ELECTRONIC PRINCIPLES AND DEVICES (4-0-0-4-4) (UE25EC141A)

Department of Electronics and Communication Engineering

ELECTRONIC PRINCIPLES AND DEVICES

Course Content

Department of Electronics and Communication.

Course Content

Unit 1: Semiconductor DIODE

Unit 2: Diode applications

Unit 3: Transistors and Operational Amplifiers

Unit 4: Digital Electronics

- Semiconductor diode under Forward and Reverse bias
- Shockley's equation
- Zener and Avalanche breakdown
- Temperature effects
- Ideal versus Practical diode
- Diode resistances
- Diode equivalent circuits

- Series diode configurations
- Parallel and Series-Parallel configurations
- Logical operations using diode
- Diode Clippers and Clampers

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- Block diagram of regulated power supply
- Half-wave, Full-wave and bridge rectifier, Ripple factor and Peak inverse voltage derivations
- Shunt capacitor filter-working, output waveform and ripple factor equation.
- Zener diode characteristics
- Zener diode voltage regulator
- **Assignment (Write-up)**

- Transistors: Construction, operation
- Transistor configurations - Common base and common emitter configurations – input and output characteristics.
- Transistor amplifying action.
- Limits of operation, Operating point.
- Biasing circuits: Fixed bias, Emitter bias, Voltage divider bias
- Bias circuit design, Bias stabilization
- Single stage CE Amplifier.

- **Op-Amp:** Introduction, Op-Amp Basics
- Ideal voltage transfer curve
- Op-Amp parameters and its values for Op-Amp 741 – Input and output offset voltages, Input and output resistances, Gain-Bandwidth product (GBW), Slew Rate, Common Mode Rejection Ratio (CMRR) (Definitions and significance only), Ideal Op-amp
- Negative feedback.
- Practical Op-Amp circuits: Inverting Amplifier, Non-inverting Amplifier, Voltage follower, Summing Amplifier, Constant Gain Amplifier, Voltage Subtraction, Comparator.
- **Simulation Lab:** Banana Problem

- Number Systems – binary, decimal, and hexadecimal
- Binary Addition and Subtraction
- 2’s complement subtraction
- Boolean Algebra
- Logic gates
- Basic Theorem and Properties of Boolean Algebra
- Boolean Functions

- Canonical and Standard Form
- Other Logical Operations
- Combinational Logic Circuits: Half Adder and Full adder
- Sequential Circuits: Flip-Flops-RS, D, T, JK
- Registers: SISO
- Counters: 3-Bit Asynchronous counter
- **Simulation/Hardware Lab:** Orange Problem

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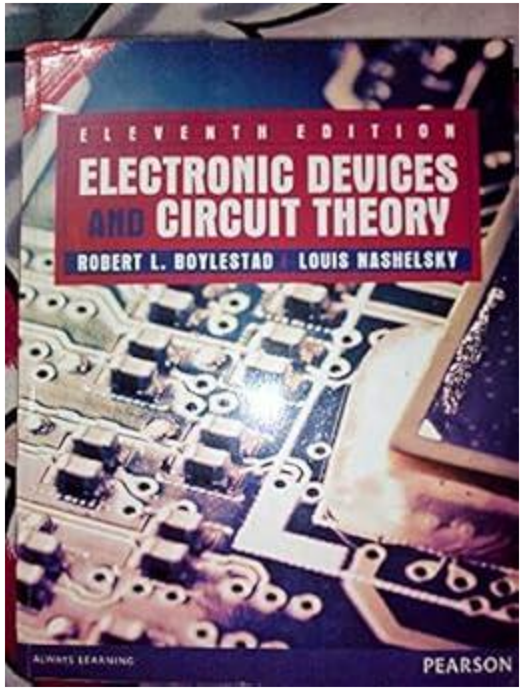
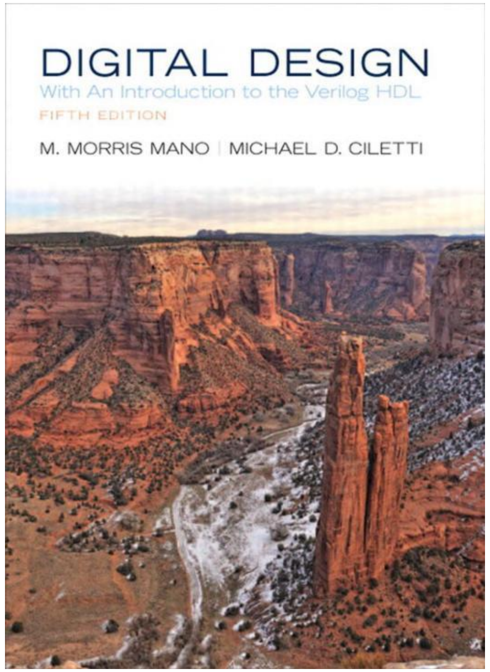
- Text book for UNIT 1, 2 and 3

https://kolegite.com/EE_library/books_and_lectures/%D0%95%D0%BB%D0%B5%D0%BA%D1%82%D1%80%D0%BE%D0%BD%D0%B8%D0%BA%D0%B0/Electronic%20Devices%20and%20Circuit%20Theory%20-%2011th%20Edition.pdf



- Text book for UNIT 4

https://archive.org/details/digital-design-5th-edition-m-morris-mano-and-michael-d-ciletti



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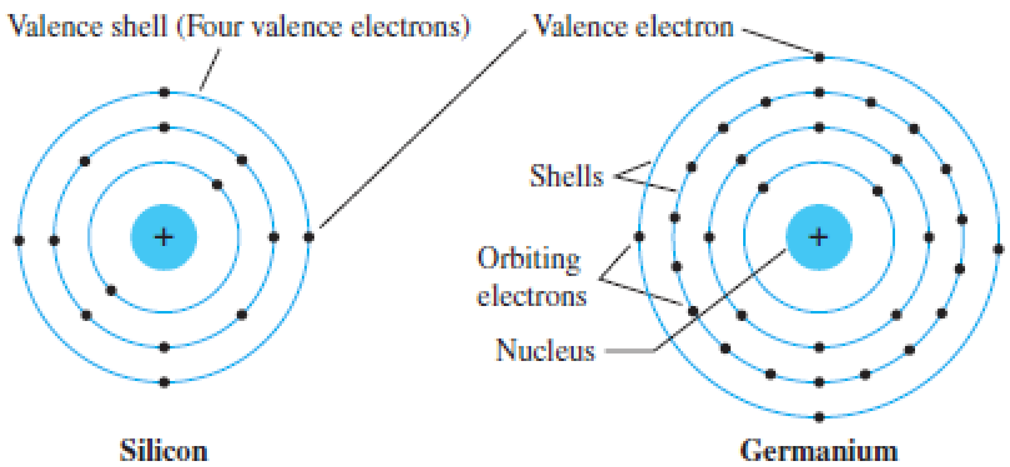
Unit 1 - Semiconductor Diodes

An Introduction to Semiconductor



Atomic number of silicon=14

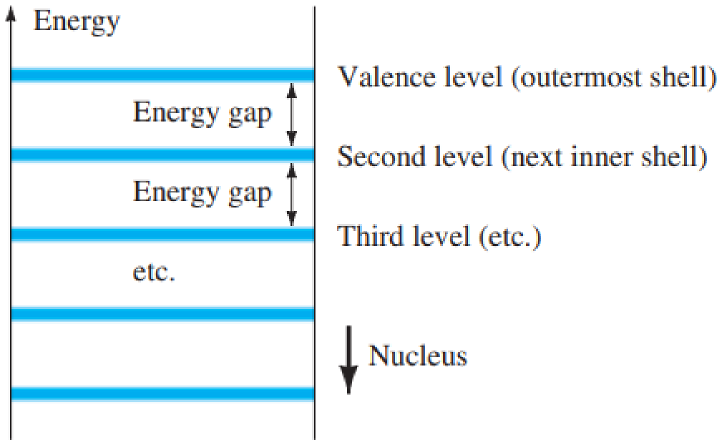
$1s^2 2s^2 2p^6 3s^2 3p^2$

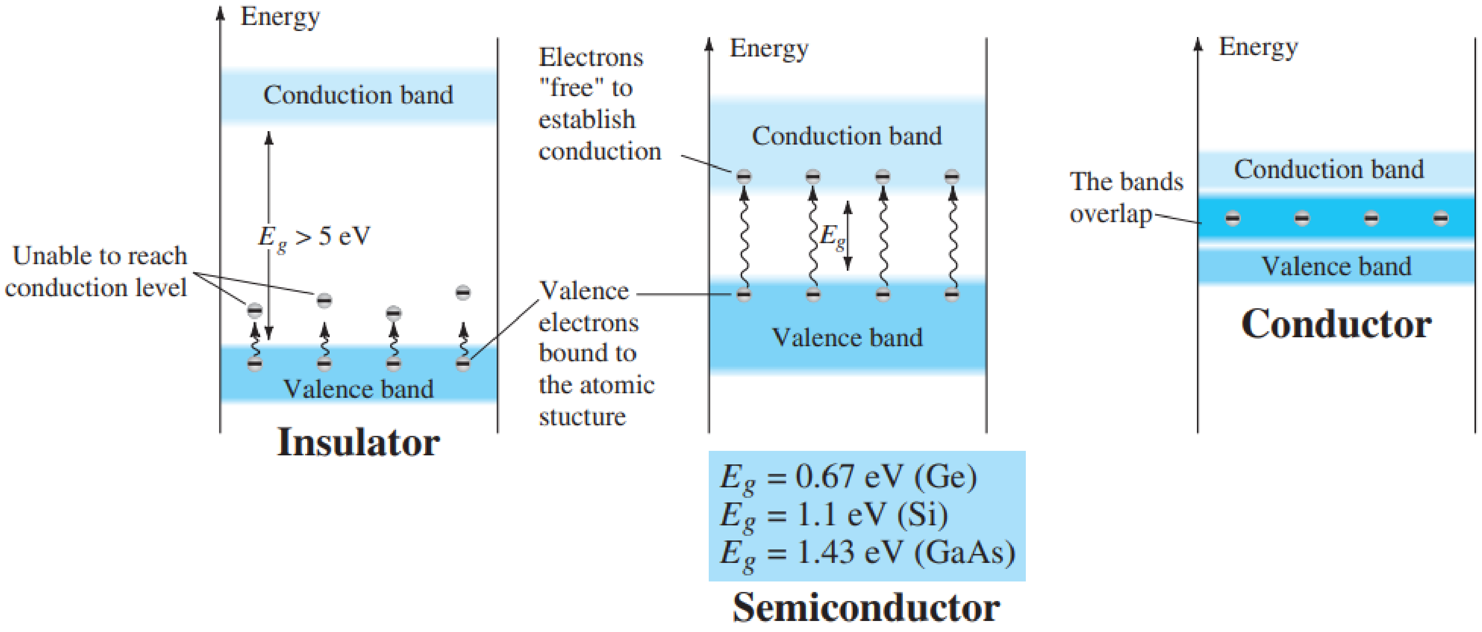
Atomic number of germanium=32

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^2$.

- Semiconductors are a special class of elements having a conductivity between that of a good conductor and that of an insulator.
- The three semiconductors used most frequently in the construction of electronic devices are Ge, Si, and GaAs.

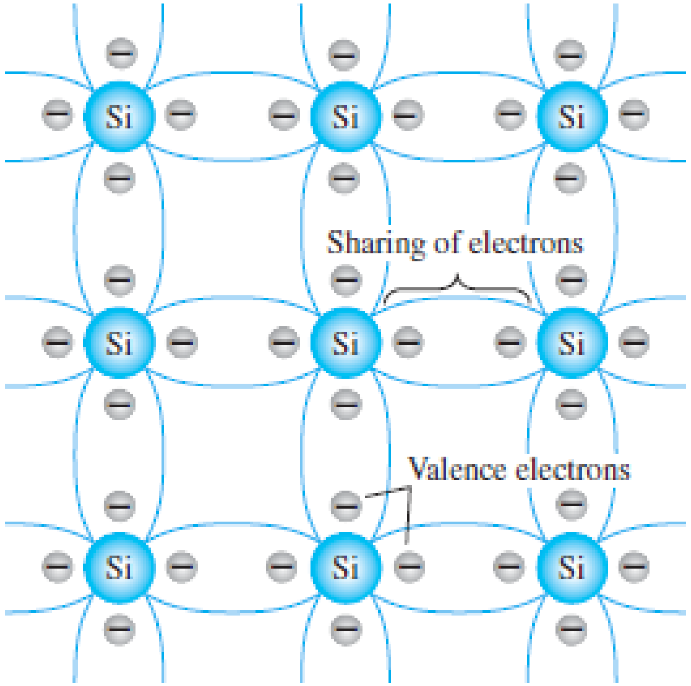
An Introduction to Semiconductor

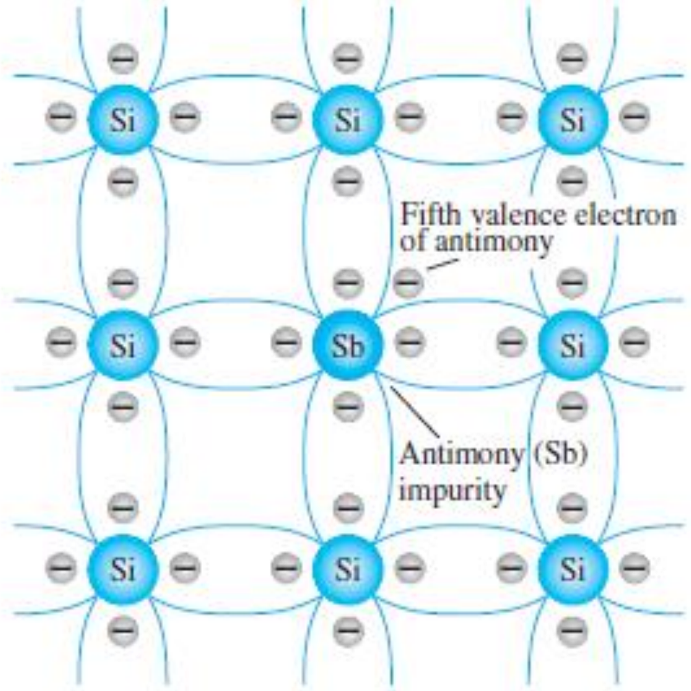




- The term intrinsic is applied to any semiconductor material that has been carefully refined to reduce the number of impurities to a very low level—essentially as pure as can be made available through modern technology.

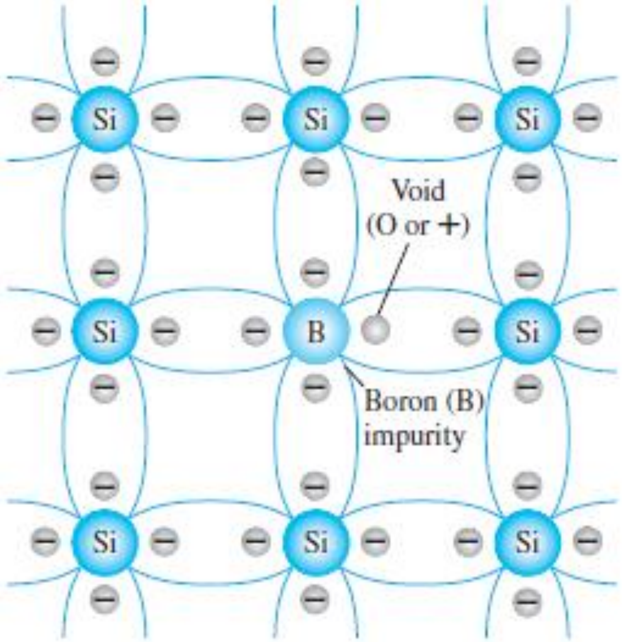
- A semiconductor material that has been subjected to the doping process is called an extrinsic material.





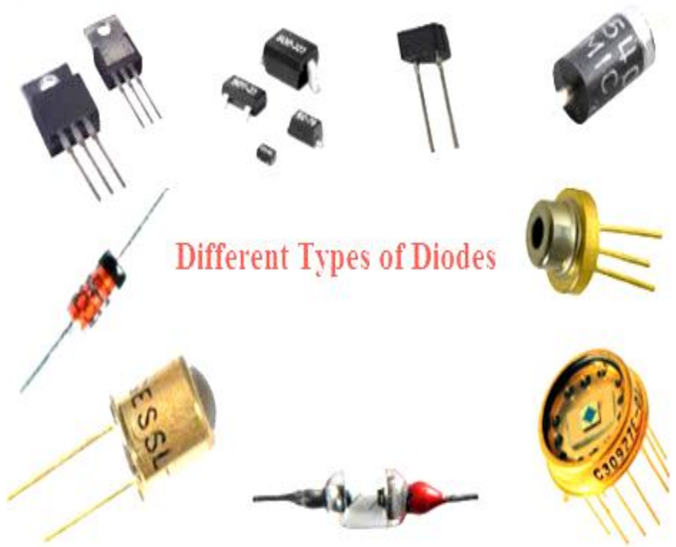
An *n -type material is created by introducing impurity elements that* have *five valence electrons (pentavalent), such as antimony, arsenic , and phosphorus.*

The *p-type material is formed by doping with impurity* atoms having *three valence electrons(trivalent), such as boron , gallium , and indium.*



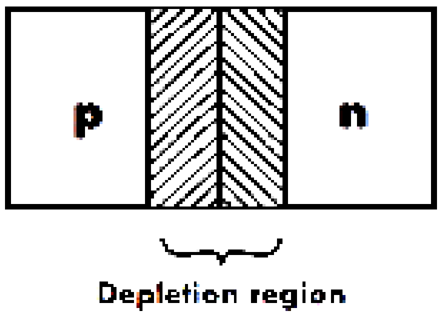
Diode : Two – electrodes

- We can construct our first solid-state electronic device: The semiconductor diode by sandwiching p-type and n-type material together to form a depletion region between the two.
- It is fabrication of one material with a majority carrier of electrons to one with a majority carrier of holes.

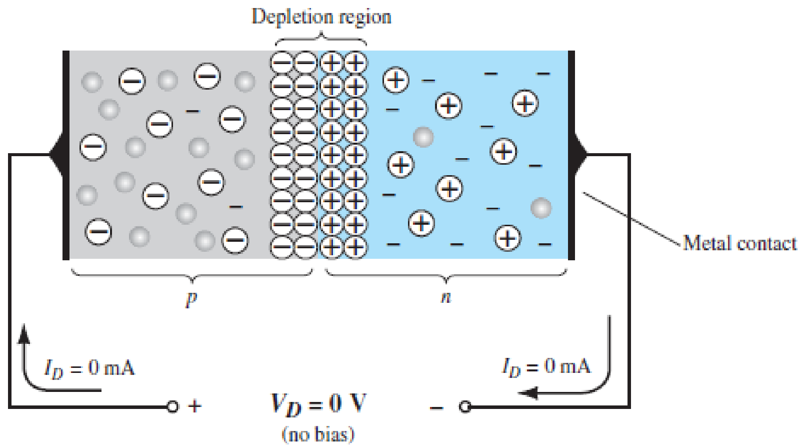


Biasing of diodes :

- Forward Bias: A material type connected to the same polarity terminal of the voltage source
- Reverse Bias: A material type connected to the opposite polarity terminal of the voltage source



Diode operation under different biasing conditions



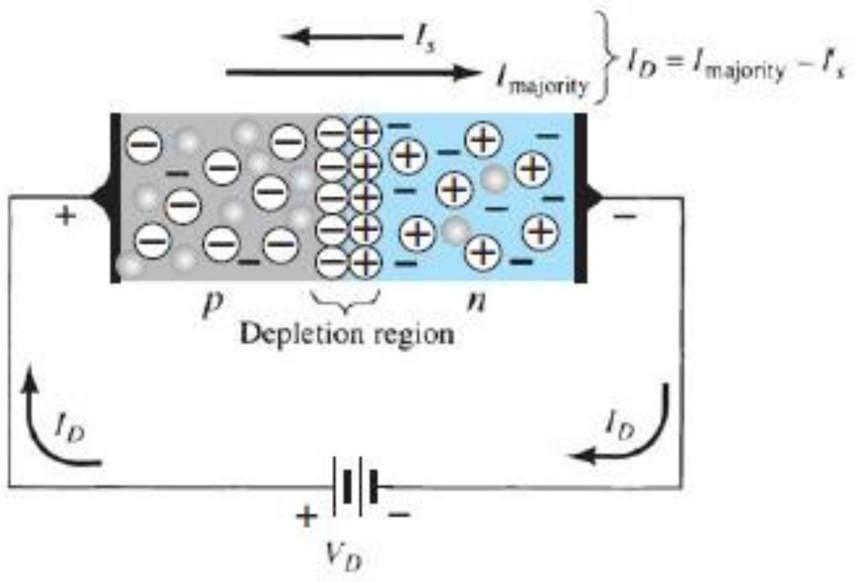
No bias

In the absence of an applied bias across a semiconductor diode, the net flow of charge in one direction is zero.

No – bias condition:

- At the instant the two materials are "joined" the electrons and the holes in the region of the junction will combine, resulting in a lack of free carriers in the region near the junction, as shown in Fig.
- Note in Fig. that the only particles displayed in this region are the positive and the negative ions remaining once the free carriers have been absorbed.
- ***This region of uncovered positive and negative ions is called the depletion region due to the "depletion" of free carriers in the region.***

Diode operation under different biasing conditions



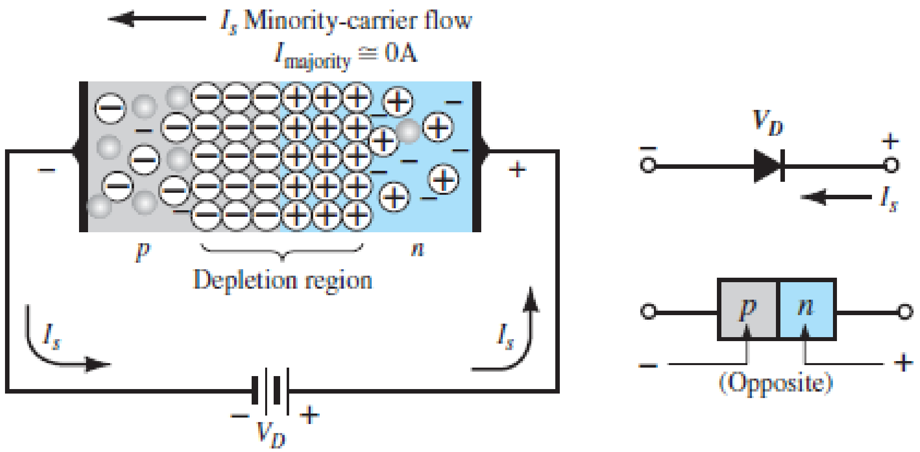
Forward Bias

The current that exists under forward-bias conditions is called the forward-bias current and is represented by I_D.

Forward – bias condition

- A *forward-bias* or "on" condition is established by applying the positive potential to the *p*-type material and the negative potential to the *n*-type material as shown in Fig.
- The application of a forward-bias potential V_D will "pressure" electrons in the *n*-type material and holes in the *p*-type material to recombine with the ions near the boundary and reduce the width of the depletion region as shown in Fig.

Diode operation under different biasing conditions



Reverse Bias

The current that exists under reverse-bias conditions is called the reverse saturation current and is represented by I_s.

Reverse – bias condition:

- When a P-N junction is reverse-biased as shown in Fig., the number of uncovered positive ions in the depletion region of the *n*-type material will increase due to the large number of free electrons drawn to the positive potential of the applied voltage.
- For similar reasons, the number of uncovered negative ions will increase in the *p*-type material.
- The net effect, therefore, is a widening of the depletion region. This widening of the depletion region will establish too great a barrier for the majority carriers to overcome, effectively reducing the majority carrier flow to zero.

Semiconductor Diode's Characteristics & Parameters

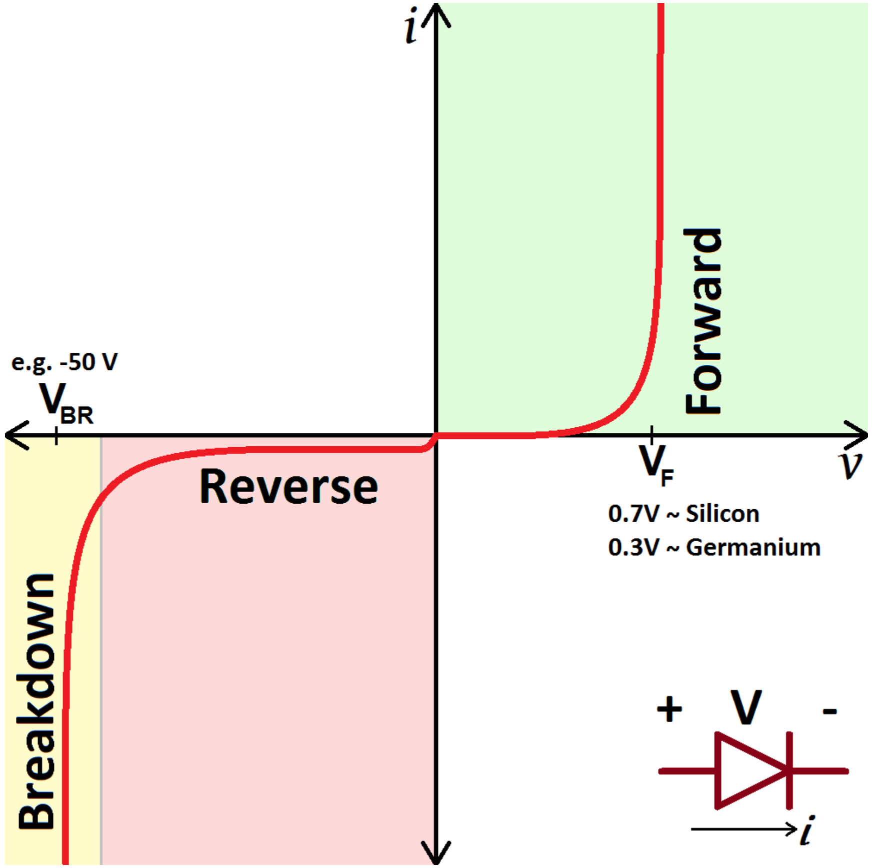
From the characteristics curve of a semiconductor diode the following regions and parameters have been observed under,

Forward Bias

- Knee Voltage
- Forward Current Rating
- Maximum Power Dissipation

Reverse Bias

- Reverse Saturation Current
- Break down Voltage
- Peak Inverse Voltage Rating



Diode's Current Expression (Shockley's Current Equation)

Shockley's Equation also called the **diode equation** helps us determine the current at a given temperature knowing the diode voltage and saturation current.

$$I_D = I_S\left(e^{\frac{qV_D}{nkT}} - 1\right)$$

k = 1.38 x10^{-23} Joule/Kelvin.

q=1.6 × 10^{-19} coulomb

- When V_D is negative

$$I_D \sim -I_S$$

- When V_D is positive

$$I_D \sim I_S e^{\frac{qV_D}{nkT}}$$

Where

I_D and V_D are the diode current and voltage, respectively

q is the charge on the electron

n is the ideality factor: n = 1 for indirect semiconductors (Si, Ge, etc.)

n = 2 for direct semiconductors (GaAs, InP, etc.)

k is Boltzmann's constant

T is temperature in Kelvin

kT/q is also known as V_{th}, the thermal voltage. At 300K (room temperature),

kT/q = 25.9mV

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Diode's Current Expression (Shockley's Current Equation)

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EXAMPLE 1.1 At a temperature of 27°C (common temperature for components in an enclosed operating system), determine the thermal voltage V_T.

Solution: Substituting into Eq. (1.3), we obtain

$$T = 273 + °\text{C} = 273 + 27 = 300\ \text{K}$$

$$V_T = \frac{kT_K}{q} = \frac{(1.38 \times 10^{-23}\ \text{J/K})(30\ \text{K})}{1.6 \times 10^{-19}\ \text{C}}$$

$$= 25.875\ \text{mV} \cong 26\ \text{mV}$$

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Q. No 1. Calculate the thermal voltage when the temperature is 25°C

Solution:

$k = 1.38 \times 10^{-23}$ Joule/Kelvin.

$q = 1.6 \times 10^{-19}$ coulomb

Thermal voltage $V_T = k\,T/q$

Where k is the Boltzmann constant and q is the charge of electron. This can be reduced to

$V_T = T/11600$ because $q/k = 11600$

Therefore, $V_T = 298/11600 = 0.0257V$

$V_T = 25.7mV$

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Q.No.2 Calculate the forward bias current of a Si diode when forward bias voltage of 0.4V is applied, the reverse saturation current is 1.17×10^{-9}A and the thermal voltage is 25.2mV.

Solution: $I_D = I_s(e^{V_D/nV_T} - 1)$, I_s = reverse saturation current

η = ideality factor, V_T = thermal voltage, V_D = applied voltage

Since in this question ideality factor is not mentioned it can be taken as one.
$I_s = 1.17 \times 10^{-9}$A, $V_T = V_T = kT/q = 0.0252$V, $\eta = 1$, $V_D = 0.4$V

Therefore, $I_D = 1.17\times10^{-9} \times (e^{0.4/0.0252} - 1)$

$I_D = 9.156$mA.

Numerical on Diode's Current Equations

Q. No 3 Given a diode current of 8 mA and η =1, find the reverse saturation current (I_s) if the applied voltage is 0.5 V and the room temperature is 25°C.

Solution: Equation for diode current (Shockley's Equation) $I_D = I_s(e^{V_D/nV_T} - 1)$

Given: I_D = **diode current = 8 mA**, η = ideality factor = 1, V_D = Applied voltage = 0.5V

We have to find V_T = Thermal voltage and Reverse saturation current Is

$$V_T = \frac{kT_K}{q} = \frac{(1.38\times10^{-23}\ \text{J/K})(25°\text{C} + 273°\text{C})}{1.6\times10^{-19}\ \text{C}}$$

$$= 25.70\ \text{mV}$$

$$8\text{mA} = I_s(e^{(0.5\text{V})/(1)(25.70\ \text{mV})} - 1) = I_s(28\times10^8)$$

$$I_s = \frac{8\ \text{mA}}{2.8\times10^8} = 28.57\ \text{pA}$$

Numerical on Diode's Current Equations

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Q. No 4: Calculate the applied voltage V_D, if diode current is 6 mA, Thermal Voltage is 26 mV, Ideality factor is 1, and Reverse saturation current is 1 nA.

Solution: **Given:** I_D = 6 mA, V_T = 26 mV, η = 1, I_S = 1 nA, V_D = Applied voltage = ……..V

Equation for diode current (Shockley's Equation)

$$I_D = I_s(e^{V_D/nV_T} - 1)$$

$$6\text{ mA} = 1\text{ nA}(e^{V_D/(1)(26\text{ mV})} - 1)$$

$$6\times10^6 = e^{V_D/26\text{ mV}} - 1$$

$$e^{V_D/26\text{ mV}} = 6\times10^6 - 1 \cong 6\times10^6$$

$$\log_e e^{V_D/26\text{ mV}} = \log_e 6\times10^6$$

$$\frac{V_D}{26\text{ mV}} = 15.61$$

$$V_D = 15.61(26\text{ mV}) \cong \mathbf{0.41\ V}$$

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Q. No 5 Consider a silicon diode with η=1.2. Find change in voltage if the current changes from 0.1mA to 10mA.

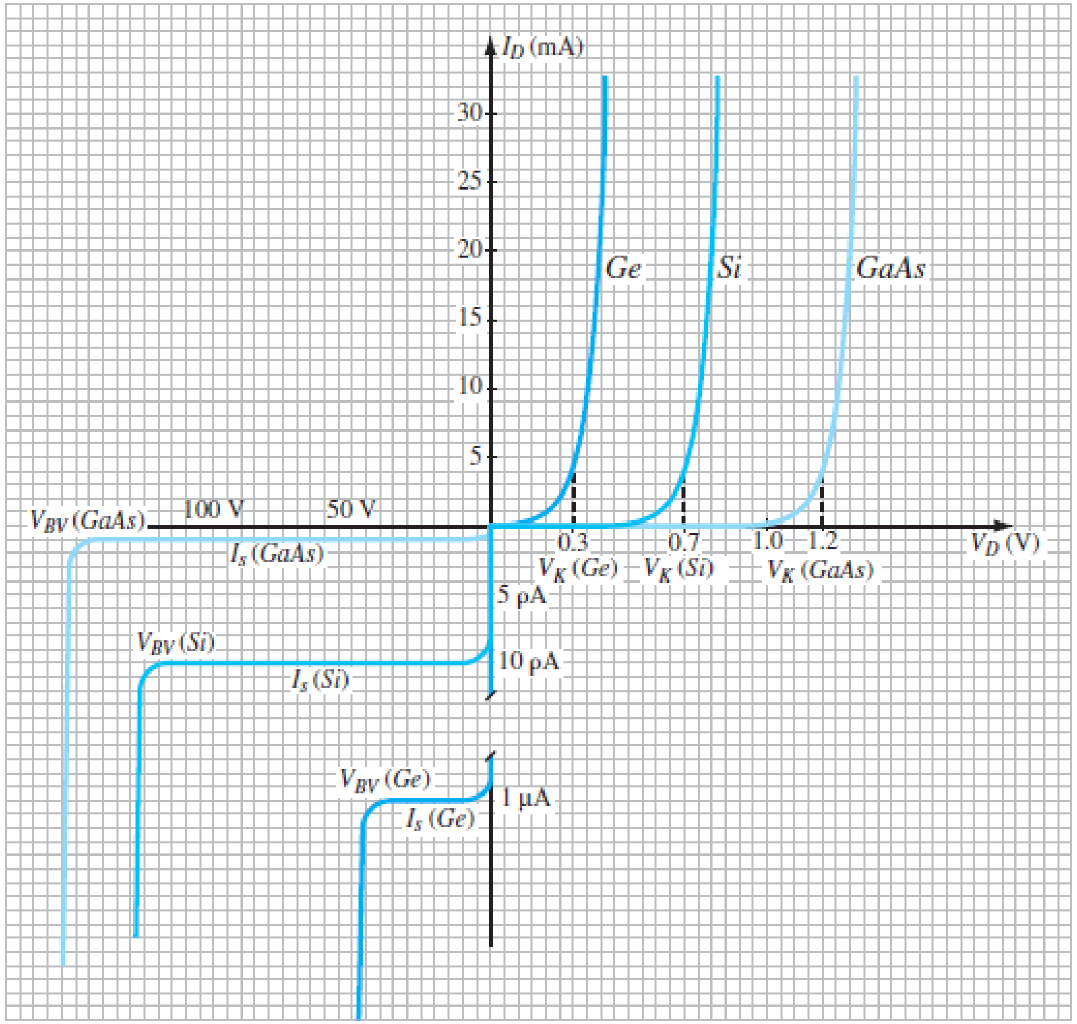
Solution: Equation for diode current $I=I_0\times(e^{(V/\eta V_T)}-1)$

Where I_0 = reverse saturation current, η = ideality factor
V_T = thermal voltage, V = applied voltage

$\eta = 1.2$, $I_2 = 10mA$, $I_1 = 0.1mA$ and take $V_T = 0.026V$

Change in voltage $\Delta V = \eta V_T \ln(\frac{I_2}{I_1}) = 1.2\text{x}0.026\text{x}\ln(10 \times \frac{10^{-3}}{0.1\times10^{-3}}) = 0.143V$

Comparison of diode characteristics of Ge, Si, and GaAs

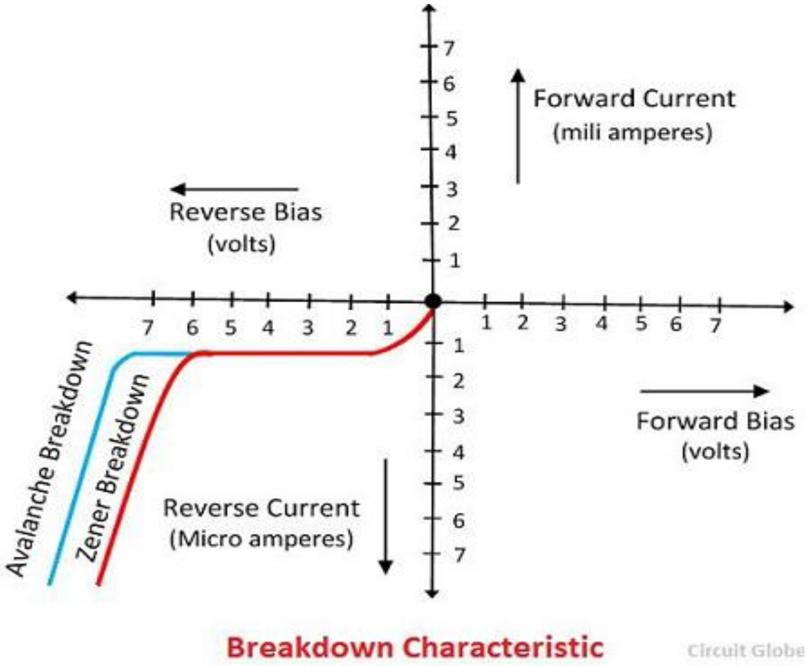


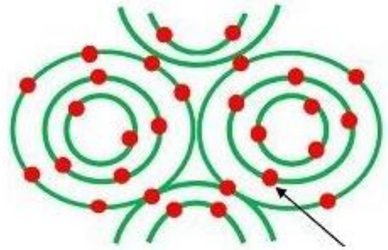
Types of Diode Breakdown

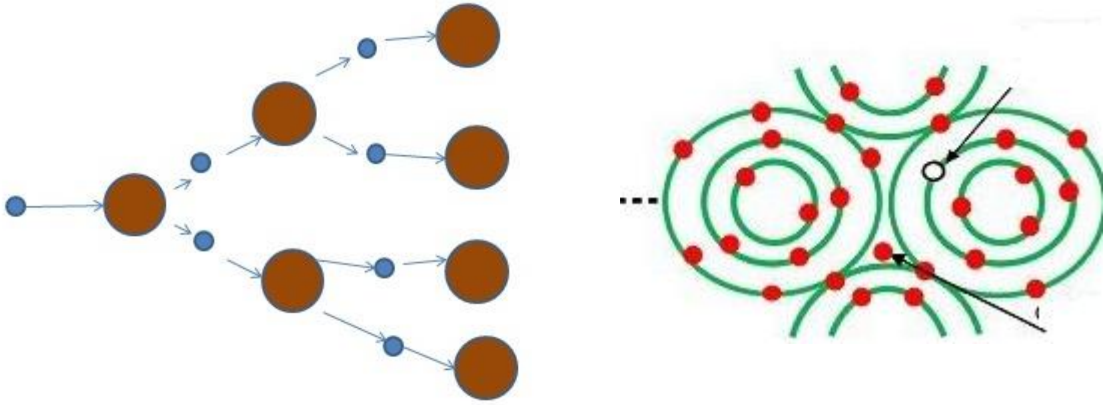
- **Avalanche breakdown :** In the reverse bias condition as the voltage increases the free charge carriers obtain velocity and associated kinetic energy and release additional carriers through collision with other atomic structures.

- Hence Covalent bonds are broken and electron–hole are generated.

- These charge carriers acquire energy from the applied potential and produce more and more free charge carriers. This cumulative process is called Avalanche multiplication or ionization process.







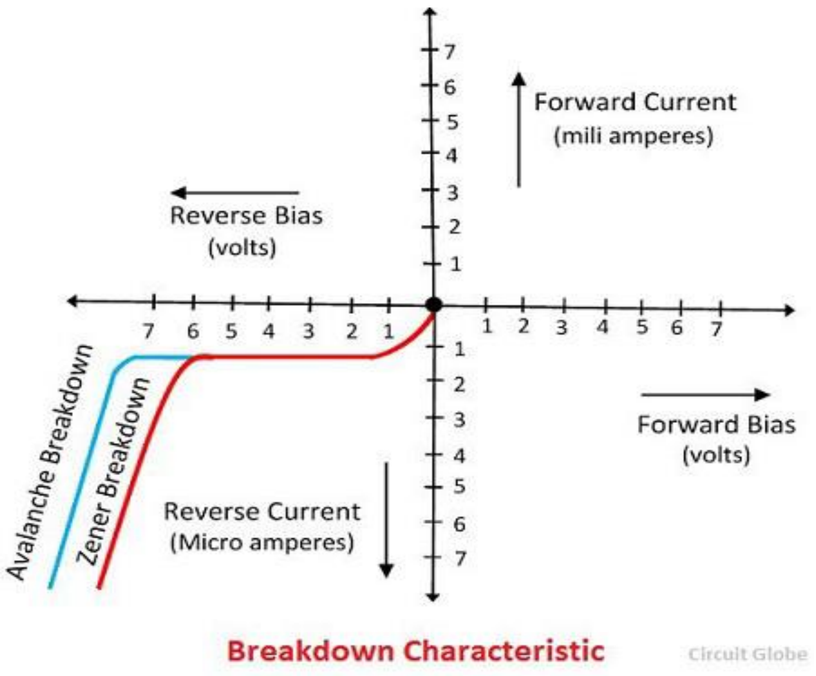
Carrier Multiplication or avalanche breakdown

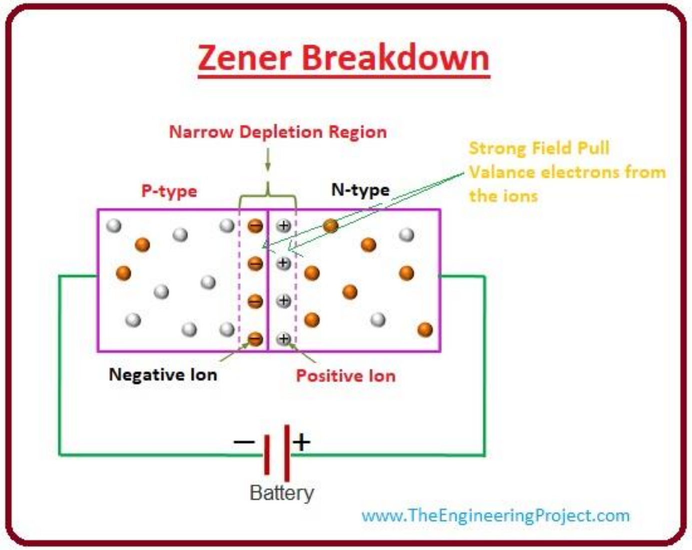
Types of Diode Breakdown

- **Zener breakdown :** Zener break down occurs when both P and N type material are heavily doped in a semiconductor diode. Hence the depletion layer region is narrow down.

- When a small reverse bias voltage is applied across a diode a very strong electric fied is produced.

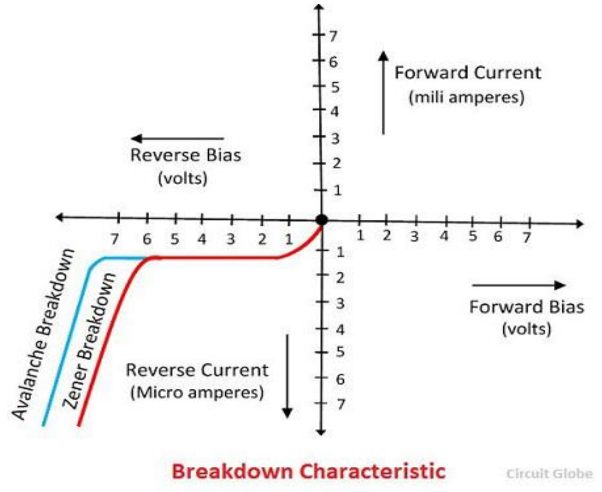
- Due to this electric field covalent bond breaks and produces large number of free charge carriers.





Types of Diode Breakdown

	ZENER BREAKDOWN	AVALANCHE BREAKDOWN
01	The process in which the electrons move across the barrier from the valence band of p-type material to the conduction band of n-type material is known as Zener breakdown.	The process of applying high voltage and increasing the free electrons or electric current in semiconductors and insulating materials is called an avalanche breakdown.
02	This is observed in Zener diodes having a Zener breakdown voltage Vz of 5 to 8 volts.	This is observed in Zener diode having a Zener breakdown voltage Vz greater than 8 volts.
03	The valence electrons are pulled into conduction due to the high electric field in the narrow depletion region.	The valence electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gain their velocity due to their collision with other atoms.
04	The increase in temperature decreases the breakdown voltage.	The increase in temperature increases the breakdown voltage.
05	The VI characteristics of a Zener breakdown has a sharp curve.	The VI characteristic curve of the avalanche breakdown is not as sharp as the Zener breakdown.
06	It occurs in diodes that are highly doped.	It occurs in diodes that are lightly doped.



Temperature Effects on V-I Characteristics of a Diode

- The Effect of variation in temperature across a semiconductor diode is observed both in the forward as well as in reverse characteristics.

- Rise in temperature generates more electron-hole pair thus conductivity increases and thus increases in current.

- PN junction diode parameters like reverse saturation current, bias current, reverse breakdown voltage and barrier voltage are dependent on temperature.

- Increase in the temperature increases carrier concentration. As a result, knee voltage decreases & breakdown voltage increases while reverse saturation current increases.

Temperature Effects on V-I Characteristics of a Diode

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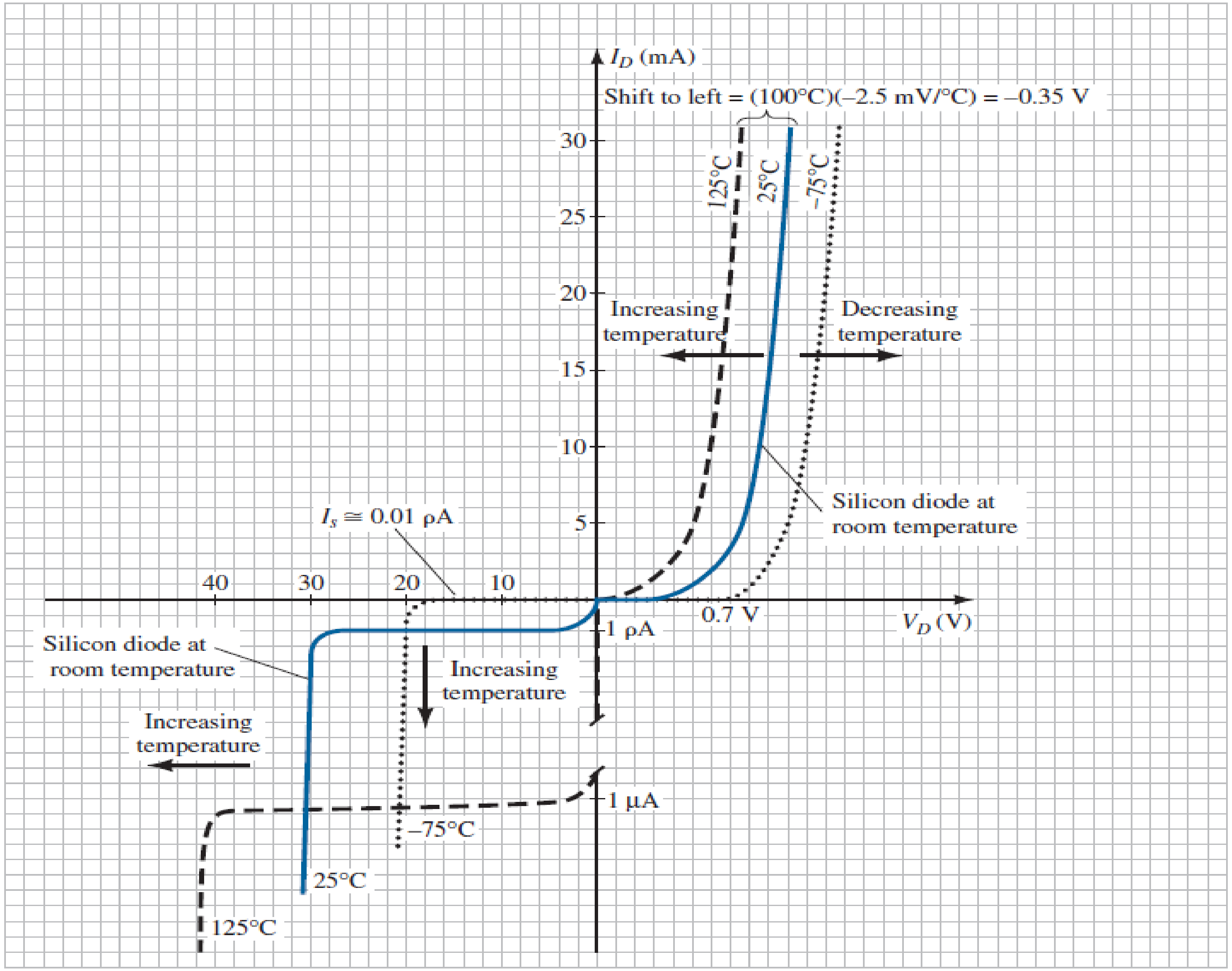
- Under Forward Bias the Change in Temperature across the diode: Barrier voltage is dependent on temperature hence it decreases by 2.5mV/ °C rise in temperature for both germanium and silicon.
- Under Reverse Bias the Change in Temperature across the diode: Reverse saturation current (I_S) of diode increases with increase in the temperature. The rise is 7%/°C for both germanium & silicon and approximately doubles for every 10°C rise in temperature.
- Reverse breakdown voltage (V_R) also increases as the temperature increases

Temperature Effects on V-I Characteristics of a Diode



An Example - Temperature Effects on A Semiconductor diode

Example: The Reverse saturation current of silicon diode at 20°C is 0.1μA. Determine its value if the temperature is increased by 40 °C .

ANS:

$$Given\ Data\ at\ T = 20^{o}C : I_s = 0.1\mu A$$

$$T = 30^{o}C : I_s = 0.2\mu A$$

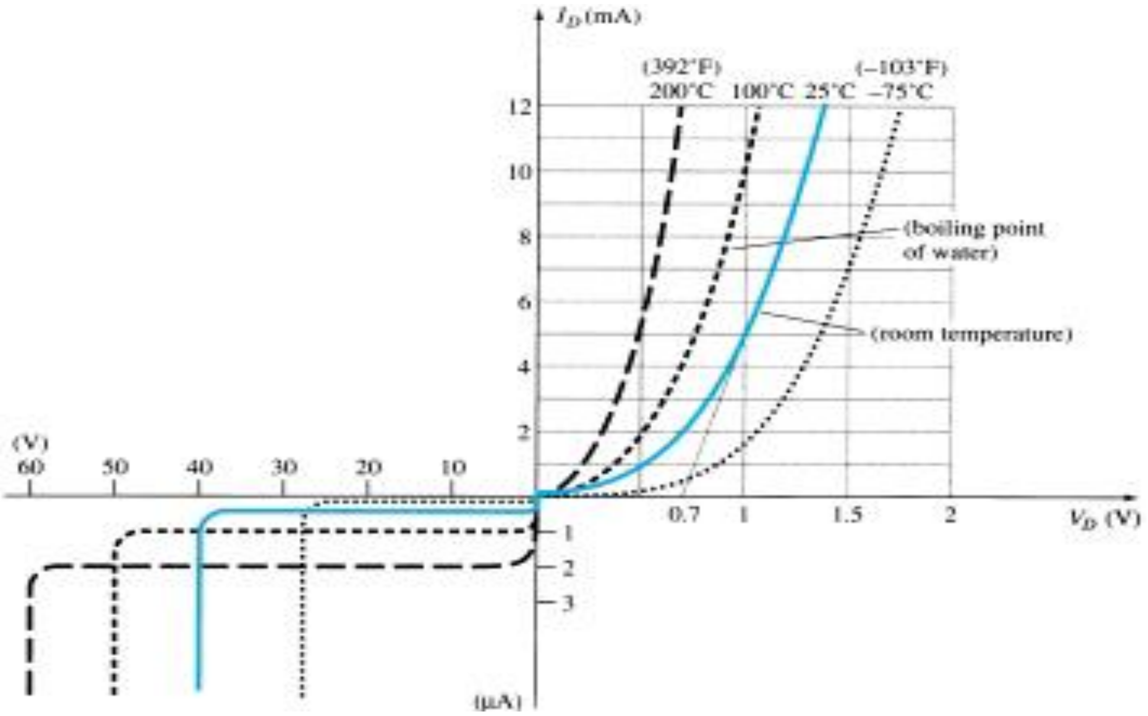
$$T = 40^{o}C : I_s = 0.4\mu A$$

$$T = 50^{o}C : I_s = 0.8\mu A$$

$$\mathrm{T} = 60^{\mathrm{o}}\mathrm{C} : \mathrm{I_s} = 1.6\mu\mathrm{A}$$

Temperature Effects on A Semiconductor diode

1. The reverse saturation current Is will double in magnitude for every 10°C increase in temperature.



2. The Knee voltage shifts to the left at a rate of 2.5mV per degree centigrade increase in temperature

Temperature Effects: Numerical

Q No 1. The knee voltage of a Si diode is 0.7V and its reverse Saturation current is 20nA at 25^oC. Determine these values at 40^oC.

Solution:

Knee voltage shift left at a rate of 2.5mV per centigrade degree increase in temperature.

Therefore for a Change in temperature is = $40^oC-25^oC = 15^oC$

Change in knee voltage will be =2.5mV X 15= 0.0375V

Hence V_K at 40^oC = 0.7-0.0375= 0.6625 V,

Reverse Saturation Current doubles for every 10^oC rise in Temperature

I_S at 40^oC = $2^{(40-25/10)}$ X 20nA = 2.82X20nA = 56.56nA.

Q No 2. The reverse saturation current of a Germanium diode is 200μA at room temperature of 27°C. Calculate the current in forward biased condition, if forward biased voltage is 0.2V at room temperature. If temperature is increased by 30°C, calculate the reverse saturation current and the forward current for the same forward voltage at new temperature.

Solution:

$k = 1.38 \times 10^{-23}$ Joule/Kelvin.

$q=1.6 \times 10^{-19}$ coulomb

$V_T = kT/q = 25.9mV$

$I_D = I_s \times (e^{(V_D/\eta V_T)} - 1) = 200\mu A \times e^{(0.2/0.0259)} = 0.451A$

If the temperature is increased by 30°C New temperature is 27+30= 57°C

Therefore Is= 200μ X2^3= 1600 μA therefore at new V_T at 57°C is 28.4mV

Hence I_D at 57°C = 1.83A.

Temperature Effects: Numerical

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Q No 3. A Ge diode has a reverse saturation current of 5μA at temperature 300K find diode current at 40^oC . When forward bias voltage is 0.27.

Solution:

.

Given Is at 27^oC is 5μA

$k = 1.38 \times 10^{-23}$ Joule/Kelvin.

$q = 1.6 \times 10^{-19}$ coulomb

Therefore, I_s at 40^oC is = $5\mu \times 2^{(40-27/10)}$

= 5μ X 2.462

=12.31 μ A

Hence V_T at 40^oC = kT/q= 26.9mV

Therefore $I_D = I_s \times (e^{(VD/\eta V_T)} - 1) = 12.31\mu A \times e^{(V_D/\eta V_T)} = 281.49mA$

Temperature Effects: Numerical

Q No 4. The reverse saturation current of a Si diode is 2pA at 27°C. Determine the forward biased voltage across the diode at 57°C, if the forward current through the diode at 57°C is 50mA.

Solution:

$k = 1.38 \times 10^{-23}$ Joule/Kelvin.

$q = 1.6 \times 10^{-19}$ coulomb

Reverse saturation current doubles for every 10°C rise in temperature

Hence at if reverse saturation current at 27°C is 2pA

Then reverse saturation current at 37°C is 4pA

Then reverse saturation current at 47°C is 8pA

Then reverse saturation current at 57°C is 16pA

Therefore V_T 57°C is =k x 330/q= 28.42mV

Hence by using $I_D = I_s \times (e^{(V_D/\eta V_T)} - 1) = 50mA$

$$50/16 = e^{V_D/\eta V_T} \rightarrow \ln(50/16) = V_D/28.42m \rightarrow V_D = 0.686V \text{ at } 57^oC.$$

Temperature Effects: Numerical

Q No 5. The reverse saturation current of a Germanium diode is 100µA at room temperature of 28°C. Calculate the current in forward biased condition, if forward biased voltage is 0.3V at room temperature. If temperature is increased by 25°C, calculate the reverse saturation current and the forward current for the same forward voltage at new temperature.

Solution:

$V_T = kT/q = 25.9mV$

$I_D = I_s \times (e^{(V_D/\eta V_T)} - 1)$

If the temperature is increased by 28°C New temperature is 28+25= 53°C

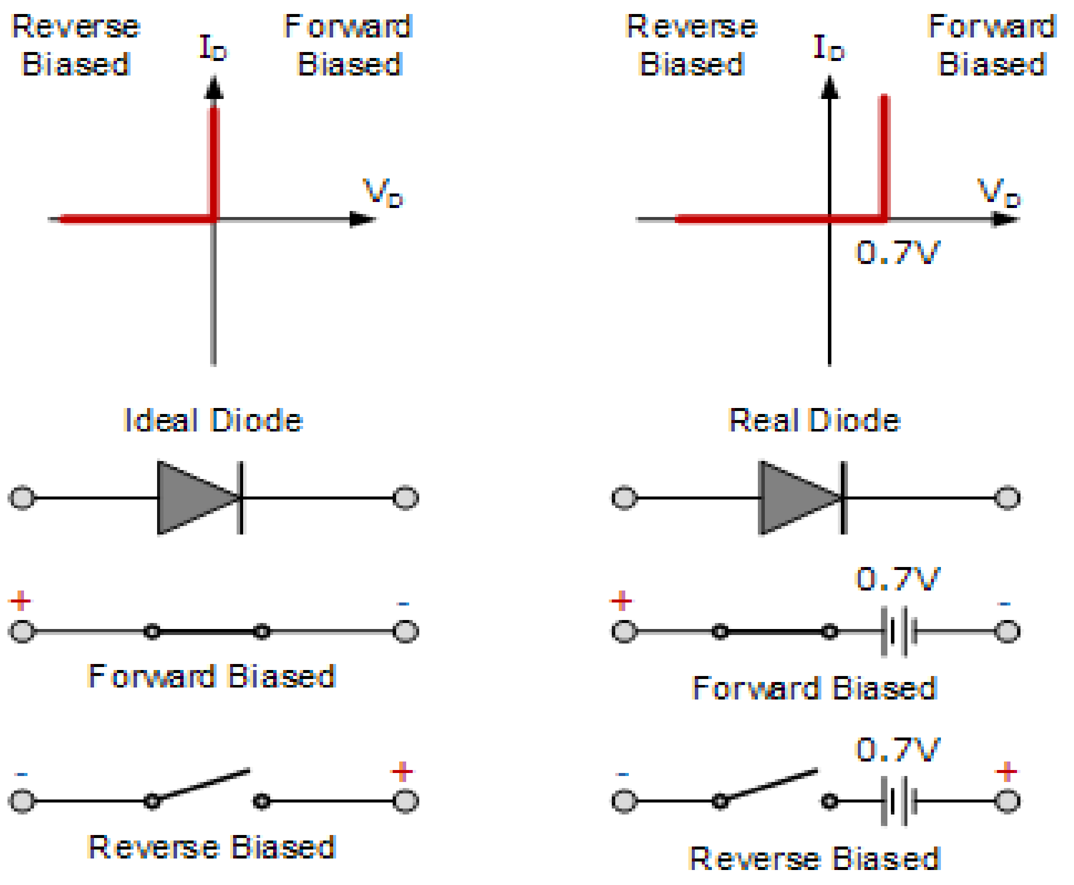
Therefore $I_s = 100\mu \times 2^{2.5} = 565.68\ \mu A$. Therefore, new V_T at 53°C is 28.117 mV

Hence I_D at 53°C = 24.31 A.

Ideal and Practical Diode Characteristics:

Ideal Diode: When an ideal diode is forward biased, it offers no resistance & acts like a closed switch. Likewise, the ideal diode under reverse bias offers infinite resistance hence, it acts like open switch.

Practical Diode: A diode which is said to be forward biased it starts conducting at knee voltage & under reverse bias no current due to majority charges hence a practical diode is considered to be open switch (minority charges current ignored).



For Si, $V_K = 0.7V$

Diode Resistances

- An actual diode offers a very small resistance (not zero) when forward biased and is called a forward resistance
- Whereas, it offers a very high resistance (not infinite) when reverse biased and is called as a reverse resistance

- Type of applied voltage or signal will define

the following resistance levels

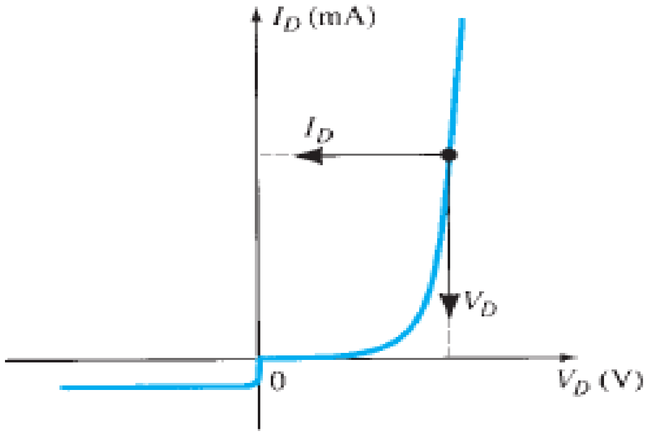
i. DC or Static Resistance

ii. AC or Dynamic Resistance

iii. Average AC Resistance

DC or Static Resistance

- The application of a dc voltage to a circuit containing a semiconductor diode will result in an operating point on the semiconductor diode characteristic curve.
- Finding the corresponding levels of V_D and I_D at particular operating point gives the DC resistance.



$$R_D = \frac{V_D}{I_D}$$

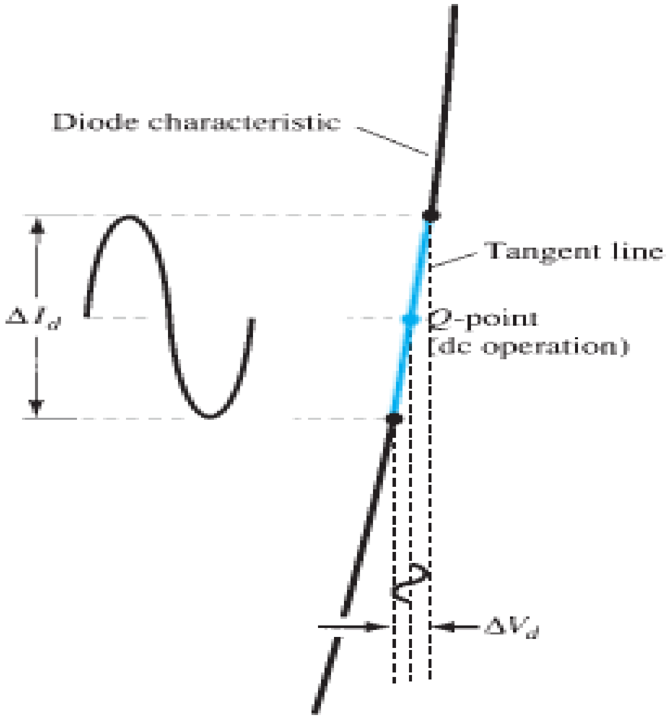
- Typically, the dc resistance of a diode in:

Forward bias : 10 Ω to 80 Ω

Reverse Bias: 10 MΩ

AC or Dynamic Resistance

- The application of a small AC voltage to a circuit containing a semiconductor diode offers AC resistance.
- A straight line drawn tangent to the curve through the Q –point will define a particular change in voltage and current determines the ac or dynamic resistance for this region of the diode characteristics.



$$\boxed{r_d = \frac{\Delta V_d}{\Delta I_d}}$$

AC or Dynamic Resistance

- Dynamic resistance can be found simply by substituting the quiescent value of the diode current into the equation also

$$\boxed{r_d = \frac{26\ \text{mV}}{I_D}} \quad \text{ohms}$$

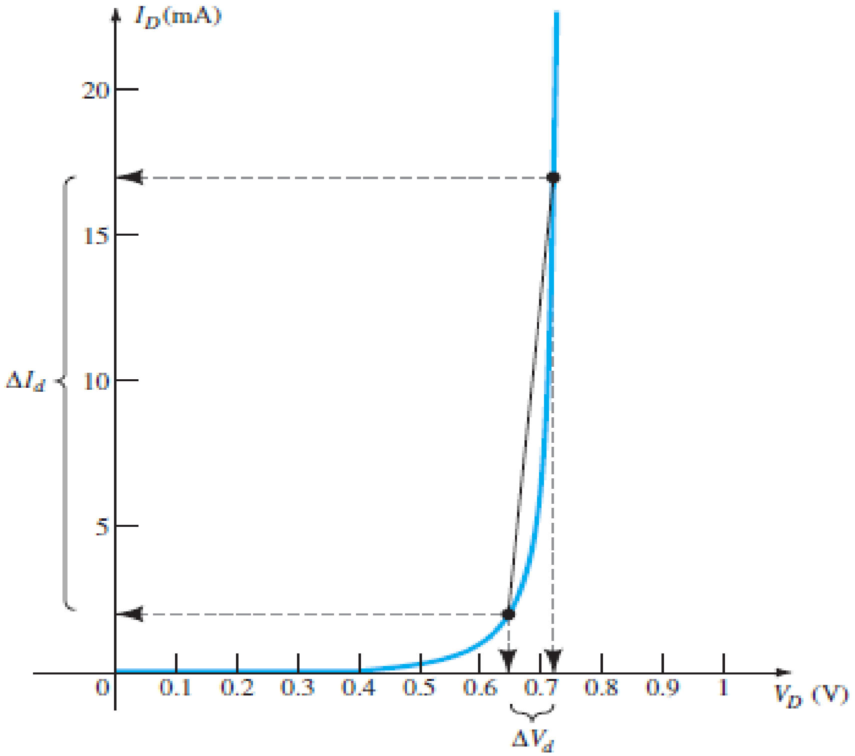
$$\boxed{r'_d = \frac{26\ \text{mV}}{I_D} + r_B} \quad \text{ohms}$$

- Where, r_B is bulk or body resistance

- Typically, the ac resistance of a diode in the active region will range from 1 Ω to 100 Ω.

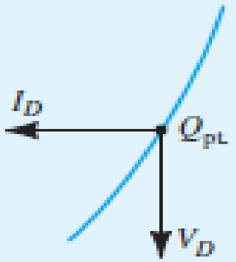
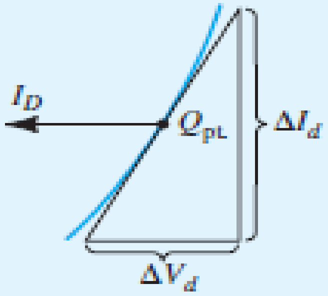
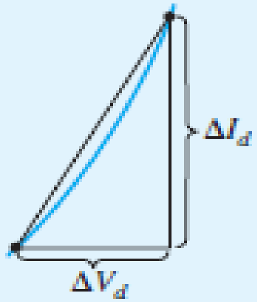
Average AC Resistance

- If applied input signal is sufficiently large to produce a broad swing and the resistance determined by a straight line drawn between the two intersections established by the maximum and minimum values of input voltage is called Average AC Resistance



$$r_{av} = \left.\frac{\Delta V_d}{\Delta I_d}\right|_{\text{pt. to pt.}}$$

Summary of Resistances

Type	Equation	Special Characteristics	Graphical Determination
DC or static	$R_D = \frac{V_D}{I_D}$	Defined as a point on the characteristics	
AC or dynamic	$r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{26\text{ mV}}{I_D}$	Defined by a tangent line at the Q-point	
Average ac	$r_{av} = \frac{\Delta V_d}{\Delta I_d}\bigg\rvert_{\text{pt. to pt.}}$	Defined by a straight line between limits of operation	

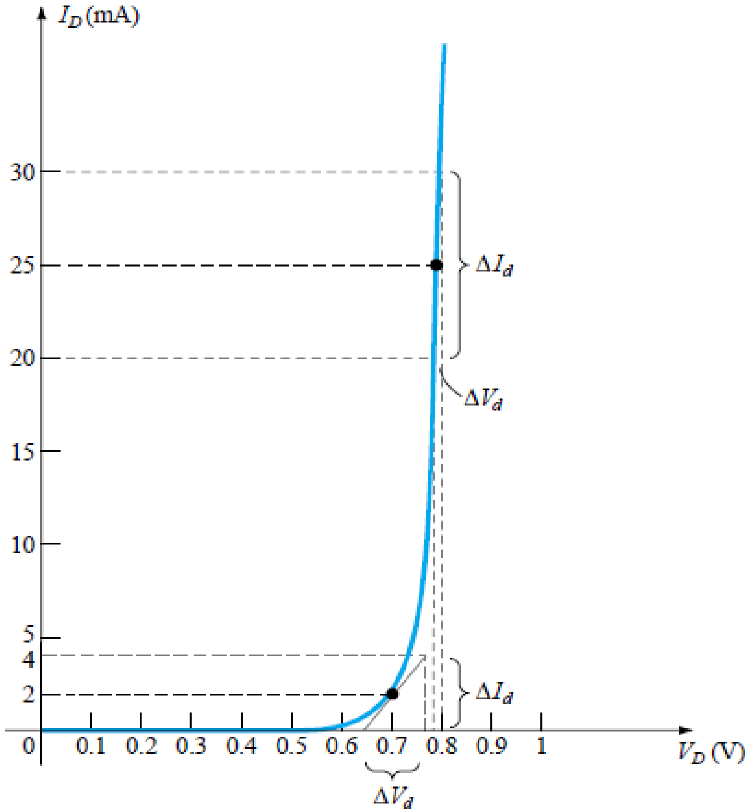
Diode Resistance: Numerical

Q No 1. For the characteristics of Fig:

(a) Determine the ac resistance at ID 2 mA.

(b) Determine the ac resistance at ID 25 mA.

(c) Compare the results of parts (a) and (b) to the dc resistances at each current level.



a)

$$\Delta I_d = 4\text{ mA} - 0\text{ mA} = 4\text{ mA}$$

$$\Delta V_d = 0.76\text{ V} - 0.65\text{ V} = 0.11\text{ V}$$

$$r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.11\text{ V}}{4\text{ mA}} = \mathbf{27.5\ \Omega}$$

b)

$$\Delta I_d = 30\text{ mA} - 20\text{ mA} = 10\text{ mA}$$

$$\Delta V_d = 0.8\text{ V} - 0.78\text{ V} = 0.02\text{ V}$$

$$r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.02\text{ V}}{10\text{ mA}} = \mathbf{2\ \Omega}$$

c)

$$R_D = \frac{V_D}{I_D} = \frac{0.7\text{ V}}{2\text{ mA}} = \mathbf{350\ \Omega}$$

$$R_D = \frac{V_D}{I_D} = \frac{0.79\text{ V}}{25\text{ mA}} = \mathbf{31.62\ \Omega}$$

Diode Resistance: Numerical

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Q No 2. Derivation of an expression for AC or Dynamic Resistance:

Solution: The derivative of a function at a point is equal to the slope of the tangent line drawn at that point.

$$\frac{d}{dV_D}(I_D) = \frac{d}{dV}[I_s(e^{kV_D/T_K} - 1)]$$

$$\frac{dI_D}{dV_D} = \frac{k}{T_K}(I_D + I_s)$$

$$\frac{dI_D}{dV_D} \cong \frac{k}{T_K}I_D$$

$$k = \frac{11{,}600}{\eta} = \frac{11{,}600}{1} = 11{,}600$$

$$T_K = T_C + 273^\circ = 25^\circ + 273^\circ = 298^\circ$$

$$\frac{k}{T_K} = \frac{11{,}600}{298} \cong 38.93$$

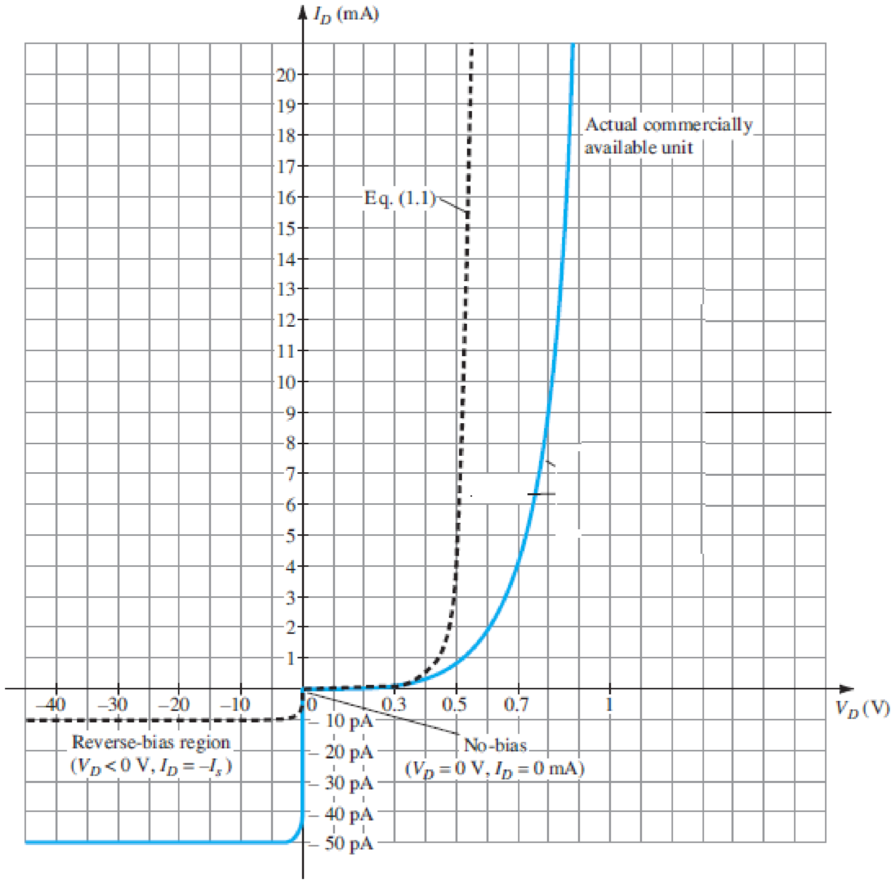
$$\frac{dI_D}{dV_D} = 38.93 I_D$$

$$\frac{dV_D}{dI_D} \cong \frac{0.026}{I_D}$$

$$\boxed{r_d = \frac{26\ \text{mV}}{I_D}}_{\text{Ge,Si}}$$

Diode Resistance: Numerical

Q No 3. Calculate the DC and AC resistance for the diode shown in the Figure given below, at a forward current of 10 mA and also compare their magnitudes.



$I_D = 10\text{ mA},\ V_D = 0.76\text{ V}$

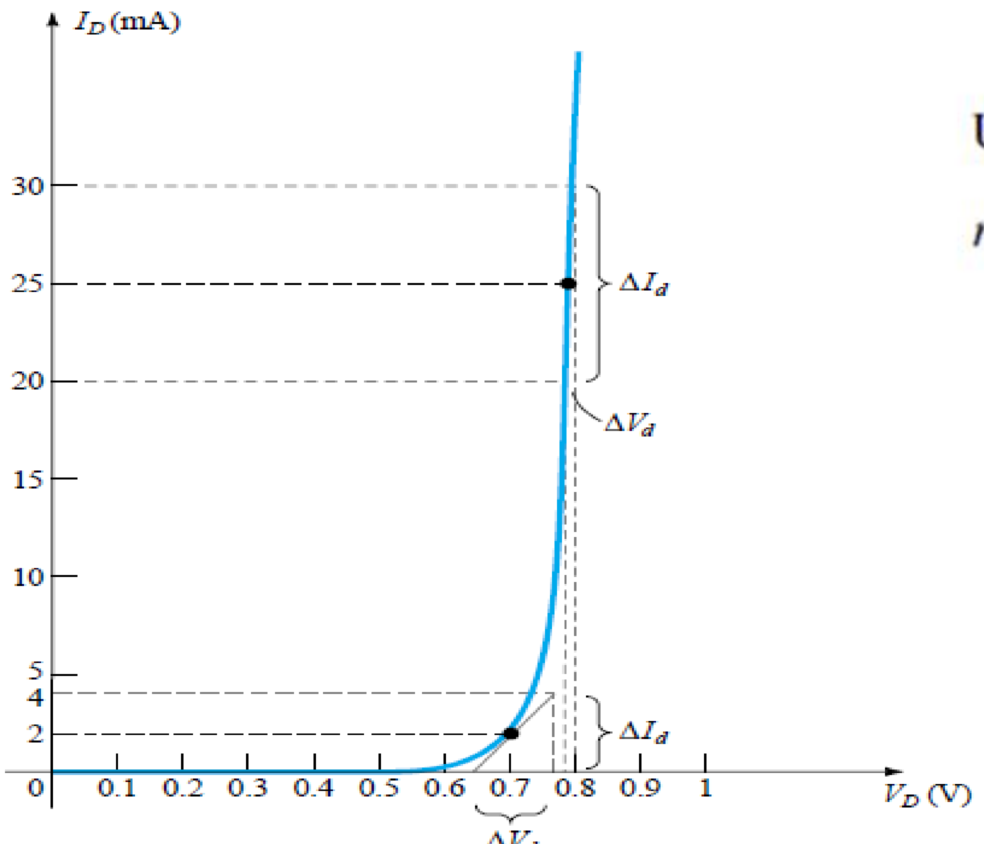
$$R_{DC} = \frac{V_D}{I_D} = \frac{0.76\text{ V}}{10\text{ mA}} = 76\ \Omega$$

$$r_d = \frac{\Delta V_d}{\Delta I_d} \cong \frac{0.85\text{V} - 0.72\text{ V}}{15\text{ mA} - 5\text{ mA}} = \frac{0.13\text{V}}{10\text{ mA}} = 13\ \Omega$$

$R_{DC} >> r_d$

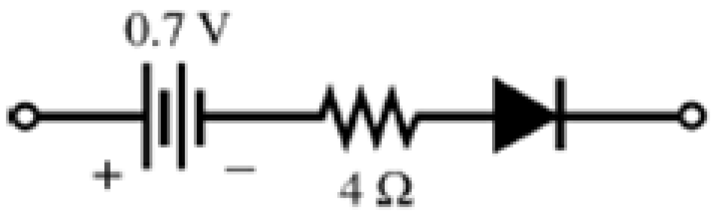
Diode Resistance: Numerical

Q No 4. Find the piecewise-linear equivalent circuit for the diode shown in the Fig. given below. Use a straight line segment that intersects the horizontal axis at 0.7 V and best approximates the curve for the region greater than 0.7 V.



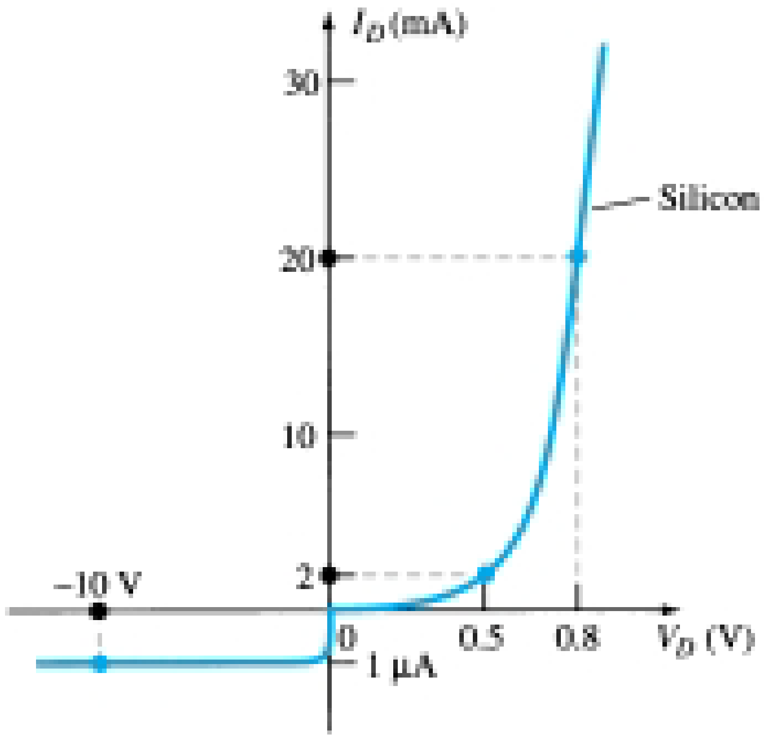
Using the best approximation to the curve beyond $V_D = 0.7$ V:

$$r_{av} = \frac{\Delta V_d}{\Delta I_d} \cong \frac{0.8\text{ V} - 0.7\text{ V}}{25\text{ mA} - 0\text{ mA}} = \frac{0.1\text{ V}}{25\text{ mA}} = 4\ \Omega$$



Diode Resistance: Numerical

Q No 5. Determine the DC resistance levels for the diode of Fig. given below at (a) I_D =2 mA (b) I_D =20 mA (c) V_D = -10 V



(a) At $I_D = 2$ mA, $V_D = 0.5$ V (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{0.5\text{ V}}{2\text{ mA}} = \mathbf{250\ \Omega}$$

(b) At $I_D = 20$ mA, $V_D = 0.8$ V (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{0.8\text{ V}}{20\text{ mA}} = \mathbf{40\ \Omega}$$

(c) At $V_D = -10$ V, $I_D = -I_s = -1\ \mu$A (from the curve) and

$$R_D = \frac{V_D}{I_D} = \frac{10\text{ V}}{1\ \mu\text{A}} = \mathbf{10\ M\Omega}$$

Diode Equivalent circuits /Diode Approximations

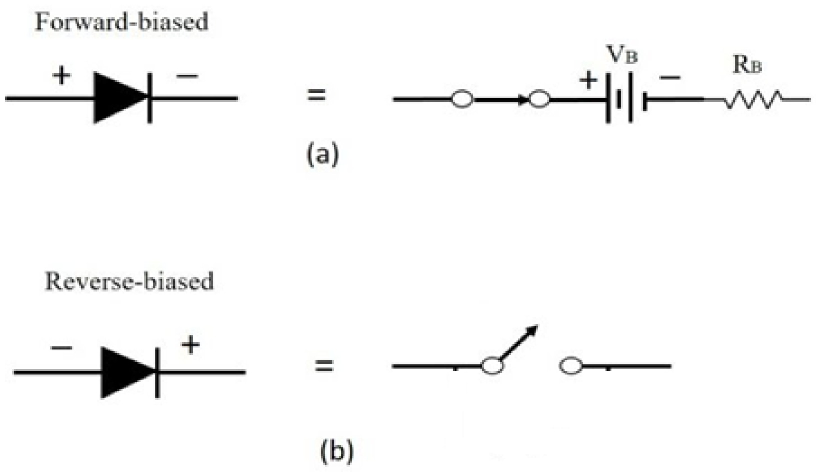
- Diode approximation is a mathematical method used to approximate the nonlinear behavior of real diodes to enable calculations and circuit analysis.

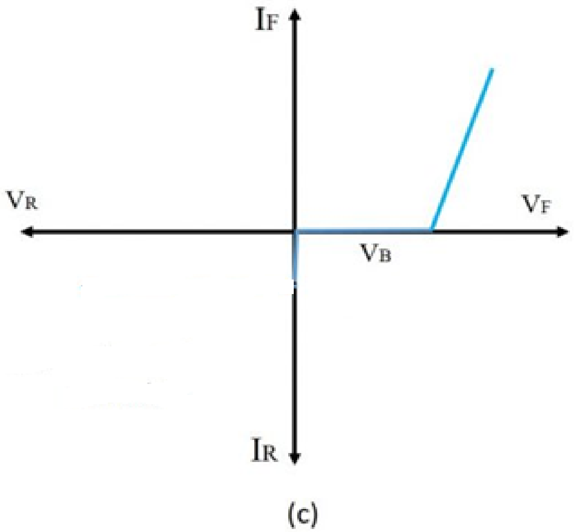
- There are three different approximations used to analyze the diode circuits, namely

I. Piecewise-linear equivalent Circuit
II. Simplified Diode Characteristics
III. Ideal Diode Characteristics

Piece-Wise Linear Diode Characteristics

- **Under forward – bias,** the diode behaves as a practical voltage source with the magnitude equal to the knee voltage in series with the the diodes average ac resistance.
- **Under reverse – bias**, the diode is an open switch and no current flows through it.
- Characteristics resemble closely to that of practical diode.
- The voltage drop across the diode is calculated using the formula $V_d = V_B + I_d * R_B$

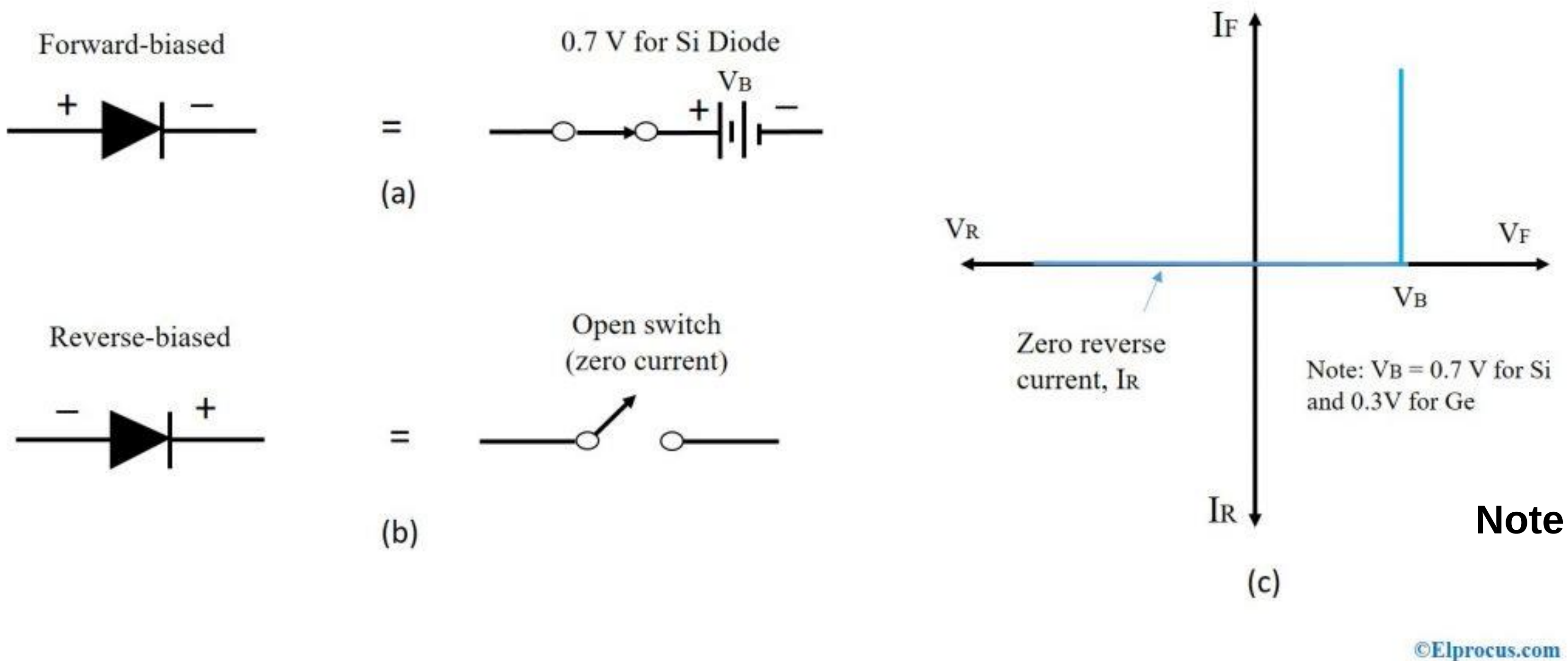




Note V_B = Knee voltage

Simplified Diode Characteristics

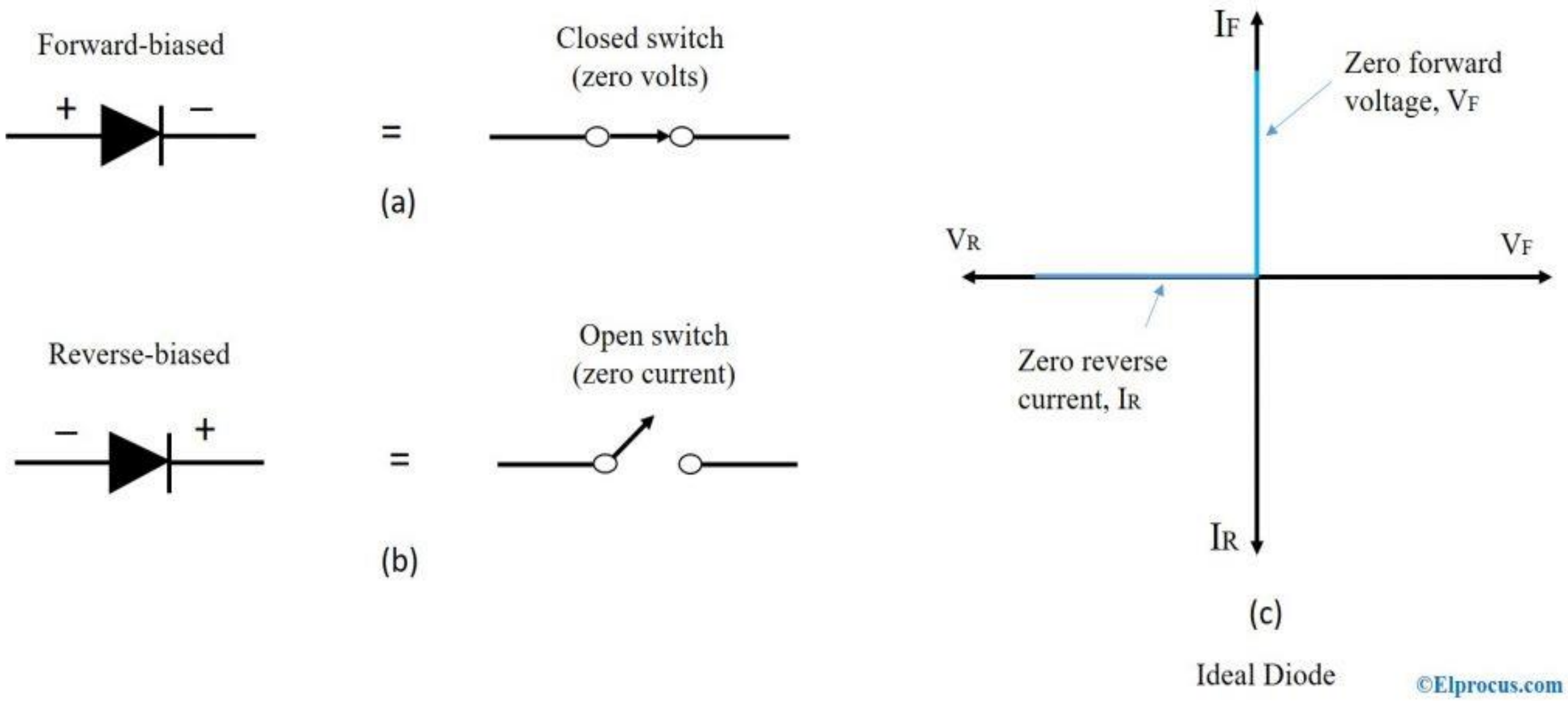
- **Under forward-bias**, the diode turns ON when a voltage of V_K or V_B is applied across it. It turns off if the applied voltage is less than V_K. Thus, the diode is represented by a voltage of V_K in series with a closed switch. Therefore, $V_d = V_B$
- **Under reverse bias**, it is an open switch.



Note V_B = Knee voltage

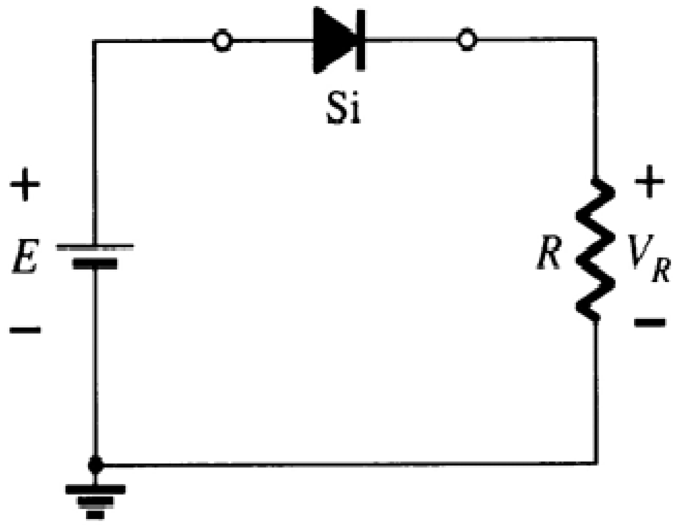
Ideal diode Characteristics

- The diode is considered as a closed switch with zero voltage drop when forward-biased ($V_d = 0$) and as an open switch when reverse biased

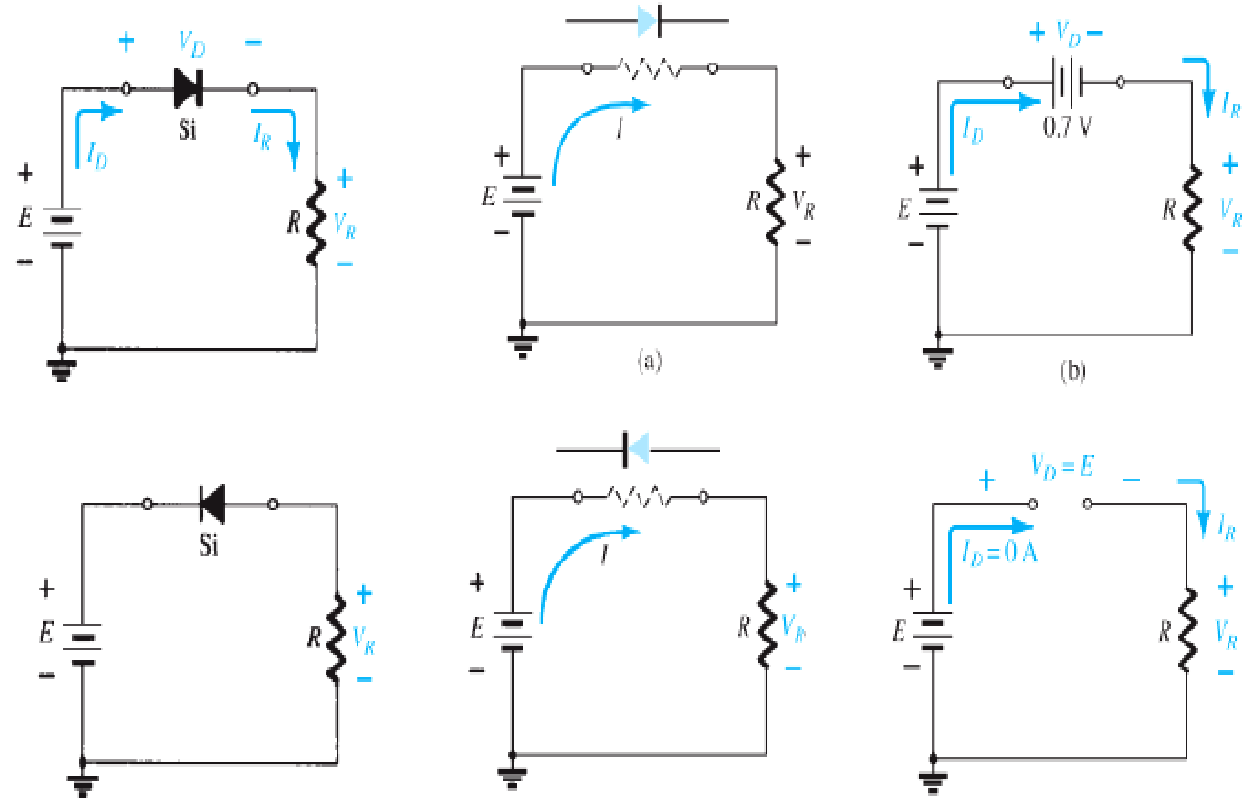


Series Diode Configuration with a resistor

- It's assumed that the forward resistance of the diode is usually so small compared to the other series elements of the network that it can be ignored.
- In general, a diode is in the "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 the applied voltage across diode (V_D) is:
  - **Silicon Diode: $V_D \geq 0.7$ V**
  - **Germanium Diode: $V_D \geq 0.3$ V**
  - **Gallium Arsenide: $V_D \geq 1.2$ V**



Series Diode Configuration with a resistor



Forward Bias Analysis (using simplified equivalent)

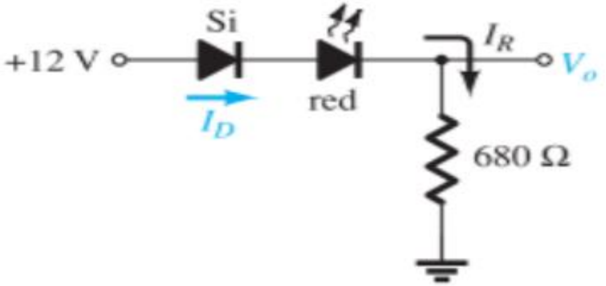
- V_D = 0.7 V (or $V_D = E$ if $E < 0.7$ V)
- $V_R = E - V_D$
- $I_D = I_R = I_T = V_R / R$

Reverse Bias Analysis

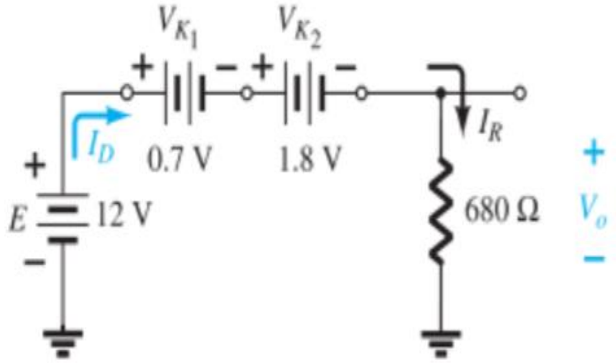
- V_D = E;
- V_R = 0 V &
- I_D = 0 A

Series Diode Configuration – A Solved Problem

1. Determine Vout and Id for the given series diode Circuit. Assume the LED Voltage as 1.8 V.



Solution: Re-draw the given circuit based on simplified diode's configuration, we get

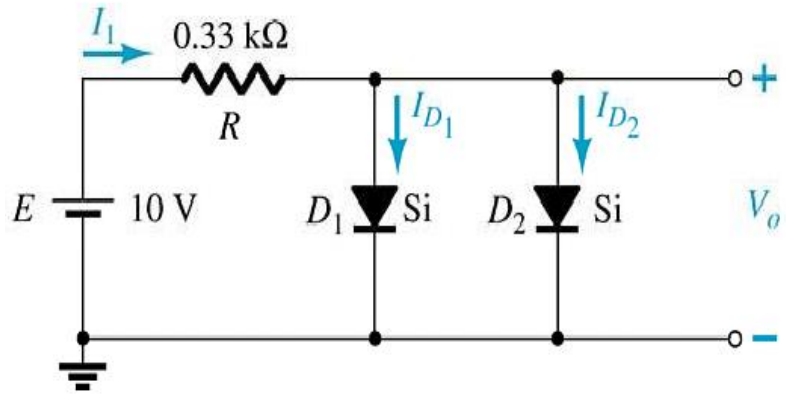


$$V_o = E - V_{K_1} - V_{K_2} = 12\text{ V} - 2.5\text{ V} = \mathbf{9.5\ V}$$

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

Parallel Diode Configuration - A Solved Problem

2. Determine Vo , I_1 , I_{D1}, and I_{D2} for the parallel diode configuration of Figure below



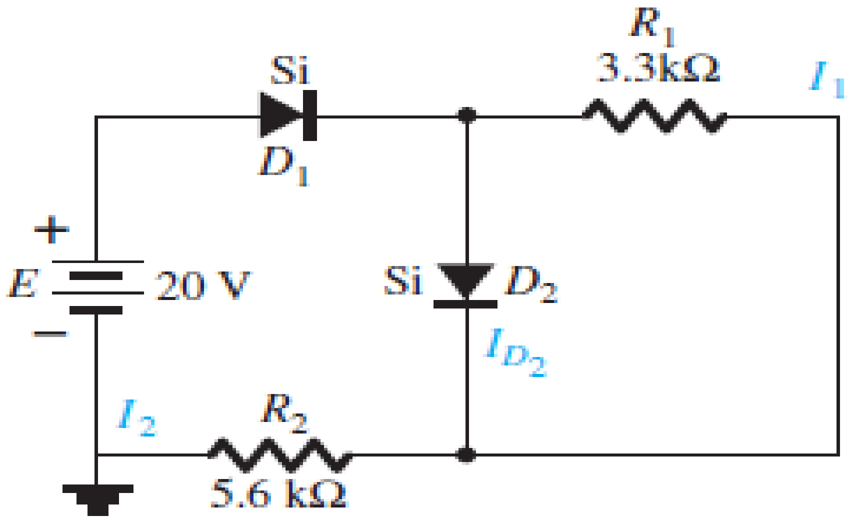
Solution: $V_o = 0.7\ \text{V}$

$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\ \text{V} - 0.7\ \text{V}}{0.33\ \text{k}\Omega} = 28.18\ \text{mA}$$

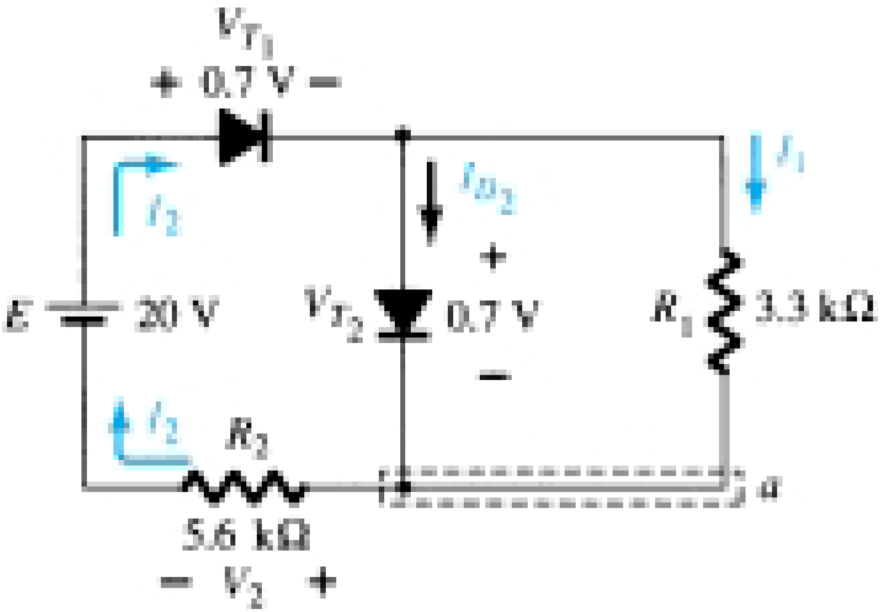
$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\ \text{mA}}{2} = 14.09\ \text{mA}$$

Series-Parallel Diode Configuration

3. Determine I_1, I_2, and I_{D2} for the series- parallel diode configuration of Figure below



Series-Parallel Diode Configuration – An Exercise Problem



$$-V_2 + E - V_{T_1} - V_{T_2} = 0$$

$$V_2 = E - V_{T_1} - V_{T_2} = 20\text{ V} - 0.7\text{ V} - 0.7\text{ V} = 18.6\text{ V}$$

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

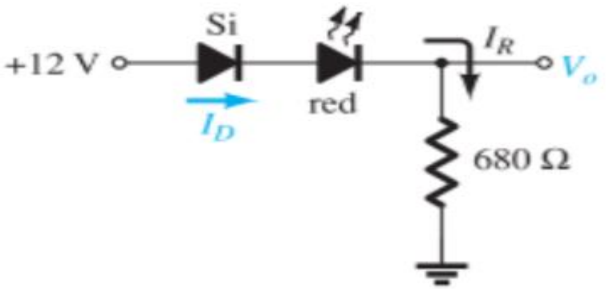
$$I_1 = \frac{V_{T_2}}{R_1} = \frac{0.7\text{ V}}{3.3\text{ k}\Omega} = \mathbf{0.212\text{ mA}}$$

$$I_{D_2} + I_1 = I_2$$

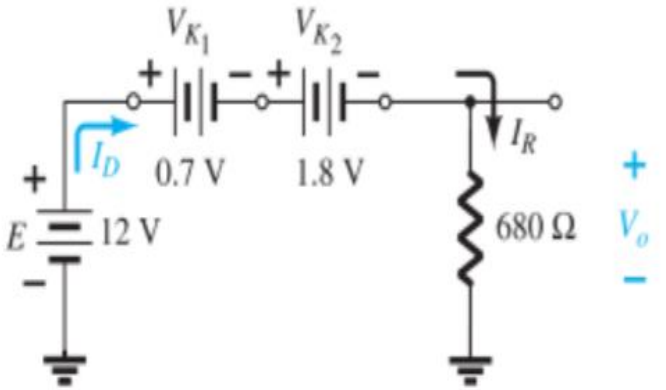
$$I_{D_2} = I_2 - I_1 = 3.32\text{ mA} - 0.212\text{ mA} = \mathbf{3.108\text{ mA}}$$

Series Diode Configuration – A Solved Problem

4. Determine V_{out} and I_d for the given series diode Circuit. Assume the LED Voltage as 1.8 V.



Solution: Re-draw the given circuit based on simplified diode's configuration, we get

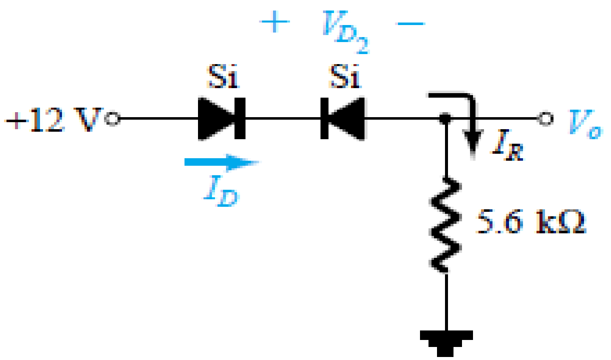


$$V_o = E - V_{K_1} - V_{K_2} = 12\text{ V} - 2.5\text{ V} = \mathbf{9.5\ V}$$

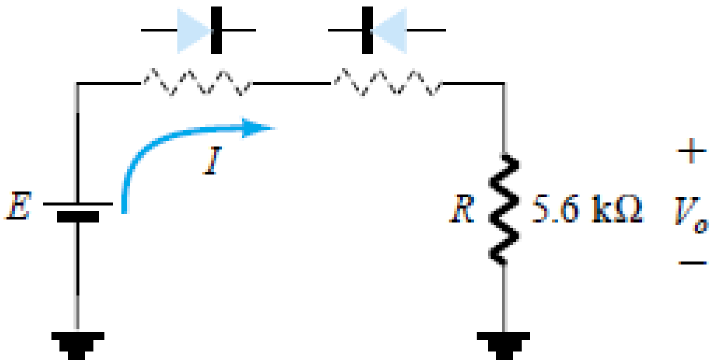
$$I_D = I_R = \frac{V_R}{R} = \frac{V_o}{R} = \frac{9.5\text{ V}}{680\ \Omega} = \mathbf{13.97\ mA}$$

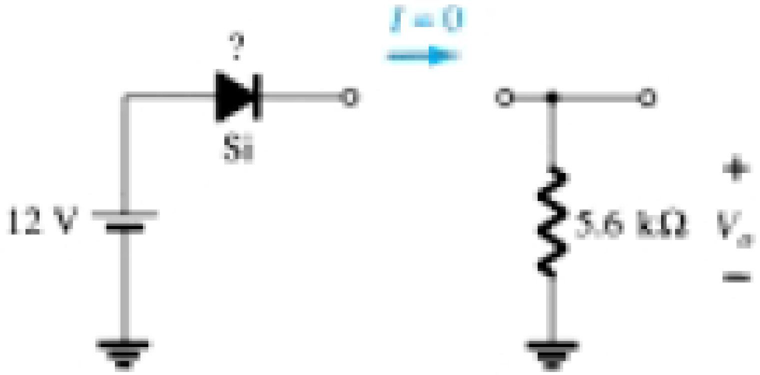
Series Diode Configuration

5. Determine I_D, V_{D2} and V_o



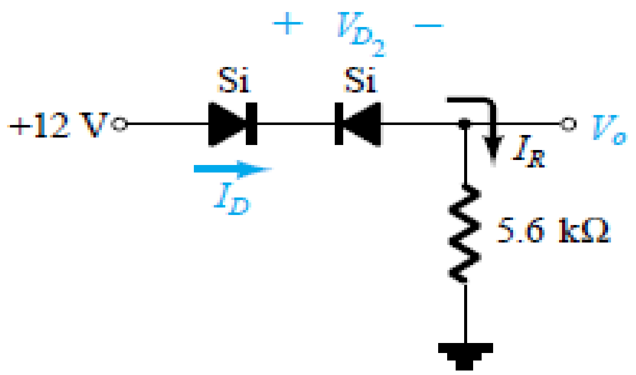
Solution: Re-draw the given circuit based on simplified diode's configuration, we get





Series Diode Configuration

$$V_o = I_R R = I_D R = (0\text{ A})R = 0\text{ V}$$



$$E - V_{D_1} - V_{D_2} - V_o = 0$$

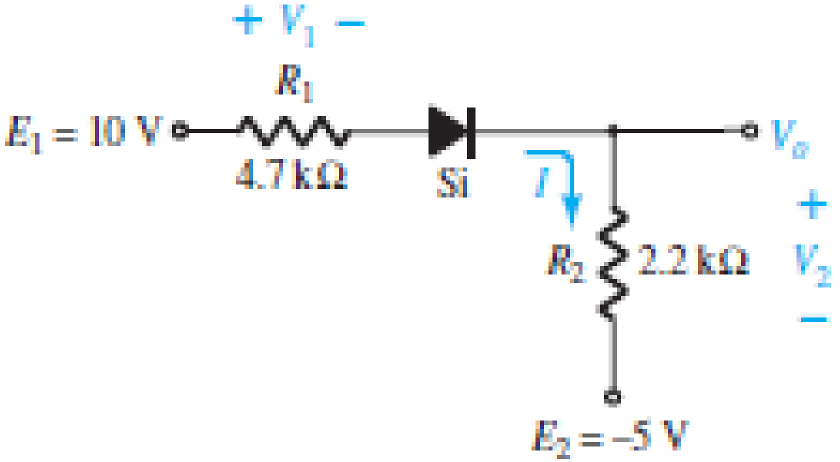
$$V_{D_2} = E - V_{D_1} - V_o = 12\text{ V} - 0 - 0$$

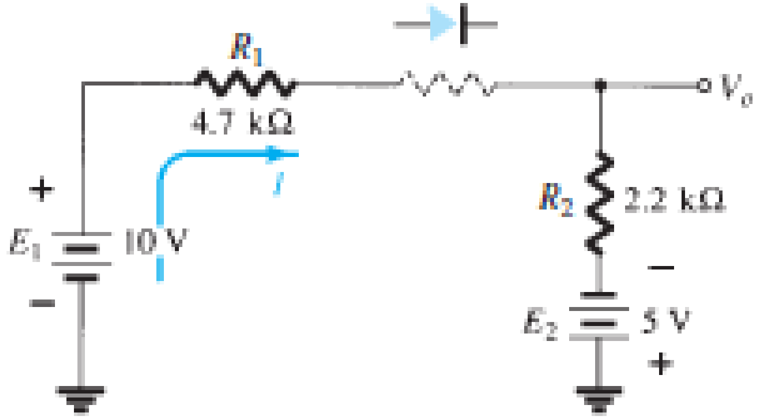
$$= \mathbf{12\ V}$$

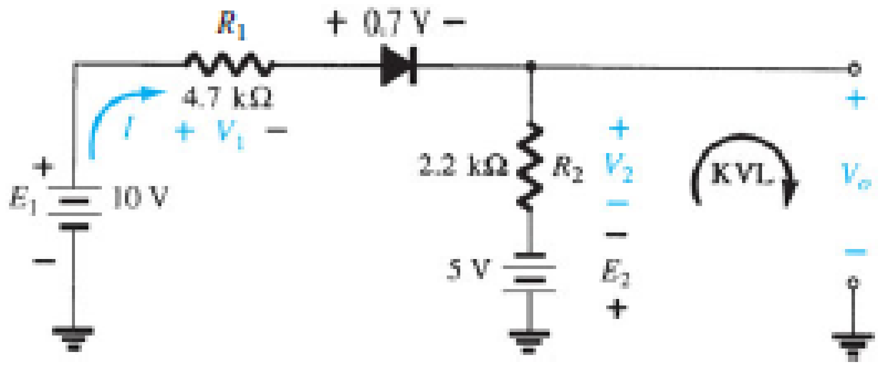
$$V_o = \mathbf{0\ V}$$

Series Diode Configuration

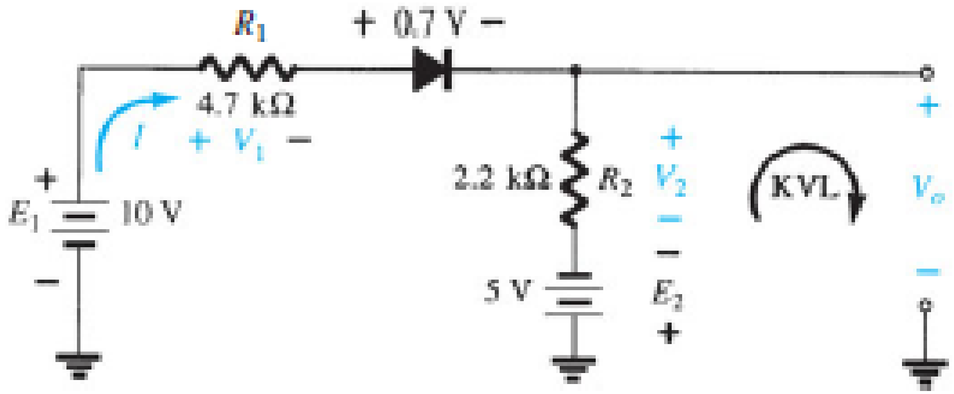
6. Determine I, V_1, V_2 and V_0







Series Diode Configuration

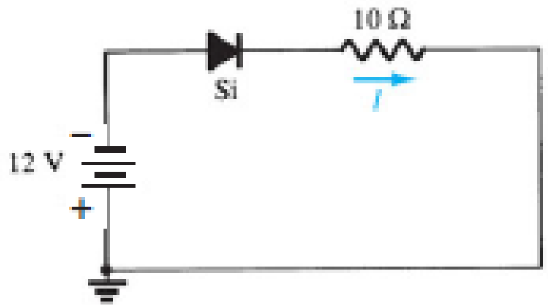


$$I = \frac{E_1 + E_2 - V_D}{R_1 + R_2} = \frac{10\text{ V} + 5\text{ V} - 0.7\text{ V}}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = \frac{14.3\text{ V}}{6.9\text{ k}\Omega}$$
$$\cong \mathbf{2.07\text{ mA}}$$

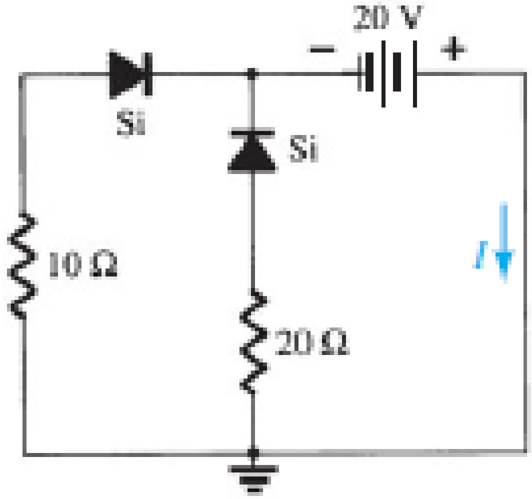
$$V_1 = IR_1 = (2.07\text{ mA})(4.7\text{ k}\Omega) = \mathbf{9.73\text{ V}}$$
$$V_2 = IR_2 = (2.07\text{ mA})(2.2\text{ k}\Omega) = \mathbf{4.55\text{ V}}$$

$$-E_2 + V_2 - V_o = 0$$
$$V_o = V_2 - E_2 = 4.55\text{ V} - 5\text{ V} = \mathbf{-0.45\text{ V}}$$

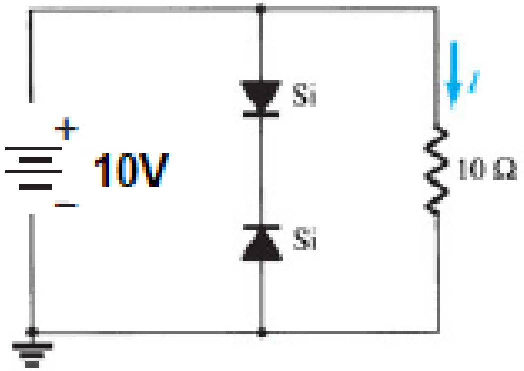
7. Determine the current I for each of the configurations



(a)



(b)



(c)

(a) $I = \mathbf{0\ mA}$; diode reverse-biased.

(b) $V_{20\Omega} = 20\text{ V} - 0.7\text{ V} = 19.3\text{ V}$ (Kirchhoff's voltage law)

$$I(20\ \Omega) = \frac{19.3\text{ V}}{20\ \Omega} = 0.965\text{ A}$$

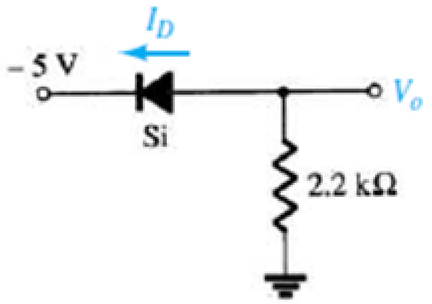
$$V(10\ \Omega) = 20\text{ V} - 0.7\text{ V} = 19.3\text{ V}$$

$$I(10\ \Omega) = \frac{19.3\text{ V}}{10\ \Omega} = 1.93\text{ A}$$

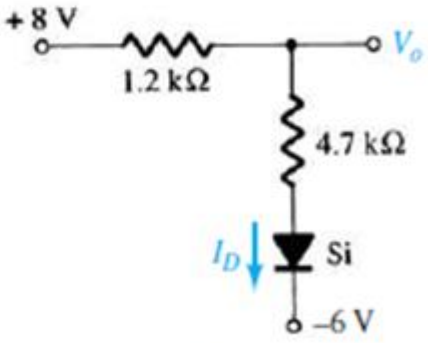
$$I = I(10\ \Omega) + I(20\ \Omega)$$
$$= \mathbf{2.895\ A}$$

(c) $I = \dfrac{10\text{ V}}{10\ \Omega} = \mathbf{1\ A}$; center branch open

8. Determine V_0 and I_D for the networks



(a)



(b)

(a) Diode forward-biased,

Kirchhoff's voltage law (CW): $-5\text{ V} + 0.7\text{ V} - V_o = 0$

$$V_o = \mathbf{-4.3\ V}$$

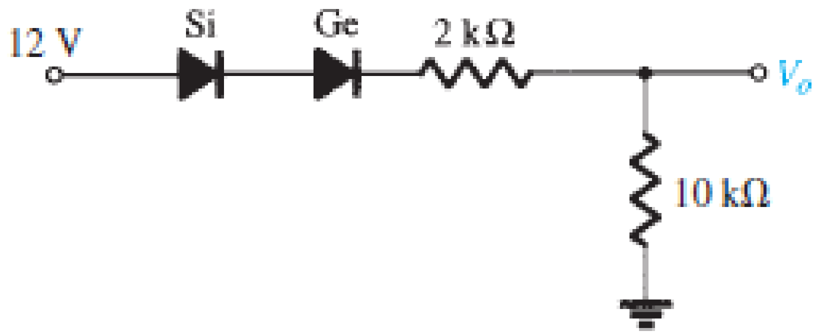
$$I_R = I_D = \frac{|V_o|}{R} = \frac{4.3\text{ V}}{2.2\text{ k}\Omega} = \mathbf{1.955\ mA}$$

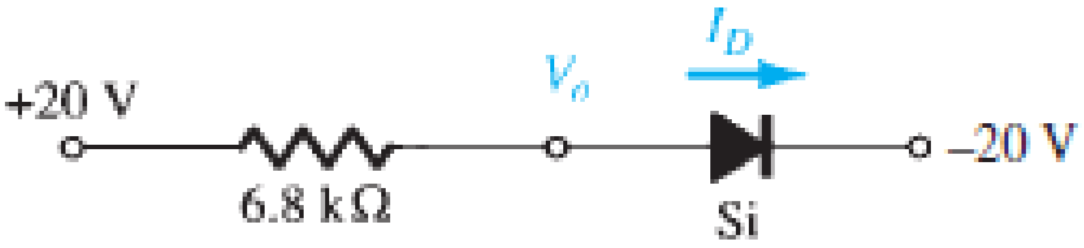
(b) Diode forward-biased,

$$I_D = \frac{8\text{ V} + 6\text{ V} - 0.7\text{ V}}{1.2\text{ k}\Omega + 4.7\text{ k}\Omega} = \mathbf{2.25\ mA}$$

$$V_o = 8\text{ V} - (2.25\text{ mA})(1.2\text{ k}\Omega) = \mathbf{5.3\ V}$$

9. Determine the level of V_0 for each network





(a) $$V_o = \frac{10\ \text{k}\Omega(12\ \text{V} - 0.7\ \text{V} - 0.3\ \text{V})}{2\ \text{k}\Omega + 10\ \text{k}\Omega} = \mathbf{9.17\ V}$$

(b) Diode forward-biased

$$I_D = \frac{20\ \text{V} + 20\ \text{V} - 0.7\ \text{V}}{6.8\ \text{k}\Omega} = \mathbf{5.78\ mA}$$

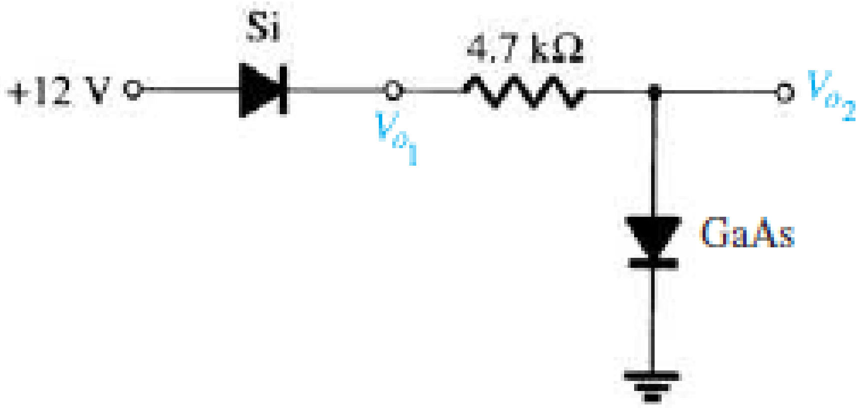
Kirchhoff's voltage law (CW):

$$+V_o - 0.7\ \text{V} + 20\ \text{V} = 0$$

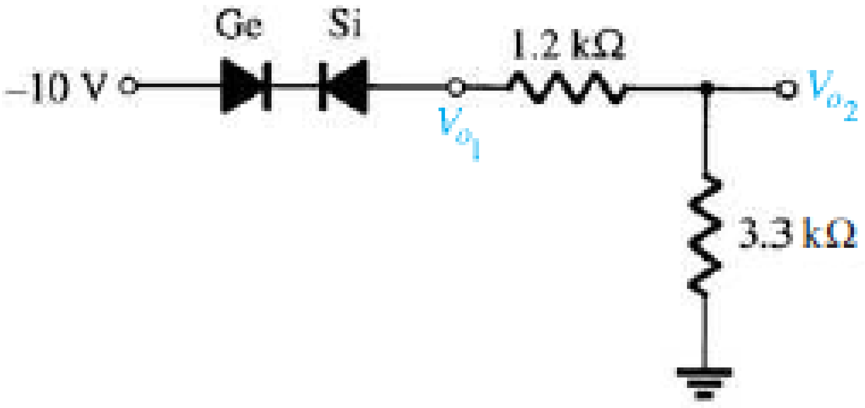
$$V_o = \mathbf{-19.3\ V}$$

Series Diode Configuration

10. Determine V_{01} and V_{02} for the circuits



(a)



(b)

(a) $V_{o_1} = 12\text{ V} - 0.7\text{ V} = \mathbf{11.3\text{ V}}$

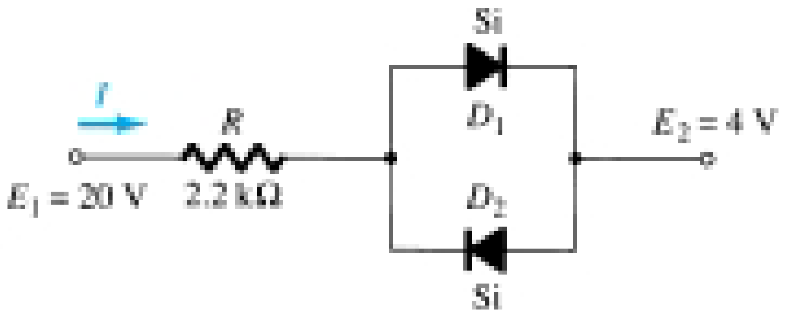
$V_{o_2} = \mathbf{1.2\text{ V}}$

(b) $V_{o_1} = \mathbf{0\text{ V}}$

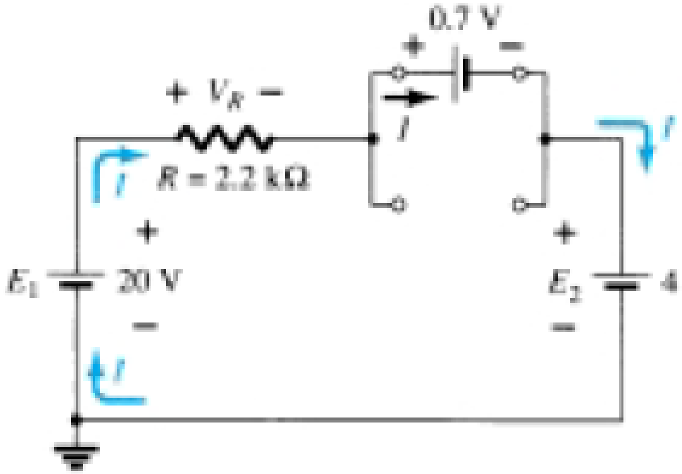
$V_{o_2} = \mathbf{0\text{ V}}$

Parallel Diode Configuration - A Solved Problem

11. Determine I for the parallel diode configuration of Figure below



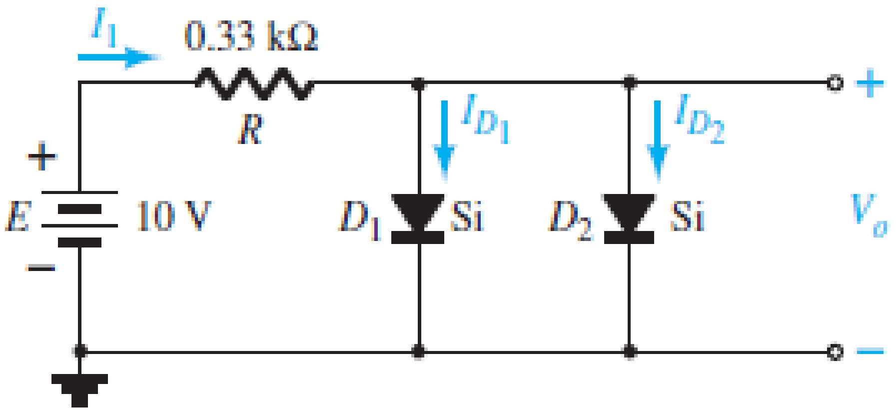
Solution:

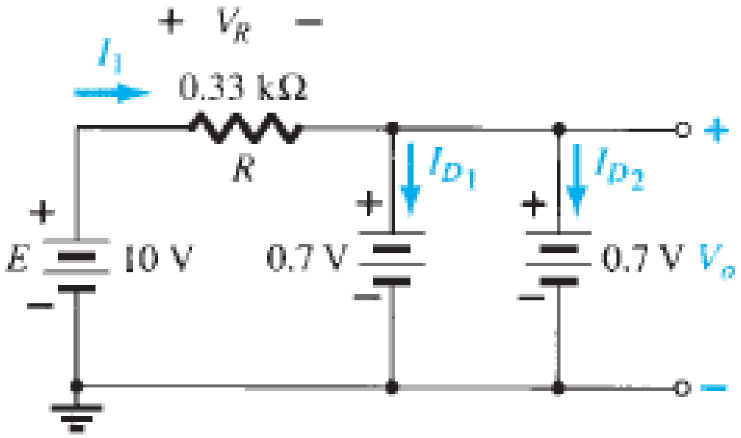


$$I = \frac{E_1 - E_2 - V_D}{R} = \frac{20\text{ V} - 4\text{ V} - 0.7\text{ V}}{2.2\text{ k}\Omega} \cong \mathbf{6.95\text{ mA}}$$

Parallel Diode Configuration - A Solved Problem

12. Determine V_0, I_1, I_2 in the diode circuit





$$V_o = 0.7\ \text{V}$$

The current is

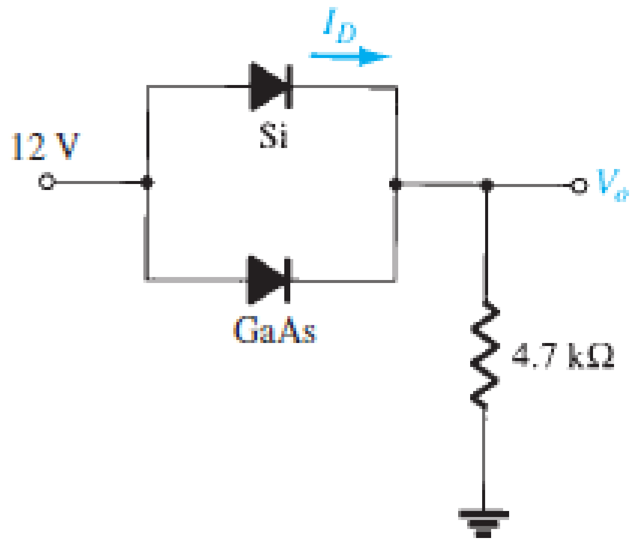
$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\ \text{V} - 0.7\ \text{V}}{0.33\ \text{k}\Omega} = 28.18\ \text{mA}$$

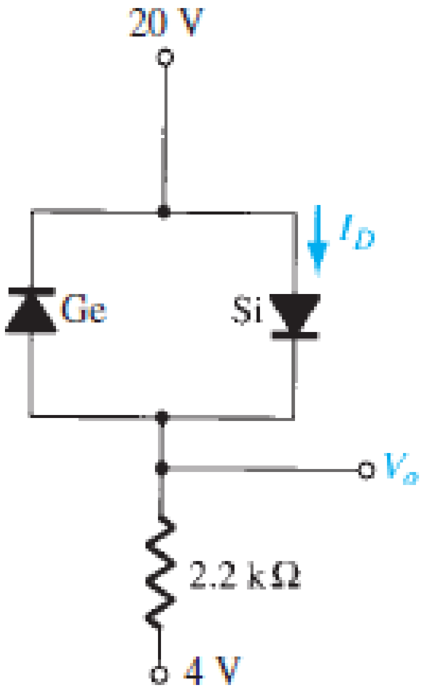
Assuming diodes of similar characteristics, we have

$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\ \text{mA}}{2} = 14.09\ \text{mA}$$

Parallel Diode Configuration - A Solved Problem

13. Determine I_D and V_0 for the circuits shown





(a) Both diodes forward-biased
Si diode turns on first and locks in 0.7 V drop.

$$I_R = \frac{12\text{ V} - 0.7\text{ V}}{4.7\text{ k}\Omega} = 2.4\text{ mA}$$

$$I_D = I_R = \mathbf{2.4\text{ mA}}$$

$$V_o = 12\text{ V} - 0.7\text{ V} = \mathbf{11.3\text{ V}}$$

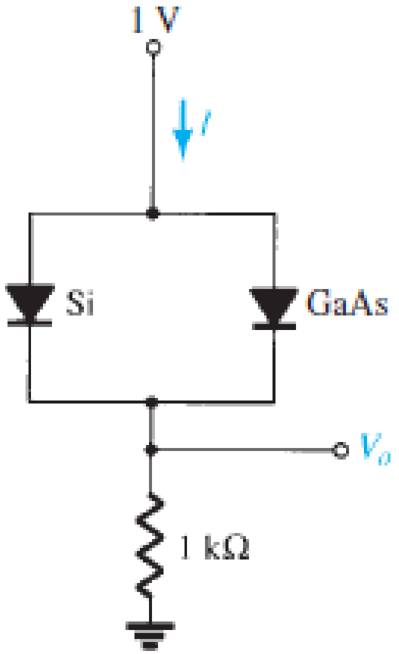
(b) Right diode forward-biased:

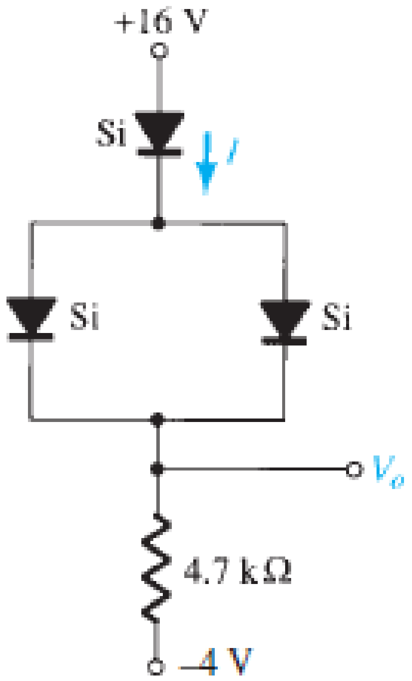
$$I_D = \frac{20\text{ V} + 4\text{ V} - 0.7\text{ V}}{2.2\text{ k}\Omega} = \mathbf{10.59\text{ mA}}$$

$$V_o = 20\text{ V} - 0.7\text{ V} = \mathbf{19.3\text{ V}}$$

Parallel Diode Configuration - A Solved Problem

14. Determine I and V_0 for the circuits shown





Si diode "on" preventing GaAs diode from turning "on":

$$I = \frac{1\text{ V} - 0.7\text{ V}}{1\text{ k}\Omega} = \frac{0.3\text{ V}}{1\text{ k}\Omega} = \mathbf{0.3\text{ mA}}$$

$$V_o = 1\text{ V} - 0.7\text{ V} = \mathbf{0.3\text{ V}}$$

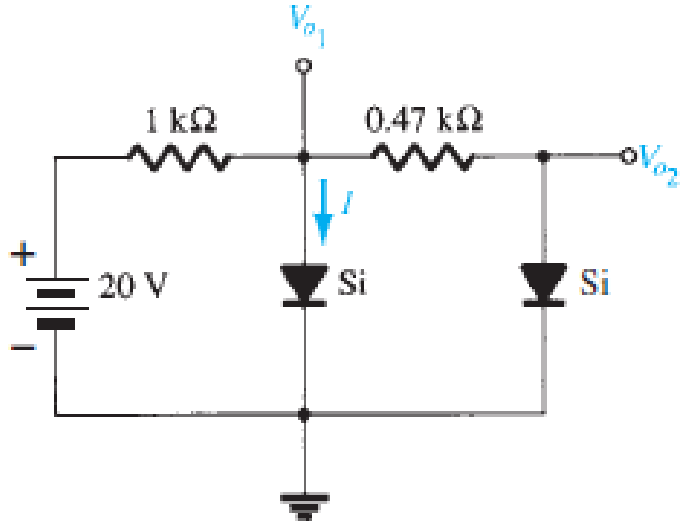
$$I = \frac{16\text{ V} - 0.7\text{ V} - 0.7\text{ V} + 4\text{ V}}{4.7\text{ k}\Omega} = \frac{18.6\text{ V}}{4.7\text{ k}\Omega} = \mathbf{3.96\text{ mA}}$$

$$V_o = 16\text{ V} - 0.7\text{ V} - 0.7\text{ V} = \mathbf{14.6\text{ V}}$$

Parallel Diode Configuration - A Solved Problem

PES UNIVERSITY

15. Determine I, V_{01} and V_{02}



Both diodes forward-biased:

$V_{o_1} = \mathbf{0.7\ V}$, $V_{o_2} = \mathbf{0.7\ V}$

$$I_{1\,\text{k}\Omega} = \frac{20\text{ V} - 0.7\text{ V}}{1\text{ k}\Omega} = \frac{19.3\text{ V}}{1\text{ k}\Omega} = 19.3\text{ mA}$$

$I_{0.47\,\text{k}\Omega} = 0\text{ mA}$

$I = I_{1\,\text{k}\Omega} - I_{0.47\,\text{k}\Omega} = 19.3\text{ mA} - 0\text{ mA}$

$= \mathbf{19.3\ mA}$

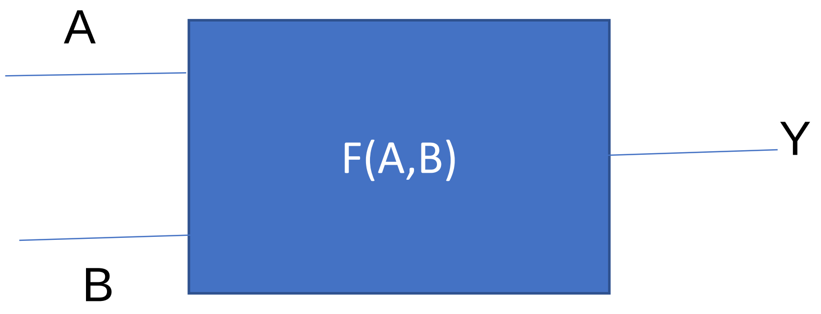
Logical operation:

It is an Operation that acts on binary numbers to produce a result according to the Laws of Boolean Logic.

A Logic Gate is a basic building block of Digital circuits.

Logic gate is considered as a device that has the ability to produce one output level with the combinations of input levels.

Example : AND,OR and NOT functions



Logical operations:

Logic gates are implemented by using diodes, transistors, and by other several devices.

Hence logic gates can also be considered as electronic circuits.

The logic gates obtained by Diode is called Diode Resistor Logic.

Inputs and outputs of logic gates are in two levels which are termed as HIGH and LOW, or TRUE and FALSE, or ON and OFF, or simply 1 and 0.

Logical Operations

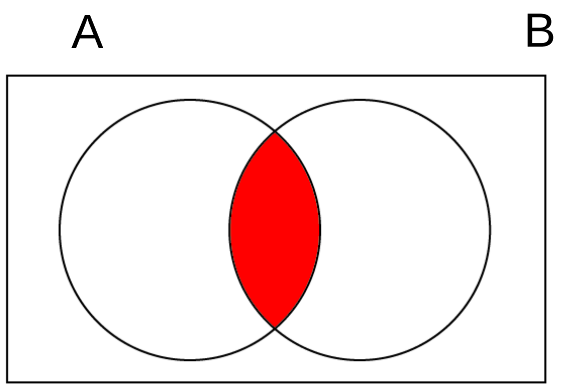
For all logic gates a Table with all combinations is listed out.

The combination of the input variables and the corresponding output is termed as "TRUTH TABLE".

It explains how the logic circuit output responds to various combinations of logic levels at the inputs.

AND Operation is explained by the following Truth Table

A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1



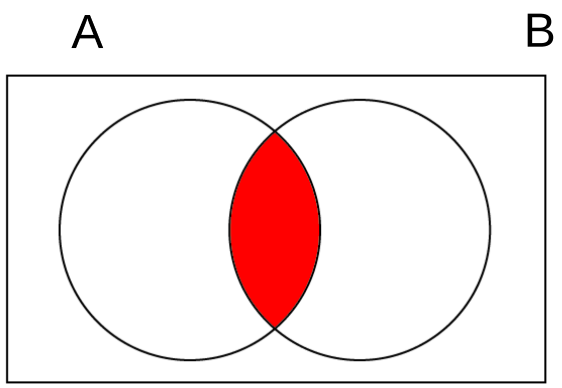
Logical Operations

An AND / OR gate may also have two or more inputs but produces only one output.

AND gate produces an output of logic 1 state when all of its inputs is in logic 1 state and produces an output of logic 0 state if any of its inputs are in logic 0 state.

AND Operation is explained by the following Truth Table

A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1



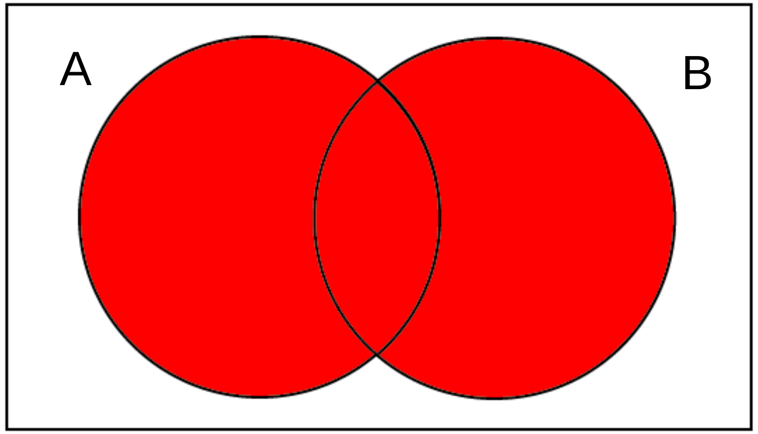
Logical Operations

An AND / OR gate may also have two or more inputs but produces only one output.

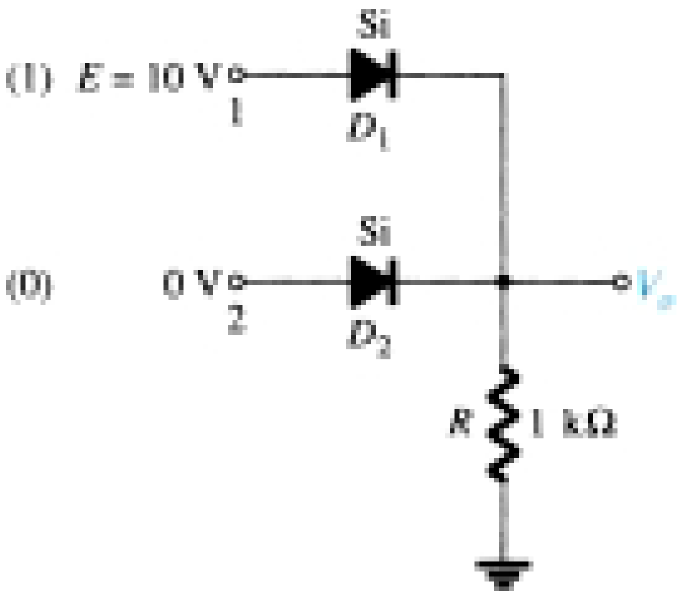
OR gate produces an output of logic 1 state even if any of its inputs is in logic 1 state and produces an output of logic 0 state if all of its inputs are in logic 0 state.

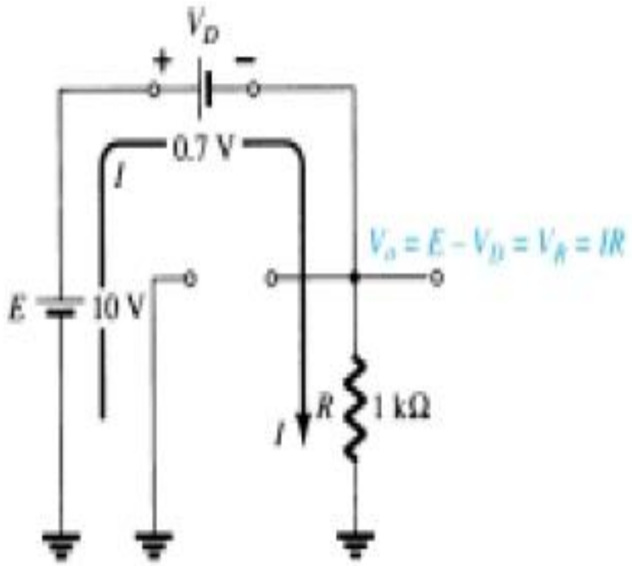
OR Operation is explained by the following Truth Table

A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1



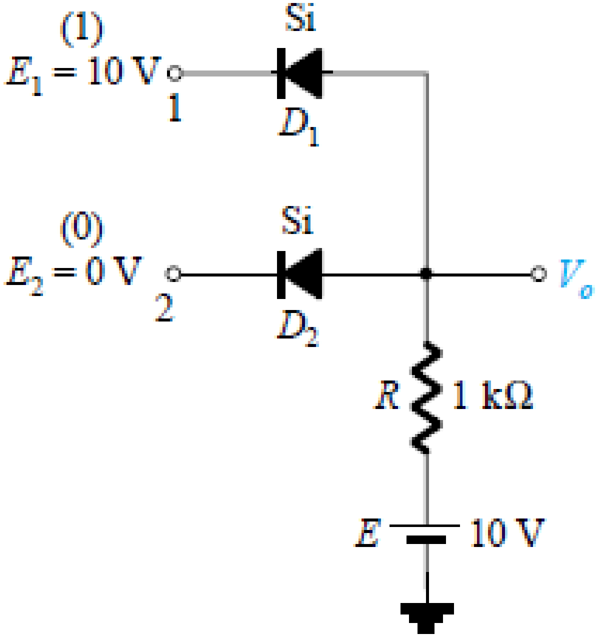
OR Operation Illustrated using Diode

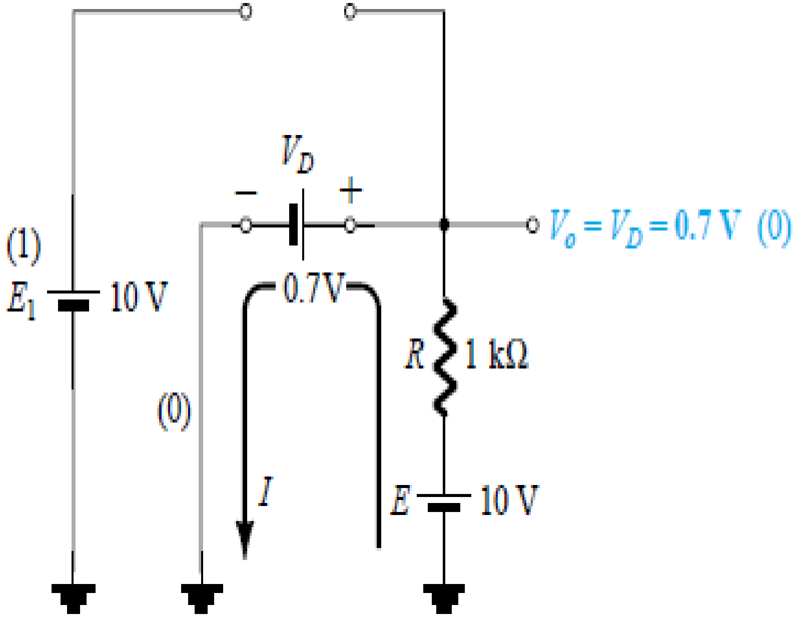




A (V1)	B(V2)	Y (Vo)
0	0	0
0	10 V	9.3 V
10 V	0	9.3 V
10 V	10 V	9.3V

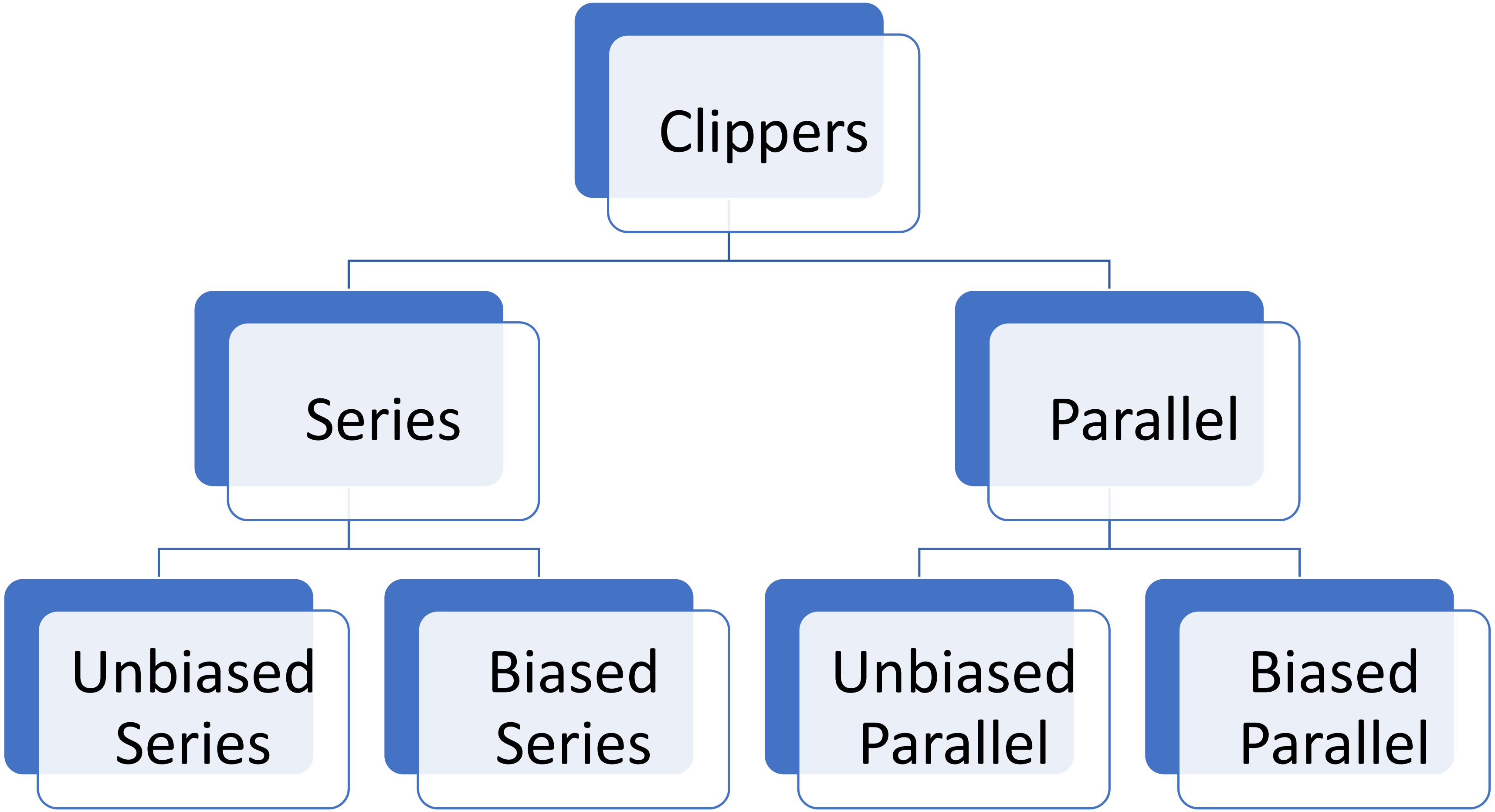
AND Operation Illustrated using Diode





A (V1)	B(V2)	Y(Vo)
0	0	0.7 V
0	10 V	0.7V
10 V	0	0.7V
10 V	10 V	10V

Clippers - Classification



Series Clippers

- The **series configuration** is defined as one where the **diode is in series with the load.**
- Fig.1(a) shows the circuit of a series clipper.
- The response of the series configuration of Fig. 1(a) to a variety of alternating waveforms is shown in Fig. 1(b).
- There are **no boundaries on the type of signals** that can be applied to a clipper.

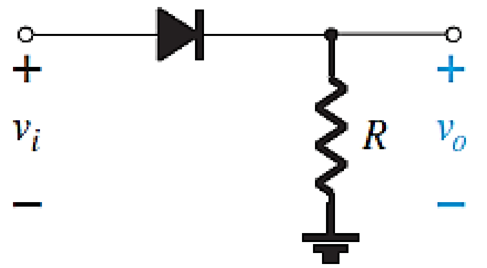


Fig. 1(a): Series Unbiased Clipper

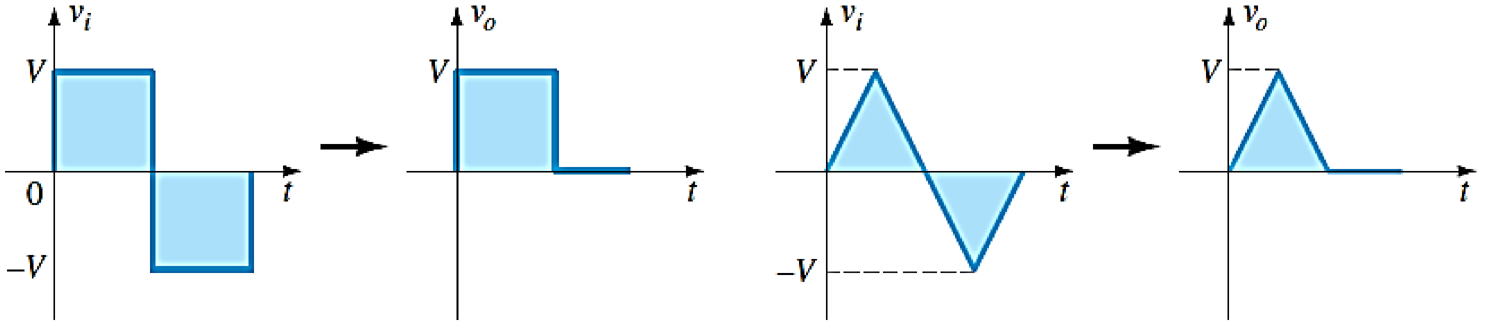


Fig. 1(b): Input-output Waveforms

Series Clippers

- Fig.2 shows the **series clipper with DC supply**. This configuration is called as **biased series clipper**.
- The **addition of a dc supply** to the network as shown in Fig. 2 can have a pronounced effect on the analysis of the series clipper configuration.
- The dc supply can be in the **leg between the supply and output** or in the **branch parallel to the output**.
- The output response is not as obvious because the **dc supply can aid or work against the source voltage.**

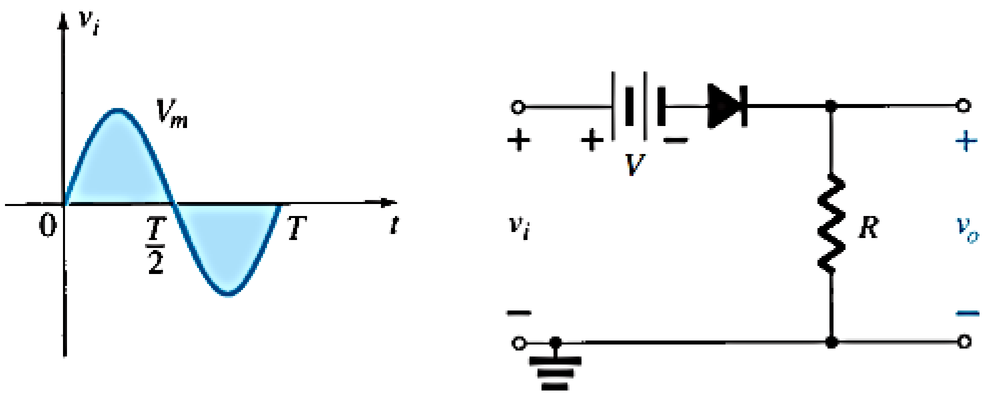


Fig. 2: Series clipper with DC supply

Series Clippers

General instructions for analysis:

1. **Take careful note of where the output voltage is defined.**
2. **Try to develop an overall sense of the response by simply noting the that how the input supply affects the conventional current direction through the diode.**

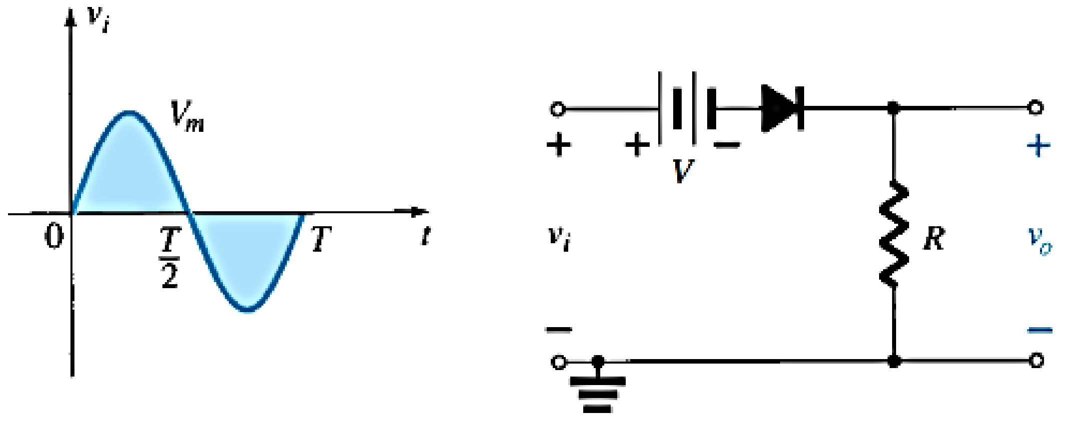


Fig. 2: Series clipper with DC supply

Series Clippers

3. Determine the "transition voltage" that will result in a change of state for the diode from the "OFF" to the "ON" state.

- Note the substitution of the short-circuit equivalent for the ideal diode in **Fig 3**, and the fact that the voltage across the resistor is 0 V because the diode current is 0 mA. The result is **v_i -V = 0 or v_i = V** is the applied (transition) voltage.
- This permits drawing a line on the sinusoidal supply voltage as shown in **Fig. 4** to define the regions where the diode is on and off.

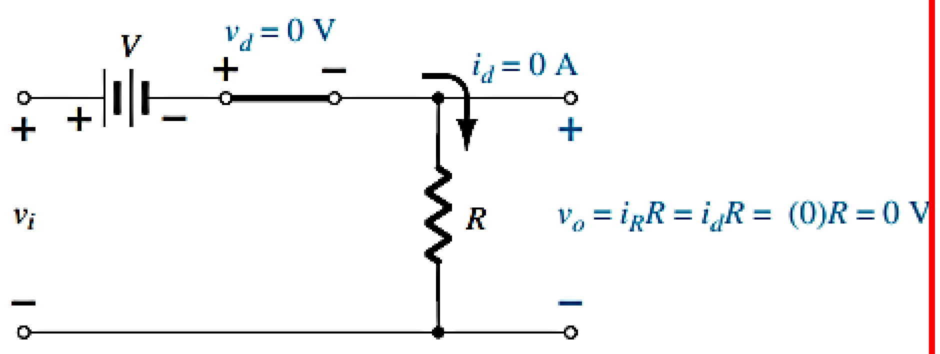


Fig. 3: Determining applied voltage for the circuit

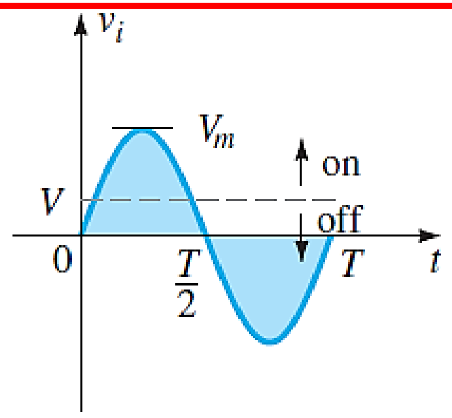


Fig.4: Define the "ON" and "OFF" regions.

Series Clippers

- For the “ON” region, as shown in **Fig. 5**, the output voltage is defined by-
  - $v_o = v_i - V$ .... (1)
- For the “OFF” region, the diode is an open circuit, $I_D = 0$ mA, and the output voltage is
  - $v_o = 0\ V$ ....(2)

4. **It is often helpful to draw the output waveform directly below the applied voltage using the same scales for the horizontal axis and the vertical axis.**

- For the “ON” condition, **Eq. (1)** can be used to find the output voltage when the applied voltage has its peak value:
  - $v_{o\_peak} = V_m - V$ ....(3)
  - Output voltage, v_o is plotted in the **Fig. 6**.

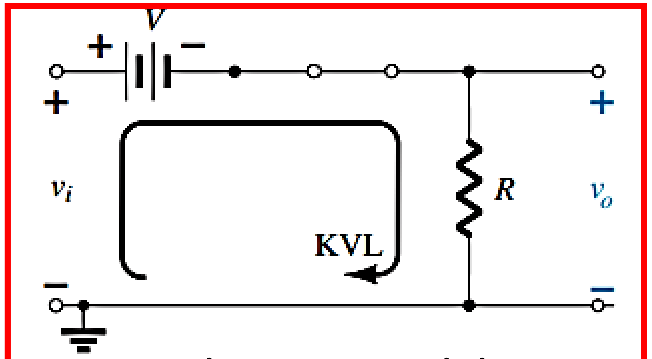


Fig. 5: Determining v_o for the diode in the “ON” state.

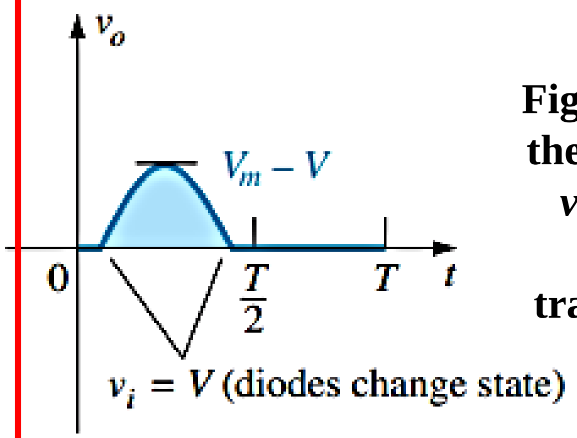


Fig. 6: Sketching the waveform of v_o above and below the transition level.

Series Clippers

EXAMPLE 1: Determine the output waveform for the sinusoidal input of Fig. 7.

Step 1: The output is directly across the resistor R.

Step 2: The positive region of v_i and the dc supply are both working in same direction to turn the diode "ON". The result is that we can safely assume the diode is in the "on" state for the entire range of positive voltages for v_i .

Once the supply goes negative, it would have to exceed the dc supply voltage of 5 V before it could turn the diode "OFF".

Step 3: The transition model is substituted in **Fig. 8**, and we find that the transition from one state to the other will occur when,

$$v_i + 5V = 0V$$

Or $v_i = -5V$ ....(1)

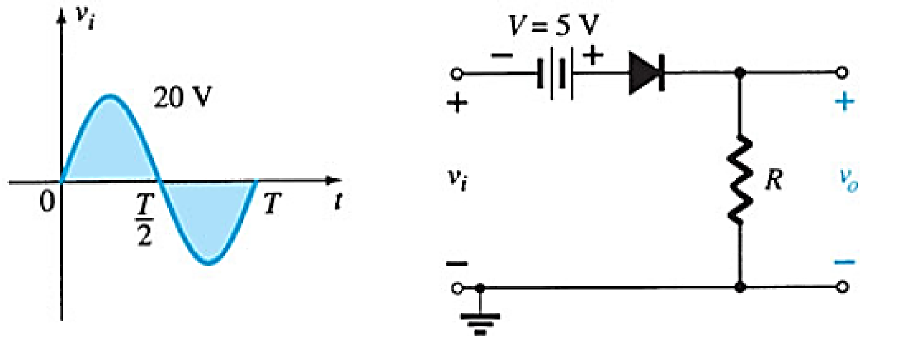


Fig. 7

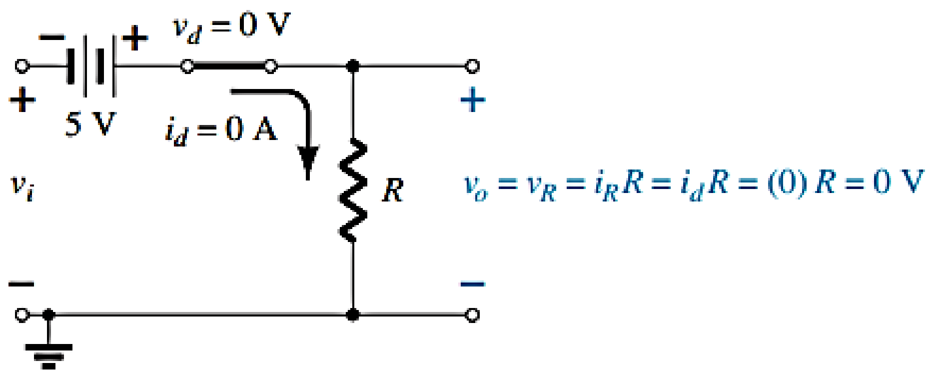


Fig. 8

Series Clippers

EXAMPLE 1 (cont…..)

Step 4: In **Fig. 9** horizontal line is drawn through the applied voltage at the transition level.

For voltages less than 5V the diode is in the open-circuit state and the output is 0 V, as shown in the sketch of v_o .

Using **Fig. 9** , we find that for conditions when the diode is on and the diode current is established the output voltage will be the following, as determined using Kirchhoff's voltage law:

$$v_o = v_i + 5V \text{ …………..(2)}$$

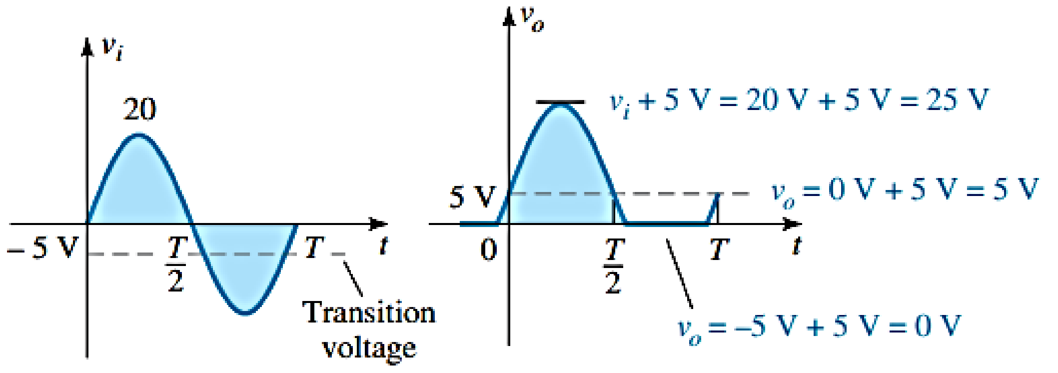


Fig. 9

Note: The analysis of clipper networks with square-wave inputs is actually easier than with sinusoidal inputs because only two levels have to be considered.

Series Clippers

EXAMPLE 2: Find the output voltage for the network examined in previous Example, if the applied signal is the square wave of **Fig. 10**.

- For $\boldsymbol{v_i}$ = 20 V (0 → T/2) the network of **Fig. 11** results. The diode is in the short-circuit state i.e. "ON", and

  $v_o = 20\text{ V} + 5\text{ V} = 25\text{ V}$ …………………(1)

- For $\boldsymbol{v_i}$ = -10 V (T/2 → T) the network of **Fig. 12**, results, moving the diode in the "OFF" state, and

  $v_o = i_R R = (0)R = 0\text{ V}$ ……………………(2)

- The resulting output voltage appears in **Fig. 13**.

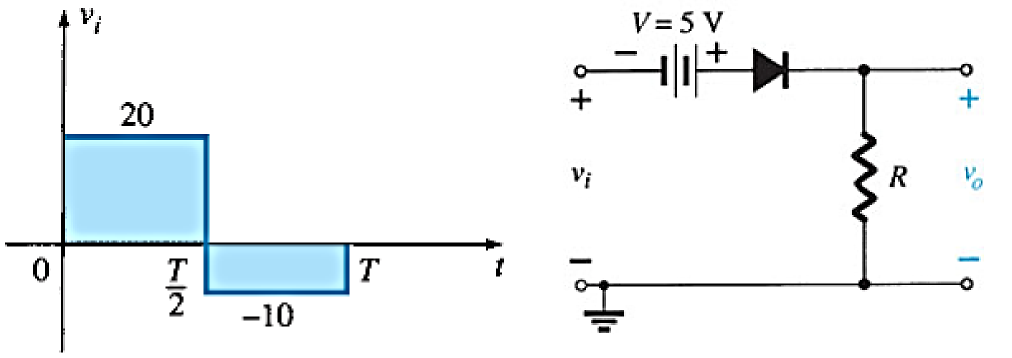


Fig. 10

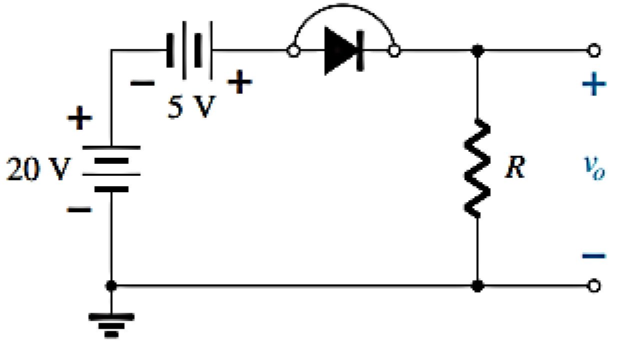


Fig. 11

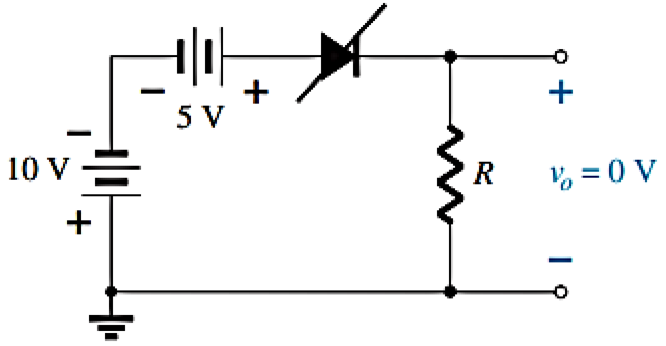


Fig. 12

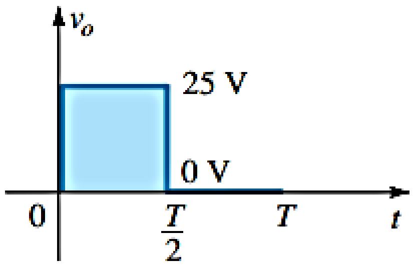


Fig. 13

Parallel Clippers without bias

- In parallel clippers, diode is connected in parallel with the load.
- The analysis of parallel configurations is very similar to that of series configurations.
- The simplest parallel clipper is shown in **Fig 14.**

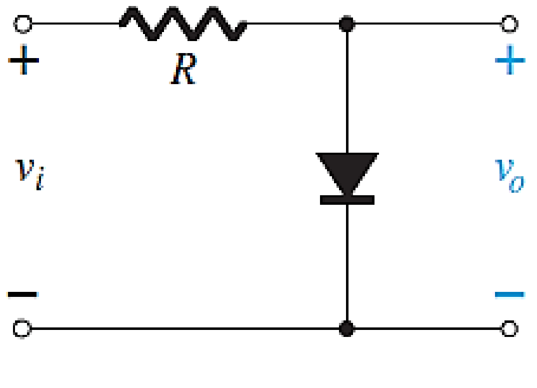


Fig. 14: Parallel Clipper

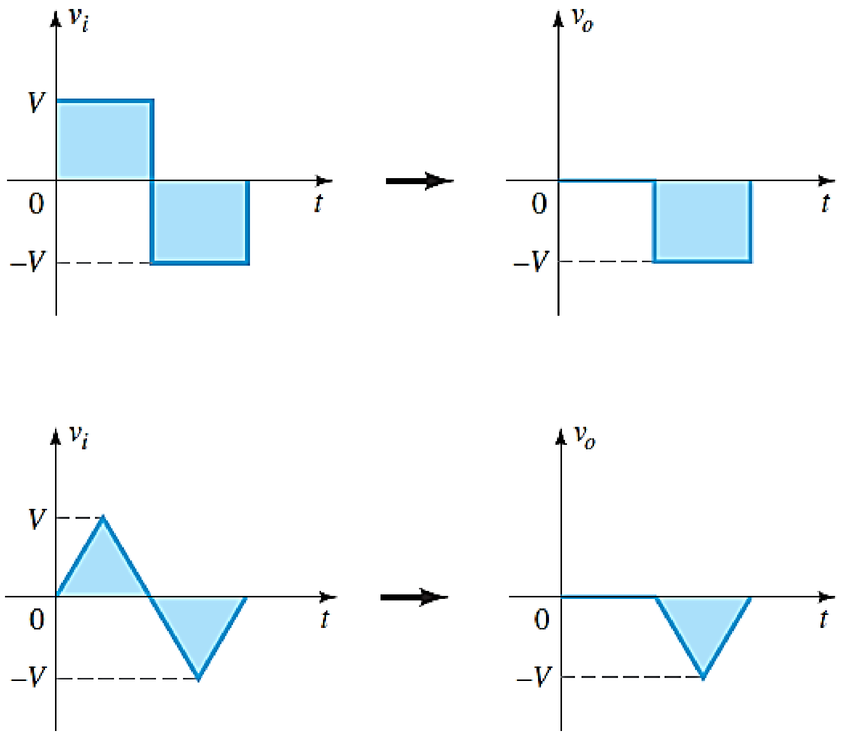


Fig. 15: Response to a parallel clipper.

Parallel Clippers with Bias

EXAMPLE 3: Determine v_o for the network of Fig. 16.

- When the diode is in its short-circuit i.e. “ON” state the output voltage will be directly across the 4-V dc supply, requiring that the output be fixed at 4 V. In other words, when the diode is “ON” the output will be 4 V.
- When the diode is an open circuit i.e. “OFF” state, the current through the series network will be 0 mA and the voltage drop across the resistor will be 0 V. That will result in $\boldsymbol{v_o = v_i}$.

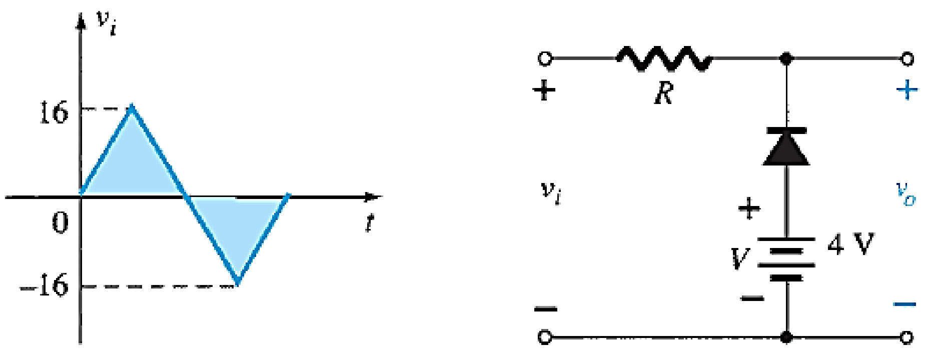


Fig. 16

Parallel Clippers

Example 3 (cont….)

- The transition level of the input voltage can be found from **Fig. 17** by substituting the short-circuit equivalent and remembering the diode current is 0 mA at the instant of transition.
- The result is a change in state when v_i = 4 V

- In **Fig. 18** the transition level is drawn along with v_o = 4 V when the diode is "ON".

Therefore, for v_i >= 4 V, v_o = v_i …………………(1)

And, for v_i <= 4 V, v_o = 4 V, ……………………..……(2)

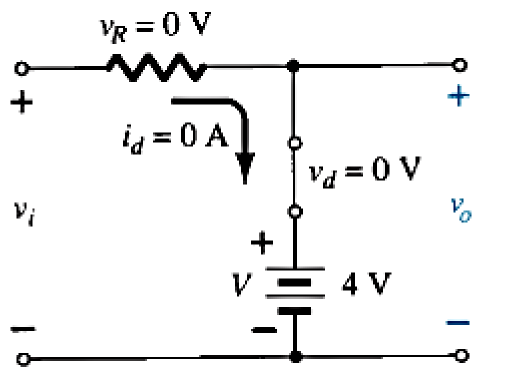


Fig. 17: Determining the transition level

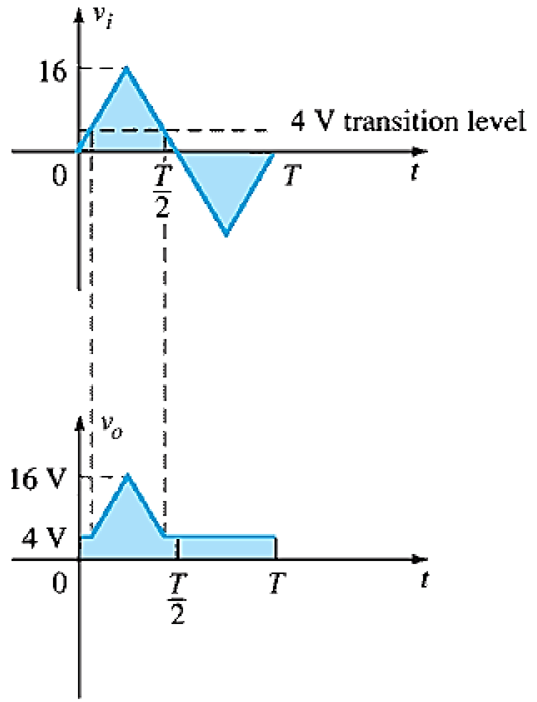


Fig. 18: Output Sketch

Parallel Clippers

EXAMPLE 4: Repeat Example 3, using a **silicon diode with V_K = 0.7 V**.

- Determine Transition voltage
    - Using the condition $i_d = 0$ A at $v_d = V_D = 0.7$ V and obtaining the network of **Fig. 19** .
    - Applying KVL, $v_i + V_K - V = 0$
    - or $v_i = V - V_K = 4\text{ V} - 0.7\text{ V} = 3.3\text{ V}$ ………(1)
- Diode will be "OFF", for $v_i > 3.3$ V (in Fig. 19) and
    - $v_o = v_i$ ………………………………….…….. (2)
- Diode will be "ON", for $v_i < 3.3$ V (in Fig. 20) and
    - $v_o = 4\text{ V} - 0.7\text{ V} = 3.3\text{ V}$ ……………………(3)

- The resulting output waveform appears in **Fig. 21** .
- Note that the only effect of V_K was to drop the transition level to 3.3 from 4 V.

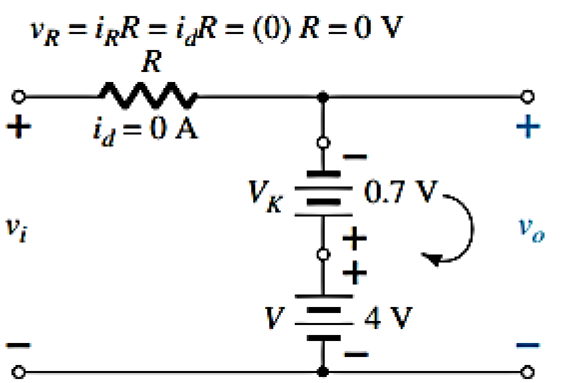


Fig. 19: Determining the output v_o

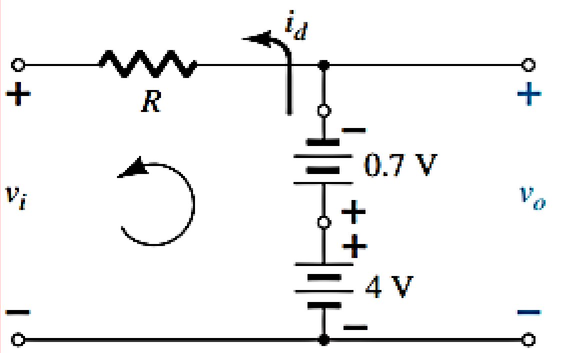


Fig. 20: Determining the output v_o

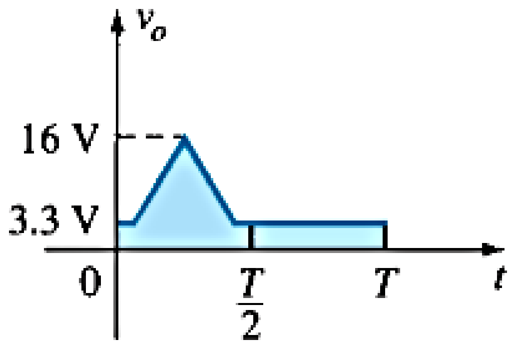
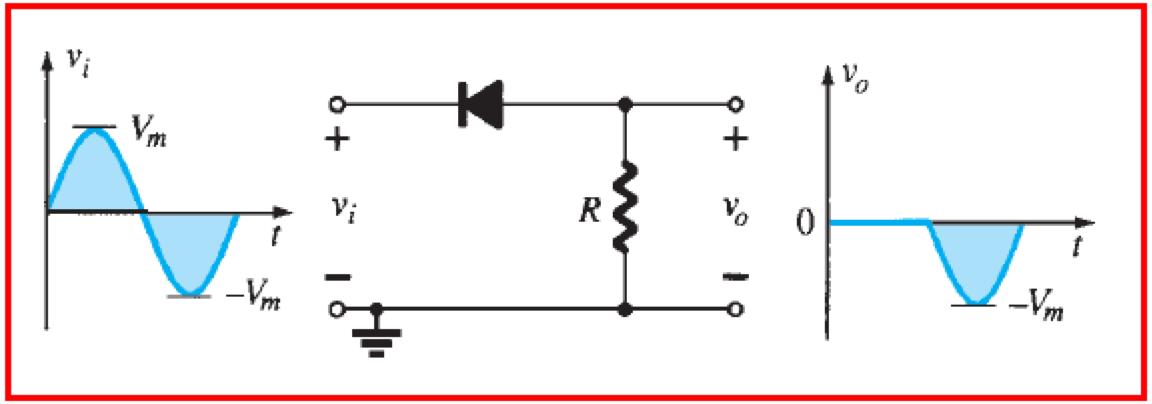


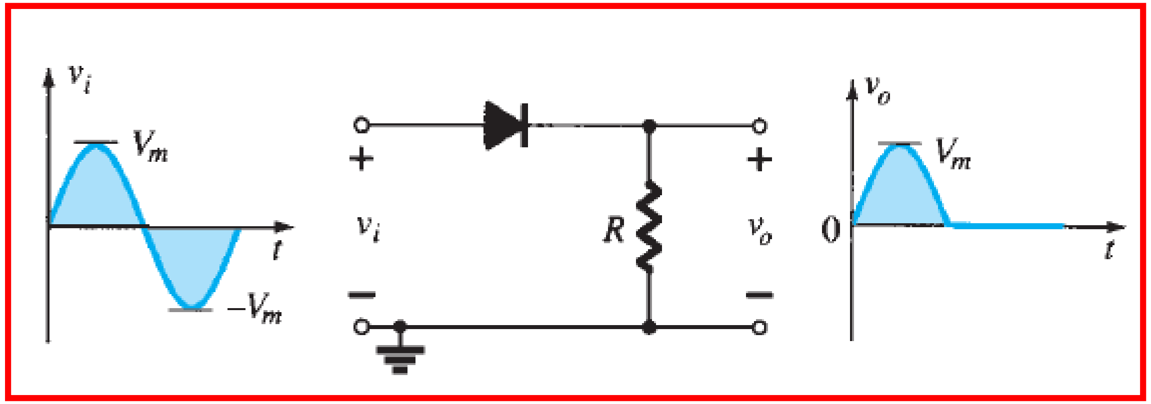
Fig. 21: Sketching v_o

Simple Series Clippers (Ideal Diodes)

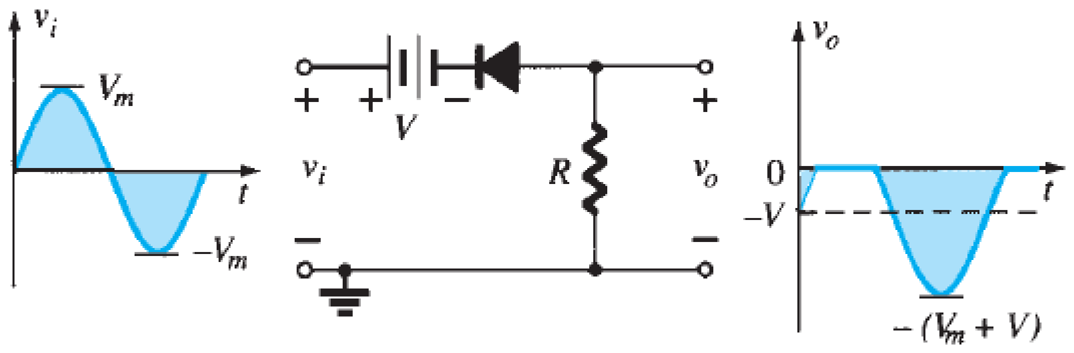


POSITIVE

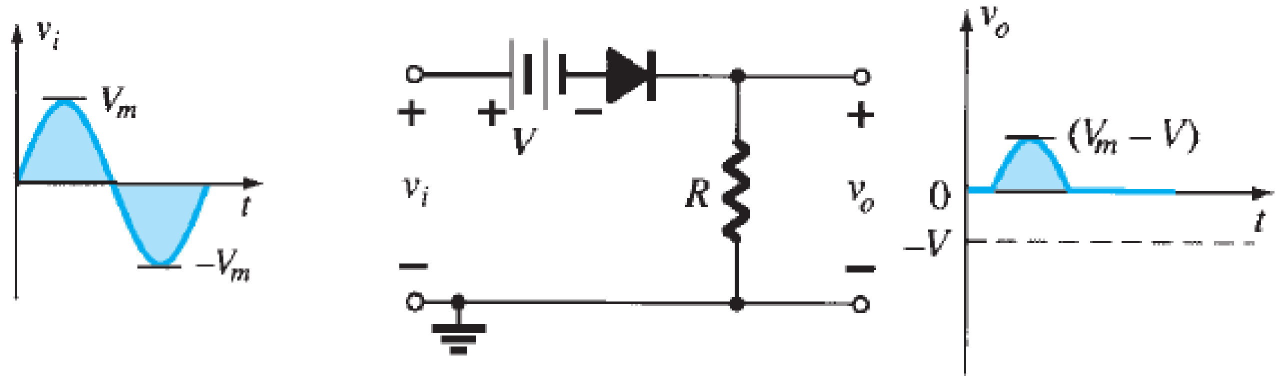
NEGATIVE



Biased Series Clippers (Ideal diodes)

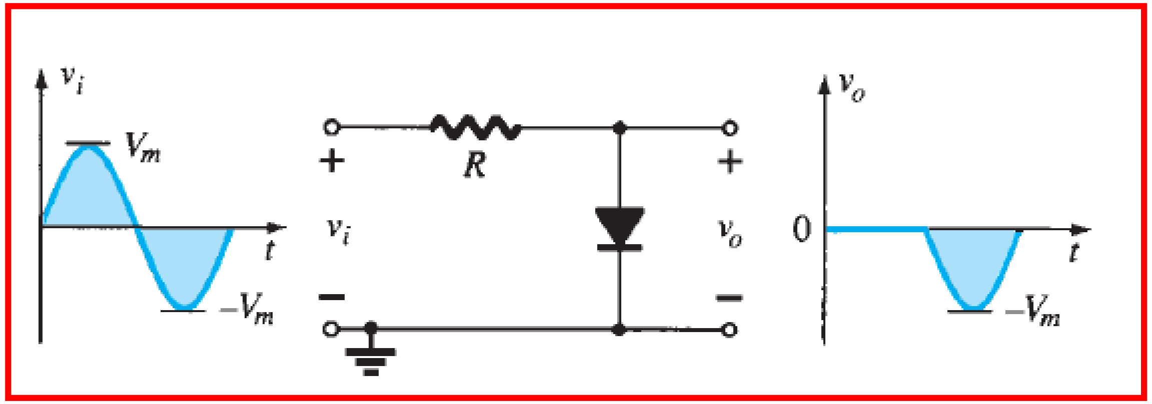


POSITIVE



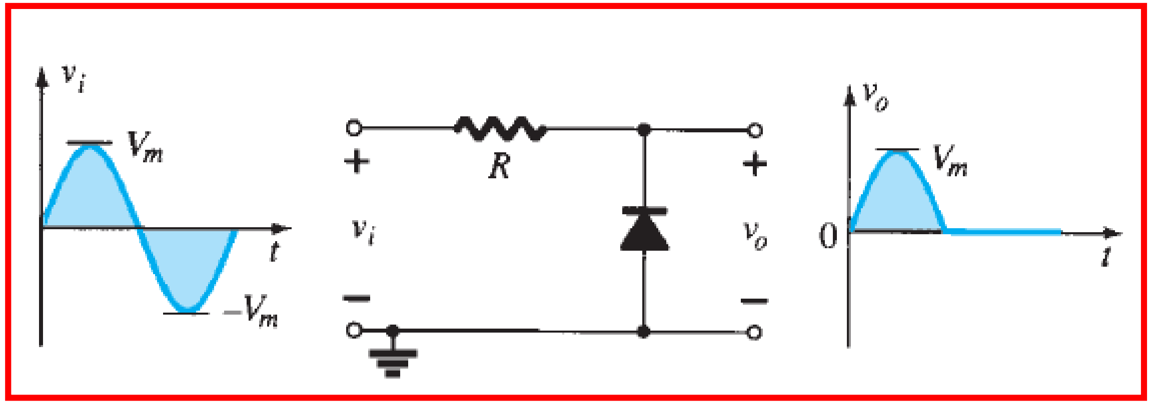
NEGATIVE

Simple Parallel Clippers (Ideal diodes)



POSITIVE

NEGATIVE



Clampers

- A clamper is a circuit with a diode, resistor, and capacitor that shifts a waveform to a new DC level without altering its shape.

- Also known as **DC restorer**.

- Clamping networks have a capacitor connected directly from input

- Resistive element connected in parallel with the output signal.

- The diode is also in parallel with the output signal but may or may not have a series dc supply as an added element.

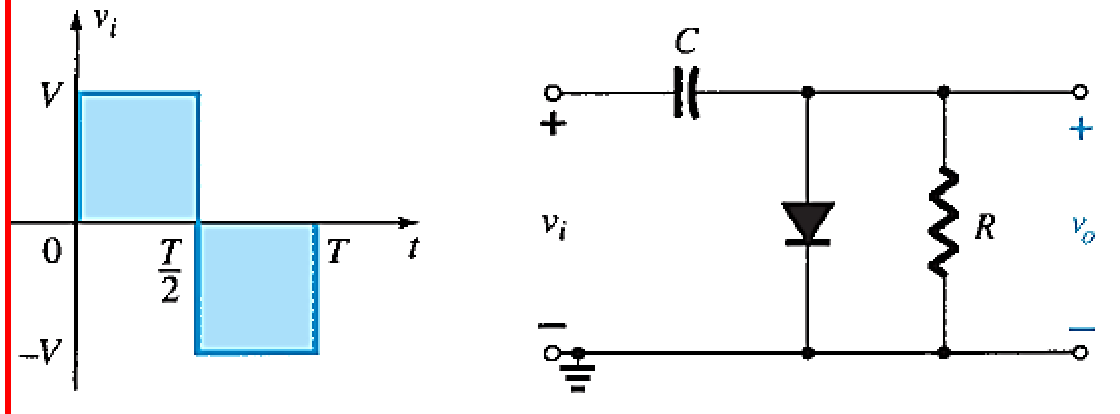


Fig.1: Clamper

Steps used for analysis:

Step 1: Examine the response of the portion of the input signal that will forward bias the diode.

- For Fig. 2, the diode is forward biased during the positive portion of the signal.
- The short-circuit equivalent for the diode results in Vo = 0 V for t = 0 to T/2 .

Step 2: During the on period of the diode, assume that the capacitor will charge up instantaneously to a voltage level determined by the surrounding network.

Step 3: Assume the capacitor retains its voltage while the diode is "off."

Step 4: Track the position and polarity of v o to ensure correct levels.

- When the input turns negative, the network appears as in Fig. 3, with the diode as an open circuit and voltage stored across the capacitor.

Step 5: Check that the total swing of the output matches that of the input. (see Fig. 4)

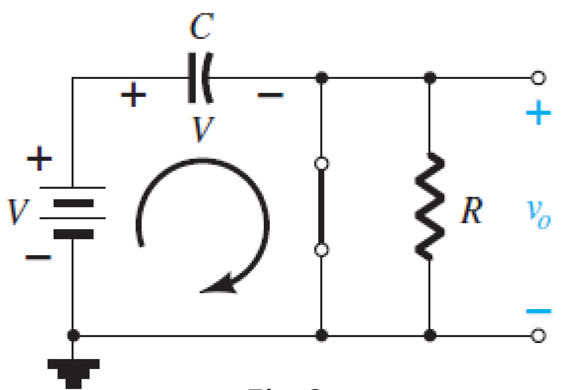


Fig.2

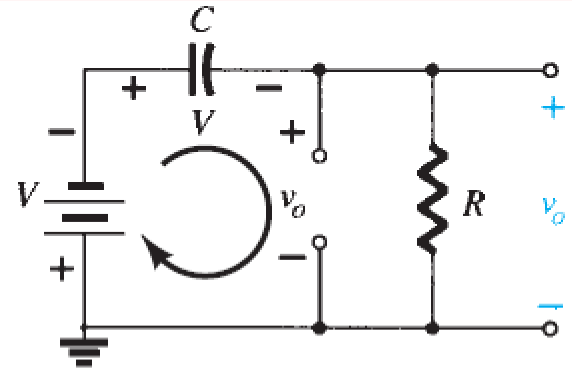


Fig.3

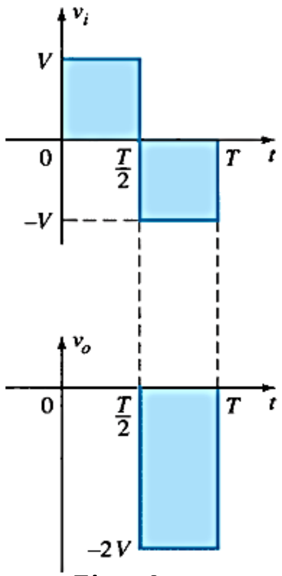


Fig. 4

Numerical

Example1: Determine Vo for the network of shown below, for the input indicated in Fig. 1.1

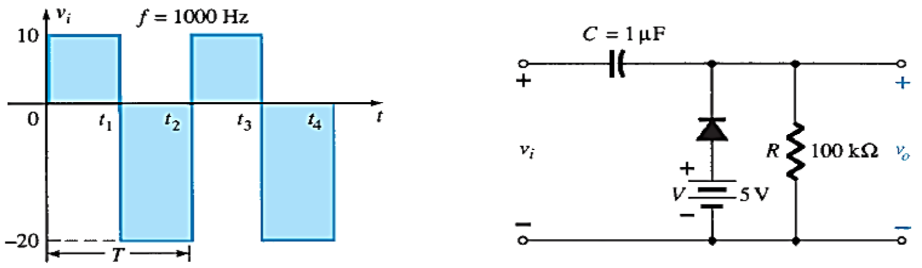


Fig. 1.1

Solution:

Note: f = 1000 Hz => time period, T= 1 ms

Step 1: For *t1→ t2 of the* v_i since the diode is in its short-circuit state. The network appears as shown in Fig. 1.2 .

Step 2: The output is across *R (also directly across the 5-V battery)*. So, v_o = *5 V.*

Applying KVL around the input loop

$-20\text{ V} + V_C - 5\text{ V} = 0$

and $V_C = 25\text{ V}$ => *the capacitor charges to 25 V.*

Step 3: For the period $t_2 \rightarrow t_3$ *the network will appear as shown in Fig. 1.3 .*

Applying KVL around the outside loop of the network

$+10\text{ V} + 25\text{ V} - v_o = 0$

$\boldsymbol{v_o = 35\text{ V}}$

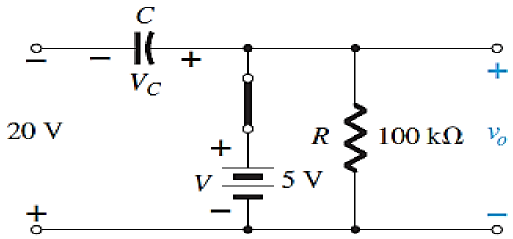


Fig. 1.2 : Determining V_o and V_C with the diode in the "on" state.

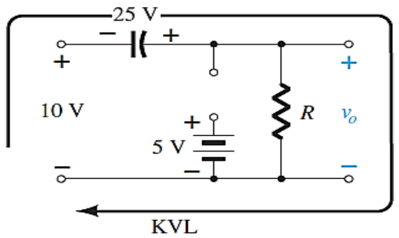


Fig. 1.3: Determining v_o with the diode in the "off" state.

Numerical

Step 4: The time constant of the network of Fig. 1.3 is determined by the product *RC and has the magnitude*
$\zeta = RC = (100\ k\Omega)(0.1\ \mu F) = 0.01\ s = 10\ ms$

The total discharge time is: $5\ \zeta = 5(10\ ms) = 50\ ms$

Step 5: The resulting output appears in Fig. 1.4 with the input signal.
Note: The output swing of 30 V matches the input swing.

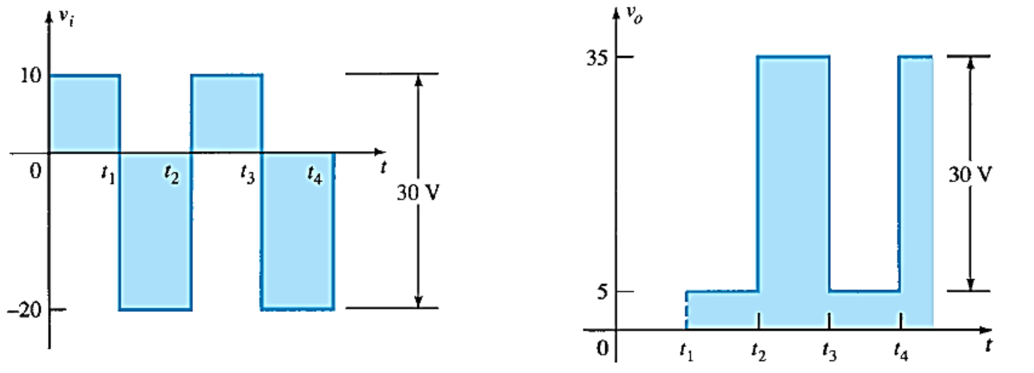


Fig. 1.4: Input and Output Waveform

Numerical

Example 2: Repeat example 1, using a silicon diode with V_k = 0.7 V.

Solution:

For the short-circuit state, the network appears as in Fig. 2.1 , and v_o *is determined by KVL in the output section as:*

$+5\ V - 0.7\ V - v_o = 0$

and $v_o = 4.3\ V$

For the input section, KVL results in

$-20\ V + V_C + 0.7\ V - 5\ V = 0$

and $V_C = 24.3\ V$

For the period $t_2 \rightarrow t_3$ *the network will now appear as in Fig. 2.2 , with the only change* being the voltage across the capacitor.

Applying KVL yields

$+10\ V + 24.3\ V - v_o = 0$

and $\boldsymbol{v_o = 34.3\ V}$

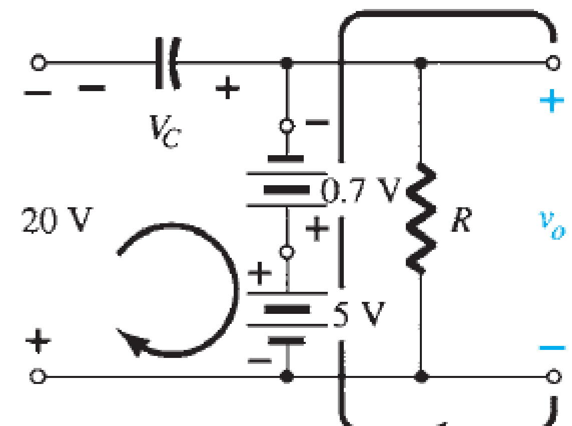


Fig.2.1

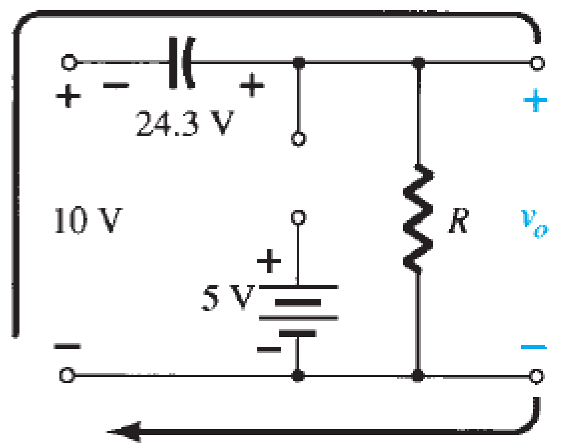


Fig.2.2

Numerical

The resulting output appears in Fig. 2.3 , verifying the statement that the input and output swings are the same.

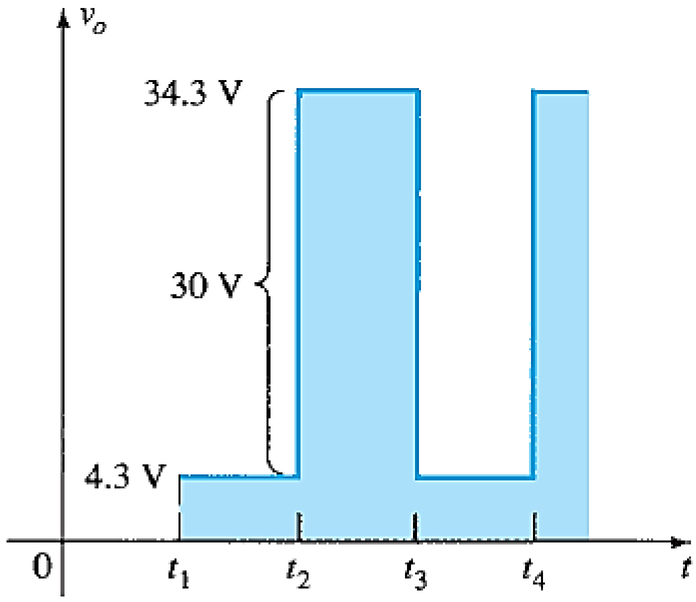
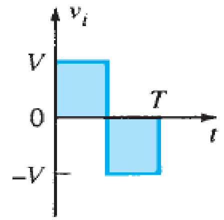
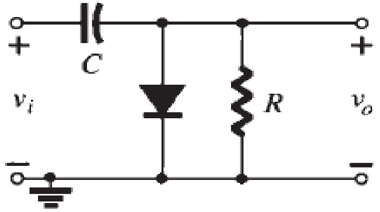
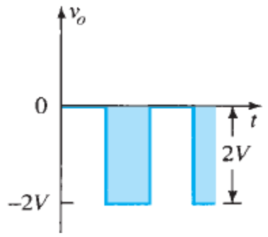
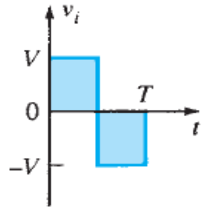
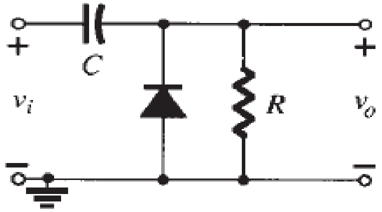
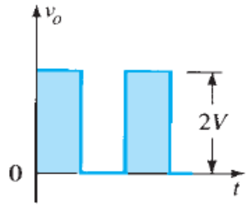
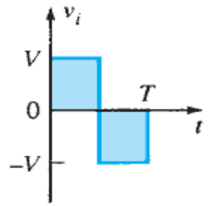
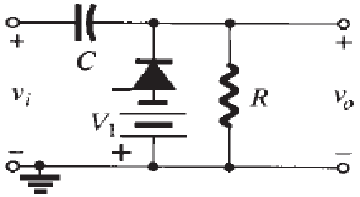
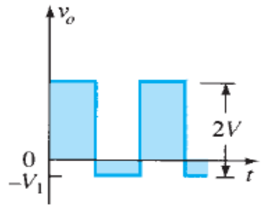


Fig. 2.3: Output Waveform

Clamping Networks

Input Waveform	Clamping Circuit	Output Waveform
		
		
		

THANK YOU

Department of Electronics and Communication