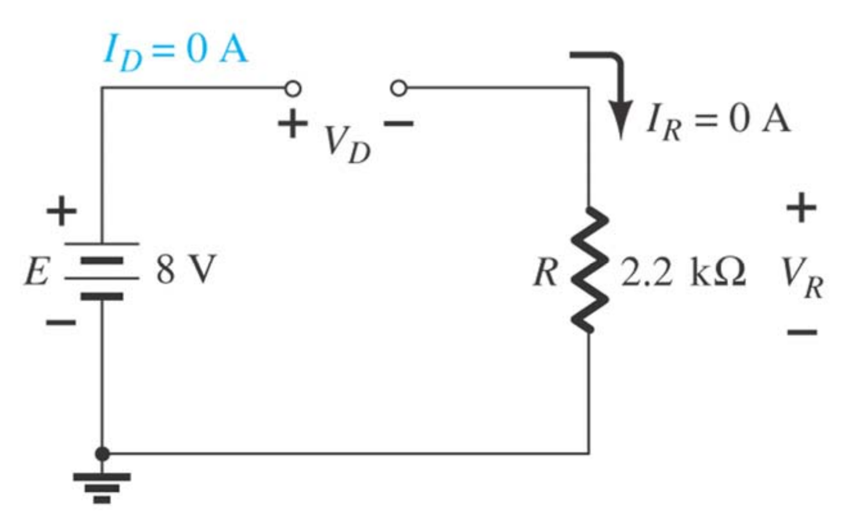

$$V_D = 0.7V$$

Using equivalent circuit and KVL

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

$$I_D = I_R = \frac{V_R}{R} = \frac{7.3V}{2.2k\Omega} = 3.32mA$$

Repeat Example with the diode reverse. Thus the equivalent circuit is

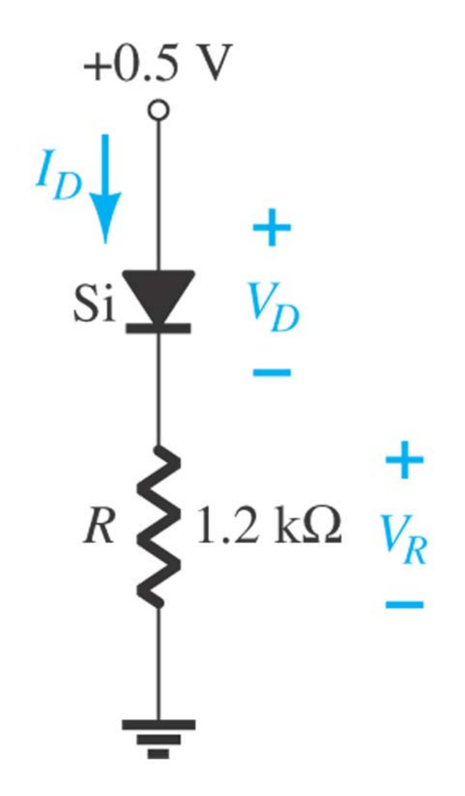



$$I_D = 0A \qquad V_R = I_R R = I_D R = 0V$$

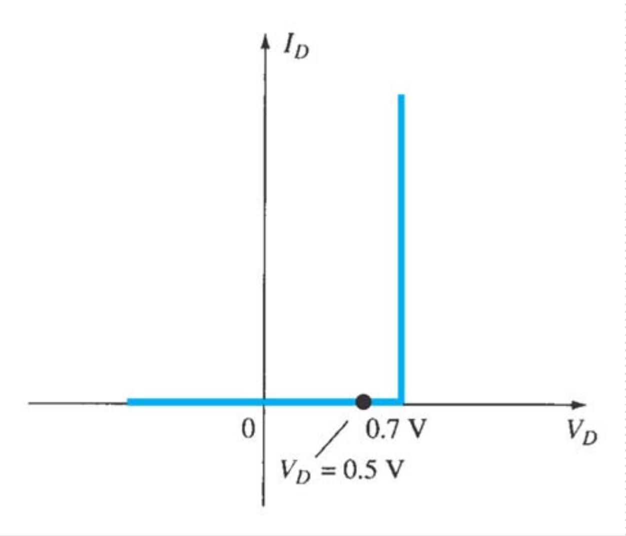
Using equivalent circuit and KVL

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

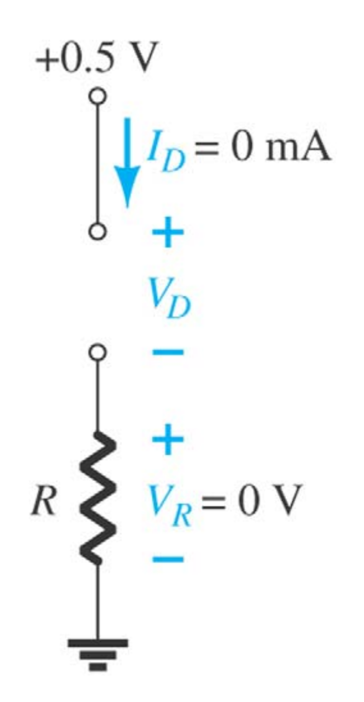
If the diode is biased with the voltage source less than $V_D$, the diode also acting like open circuit




Diode Circuit

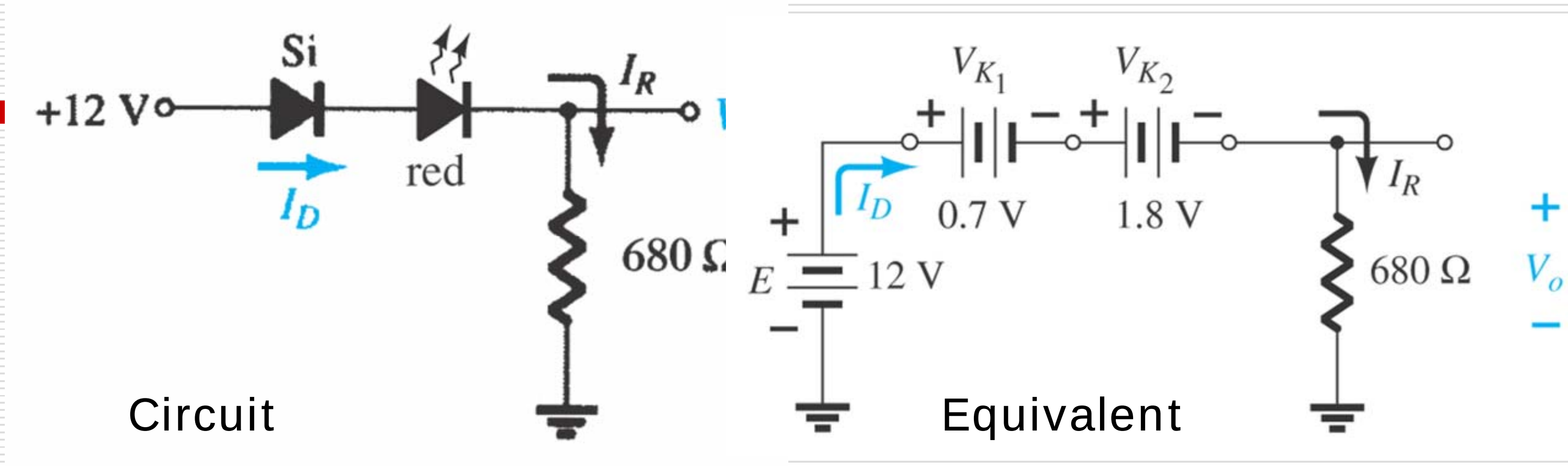



Diode Characteristic
With biasing less than 0.7V




Equivalent cct

# Determine $V_o$ and $I_D$ for the series circuit below

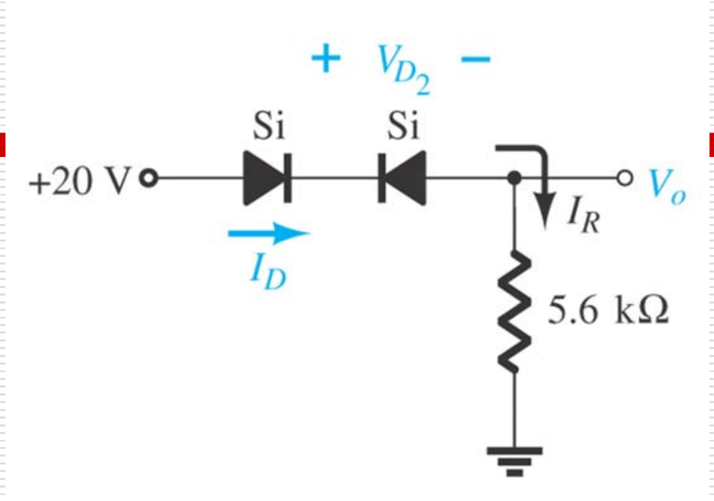


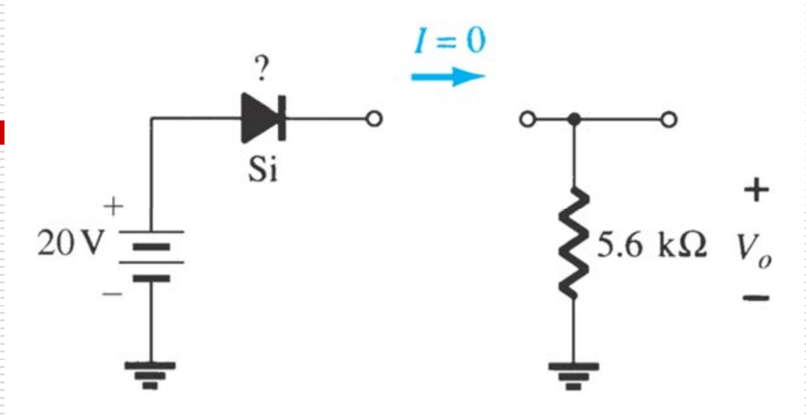

Using equivalent circuit and KVL

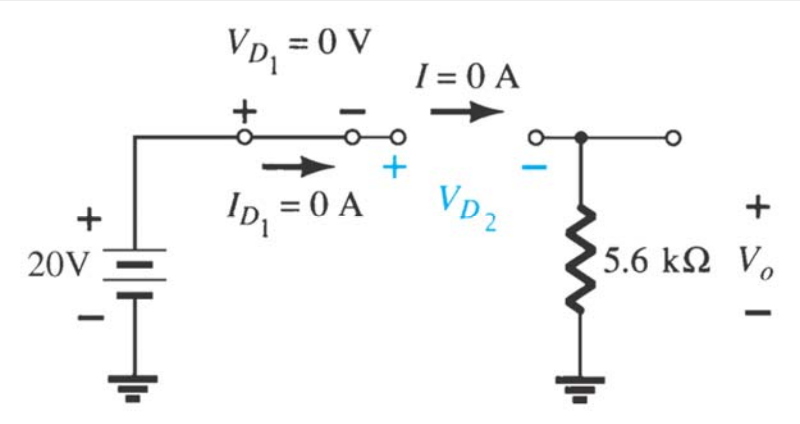
$$V_o = E - V_{K1} - V_{K2} = 12V - 0.7V - 1.8V = 9.5V$$

$$I_D = I_R = \frac{V_R}{R} = \frac{9.5V}{680\Omega} = 13.97mA$$

Determine $I_D$ , $V_D$ and $V_o$ for the circuit below




Since open circuit

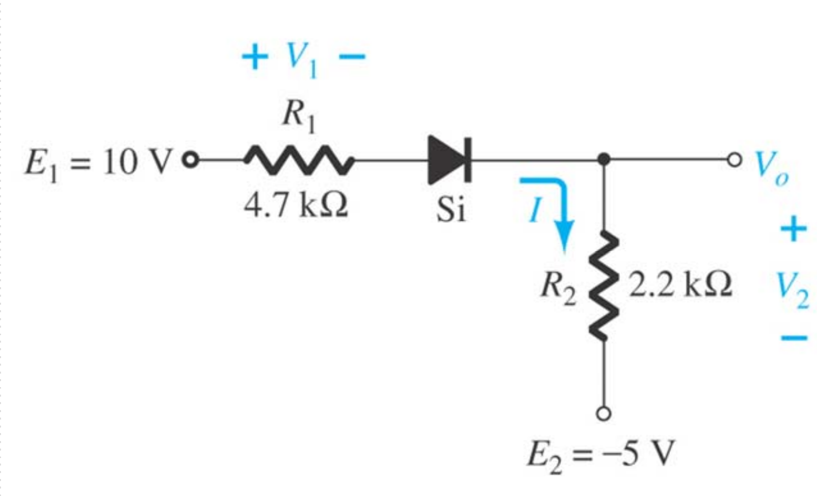
$$I_D = 0mA \qquad V_{D1} = 0V$$

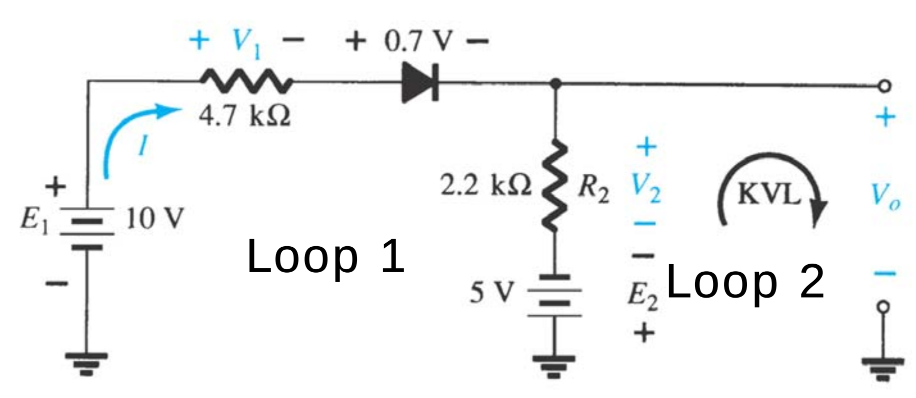
$$V_o = I_R R = I_D R = 0 \times R = 0V$$

And using KVL we have

$$V_{D2} = E - V_{D1} - V_o = 20V - 0V - 0V = 20V$$

Determine I, $V_1$, $V_2$ and $V_o$ for the series circuit below




Applying KVL in loop1

$$I = \frac{E_1 + E_2 - V_D}{R_1 + R_2} = \frac{10V + 5V - 0.7V}{4.7k\Omega + 2.2k\Omega} = 2.07mA$$

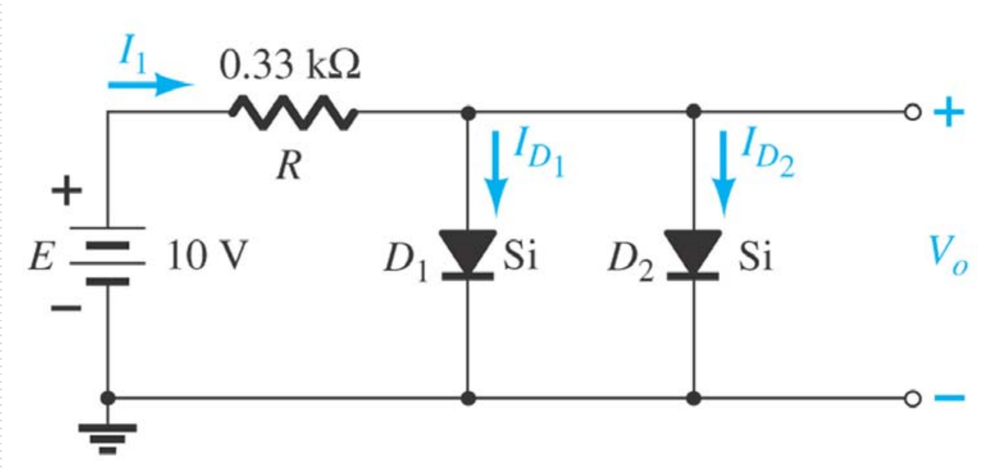
$$V_1 = IR_1 = 2.07mA \times 4.7k\Omega = 9.73V$$

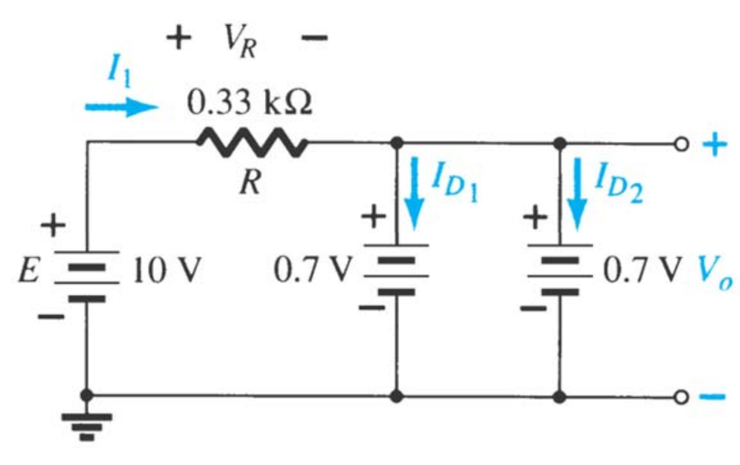
$$V_2 = IR_2 = 2.07mA \times 2.2k\Omega = 4.55V$$

And using KVL in loop 2

$$V_o = V_2 - E_2 = 4.55V - 5V = -0.45V$$

Determine $V_o$, $I_1$, $I_{D1}$ and $I_{D2}$ for the parallel diode below



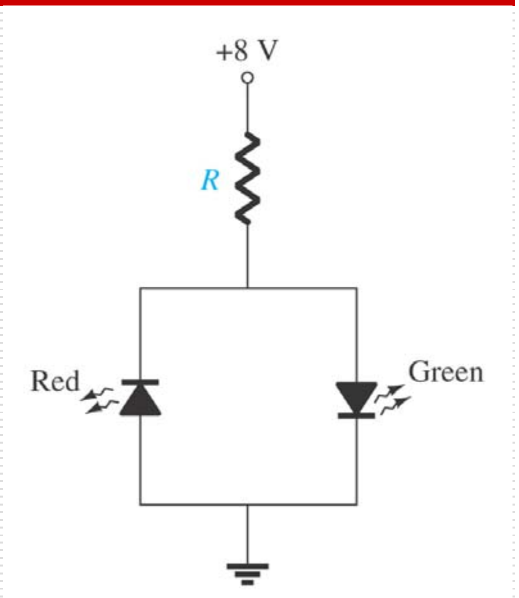

Since the source voltage is greater than the diode then the current flow and the voltage across diode is 0.7V, thus $V_o$ -0.7V

The current is $$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10V - 0.7V}{330\Omega} 2.8.18mA$$

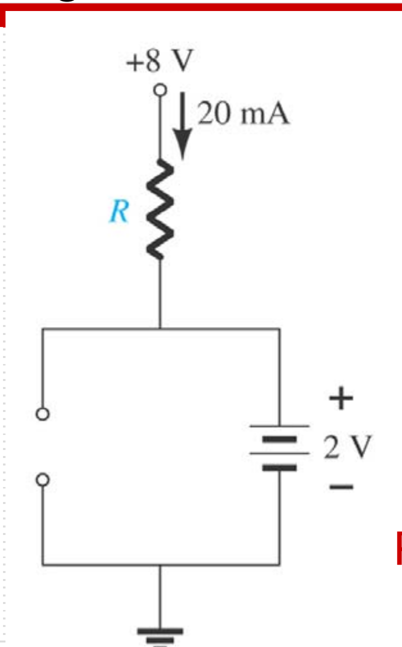
Since diodes are similar thus the current will be same, then

$$I_{D1} = I_{D2} = \frac{I_1}{2} = \frac{28.18mA}{2} = 14.09mA$$

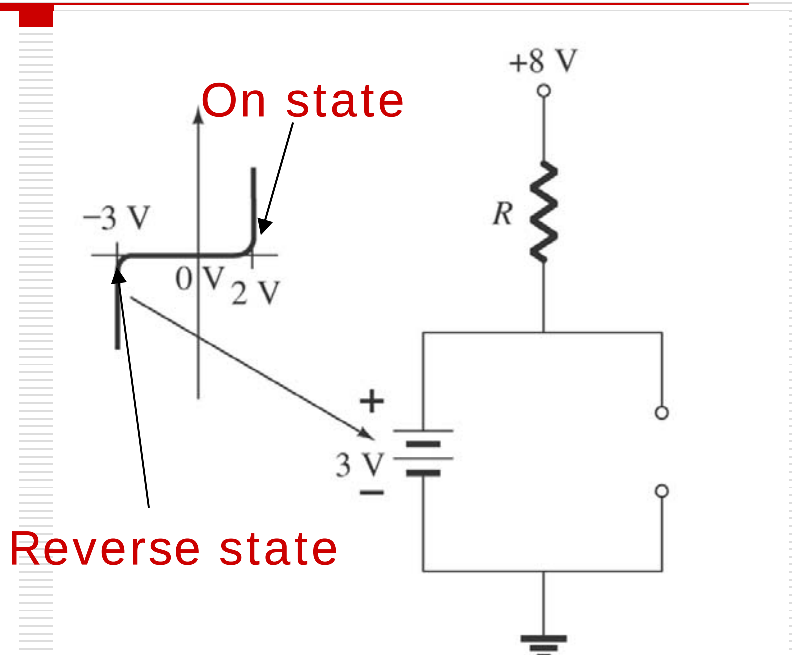
Two LEDs are used for polarity detection. Positive green and negative red. Find R to ensure 20mA through “on” diode. Both diodes have a reverse breakdown voltage of 3V and an average turn-on voltage of 2V




LEDs circuit




Equivalent Turn-on




Equivalent reverse breakdown

Note: Since the turn-on voltage is 2V so it does not exceed the reverse breakdown (3V) of the red LED. Otherwise it will damage the red diode.

## Solution

Applying Ohm's law. The current is

$$I = 20mA = \frac{E - V_{LED}}{R} = \frac{8V - 2V}{R}$$

Therefore

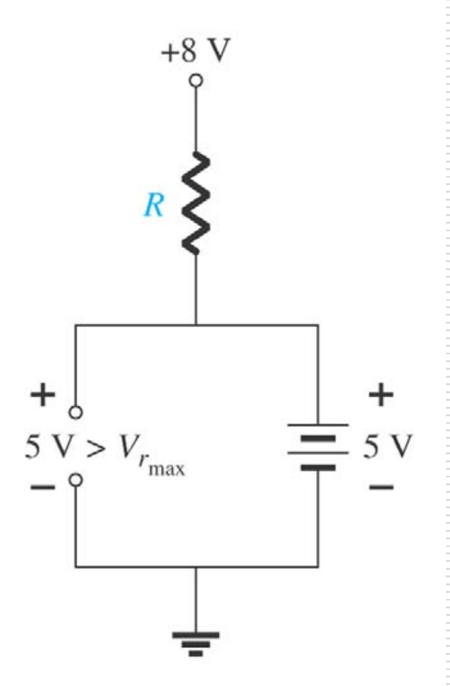
$$R = \frac{6V}{20mA} = 300\Omega$$

What happen if we replace with LED having turn-on voltage is 5V?

Applying Ohm's law. The current now is

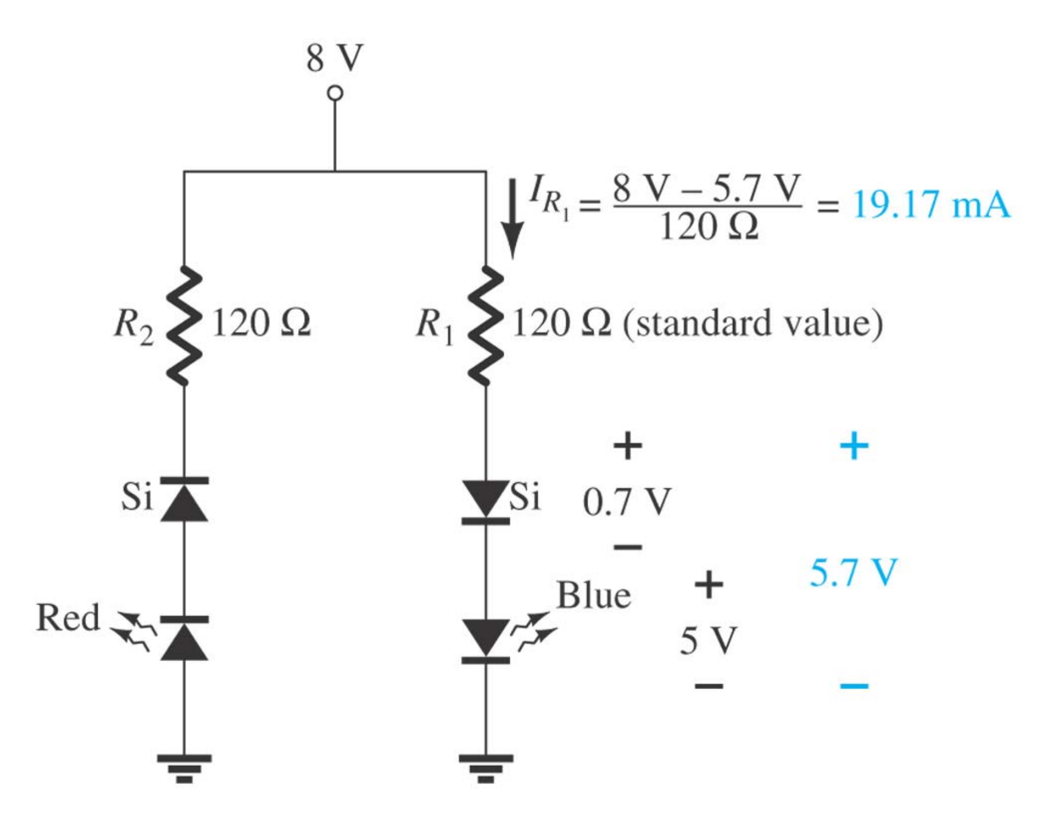
$$I = 20mA = \frac{E - V_{LED}}{R} = \frac{8V - 5V}{R}$$

Therefore $$R = \frac{3V}{20mA} = 150\Omega$$



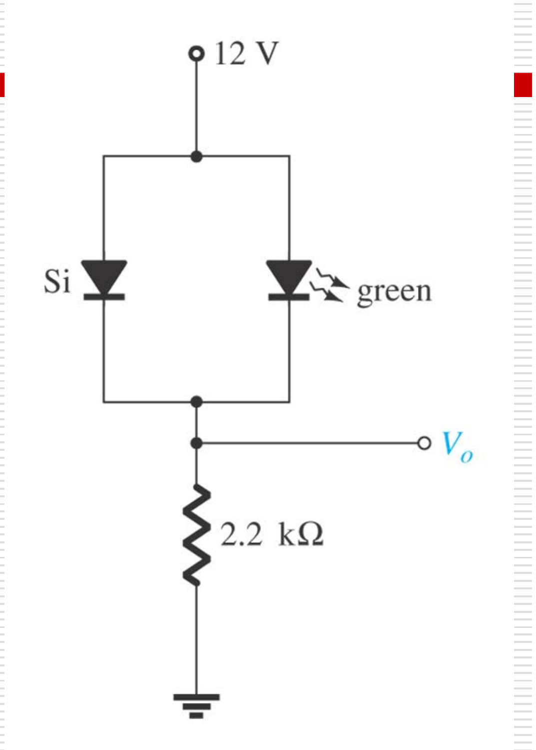

But this time the reverse biased for red LED will be 5V and exceed the breakdown voltage. The red LED will damage.

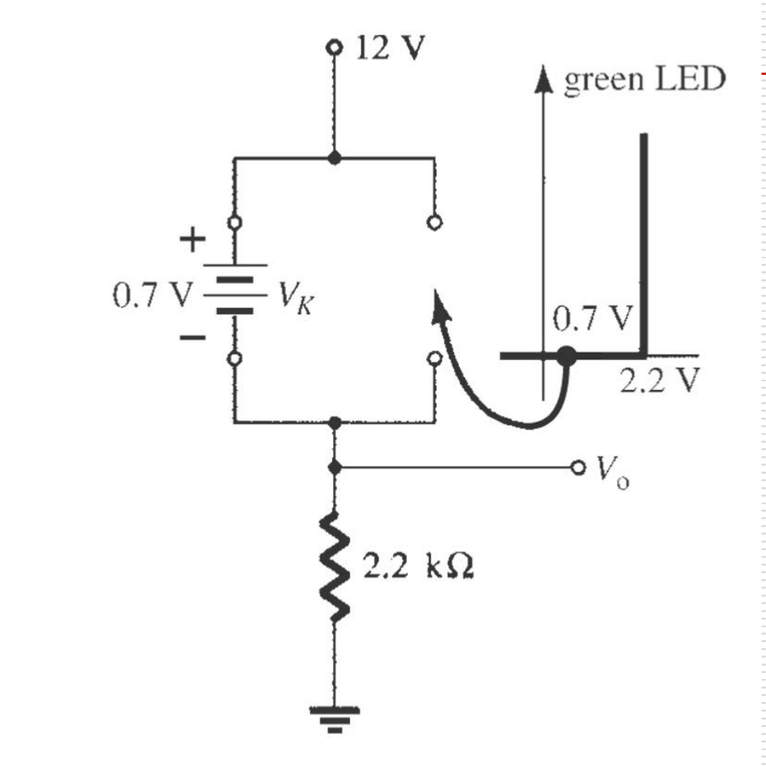
# Protective Measure for such case




The Si diode has a breakdown voltage of 20V which will stay “off” state when the apply voltage is less than 20V. So will protect the red LED.

## Determine the voltage $V_o$ for the network below

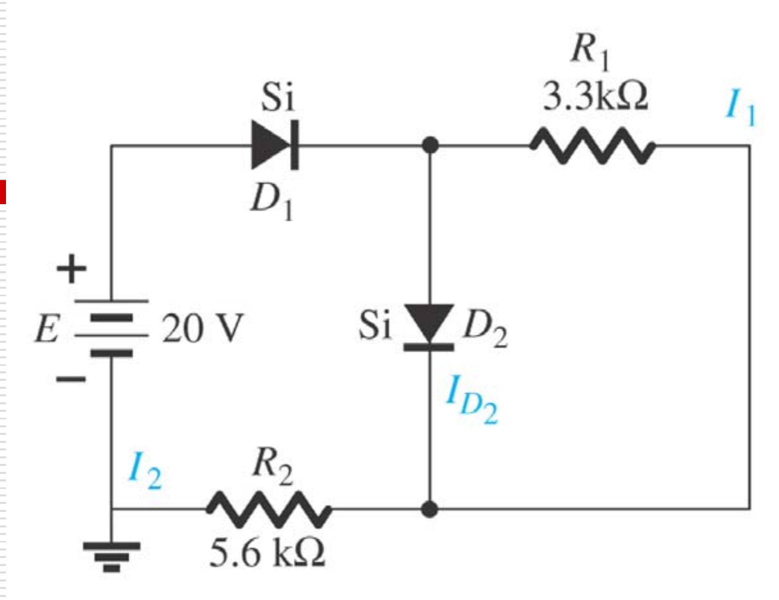


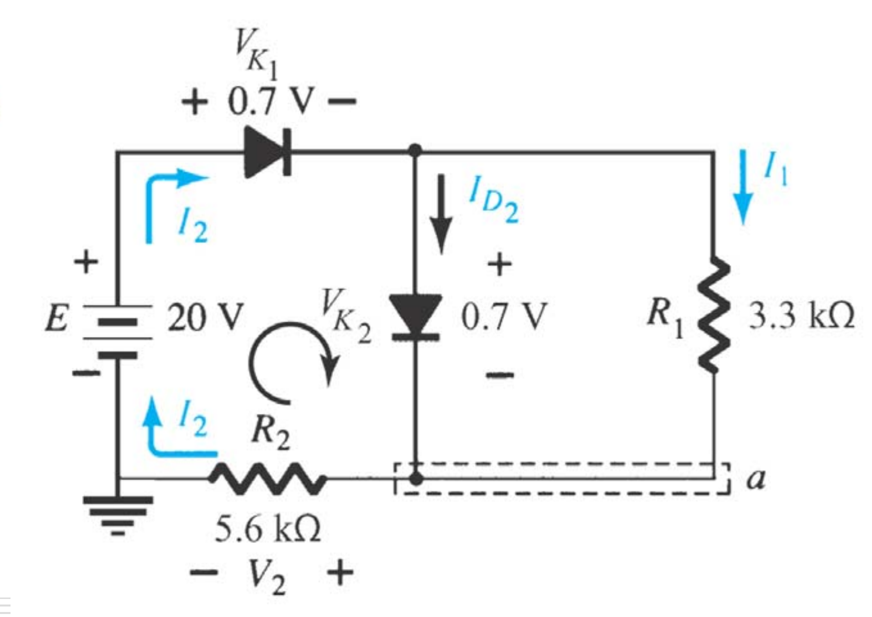




The voltage across diode is the lowest one since it will "on" first and the other still stay "off" state. Thus

$$V_o = 12V - 0.7V = 11.3V$$

Determine the currents $I_1$, $I_2$ and $I_D$ for the network below




Since $R_1$ is // $D_2$ then voltage is same

$$I_1 = \frac{V_{K_2}}{R_1} = \frac{0.7V}{3.3k\Omega} = 0.212mA$$

Applying KVL in loop 1

$$V_2 = E - V_{K_1} - V_{K_2} = 20V - 0.7V - 0.7V = 18.6V$$

Therefore

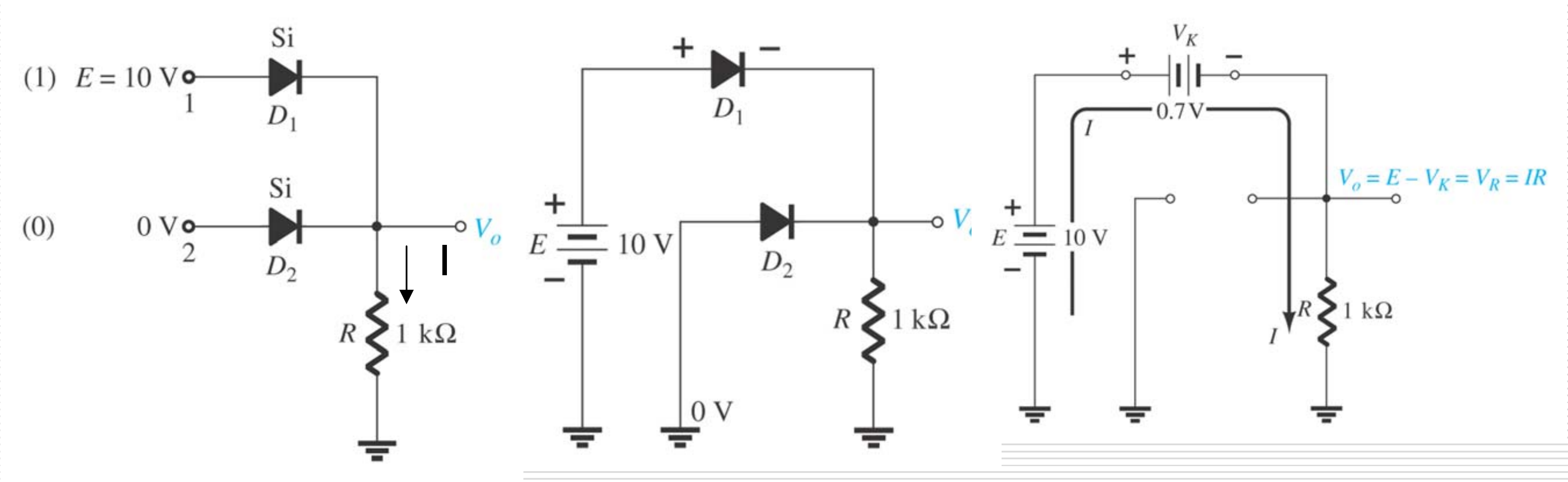
$$I_2 = \frac{V_2}{R_2} = \frac{18.6V}{5.6k\Omega} = 3.32mA$$

and

$$I_{D2} = I_2 - I_1 = 3.32mA - 0.212mA \cong 3.11mA$$

# OR Gate

Determine $V_o$ and I for network below




From fig. on the right apply KVL

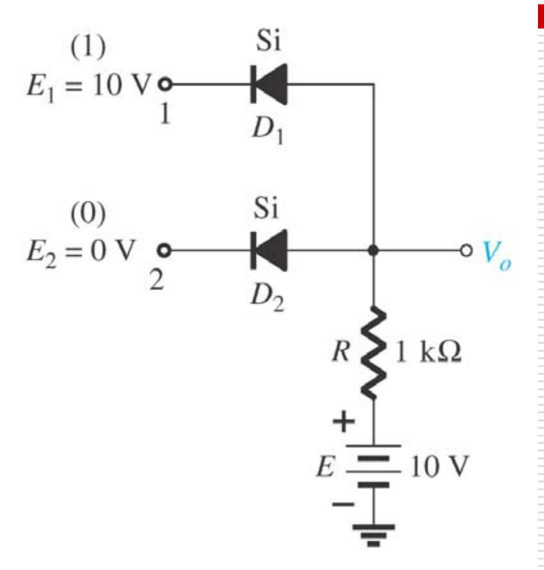
$$V_o = E - V_D = 10V - 0.7V = 9.3V$$

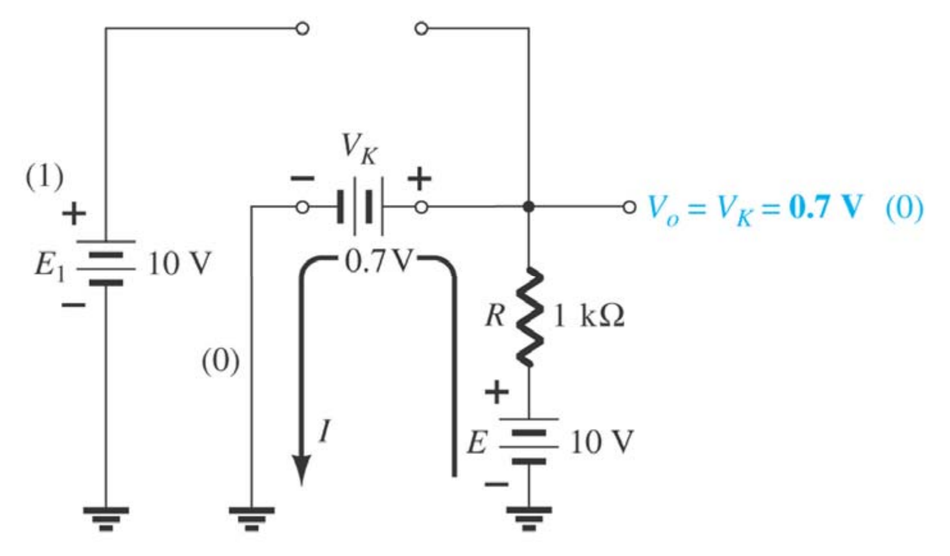
and

$$I = \frac{E - V_{D1}}{R} = \frac{10V - 0.7V}{1k\Omega} = 9.3mA$$

# OR gate

Determine the output level for the positive logic AND gate below



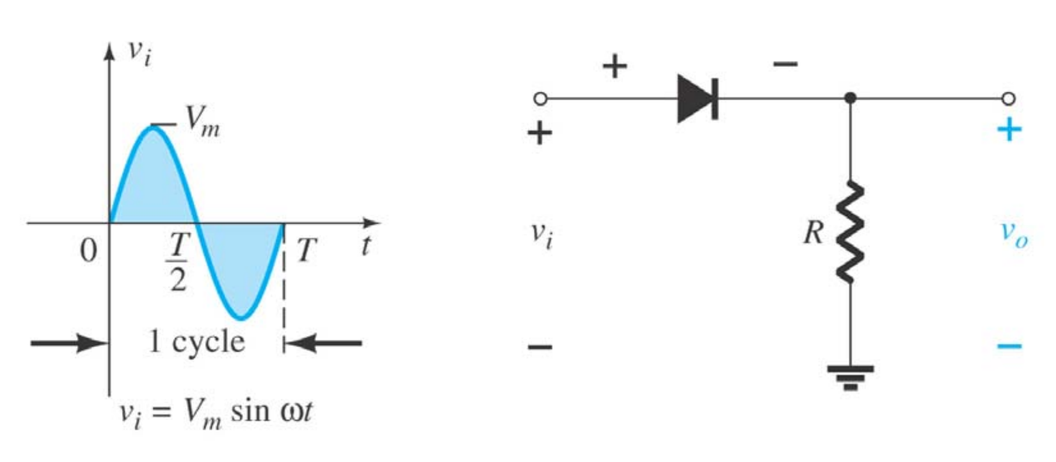




Due to forward bias of $D_2$ the output voltage is $V_o = 0.7V$

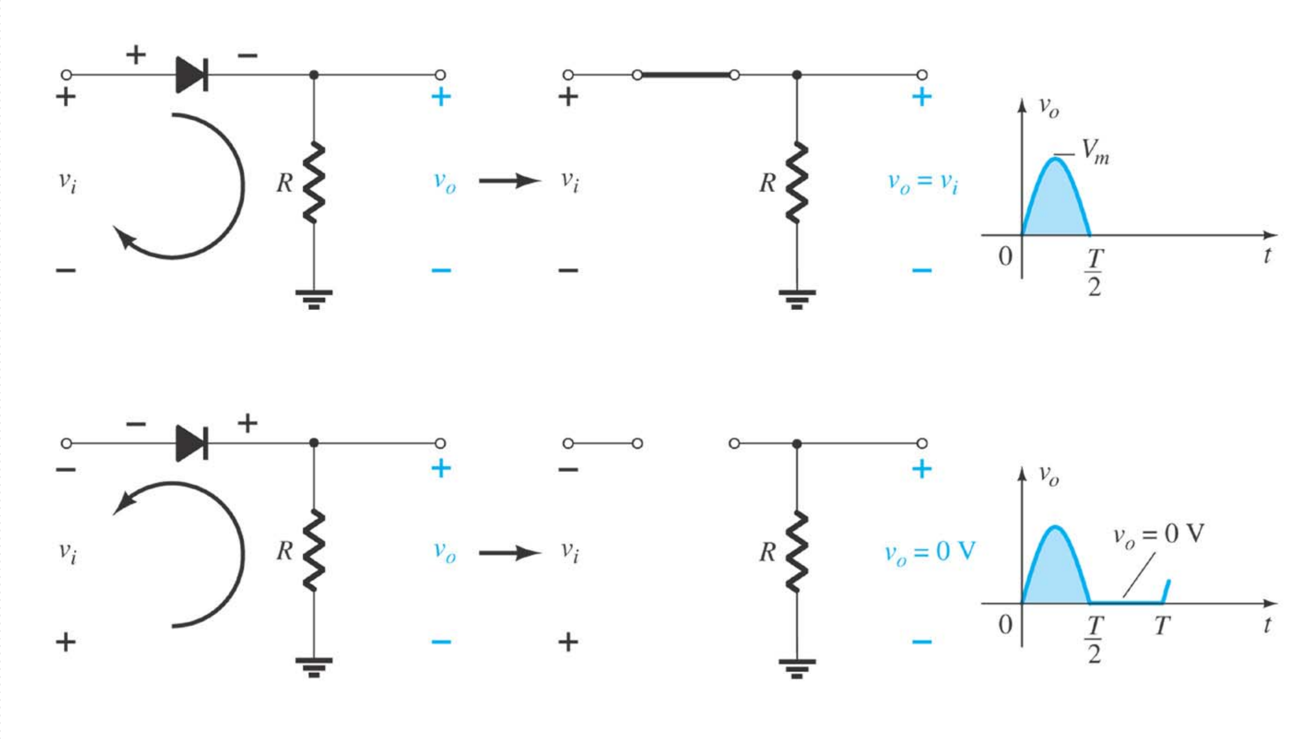
From fig. on the right apply KVL

$$I = \frac{E - V_K}{R} = \frac{10V - 0.7V}{1k\Omega} = 9.3mA$$

# Half-Wave Rectification- Sinusoidal Input

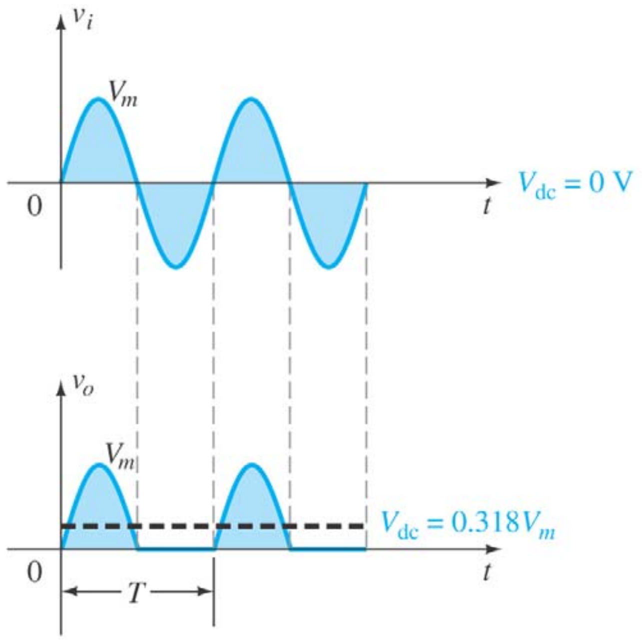



Sinusoidal input




Forward bias

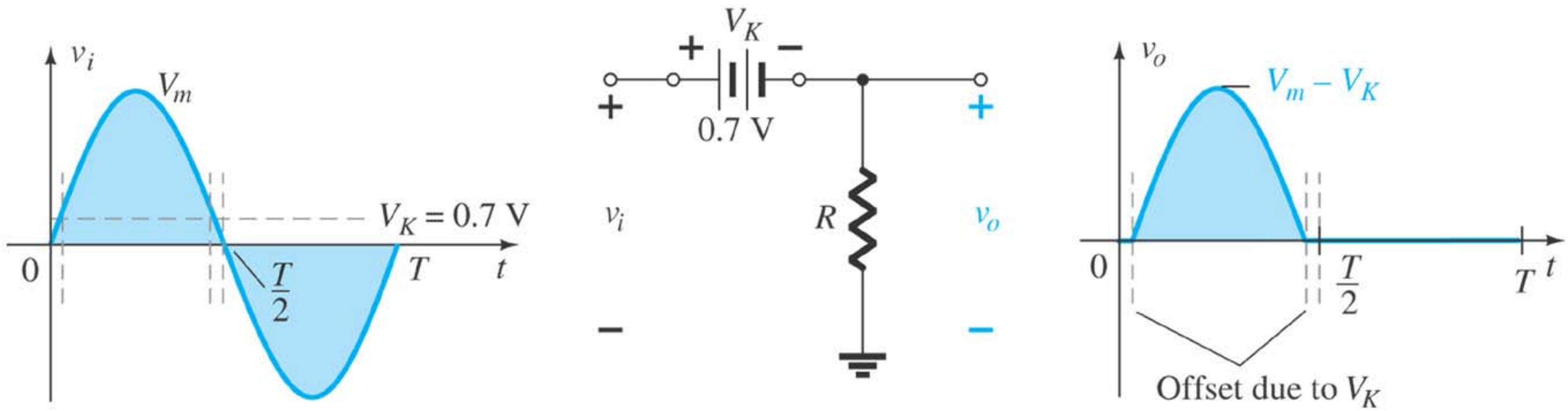
Reverse bias




For ideal rectifier the dc voltage (rms) = 0.318$V_m$ but the diode is conducted after the voltage supplied is more than 0.7V as shown below so the dc voltage will be reduced. Thus $V_{dc}$ is

$$V_{dc} \cong 0.318(V_m) \quad \text{ideal}$$

$$V_{dc} \cong 0.318(V_m - V_K) \quad \text{practical}$$

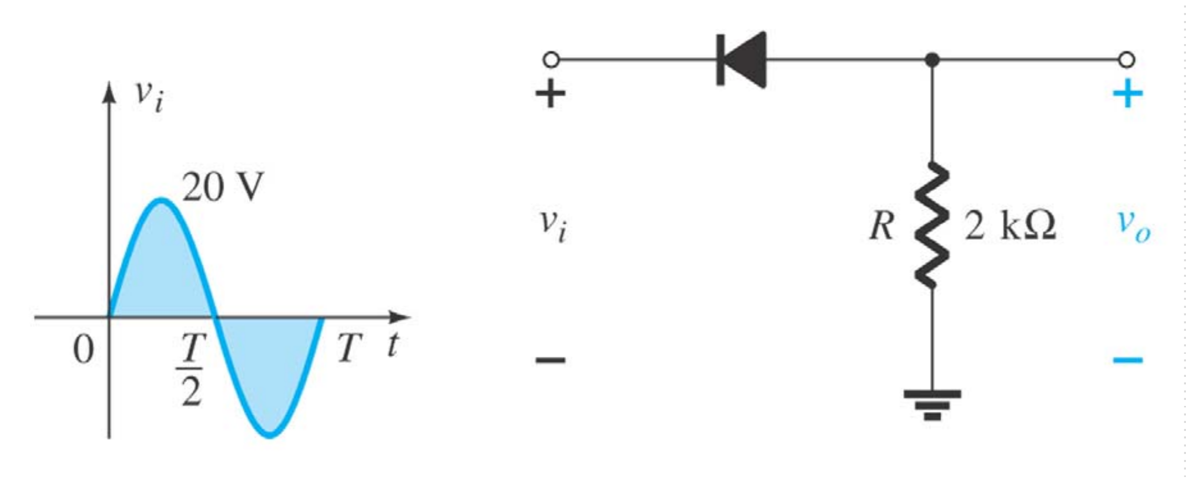


**Example; Circuit as below**

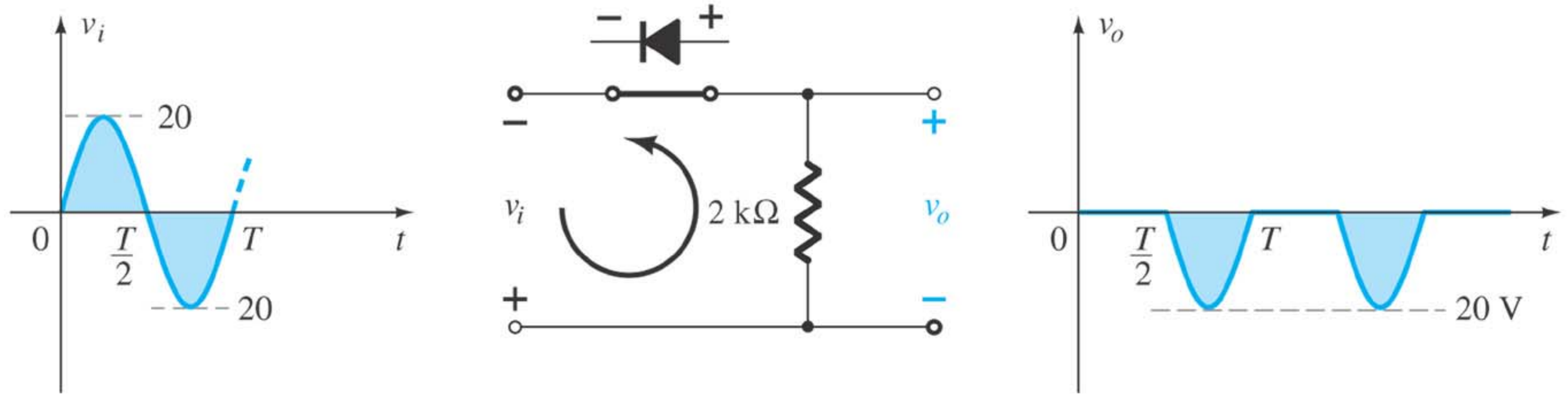
**a. Sketch the output $v_o$ and determine dc level of the output voltage for ideal diode**

**b. What is the practical diode**

**c. The Vm is increase to 200V**



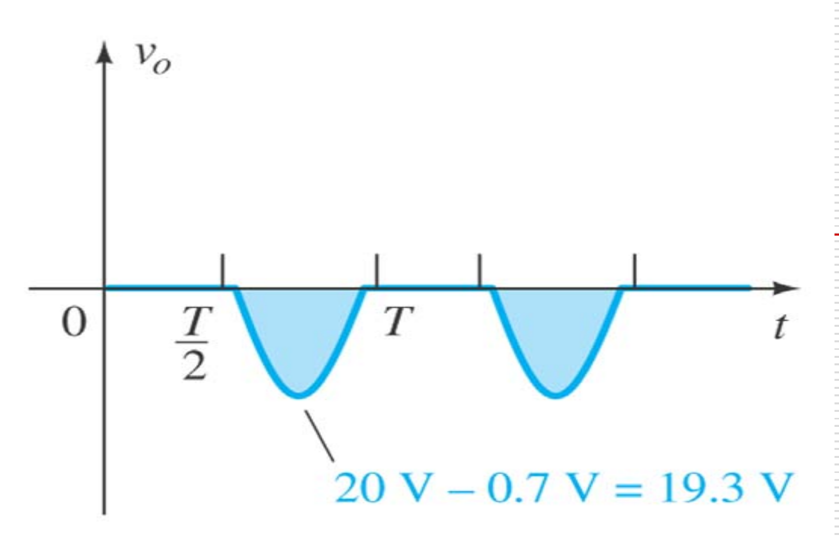
# Solution




Ideal diode circuit

$$V_{dc} \cong 0.318(V_m) = -0.318(20V) = -6.36V$$

(b)




$$V_{dc} \cong 0.318(V_m - V_K) = -0.318(20V - 0.7V) = -6.14V$$

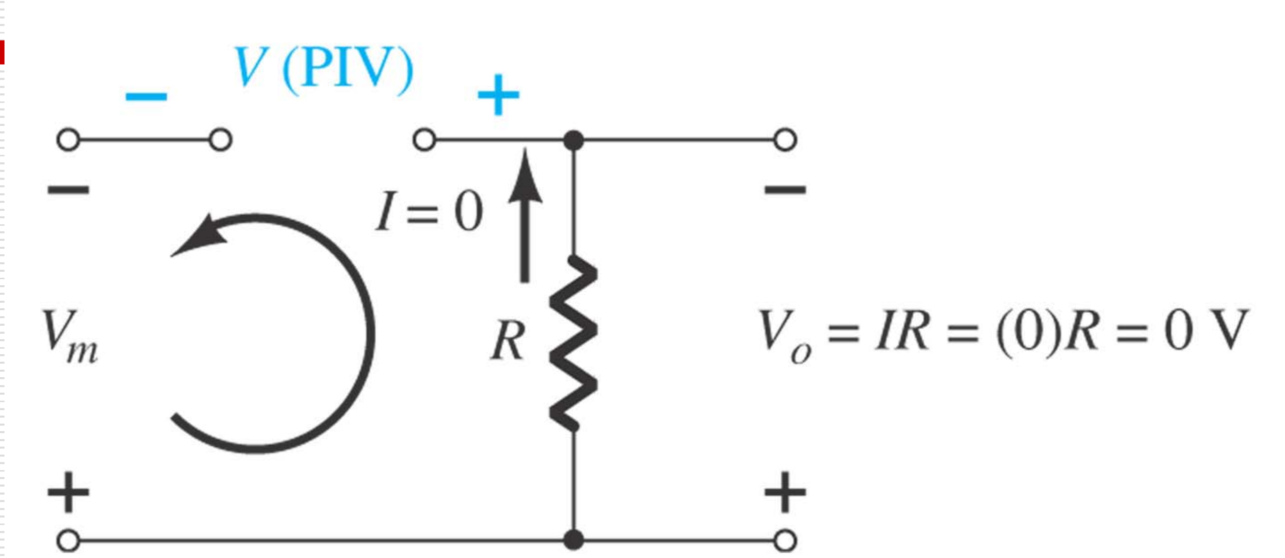
Drop about 0.22V or 3.5 %

(b) $$V_{dc} \cong 0.318(V_m) = -0.318(200V) = -63.6V$$ (ideal)

$$V_{dc} \cong 0.318(V_m - V_K) = -0.318(200V - 0.7) = -63.38V$$ (practical)

Drop about 0.22V or 0.35%

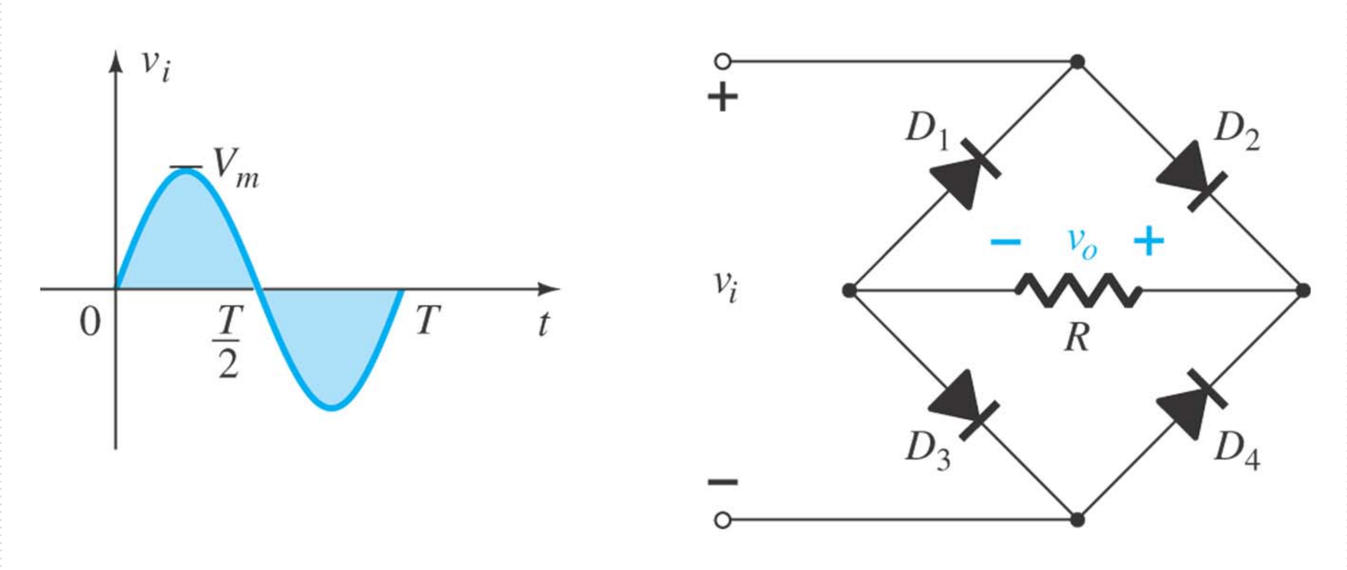
# Diode Rating




The diode rating is stated as peak inverse voltage (PIV) or peak reverse Voltage (PRV). PIV of diode must be greater than the applied voltage otherwise the diode will damage or enter the Zener avalanche region

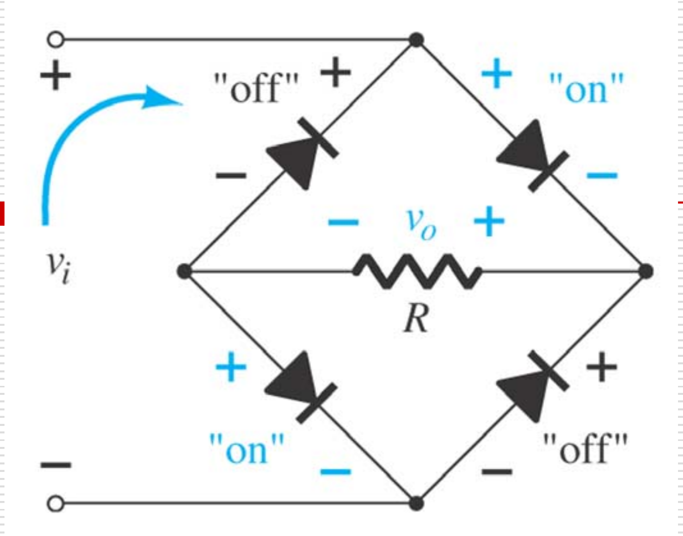
PIV(rating) $\geq V_m$ half –wave rectifier

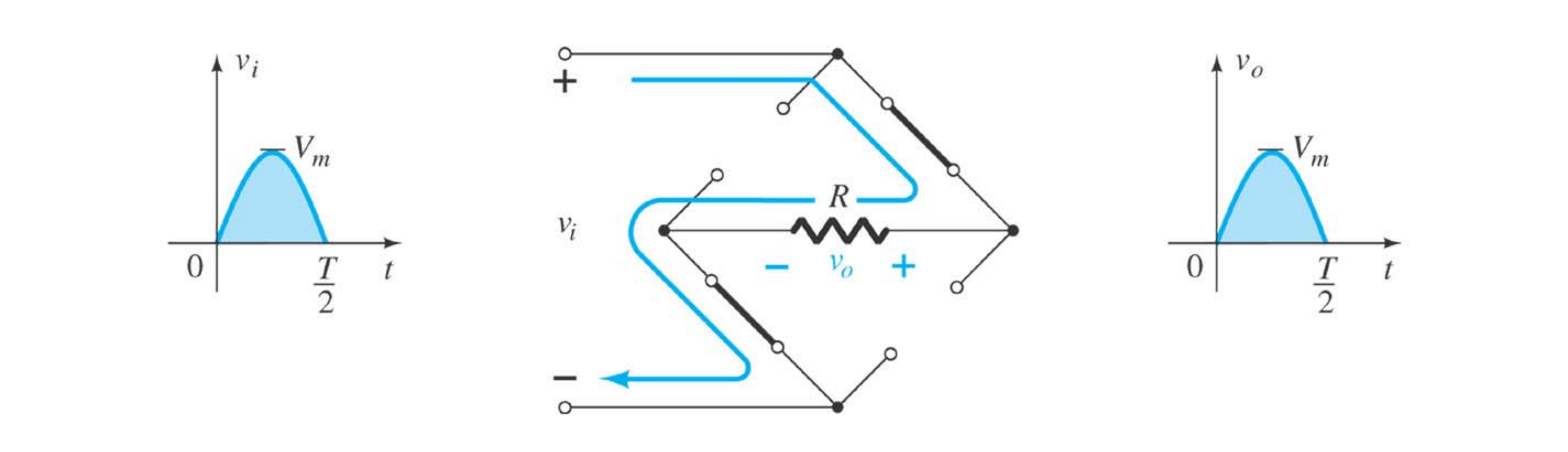
# Full-wave rectifier



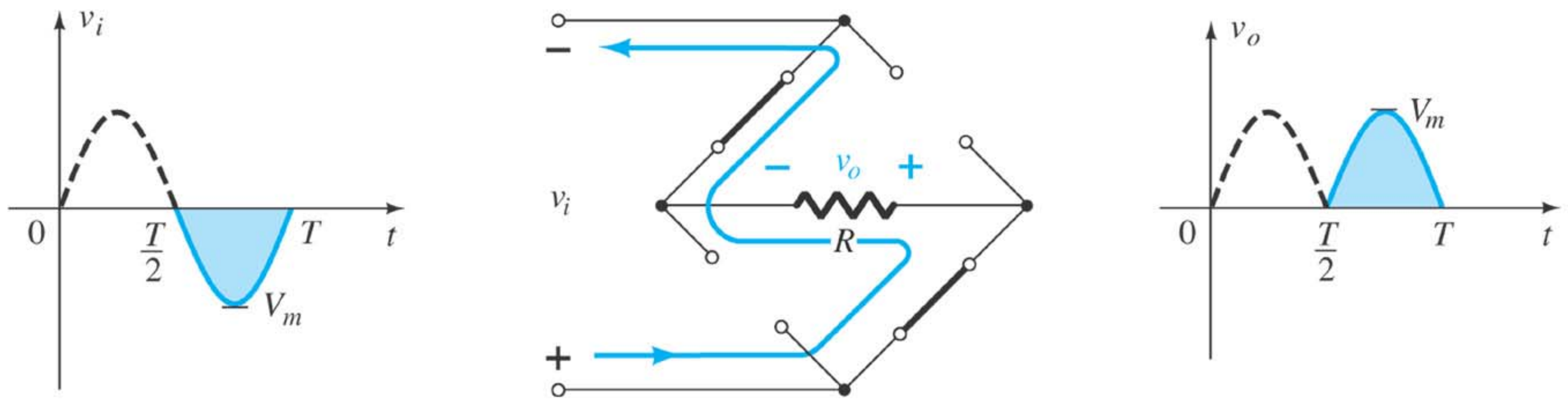

Using four diode in certain arrangement such that the circuit are able to rectifier another half of the sinusoidal wave.

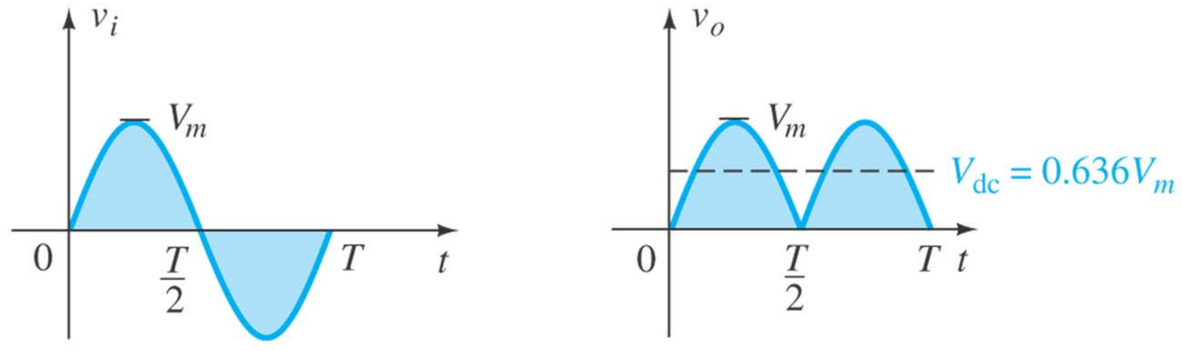
## First half



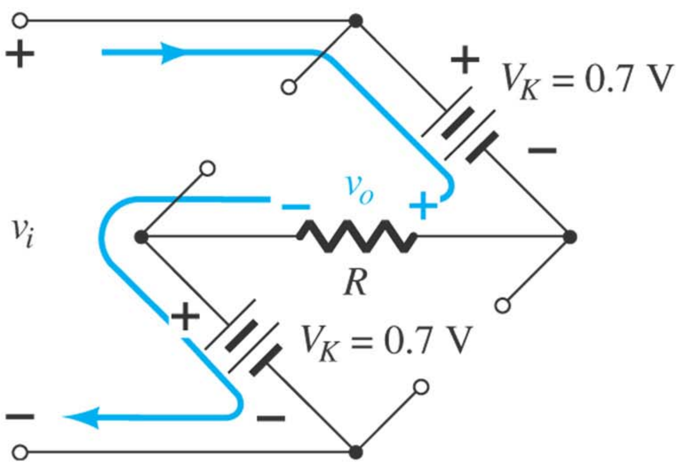
## Second half

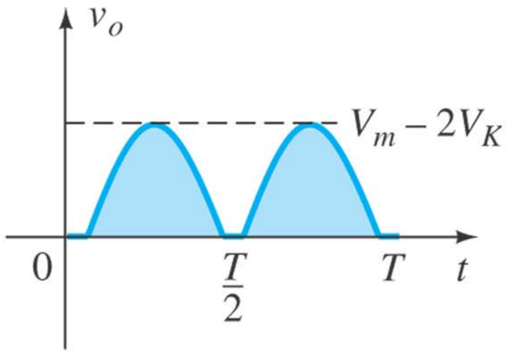





ideal

$$V_{dc} = 2(0.318V_m) = 0.636V_m$$

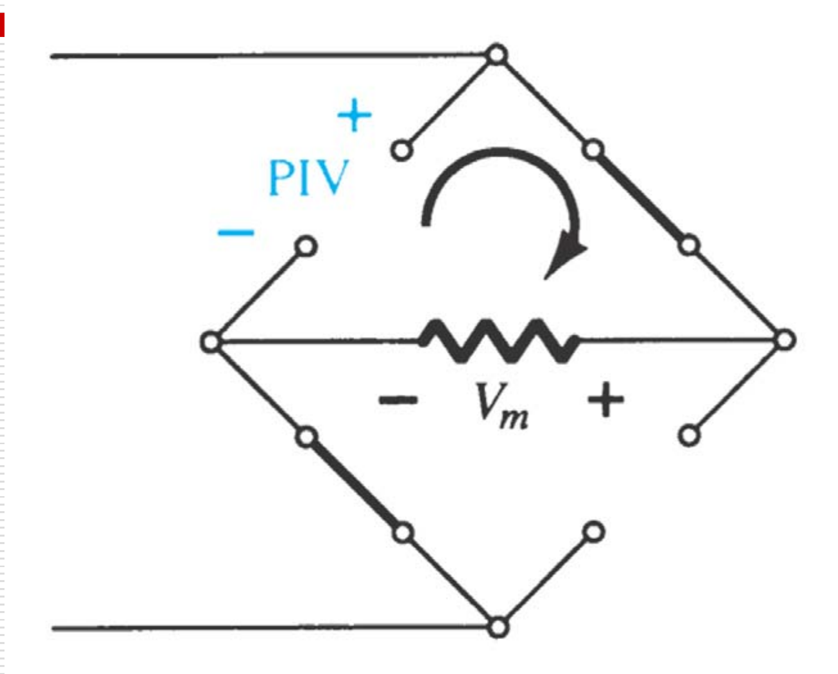



Practical diode

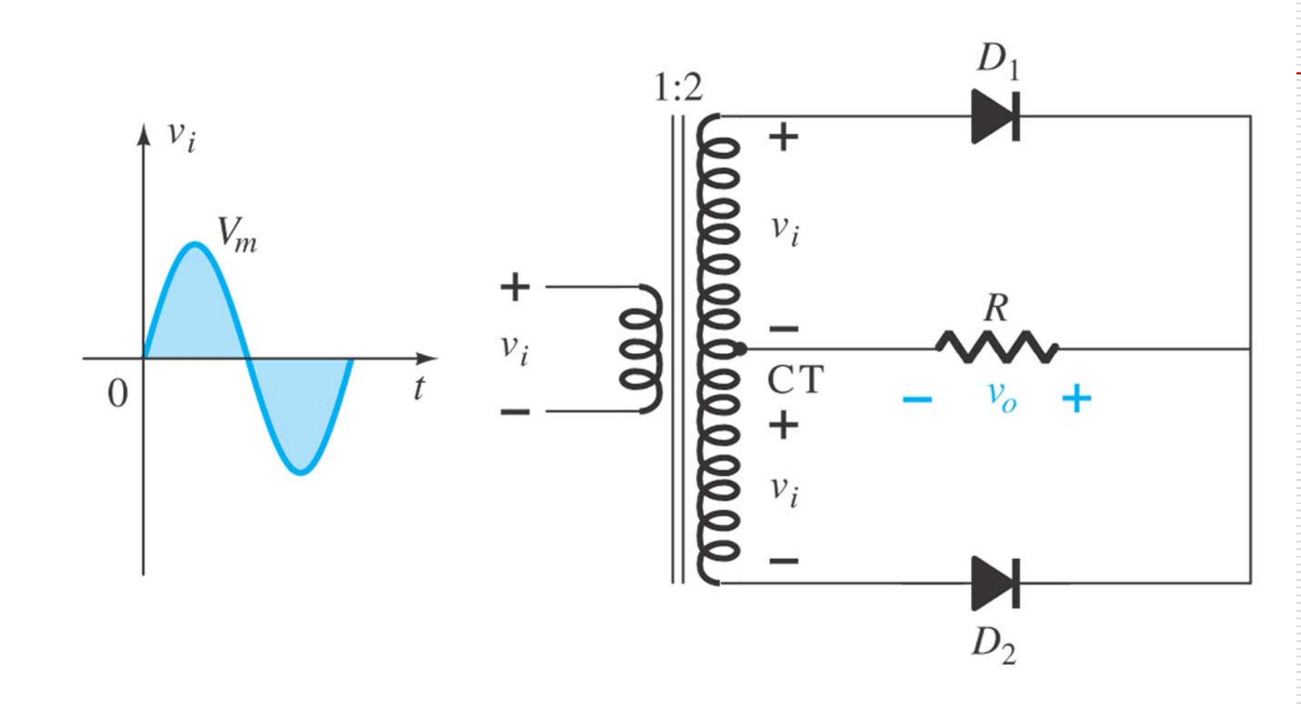
$$V_{dc} \cong 0.636(V_m - V_K)$$

# Diode Rating



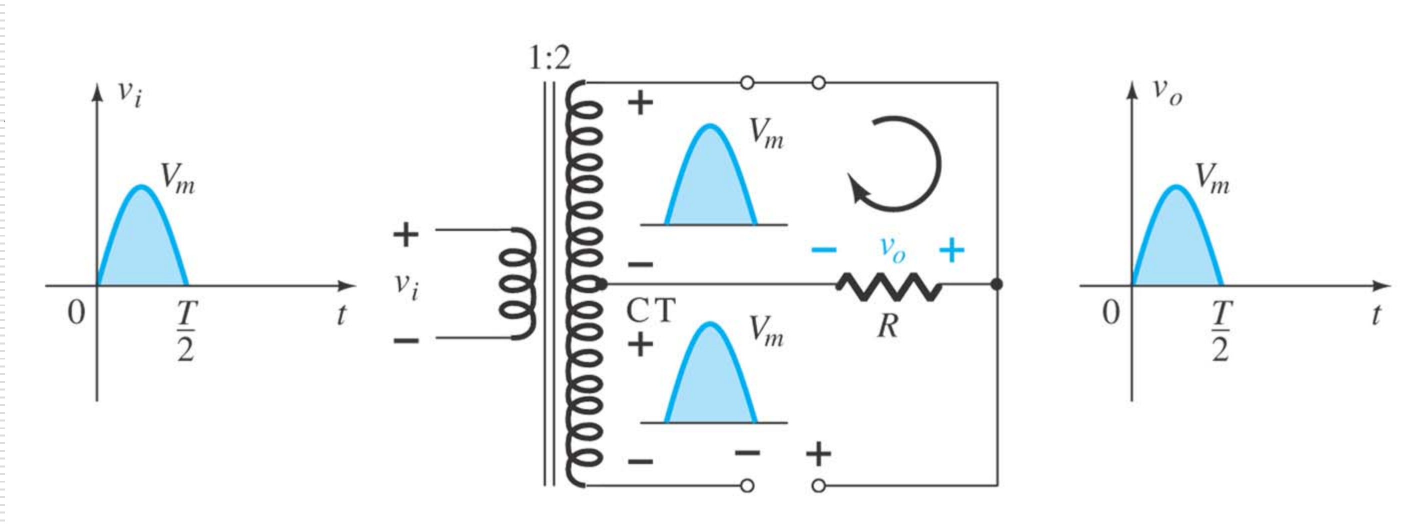

$PIV \geq V_m$

# Center-Tapped Transformer

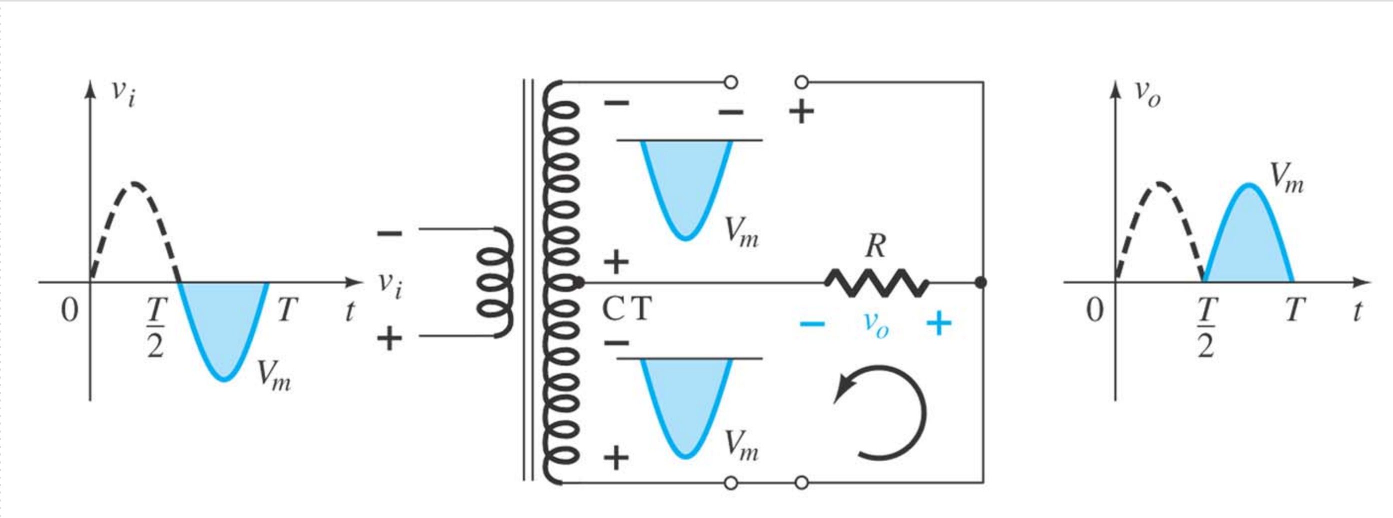



This is another way to get a full-wave rectification. However the PIV $\geq$ 2 $V_m$

# How this works.



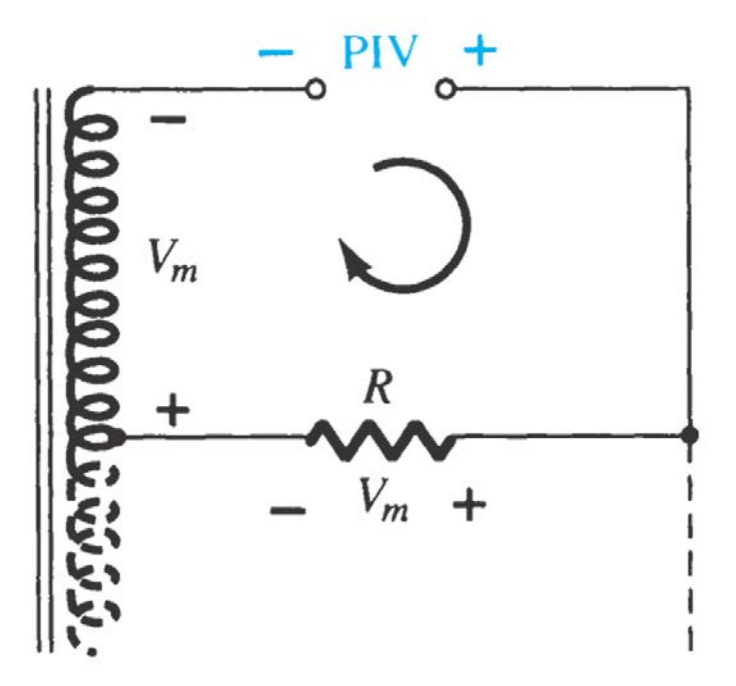

1st half




2nd half

**Robert L. Boylestad**
*Electronic Devices and Circuit Theory, 9e*

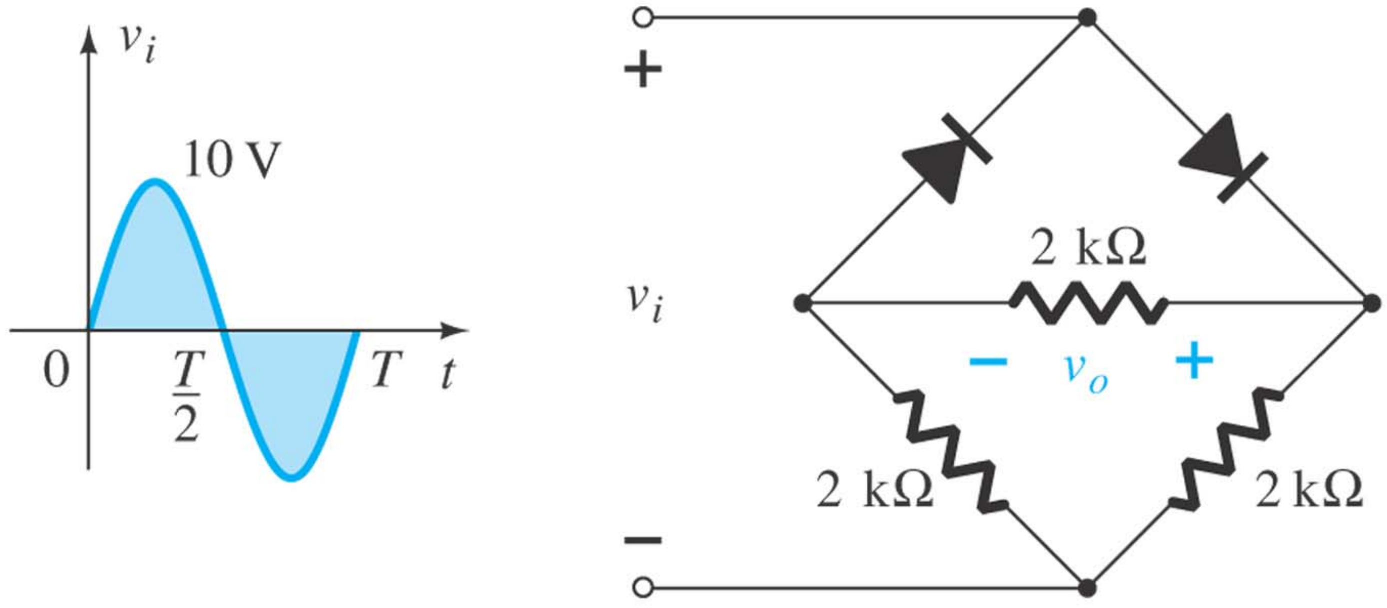
# PIV.



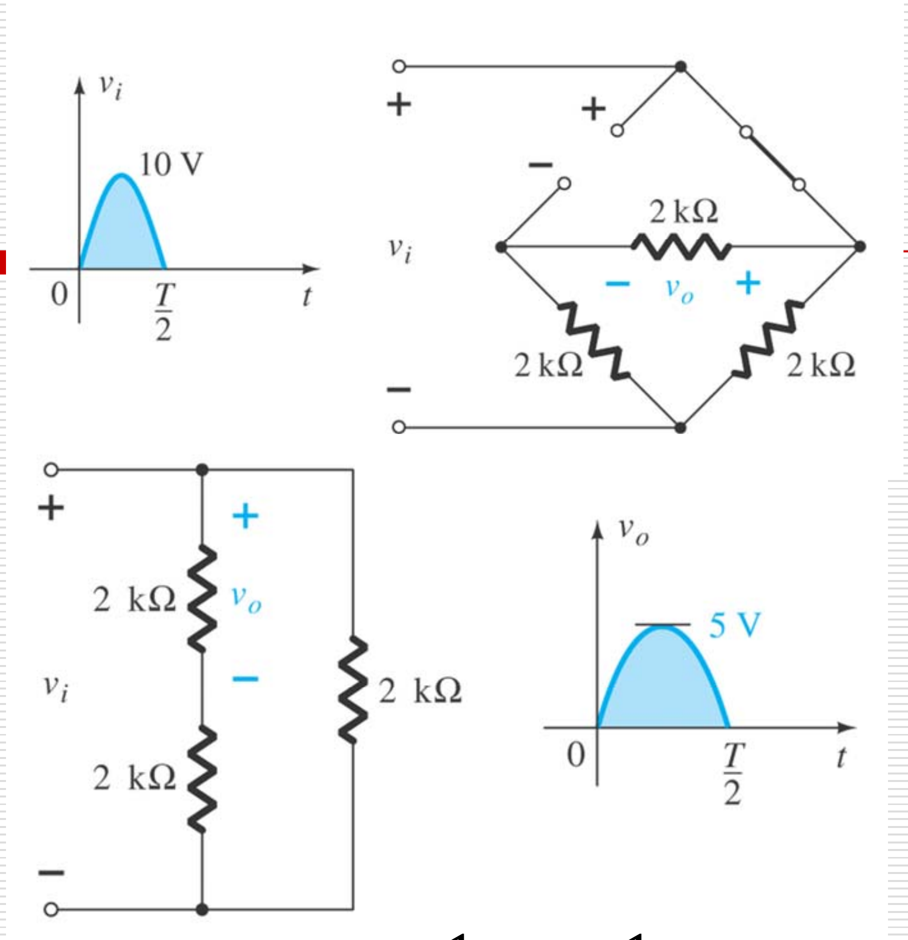

Apply KVL $PIV = V_{secondary} + V_R = V_m + V_m = 2V_m$

Therefore $PIV \geq 2V_m$

**Determine the output for the network below and calculate the output dc level and the required PIV of each diode.**



## Solution




Equivalent circuit

Redrawn network

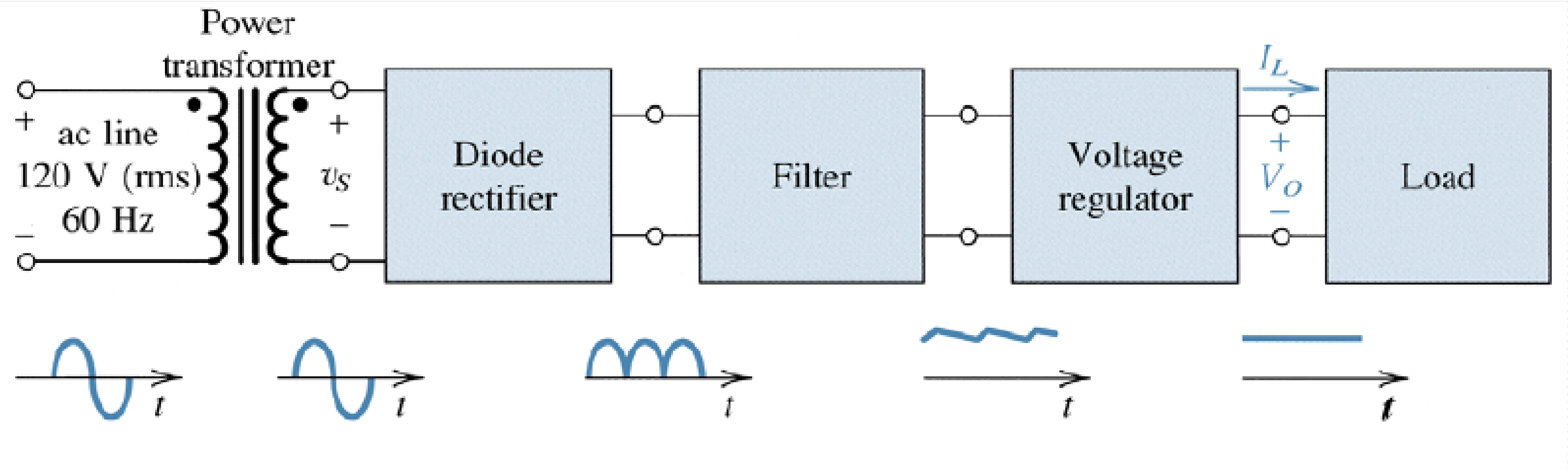
From the 2nd Fig $V_o = \frac{1}{2}V_i = \frac{1}{2}(10V) = 5V$

Therefore $V_{dc} = 0.636(V_o) = 0.6363(5V) = 3.18V$

$$PIV \geq \ V_m = 5V$$

# Rectifier Circuits

•One of the most important applications of diodes is in the design of rectifier circuits. Used to convert an AC signal into a DC voltage used by most electronics.

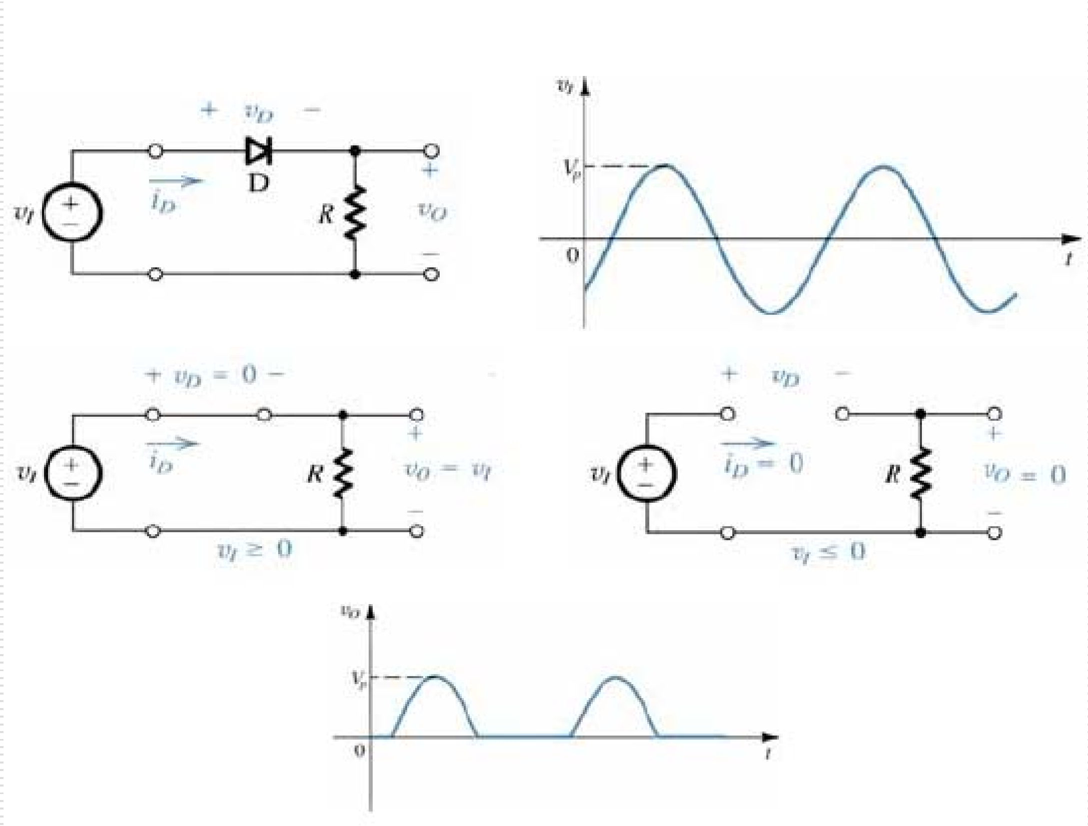


# Simple Half-Wave Rectifier

- Only lets through positive voltages and rejects negative voltages

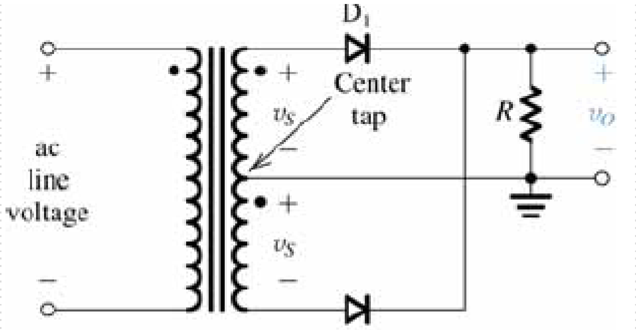
- This example assumes an ideal diode

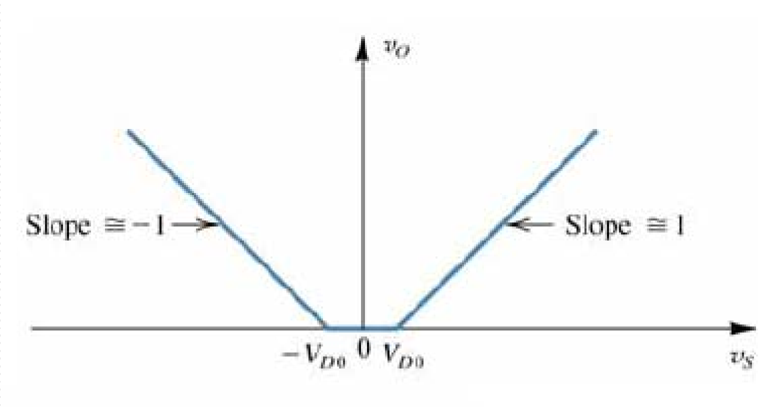
- What would the waveform look like if not an ideal diode?

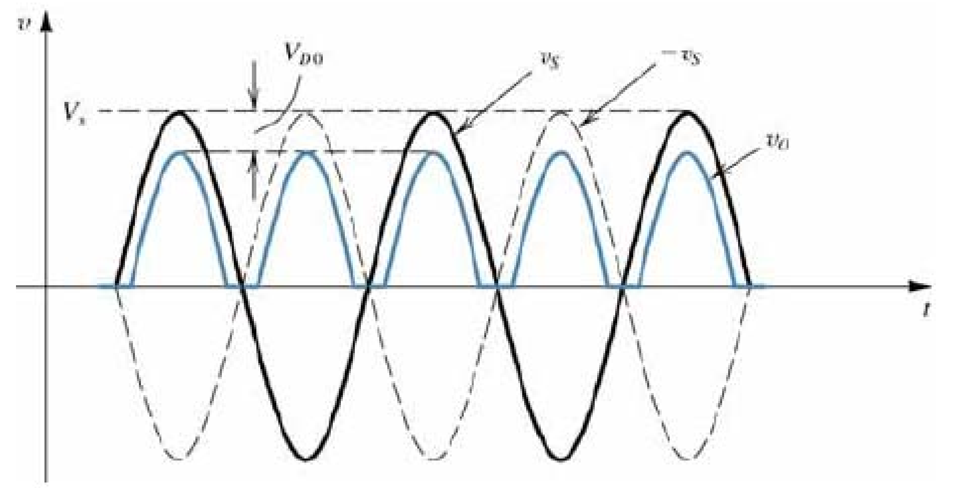


# Full-Wave Rectifier

• To utilize both halves of the input sinusoid use a center-tapped transformer…

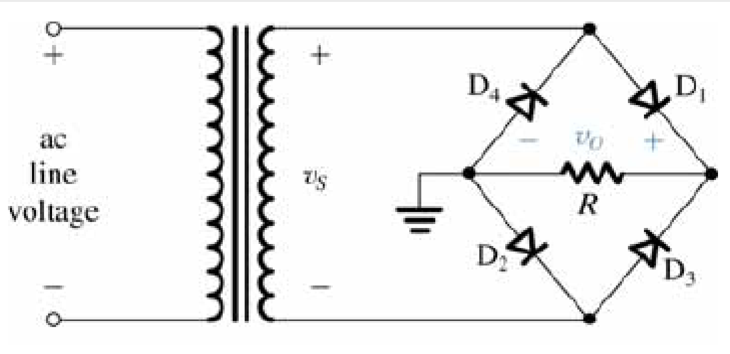


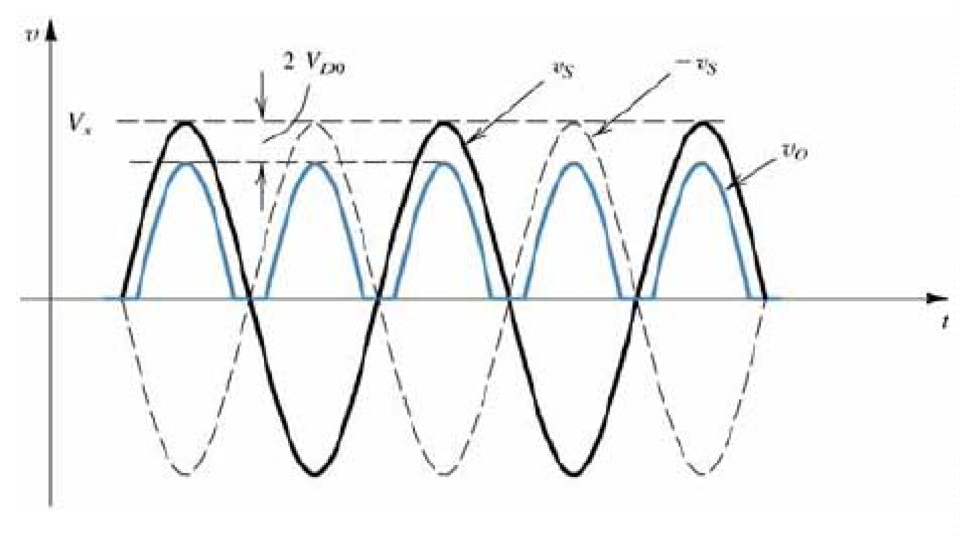



# Bridge Rectifier

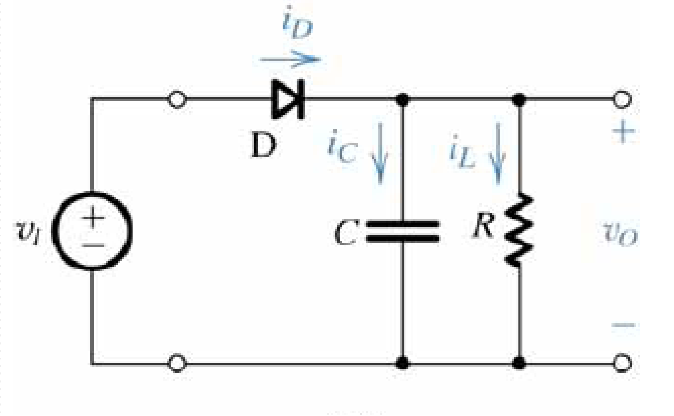
•Looks like a Wheatstone bridge. Does not require a center-tapped transformer.

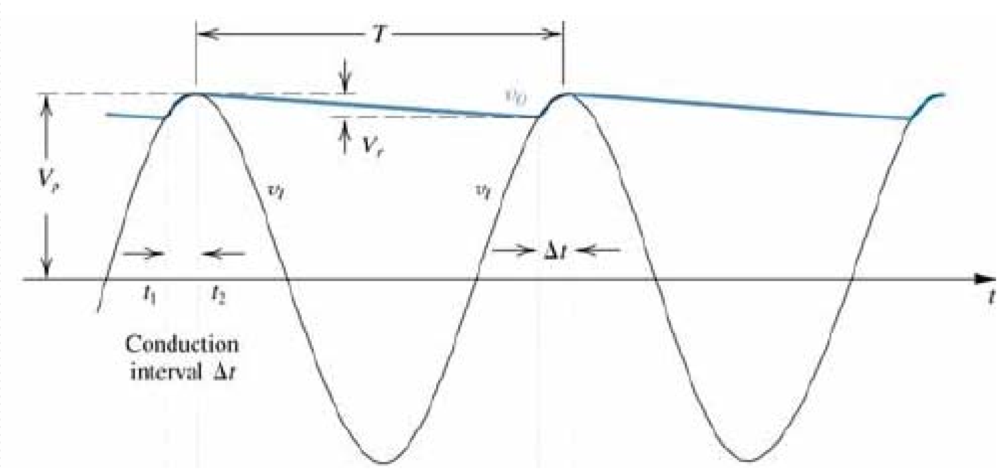


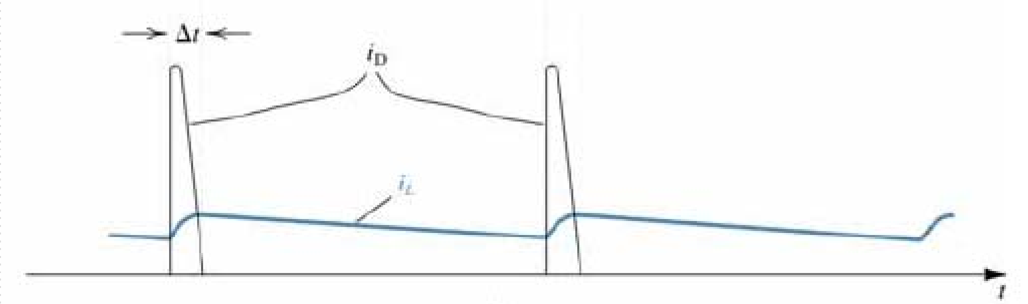




–Requires 2 additional diodes and voltage drop is double.

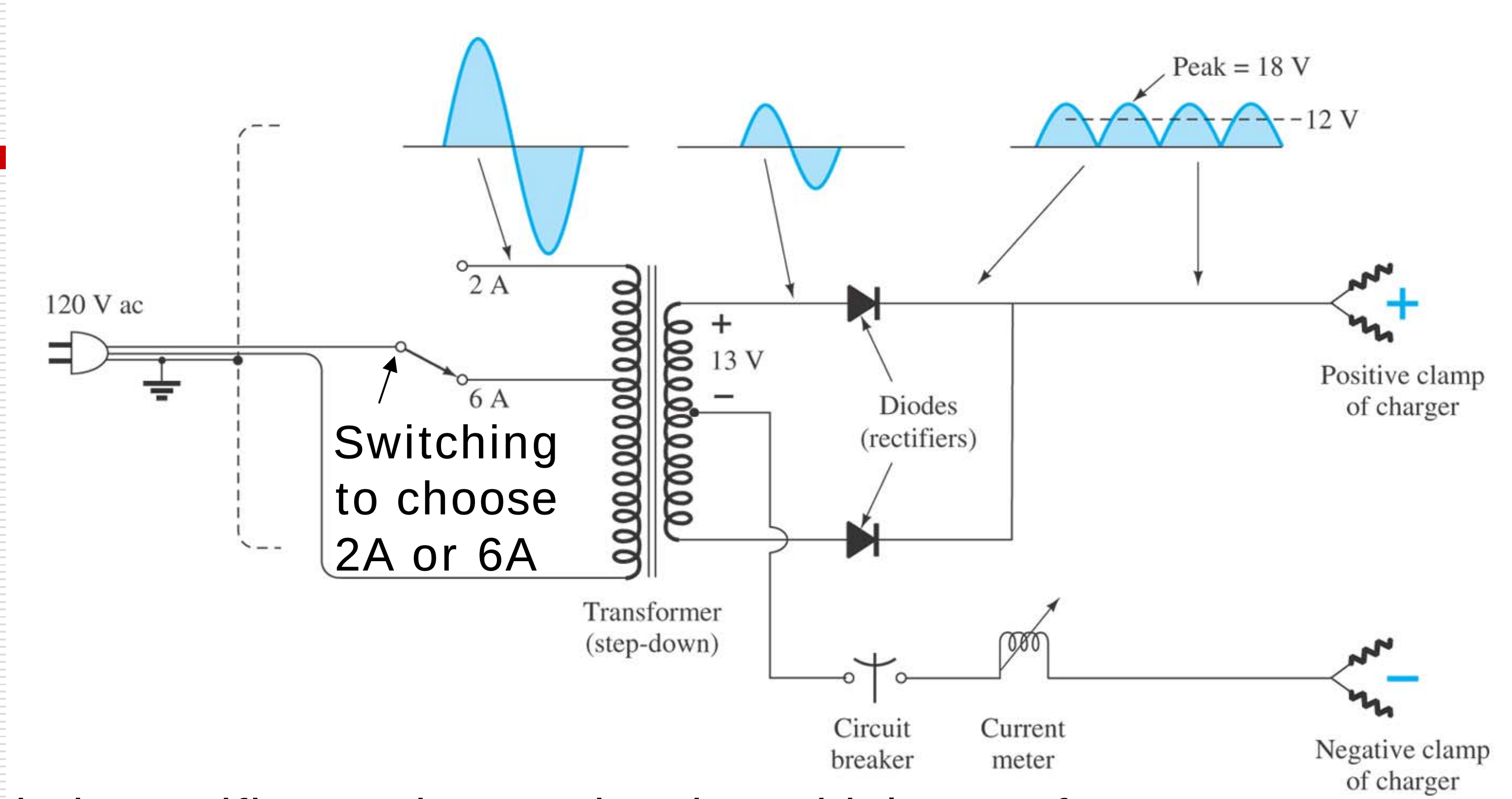
# Peak Rectifier (filtering)



# BATTERY CHARGER

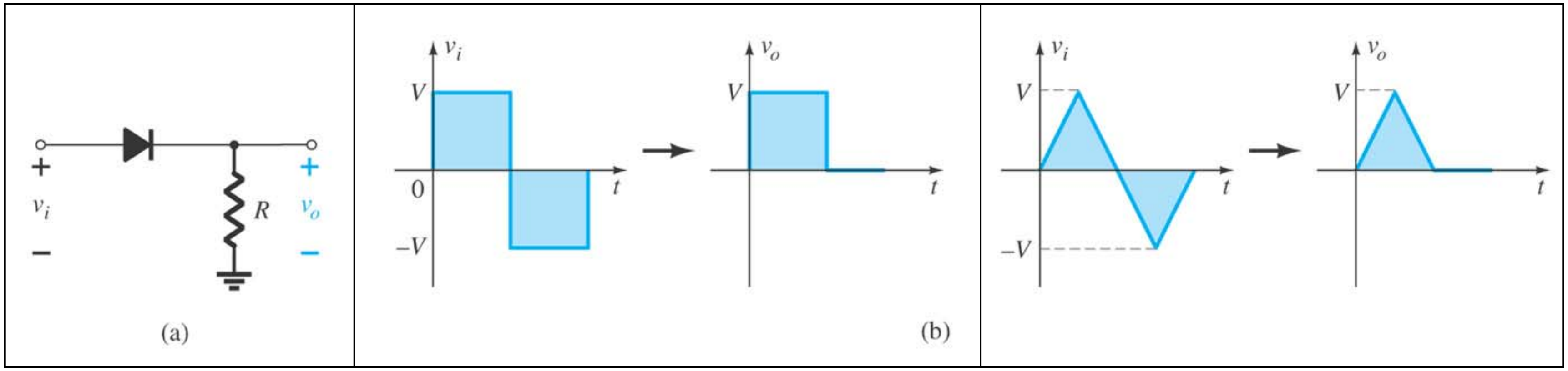



Diode rectifier to change the sinusoidal wave from transformer to develop the dc current. Some charger may have filtering and regulator to improve dc level. Transformer is to step down the main voltage to required one.

# CLIPPERS.

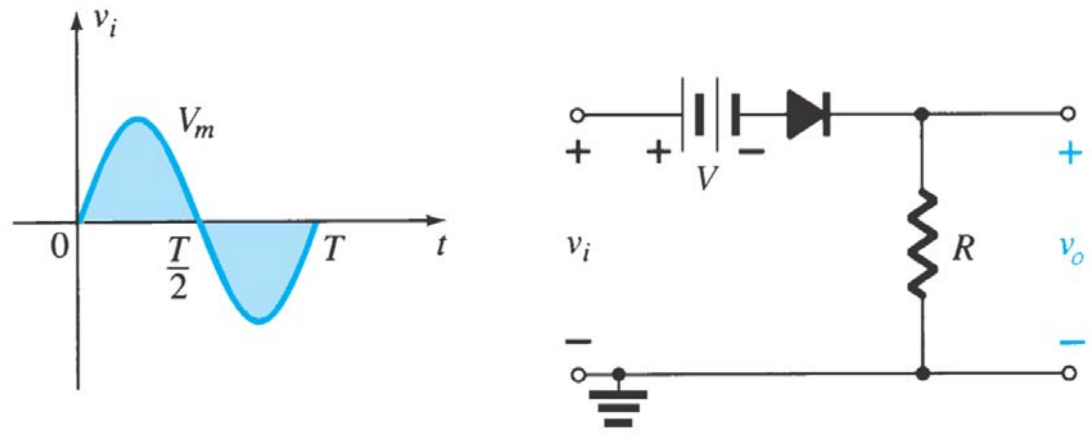
Clippers are networks that employ diodes to “clip” away a portion of an input signal without distorting the remaining part of the applied waveform. The simplest form of diode clipper is one resistor and a diode similar like half-wave rectifier. There are two categories: series and parallel

**Series clipper** (diode in series)

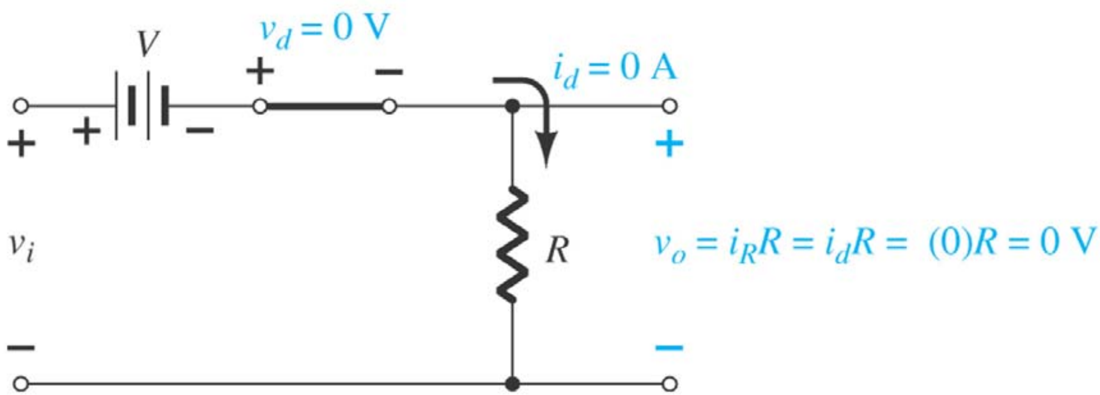



Circuit | Squared waveform | Triangular waveform

# CLIPPER WITH DC SUPPLY.




Circuit




Analysis

First where the output is?

In this case it is at R

Secondly see any dc supply that oppose the input signal. The system will be “off’ state until the input voltage is grater than the diode and the opposed voltage

$$V_m = V_{dc} + V_{diode}$$

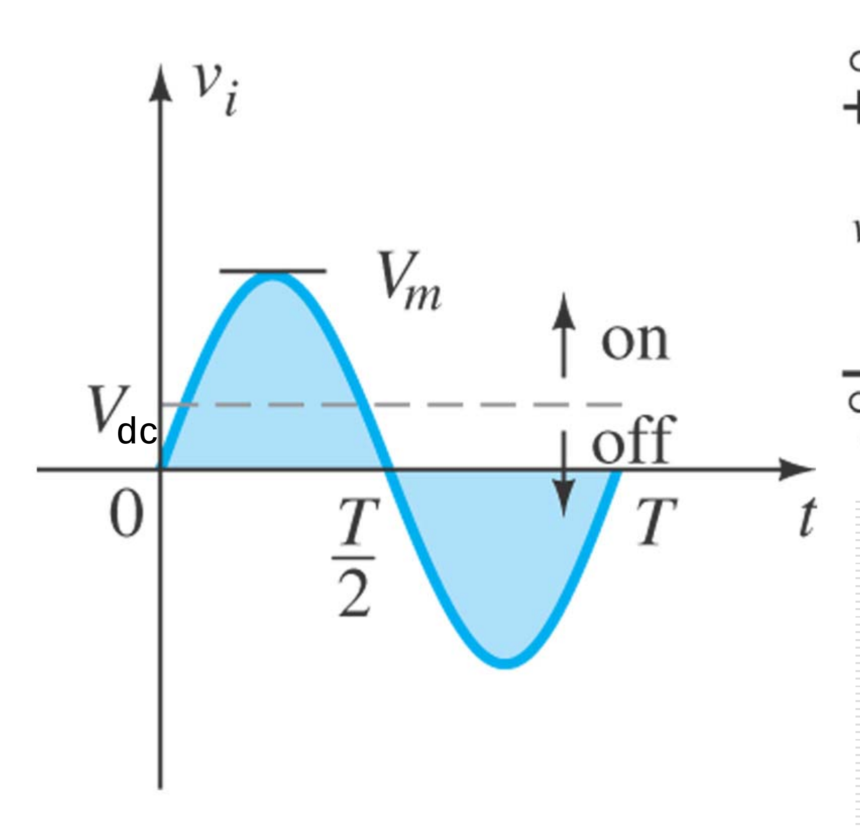
Output $V_o = V_m - V_{dc} - V_{diode}$

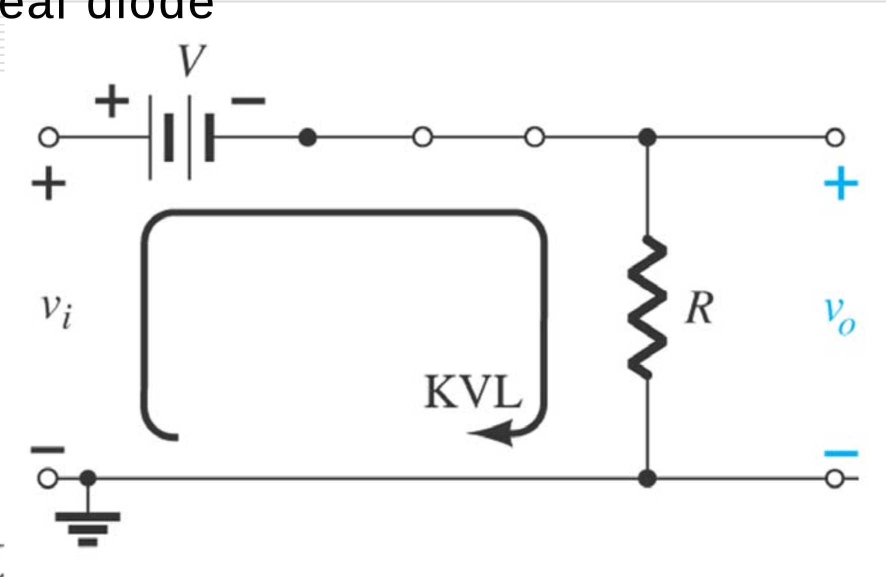
For ideal case $V_o = V_m - V_{dc}$

At transition state

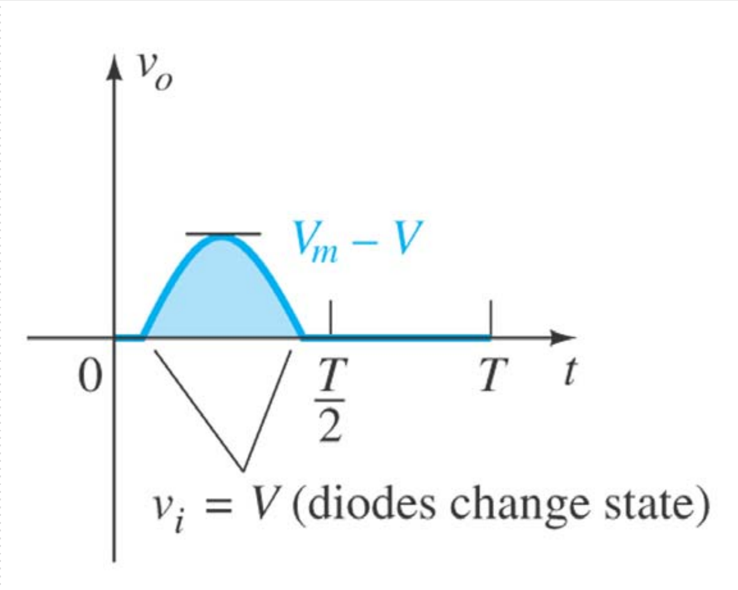
$$V_o = I_R R = (0)R = 0V$$

Analysis for ideal diode



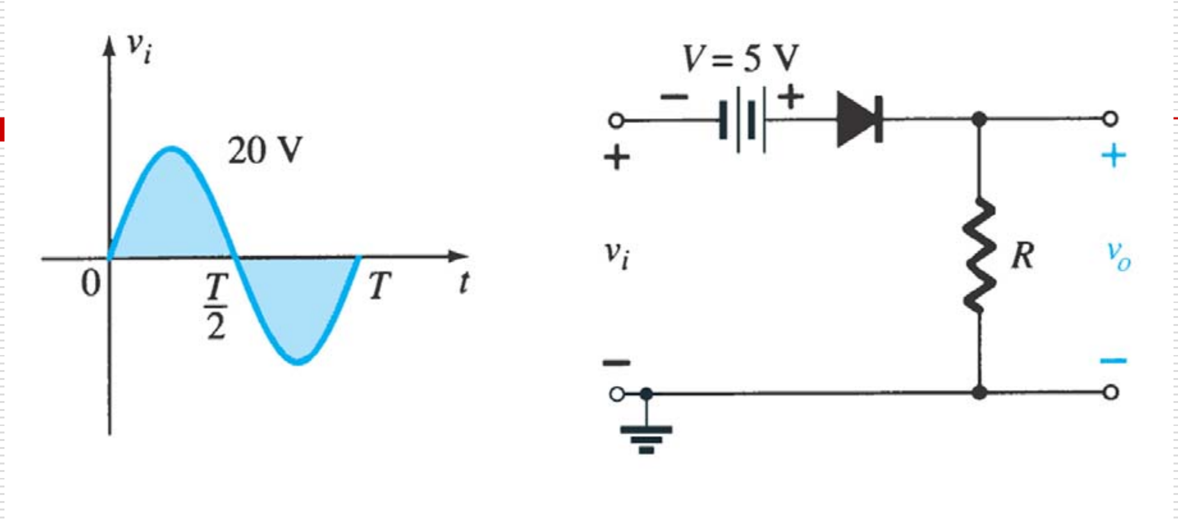



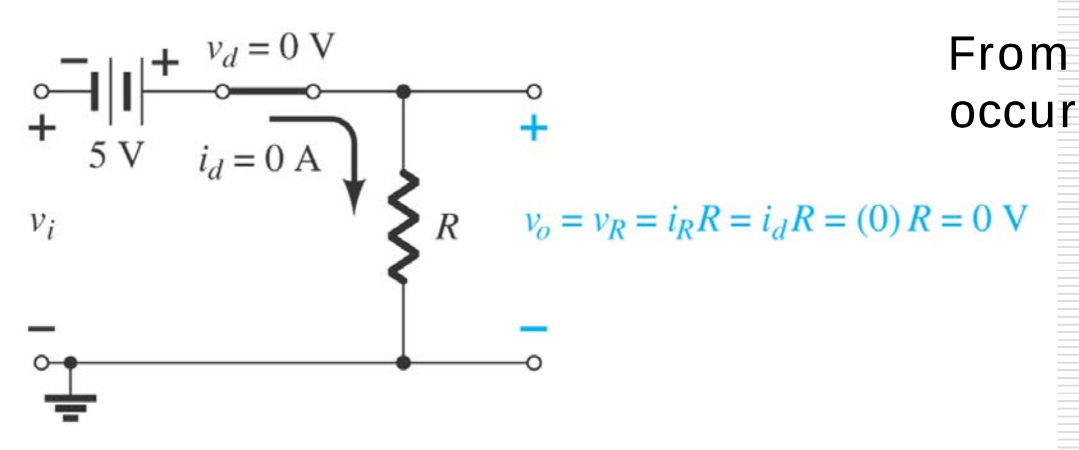

After conduction




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

## Determine the output waveform for the sinusoidal input

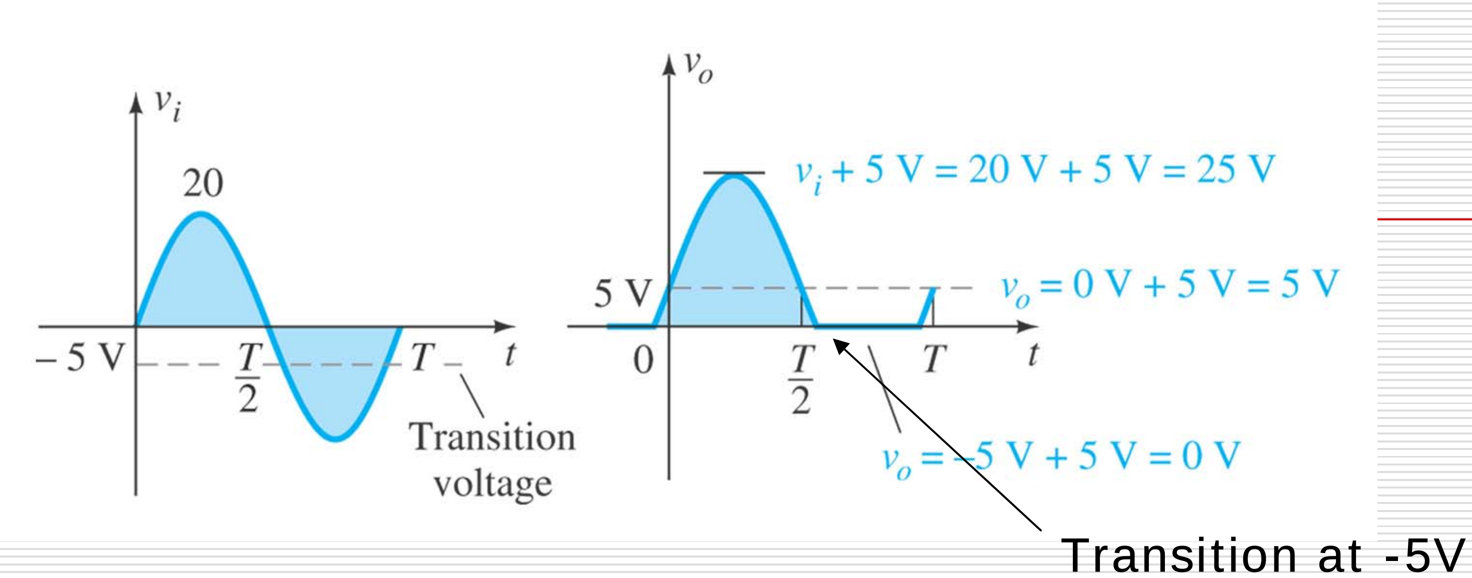



From Fig. transition state will occur at

$$V_i + 5V = 0V$$

$$V_i = -5V$$



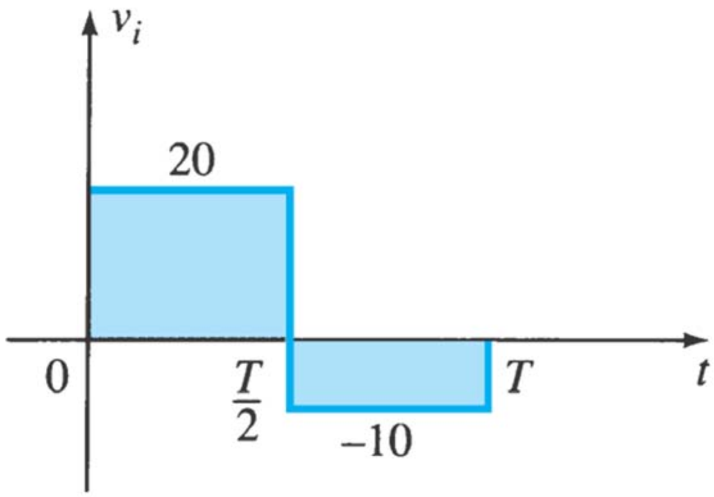

After transition using KVL, the peak is

$$V_o = V_m + 5V$$

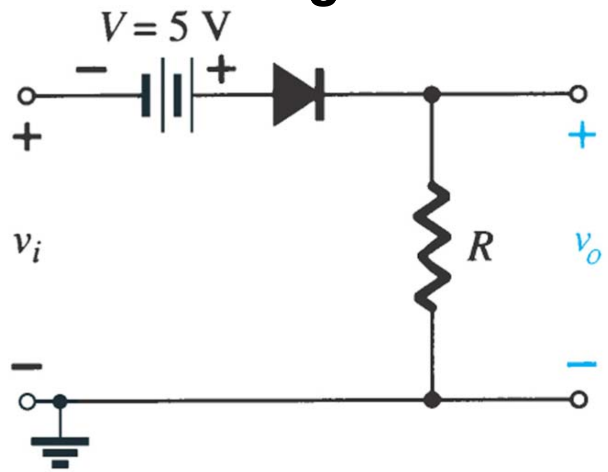
$$V_o = 20V + 5V = 25V$$

The waveform is seen to be off-set by 5V

## Determine the output waveform for the square wave input as shown in the Fig.



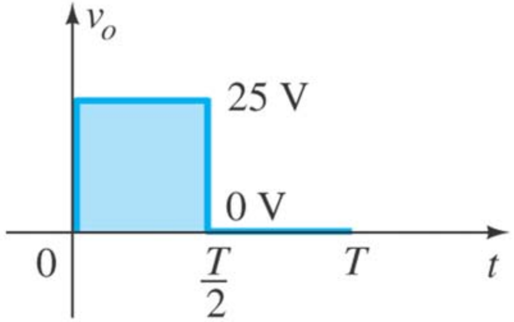

input




circuit

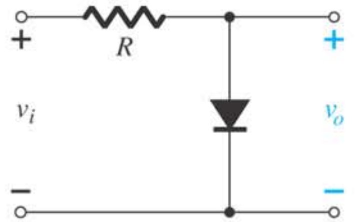
For 0 → T/2 $$V_o = 20V + 5V = 25V$$

For T/2 → T $$V_o = 0V$$

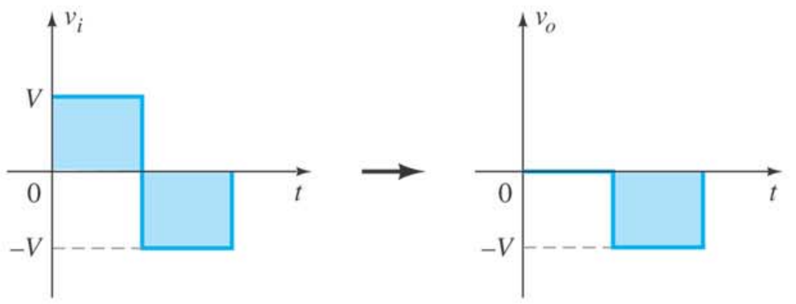


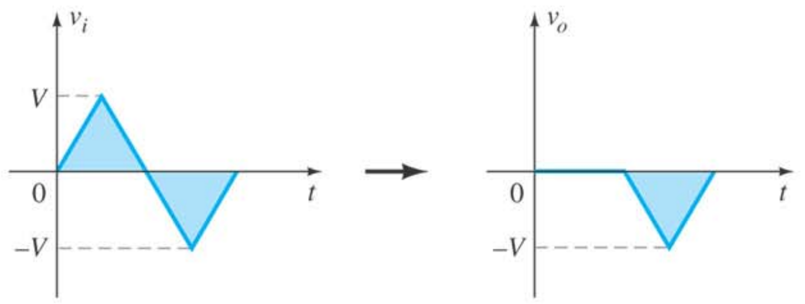

output

# Parallel Clipper




Circuit



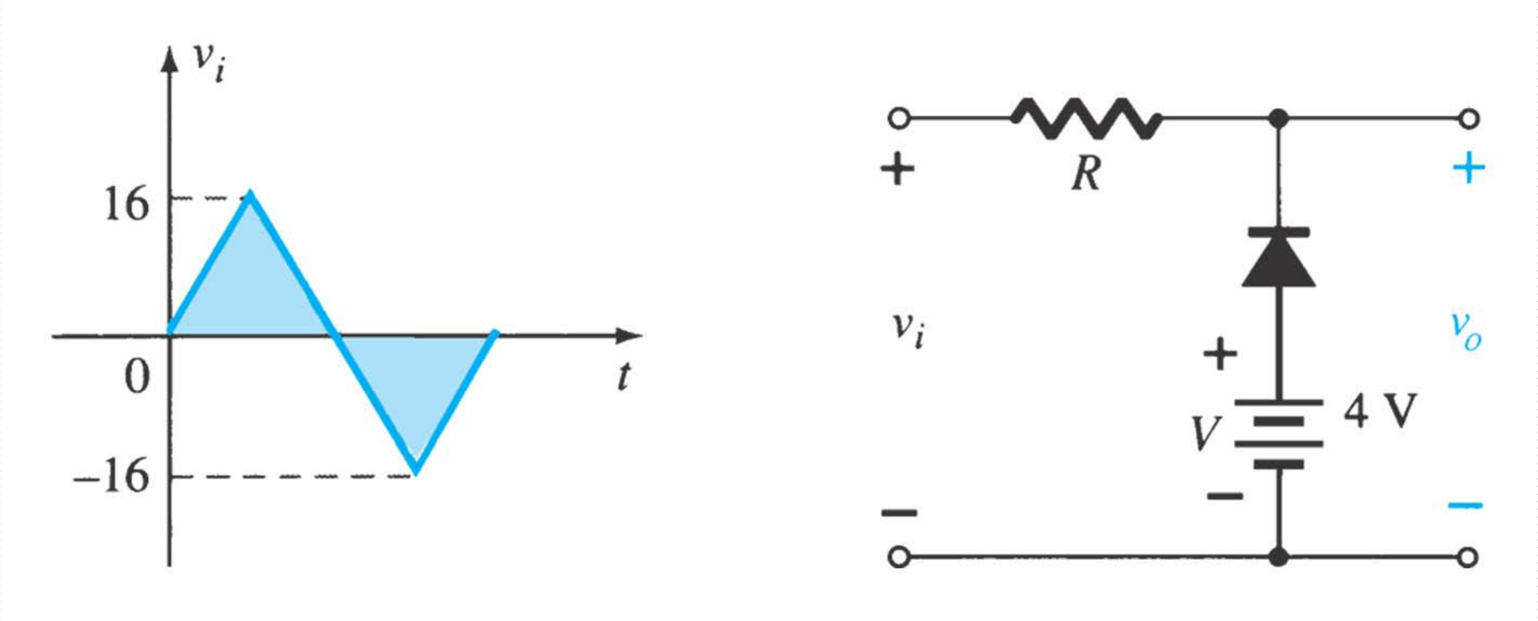



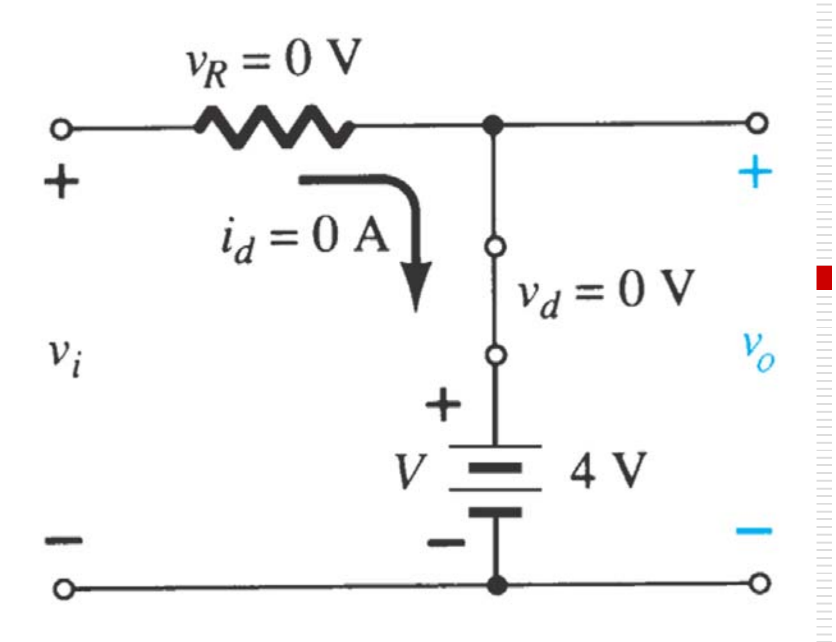

Square wave input

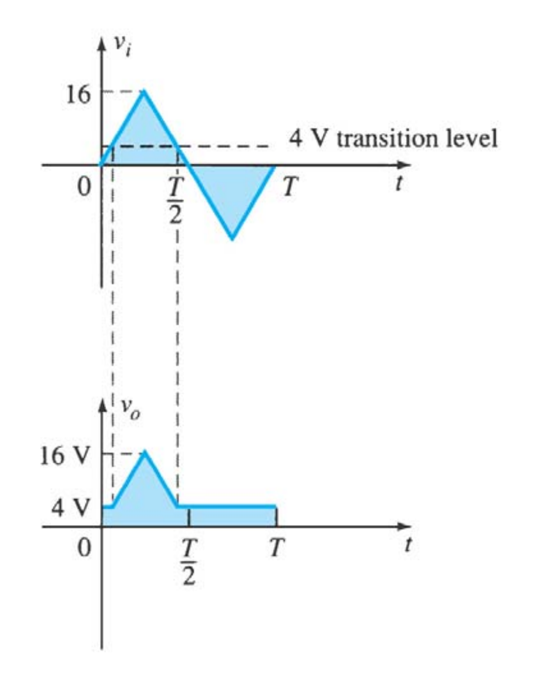
Triangular wave input

*Here, the diode is shunted in the circuit

Determine Vo for the following network





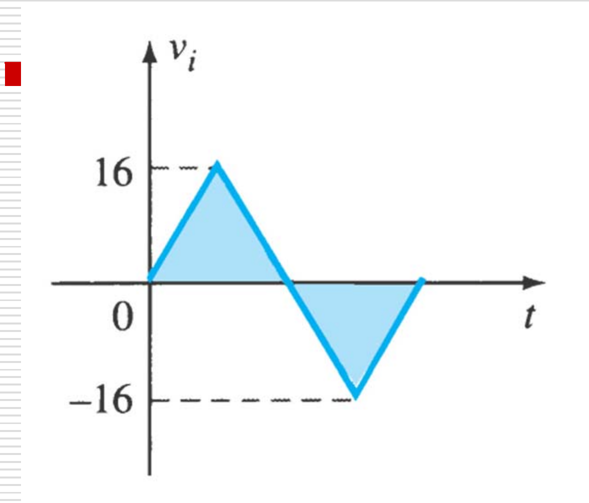



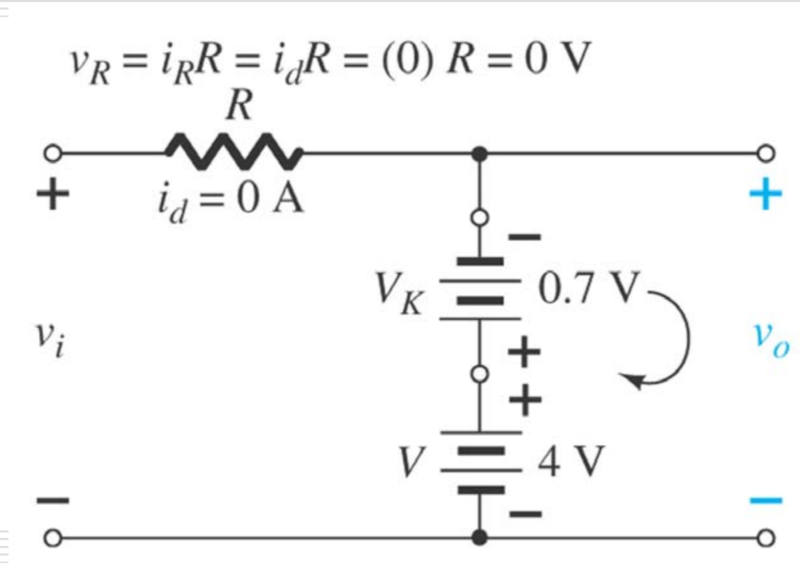

The transition level will be at $V_i = 0$ since $i_d=0$

When $V_i$ more than V=4 V , $V_o$ will follow $V_i$

When $V_i$ less than V=4V , $V_o$ will stay at V=4V

If the diode has $V_K$=0.7V, find $V_o$.

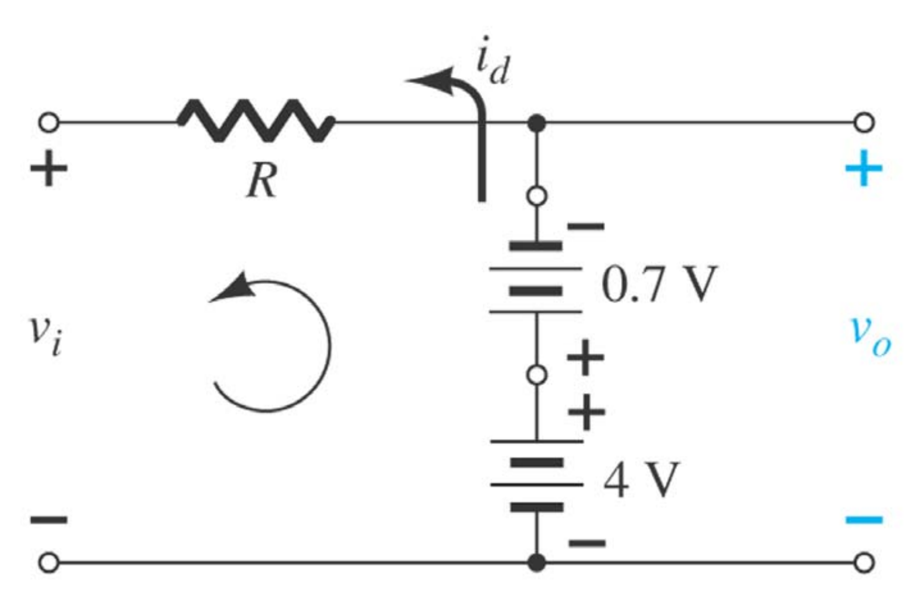


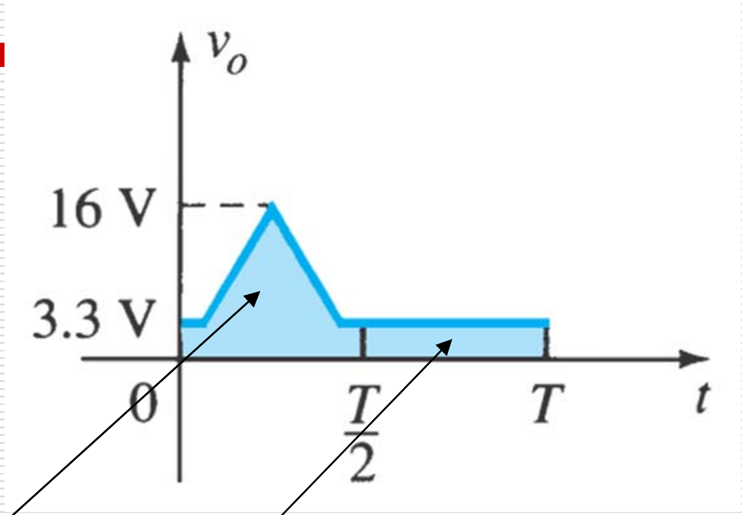




Applying KVL at transition will be

$$V_i + V_K - V = 0V$$

$$V_i = V - V_K = 4V - 0.7V = 3.3V$$

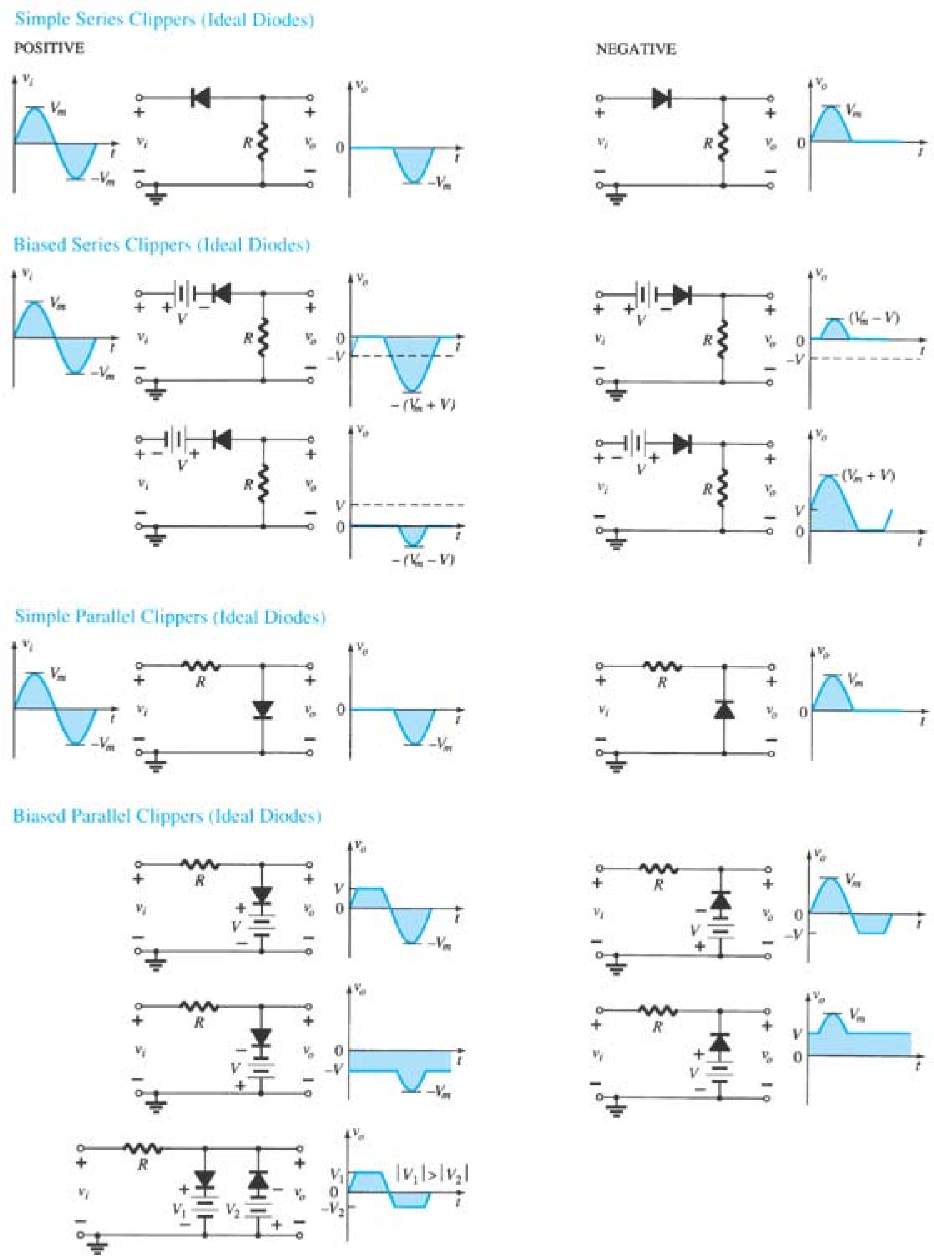



When $V_i$ > 3.3V then $V_o$=$V_i$

When Vi< 3.3V then

$$V_o = 4V - 0.7V = 3.3V$$


Simple Series Clippers (Ideal Diodes)
POSITIVE
NEGATIVE
Biased Series Clippers (Ideal Diodes)
−(Vm + V)
−(Vm − V)
(Vm − V)
(Vm + V)
Simple Parallel Clippers (Ideal Diodes)
Biased Parallel Clippers (Ideal Diodes)
|V1| > |V2|