GURU NANAK DEV ENGINEERING COLLEGE
BIDAR -585403

Affiliated to Visvesvaraya Technological University, Belagavi
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2022 SCHEME

BASIC ELECTRONICS
(BBEE103/203)

[As per Choice Based Credit System (CBCS)]

(Strictly for internal circulation only)

MODULE- 1

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Module – 1

Semiconductor Diodes: Introduction, PN Junction diode, Characteristics and Parameters, Diode Approximations, DC Load Line analysis (Text 1: 2.1,2.2,2.3,2.4)
Diode Applications: Introduction, Half Wave Rectification, Full Wave Rectification,Full Wave Rectifier Power Supply: Capacitor Filter Circuit, RC π Filter (includes numerical) (Text 1: 3.1,3.2,3.4,3.5)
Zener Diodes: Junction Breakdown, Circuit Symbol and Package, Characteristics and Parameters, Equivalent Circuit, Zener Diode Voltage Regulator. (Text1:2.9, 3.7)

Text Books :

1. Electronic Devices and Circuits, David A Bell, 5th Edition, Oxford, 2016

Module - 1

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* Semiconductor Diodes

The term diode refers to a two-electrode or two terminal device. A semiconductor diode is simply a p-n junction with a connecting lead on each side.

A diode is a oneway device. It offers a low resistance when forward biased and behaving almost as an open switch when reverse biased.

Some diodes are low current devices for use in switching circuits. High current diodes are most often used as rectifiers for ac to dc conversion. Zener diodes are operated in reverse breakdown because they have a very stable breakdown voltage.

* pn-junction diode.

When P-type and N-type semiconductors are suitably joined together, it forms a PN juntion. A pn-junction forms a popular semiconductor device called diode.

A pn junction has the ability to permit substantial current flow when forward biased and to block current when reverse biased. Thus it can be used as switch 'on' when forward biased, and 'off' when reverse biased. A pn junction provided with copper wire connecting leads becomes an electronic device known as diode.

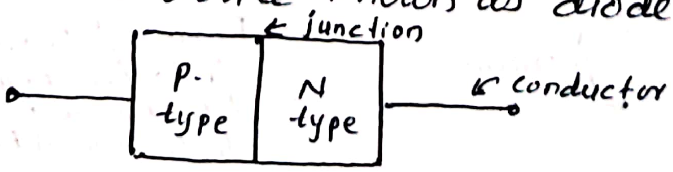
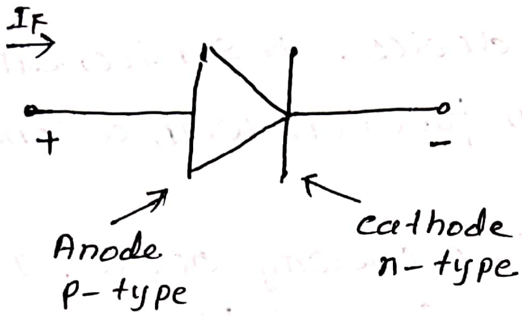


Fig. shows a pn junction with conductors for connecting the device to a circuit.

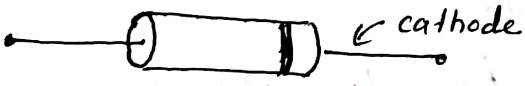
The circuit symbol for a diode is an arrow head and bar as shown in fig.



A pn junction diode can be destroyed by high level of forward current over heating the device. It can also be destroyed by a large reverse voltage causing the junction to breakdown. For particular diode, the maximum forward current and reverse voltage are specified on the manufacturer's data sheets.

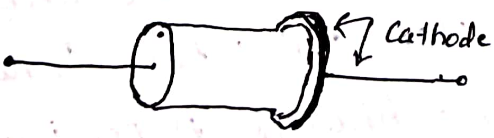
The fig. shows the types of diodes based on forward current carrying and reverse voltage withstanding capacity.

- low current diode



- Forward current up to 100 mA
- Reverse voltage up to 75 V.

- Medium current diode



- Forward current up to 400 mA
- Reverse voltage up to 200V

- High current diode.

- Forward current up to Few Amperes
- Reverse voltage up to several hundred volts.

* Characteristics and Parameters.

Applying external dc voltage to any electronic device is called biasing.

- Forward and Reverse characteristics.
  (V-I) characteristics of a diode).

Forward biased Diode.

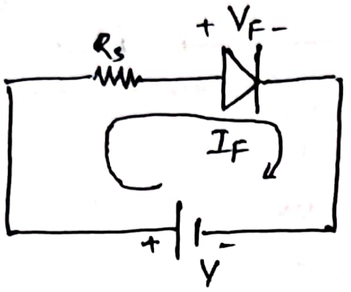


Fig. 1

Reverse biased Diode.

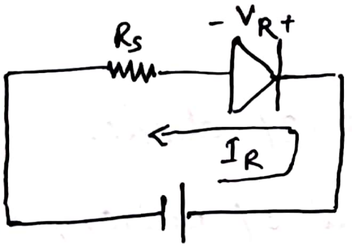


Fig. 2

Fig a) & Fig b) shows typical forward and reverse characteristics for silicon and germanium diodes.

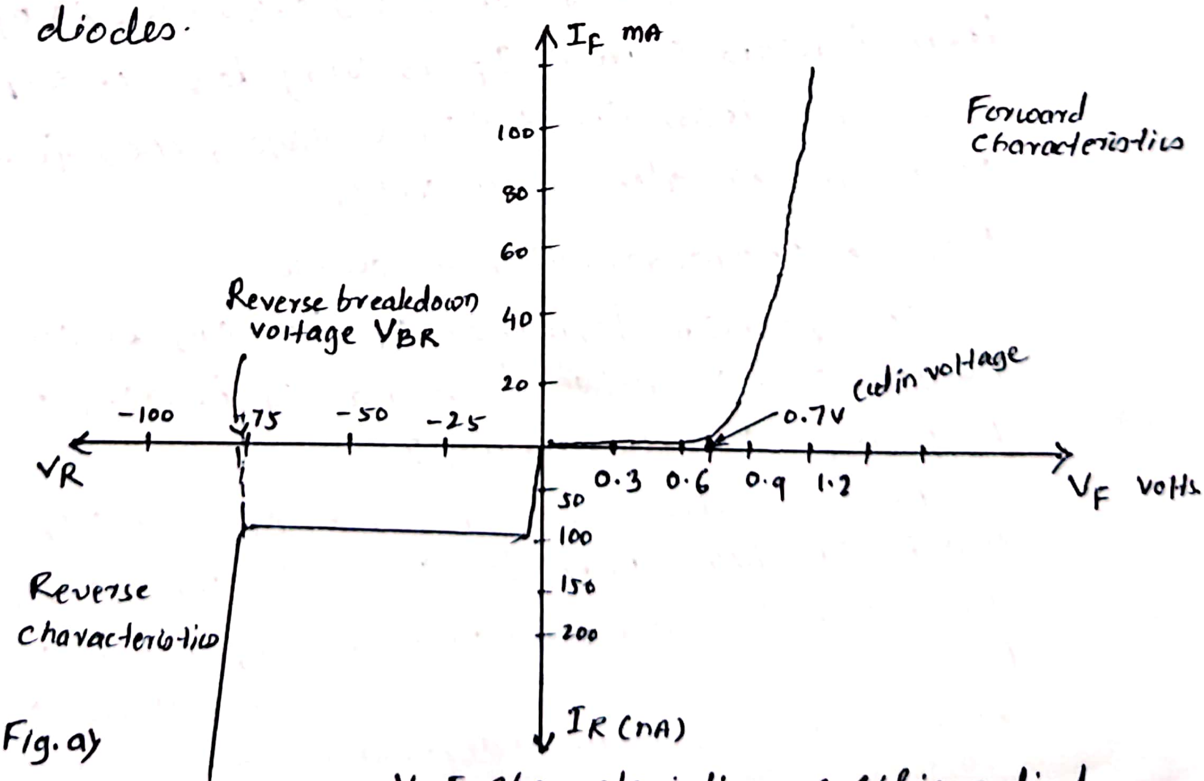
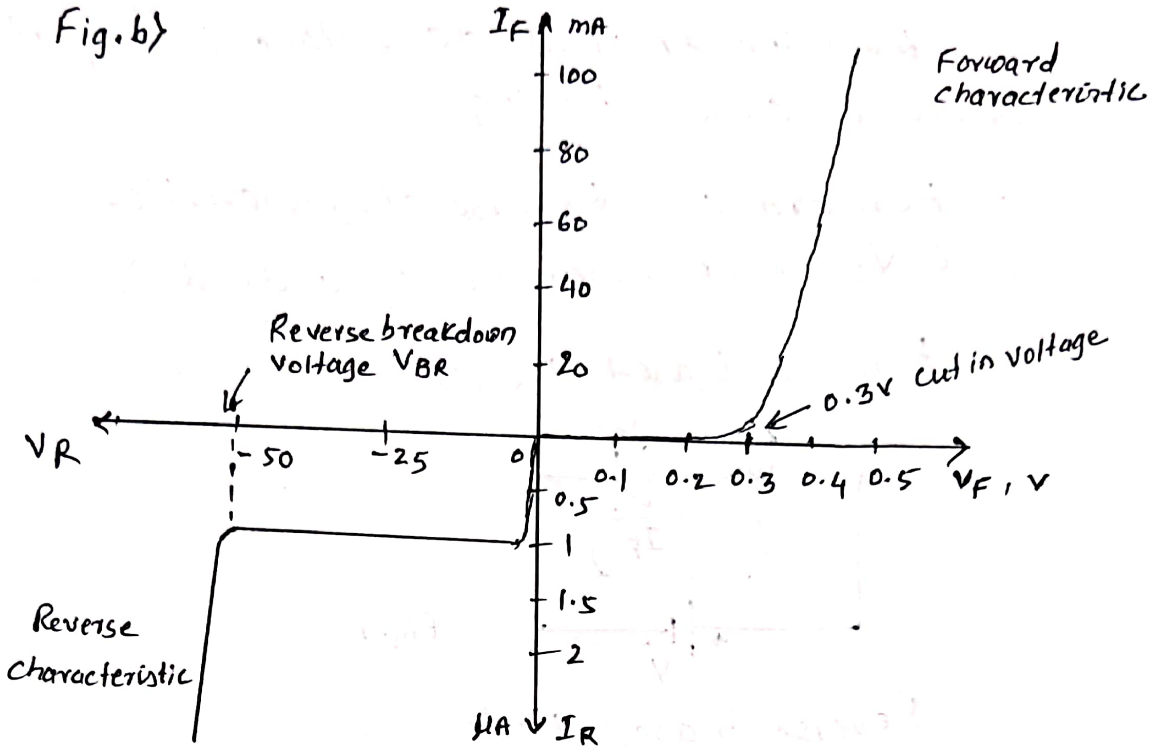


Fig. a)

V-I characteristics of silicon diode

V-I characteristics of germanium diode.

Fig. b)



- Forward characteristics of diode

The positive terminal of battery is connected to p-type and negative terminal of battery is connected to n-type. Fig. 1 If supply voltage is less than the cut in voltage (0.7V for Si and 0.3V for Ge) of diode, then forward current I_F is very low. If supply voltage is greater than the cut in voltage, then forward current I_F increases almost linearly.

- Reverse characteristics of diode.

The positive terminal of battery is connected to n-type and negative terminal of battery is connected to p-type as shown in fig. 2.

Because the diode reverse current (I_R) is very much smaller than its forward current, the reverse characteristics are plotted with expanded current scales. For silicon diode, I_R is normally less than 100 nA. and is almost completely independent of the reverse-bais voltage.

I_R is largely a minority charge carrier 'reverse saturation current'. It is due to the crossing minority charge carriers at the pn junction under reverse-bais condition. It is very less and almost negligible. Therefore under reverse-bias diode may be treated almost as an open switch.

Ex: Calculate the forward and reverse resistances offered by silicon diode, $V_F = 0.75V$, $I_F = 100\,mA$
$V_R = 50V$, $I_R = 100\,nA$.

Soln:
$$R_F = \frac{V_F}{I_F} = \frac{0.75}{100\times10^{-3}} = 7.5\,\Omega.$$

$$R_R = \frac{V_R}{I_R} = \frac{50}{100\times10^{-9}} = 500\,M\Omega.$$

When the diode reverse voltage is sufficiently increased, the device goes into reverse breakdown.

* Diode Parameters.

The diode parameters of greatest interest are.

1) V_F → Forward voltage drop.

It is the voltage mentioned at specific current and temperature.

2) I_F → Diode forward current.

It is the maximum forward current mentioned at specific temperature. under forward biased Condition without any damage to it.

3) I_R → Reverse saturation current.

It is maximum reverse saturation current produced to the flow of minority charge carriers across the junction at a given temperature.

4) V_{BR} → Reverse breakdown voltage

Also called PIV (peak Inverse voltage)

It is the maximum reverse voltage ~~at which~~ that can be applied to a pn junction diode without causing any damage to the junction.

5) r_d → dynamic resistance.

The dynamic resistance of the diode is the resistance offered to changing levels of forward voltage.

$$r_d = \frac{\Delta V_F}{\Delta I_F} \quad , \quad r_d' = \frac{26\,mV}{I_F}$$

6) $P_{D_{max}}$ → maximum power rating

It is the maximum power that can be dissipated in the diode without damaging it.

- The values of these quantities are normally listed on the diode data sheet provided by device manufacturers.

* Diode Approximations.

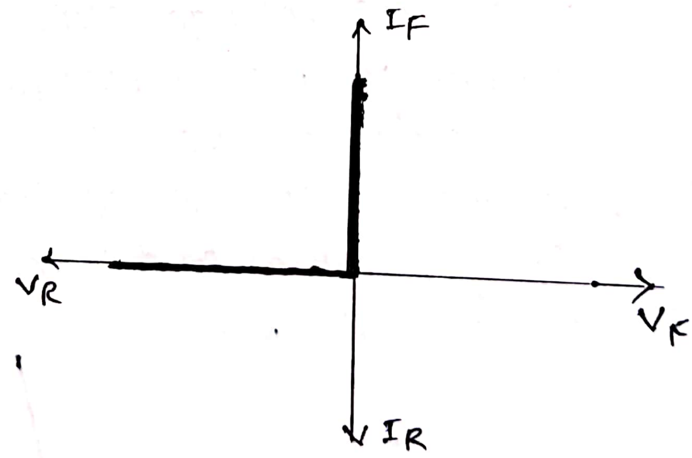
The diode characteristics can be approximated in two ways.

1) Ideal diode approximation
2) Linear piecewise approximation.

1) Ideal diode characteristic approximation

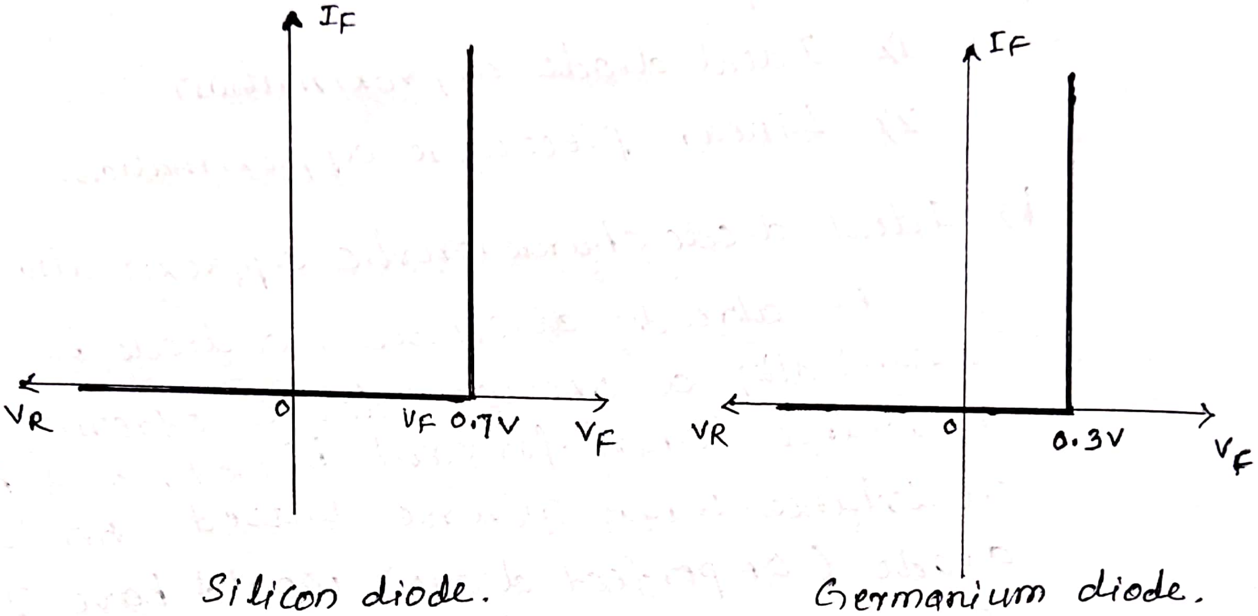
As already discussed, a diode is essentially a one way device, offering a low resistance when forward biased, and high resistance when reverse biased. An ideal diode (or perfect diode) would have zero forward resistance and zero forward voltage drop. It would also have an infinitely high reverse Resistance, which would result in zero reverse current.

Fig shows the current/voltage (V-I) characteristics of an ideal diode.



Although ideal diode does not exist, there are many applications where diodes can be assumed to be near ideal devices. But supply voltage is much larger than the diode forward voltage drop V_F, Then V_F is assumed constant equal to cut in voltage.

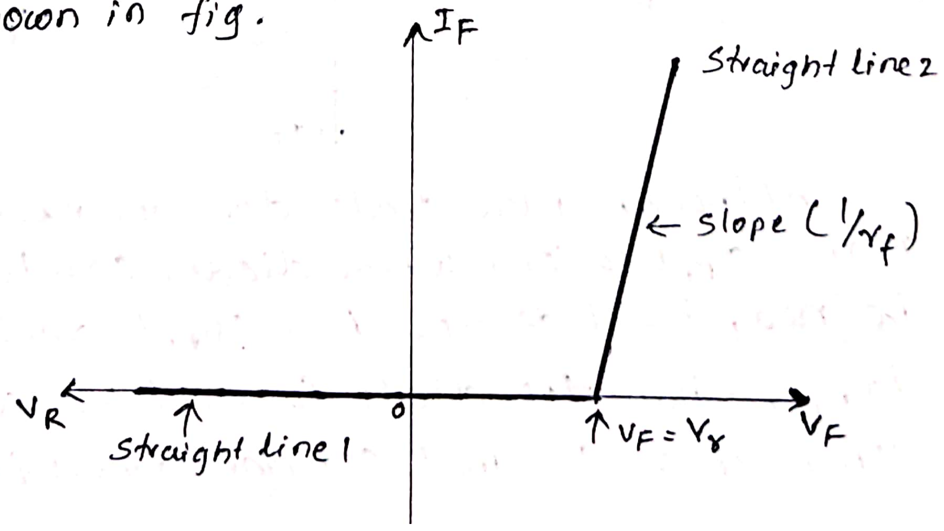
Thus practically ideal characteristics are changed as shown in fig.



2) Linear Piecewise Approximation.

The approximation of characteristics with the help of pieces of straight lines is called linear piecewise approximation.

To obtain this approximation, $V_F = V_\gamma$ (cut in voltag) is marked on the voltage axis and then a straight ~~tion~~ line is drawn with a slope equal to reciprocal of its dynamic forward resistance r_d or r_f. Thus the approximation consists of two straight line pieces, one horizontal and other with slope $1/r_f$ as shown in fig.



when the forward characteristics of a diode is not available, this approximation may be employed.

* DC equivalent of circuit of diode.

An equivalent circuit for a device is a circuit that represents the device behavior. usually, the equivalent circuit is made up of a number of components, such as resistors and voltage cells. In many practical electronic circuits, the diode is required to be replaced by its equivalent circuit.

DC equivalent circuits for a junction diode shown in following figs.

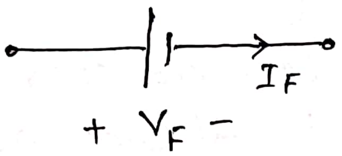
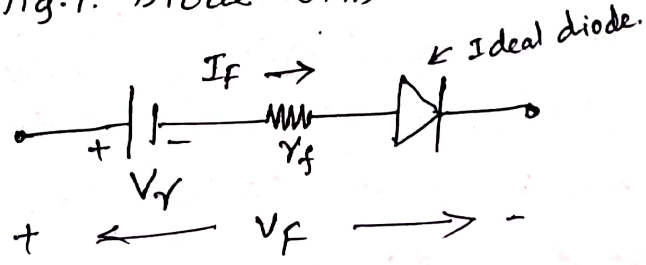


fig.1. Diode with constant forward voltage drop.

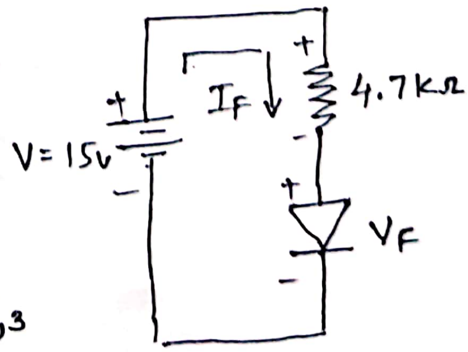


$$\boxed{V_F = V_\gamma + I_F r_f}$$

V_γ = cutin voltage.

fig.2. complete DC equivalent ckt.

Ex: A silicon diode is used in the circuit shown in fig. Calculate the diode current.



Solⁿ: $V = I_F \times 4.7\times10^3 + V_F$

for si, $V_F = 0.7\,V$

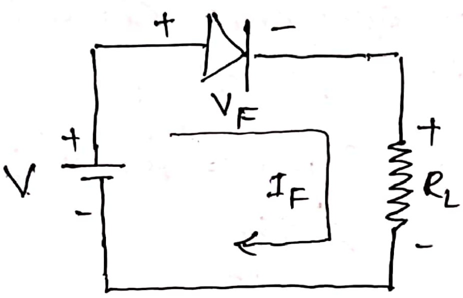
$$\therefore I_F = \frac{V - V_F}{4.7\times10^3} = \frac{15-0.7}{4.7\times10^3}$$

$I_F = 3.04\ mA$ ← Ans.

* DC Load line

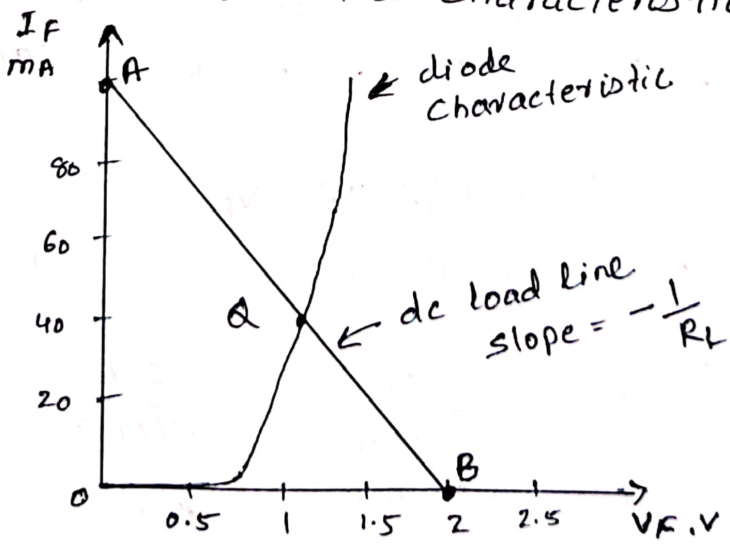
A DC load line is a straight line drawn on the diode forward characteristic which describles all the dc conditions that exists in the operation of the circuit.

Fig. shows a diode in series with load Resistance R_L and a supply voltage V. The polarity of V is such that the diode is forward biased.



The current I_F, forward current of diode flows through the circuit. As already discussed, the circuit can be determined approximately by assuming a constant diode forward voltage drop V_F. When the precise levels of the diode current and voltage must me calculated, graphical analysis (also termed as dc load line analysis) is employed.

For graphical analyis, a dc load line is drawn on the diode forward characteristics.



This dc load line is straight line that illustrates all the dc conditions that could exist within the circuit. Because the load line is always straight line, it can be constucted by plotting any two corresponding current and voltage points and then drawing a straight line through them.

To determine two points on the load line, an equation relating voltage, current and resistance is first derived for the circuit.

Applying KVL to the circuit shown in the beginning.

$$V = I_F R_L + V_F$$

$$\Rightarrow I_F = -\frac{1}{R_L} V_F + \frac{V}{R_L} \quad -1) \quad \Rightarrow y = mx + c$$

The eqn 1) is a straight line equation, which gives linear equation between V_F and I_F. This eqn. is called equation of dc load line for the diode.

- Sketching dc load line

According to eqn 1), obtain two points.

Point A, $V_F = 0$ hence $I_F = \frac{V}{R_L}$

Point B, $I_F = 0$ hence $V_F = V$

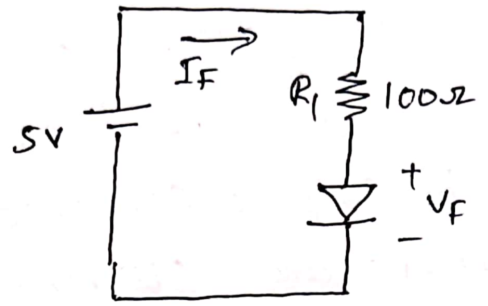
The line joining the points A and B is called dc load line of the diode.

* Q-point

It is the point where dc load line intersect diode forward characteristics. Which gives I_F & V_F values for a given value of V and R_L

Q point is also termed as quiescent point or dc bias point.

Ex: Draw the dc load line for the circuit shown in fig.



Soln: KVL to the circuit, gives.

$$V = I_F \times R_1 + V_F$$

To plot point A, substitute $V_F = 0$

$$I_F = \frac{V}{R_1} = \frac{5}{100} = 50\,mA.$$

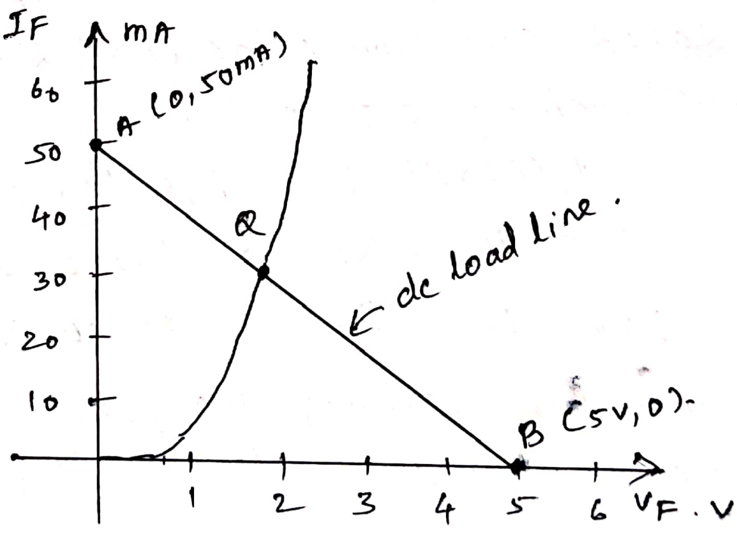
point, A (0, 50mA)

To plot point B, substitute $I_F = 0$, we get

$$V_F = V = 5V$$

point, B (5V, 0)

dc Load line.



* Diode Applications.

One of the most important applications of diodes is rectification: conversion of a sinusoidal ac waveform in to single-polarity half cycles.

Rectifier is a circuit which converts ac voltage to pulsating dc voltage using one or more p-n junction diodes.

Rectification may be performed by half-wave or full-wave rectifier circuits.

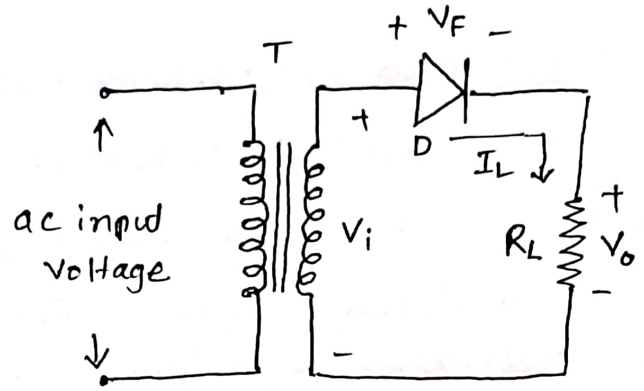
Other important diode applications include clipping, clamping, dc voltage multiplication, and logic circuits. Diode clipping circuits are used for clipping off an unwanded portion of a waveform. Clamping circuits change the dc level of a waveform without affecting the wave shape. DC voltage multipliers are applied to change the level of a dc voltage source to a desired higher level. Logic circuits produce a high or low output voltages depending upon logical operation like NOT, OR and AND etc.

* Half-Wave Rectification.

- Positive Half-wave Rectifier

A diode positive half wave rectifier circuit is shown in fig. (next page).

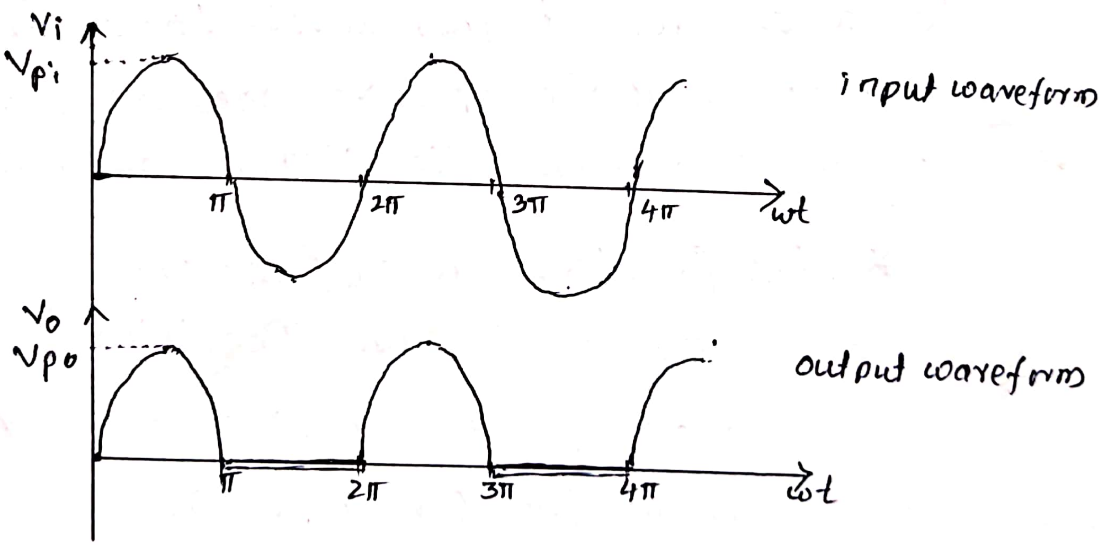
An alternating input voltage (ac) is appled via a transformer (T) to a single diode connected in series with a load resistor R_L.



The transformer is normally a step-down transformer. The diode is forward-biased during the positive half cycles of the input waveform and reverse biased during negative half cycles. During positive half cycles diode D conducts and substantial current flow through R_L. For the duration of the negative half cycles, the diode behaves almost as an open switch.

When the diode is forward-biased, the voltage drop across it is V_F and the output voltage is

$$V_{po} = V_{pi} - V_F$$ as shown in fig.



Note that $V_{pi} = \sqrt{2}\, V_i$, where V_i is the rms level of sinusoidal input voltage to the rectifier circuit (from the transformer output).

$$V_{pi} = 1.414\, V_i$$

The diode peak current, also load current, forward current is

$$I_p = \frac{V_{po}}{R_L}$$

During the negative half cycle of the input the reverse-baised diode offers a very high resistance so there is only a very small reverse current (I_R) giving an output voltage

$$-V_o = -I_R R_L$$

While the diode is reverse biased, the peak voltage of negative half-cycle of the input is applied to the terminals. Thus the peak reverse voltage, or peak inverse voltage (PIV), applied to the diode is

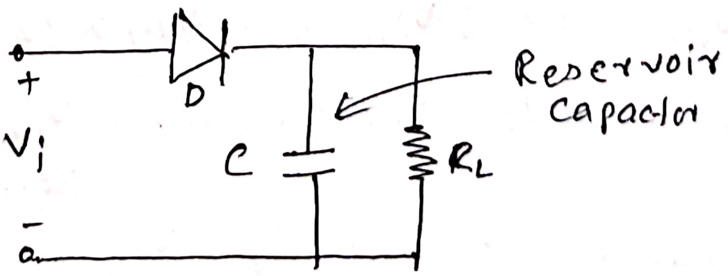
$$V_R = PIV = P_i$$

The average and rms values of the half-wave rectified waveform can be determined as

$$V_{o(ave)} = \frac{V_{po}}{\pi} = 0.318\, V_{po} \quad \&$$

$$V_{o(rms)} = \frac{V_{po}}{2} = 0.5\, V_{po}.$$

However, most rectifier circuits use a reservoir capacitor at the output terminals to smooth the rectified voltage in-to direct voltage.



- Negative Half-wave Rectifier

Fig a, shows the effect of reversing the diode polarity in the circuit fig. shown previous type rectifier.

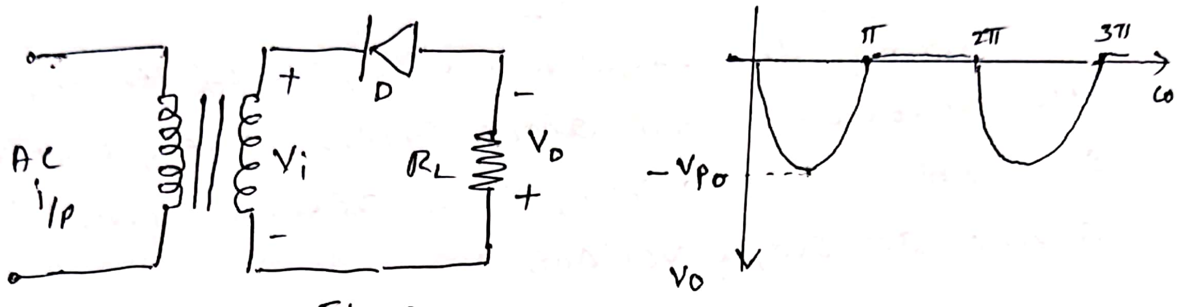
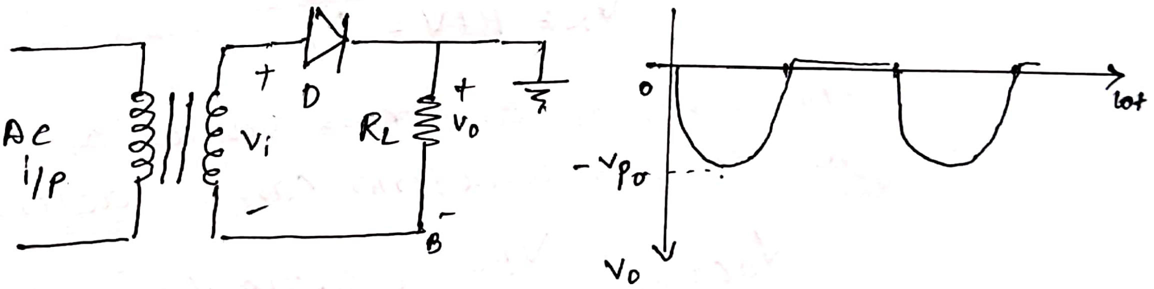


Fig. a.

The negative half-cycle of ac input waveform is passed to the load resistor R_L.

Fig. b, shows a positive half-wave rectifier circuit with the positive output terminal grounded.



Ex: A diode with $V_F = 0.7V$ is connected as a half-wave rectifier. The load resistance is 500Ω and the rms ac input is 22 V. Determine the peak output voltage, the peak load current, and diode peak reverse voltage.

Soln: $V_{pi} = 1.414\, V_{i\,rms} = 1.414 \times 22 = 31.1\,V.$

∴ peak output voltage, $V_{po} = V_{pi} - V_F = 31.1 - 0.7$

$= 30.4\,V$

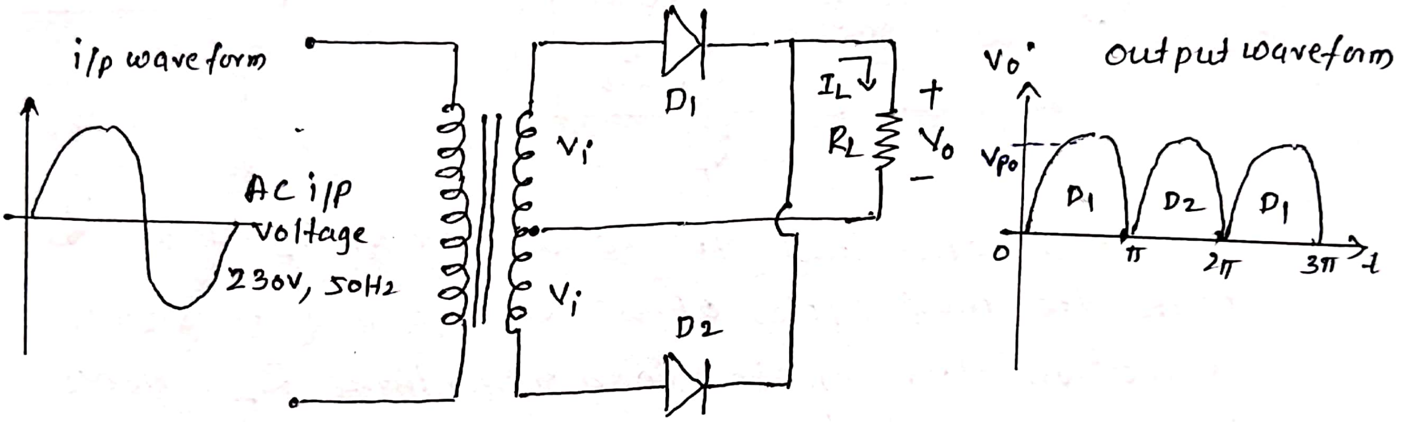
peak load current $I_p = \frac{V_{po}}{R_L} = \frac{30.4}{500} = 60.8\,mA$

$PIV = V_{pi} = 31.1\,V.$

* Full-Wave Rectification.

- Two Diode Full-wave Rectifier (with Centre-tap transformer).

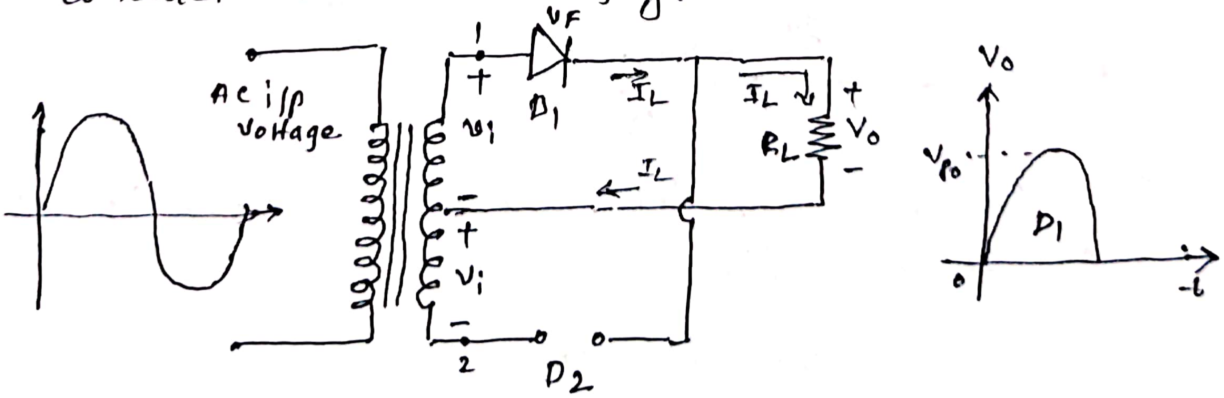
The full-wave rectifier circuit uses two diodes, and its input voltage is supplied from a transformer T with a centre-tapped secondary winding as shown in fig.



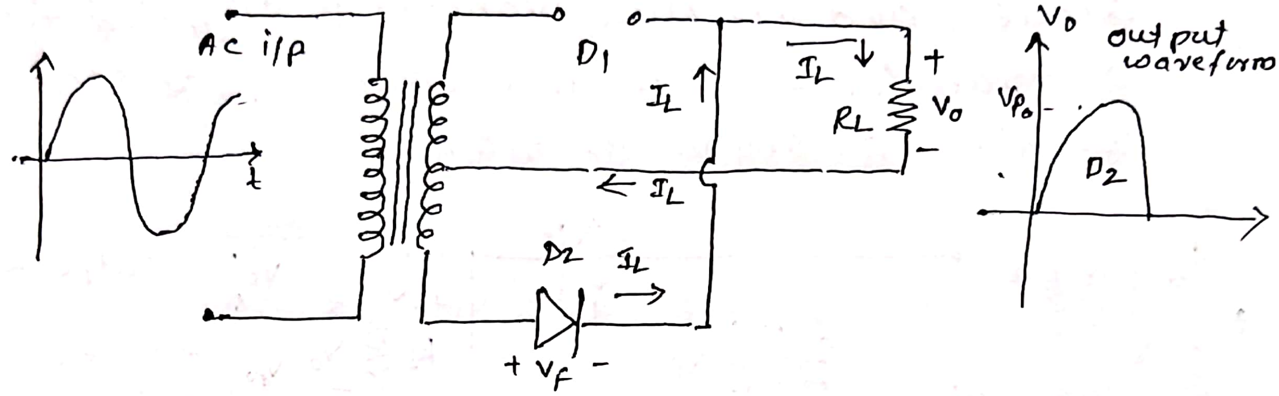
The circuit is essentially a combination of two half-wave rectifier circuits, feeding a common load.

- operation of the Circuit.

Consider the positive half cycle of ac-input voltage in which terminal 1 is +ve and terminal 2 -ve. The diode D_1 will be forward biased and hence will conduct while diode D_2 will be reverse biased and will act as an open ckt & will not conduct as shown in fig.

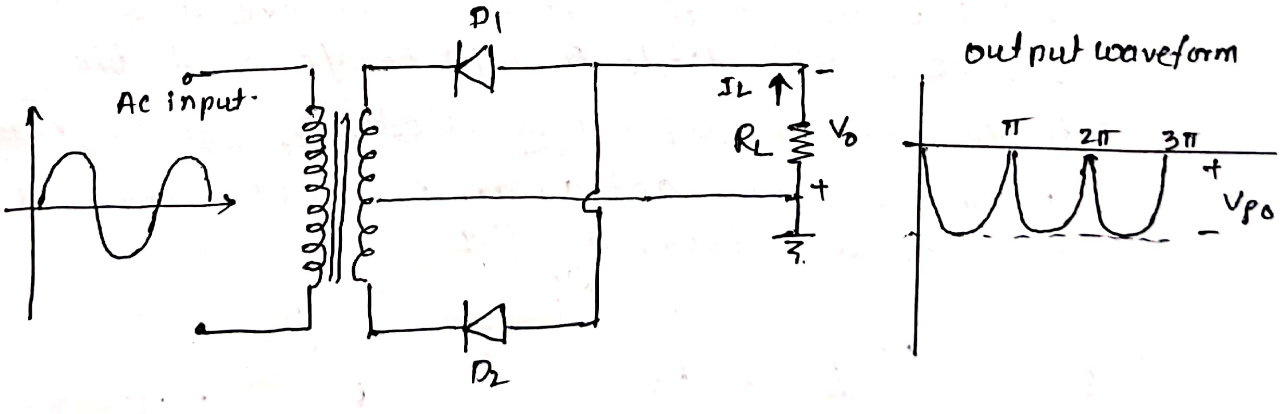


In the next half cycle of ac voltage, polarity reverses and terminal 1 becomes −ve and 2 +ve. The diode D_2 conducts being forward biased, while D_1 does not conduct being reverse biased as shown in fig.



It is noted that the load current I_L flows in both the half cycles of ac voltage and in same direction through the load resistance R_L. Hence we get rectified output across the load.

Fig (shown below) shows that if the polarity of the diodes is reversed, the output waveform is a series of sinusoidal negative half cycles; negative full-wave rectification.



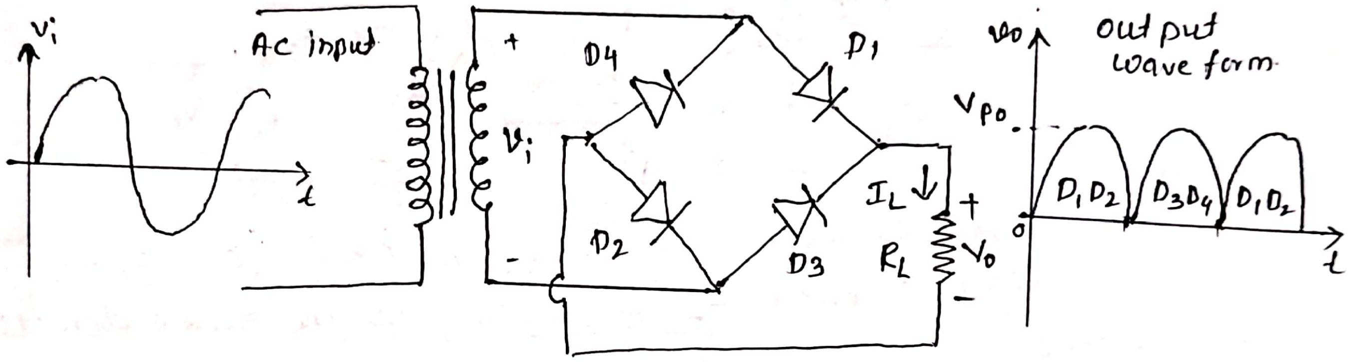
The centre tap transformer is normally grounded as shown in fig.

$$V_{po} = V_{pi} - V_F$$

* Full-Wave Bridge Rectifier.

The centre-tapped transformed used in previous rectifier is usually more expensive and requires more space than additional diodes. So a bridge rectifier is the circuit most frequently used for full-wave rectification.

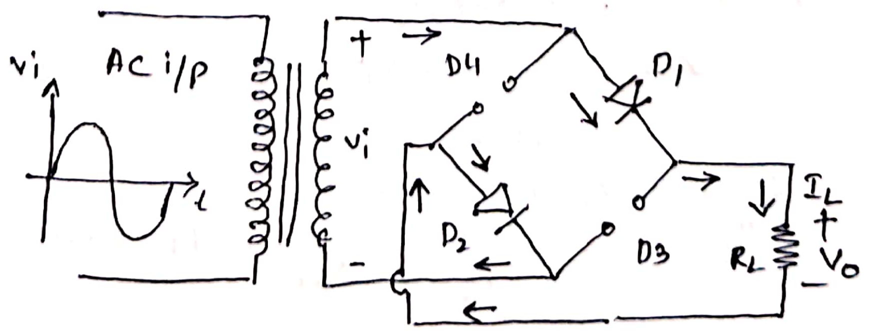
The basic bridge rectifier circuit shown in fig.



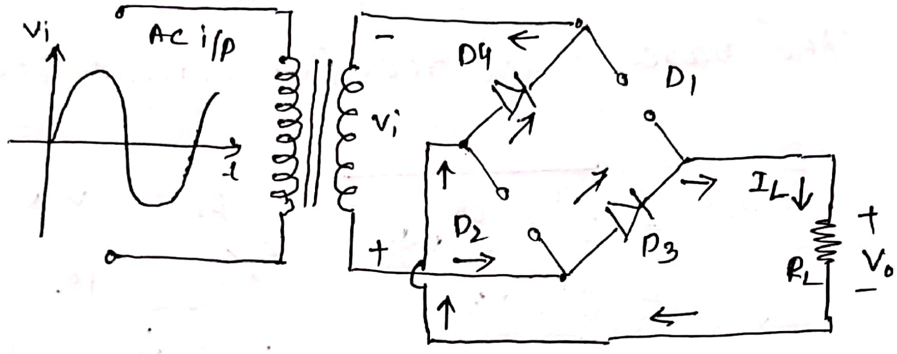
The bridge rectifier circuit is essentially a full-wave rectifier circuit, using four diodes forming the four arms of an electric bridge. To one diagonal of the bridge, the ac voltage is applied through a transformer if necessary and the rectified dc voltage is taken from the other diagonal of the bridge.

- Operation of the circuit:

During +ve half cycle diodes D_1, D_2 will be forward biased while D_3, D_4 reverse biased. The two diodes D_1 & D_2 conduct in series with load current I_L as shown in fig.



In the next half cycle, when the polarity of ac voltage reverses, diodes D_3 and D_4 will forward biased, while D_1 and D_2 reverse biased. Now the diodes D_3 and D_4 conduct in series with load and the current flows as shown in fig.



It is seen that in both half cycles of ac, the load current I_L is flowing in the same direction. Hence we get full wave rectified output.

$$V_{po} = V_{pi} - 2V_F$$

$$V_{o(ave)} = \frac{2V_{po}}{\pi} = 0.637\,V_{po}$$

$$V_{o(rms)} = \frac{V_{po}}{\sqrt{2}} = 0.707\,V_{po}.$$

Ex: Determine the peak output voltage and current for the bridge rectifier circuit when $V_i = 30$ V, $R_L = 300\,\Omega$ and the diodes have $V_F = 0.7$V.

Soln:
$$V_{pi} = 1.414 V_i = 1.414 \times 30\text{V}.$$
$$= 42.42\text{V}$$

Peak output voltage

$$V_{po} = V_{pi} - 2V_F = 42.42 - 2\times 0.7$$
$$= 41\text{ V}.$$

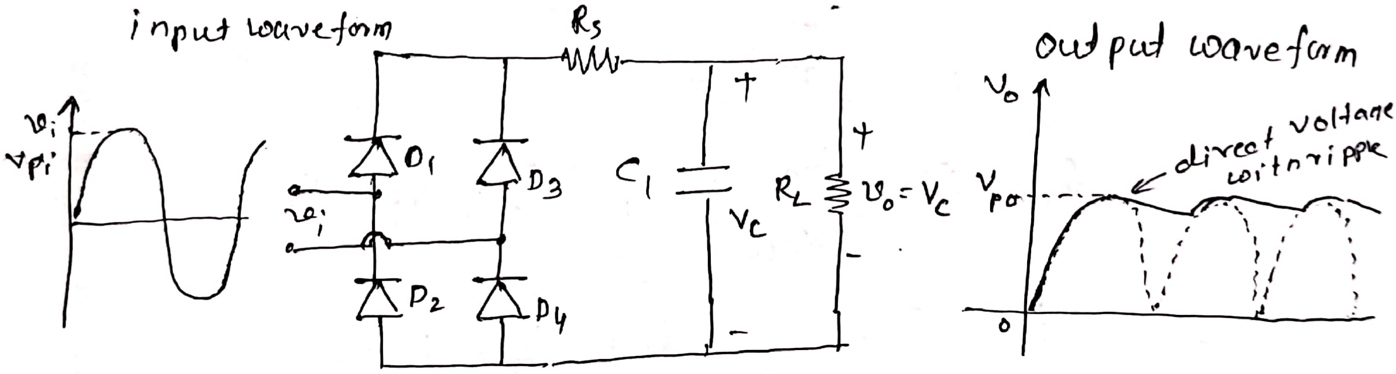
peak output current

$$I_p = I_L = \frac{V_{po}}{R_L} = \frac{41}{300} = 137\text{ mA}$$

* Full-wave Rectifier power supply.

Capacitor Filter Circuit.

When a sinusoidal ac voltage is rectified by full wave rectifier, the resulting output wave form is a series of positive half cycles of the input voltage; it is not direct voltage. To convert to direct voltage (dc voltage); a smoothing circuit or filter circuit must be employed. Fig shows a full-wave bridge rectifier circuit with a single capacitor filter (C_1) and a ~~surge~~ surge limiting resistance R_s along with load resistance R_L.



$$v_o = V_C = V_{pi} - 2V_F$$

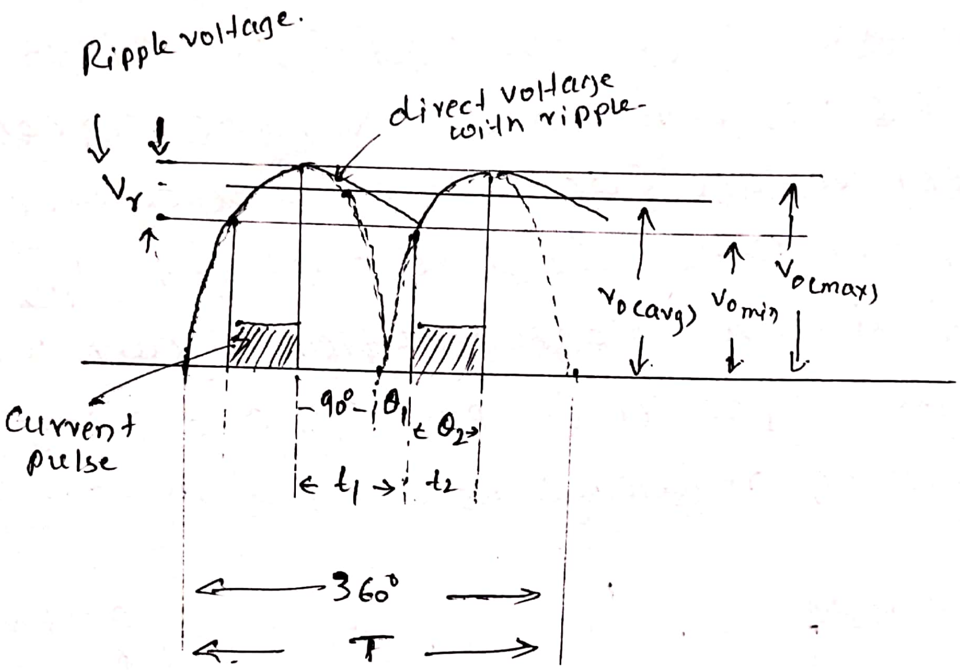
The capacitor C_1 termed as reservoir capacitor, is charged almost to the peak level of circuit input voltage when the diodes are forward biased. This occurs at v_{pi}, giving peak capacitor voltage.

$$V_C = V_{pi} - 2V_F.$$

When the input level falls below V_{pi}, the diodes becomes reverse biased because the capacitor voltage V_C remains close to ($V_{pi} - 2V_F$), with the diodes reverse biased, there is no capacitor charging current, and the capacitor begins to discharge through load.

resistor R_L. So V_C falls slowly as shown by the output waveform.

The capacitor-smoothed full-wave rectifier waveforms are shown in detail in fig.

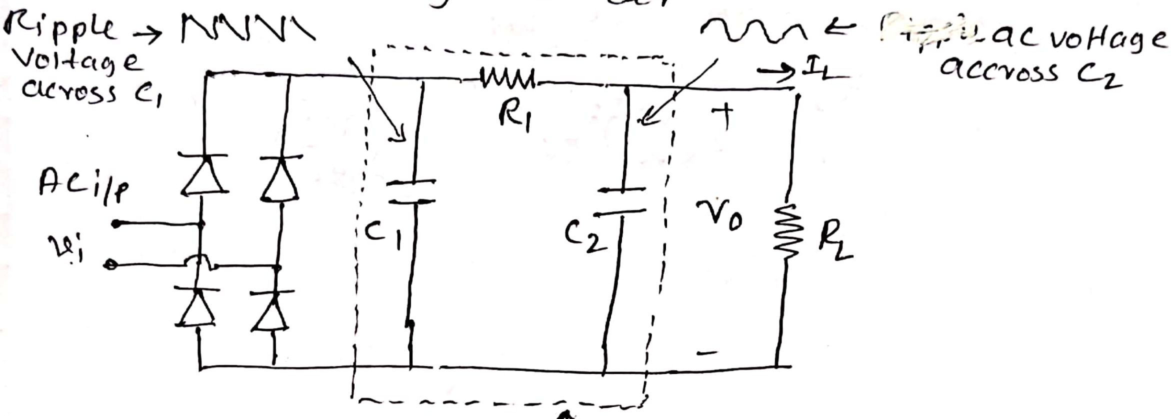


$$\theta_1 = \sin^{-1} \frac{V_{o(min)}}{V_{o(max)}} \quad ; \quad \theta_2 = 90° - \theta_1$$

$$t_2 = \frac{\theta_2 T}{360°} \quad , \quad t_1 = T/2 - t_2 .$$

* RC π Filter.

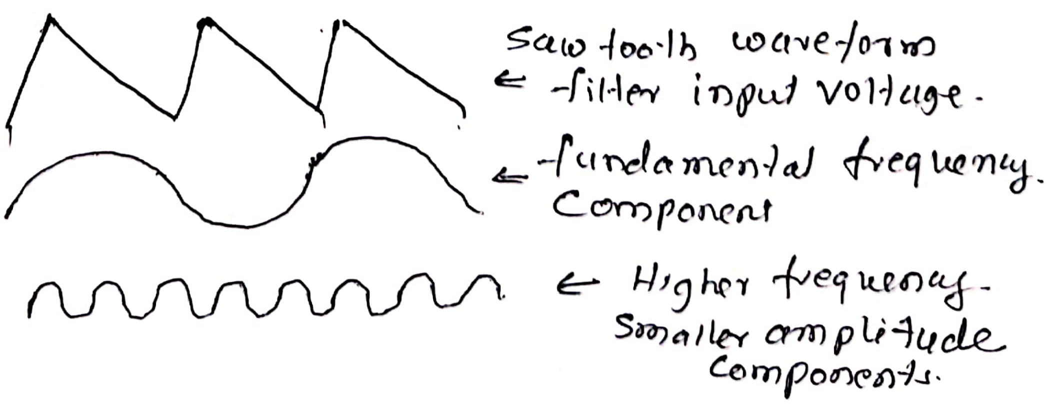
The ripple voltage V_r that appears across the reservoir capacitor in rectifier power supply can be attenuated by the use of an additional resistor and capacitor, which together function as an ac voltage divider



↑ RC π filter.

The fig shows the circuit, C_1 being the reservoir capacitor, and R_1 and C_2 the additional components. The combination of C_1, R_1, and C_2 is referred to as a π-filter, because of the π-shaped arrangement of the circuit components.

Assuming a constant output load current I_L, the reservoir capacitor continues to charge and discharge, producing a sawtooth (ripple) waveform across C_1 regardless of the presence of the additional components as shown in fig.



Higher frequencies smaller amplitude components are developed across C_2.

Voltage across C_2 is given by.

$$v_0 = \frac{v_i X_{C_2}}{\sqrt{R_1^2 + X_{C_2}^2}}$$

where v_i is the ac input voltage applied across Capacitor C_1 ; from above eqn.

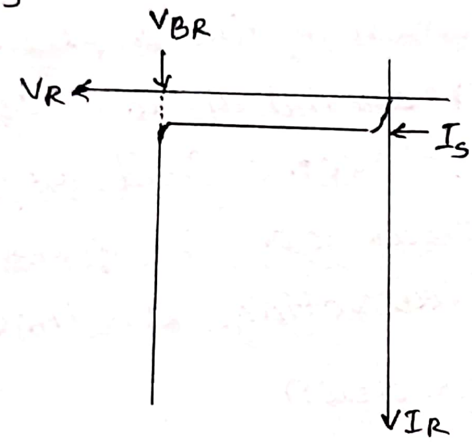
$$X_{C_2} = \frac{R_1}{\sqrt{\left(\frac{v_i}{v_0}\right)^2 - 1}} \simeq \frac{R_1}{\left(\frac{v_i}{v_0}\right)}$$

* Zener Diodes.

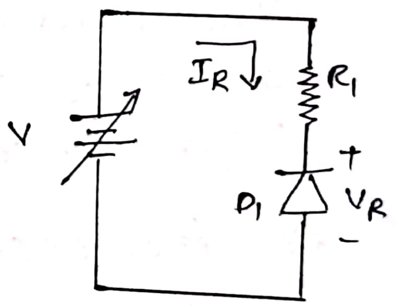
The Zener diode is a heavily doped silicon p-n junction semiconductor device, which is generally operated in its reverse breakdown region.

– Junction Breakdown.

When a junction diode is reverse biased, normally only a very small reverse saturation current flows i.e I_S on the reverse characteristics as shown in fig.



a) Diode reverse characteristic



b) Diode-resistor Circuit.

When the reverse voltage is sufficiently increased, the junction breaks down and a large reverse current flows. If the reverse current is limited by means of a suitable series resistor R_1 as shown in fig b. The power dissipation in the junction can be kept to a level that will not destroy the device.

In this case, the diode may be operated continuously in reverse breakdown. The reverse current returns to its normal level when the voltage is reduced below the reverse breakdown level V_{BR}.

Diodes designed for operation in reverse breakdown are found to have a breakdown voltage that remains extremely stable over a wide range of current levels. These diodes are known as Zener diodes.

There are two mechanisms that cause breakdown in reverse biased p-n junction.

1) Zener breakdown.

2) Avalanche breakdown.

1) Zener breakdown.

with a narrow depletion region, the electric field strength (volts/width) produced by a reverse bias voltage can be very high. The high intensity electric field causes electrons to break away from their atoms, thus converting the depletion region from an insulating material in to a conductor. This is ionization by electric field, which is also called Zener breakdown. It is usually occurs with reverse bias voltage less than 5V.

2) Avalanche breakdown.

In cases where the depletion region is too wide for Zener breakdown, the electrons in the reverse saturation current can be given sufficient energy to cause other electrons to break free when they strike atoms within the depletion region. This is termed ionization by collision. The electrons released in this way collide with other atoms to produce more free electrons in an avalanche effect. Avalanche breakdown is normally produced by. reverse voltage levels above 5V.

Although Zener and avalanche are two different types of breakdown, the name 'Zener diode' is commonly applied to all break down diodes.

- Circuit symbol and package.

The circuit symbol for a Zener diode is shown in fig.

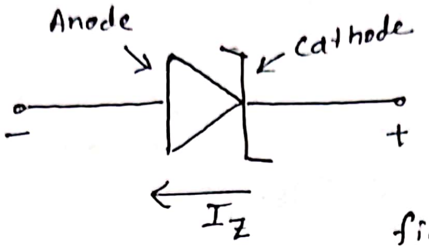
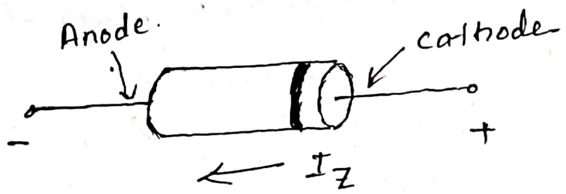


fig. circuit symbol

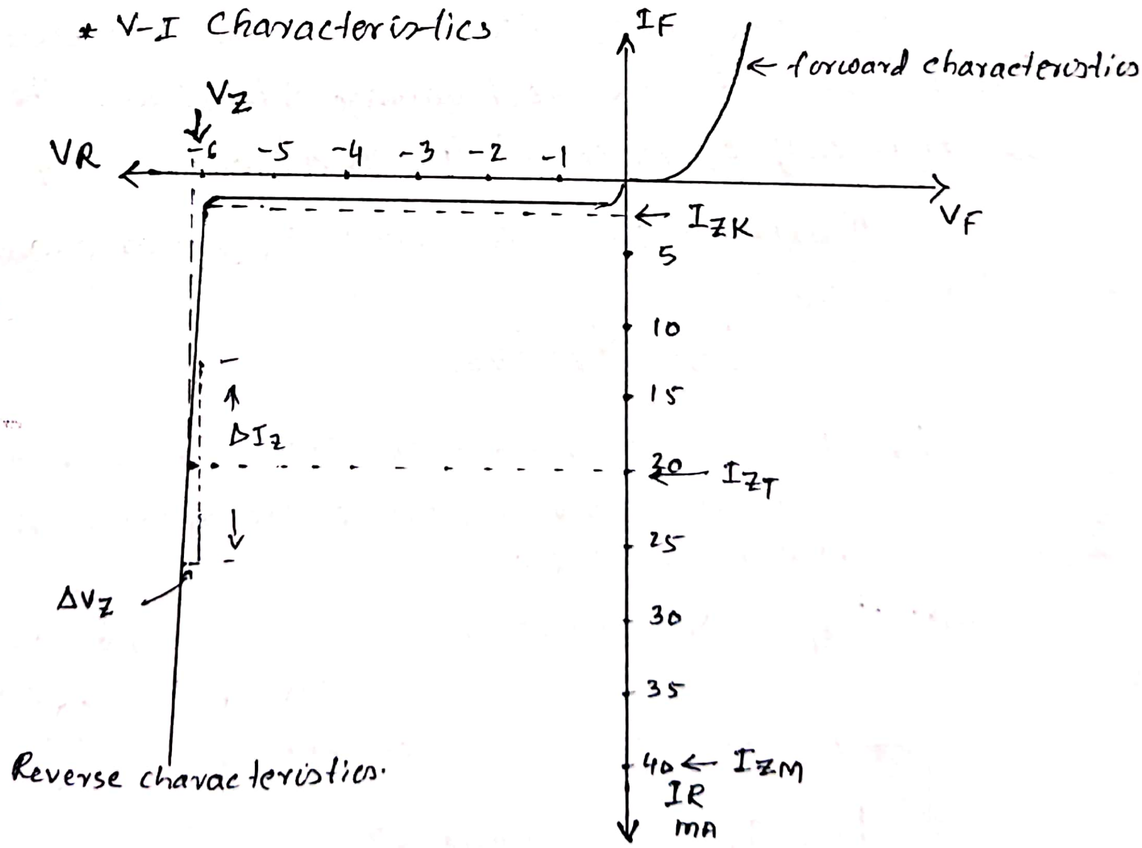
It is same as that of an ordinary diode, but the cathode bar approximately in the shape of letter Z.

Low power Zener diodes are available in a variety of packages, one of them is as shown in fig.



- Characteris and parameters of Zener diode.

* V-I Characteristics



Typical characteristics of a zener diode are shown in detail in fig. (previous page). Note that the forward characteristic is simply that of an ordinary forward biased diode.

Some important points (parameters) on the reverse characteristic are.

V_Z → Zener breakdown voltage.

I_{ZT} → Test current for measuring V_Z.

I_{ZK} → Reverse current near knee of the characteristic, the minimum reverse current to sustain breakdown.

I_{ZM} → maximum Zener current, limited by the maximum power dissipation.

The dynamic impedance (Z_z) is another important parameter that may be derived from the characteristice

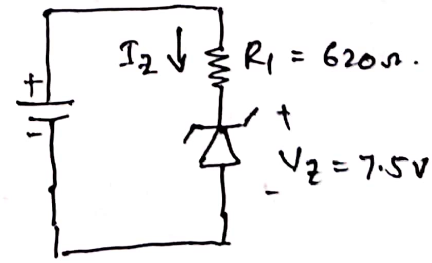
$$Z_z = \frac{\Delta V_Z}{\Delta I_Z}.$$

The zener diode current may be any level between I_{ZK} and I_{Zm}. For greatest voltage stability, the diode is normally operated at the test current I_{ZT}.

Maximum power dissipation of Zener diode is given by

$$P_D = V_Z \cdot I_{ZM}.$$

Ex: For the Zener diode ckt shown, $V = 20V$, $R_1 = 620\Omega$ and $V_Z = 7.5V$. Calculate the diode current & power dissipation



Soln:
$$V_{R_1} = V - V_Z = 20 - 7.5$$
$$= 12.5V.$$

$$I_Z = I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{12.5}{620} = 20.16\,mA$$

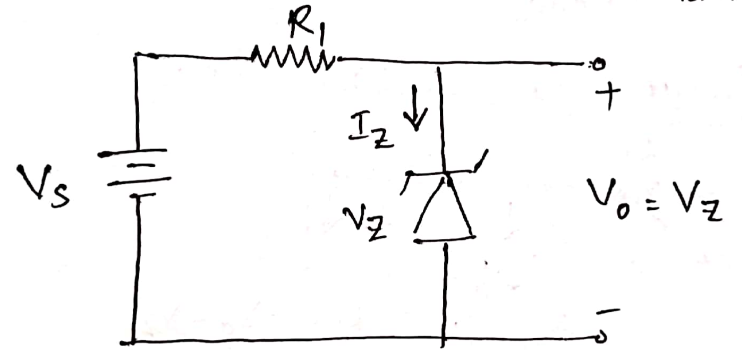
$$P_D = I_Z \cdot V_Z = 20.16 \times 10^{-3} \times 7.5$$
$$= 151\,mW.$$

* Zener Diode Voltage Regulator.

- Regulator Circuit with No Load.

Voltage regulator circuit is the one which is designed to keep the output voltage constant under varying input voltage conditions and varying load conditions.

The most important application of Zener diode is in dc voltage regulator circuits. The circuit shown in fig is usually employed as a voltage ~~source~~ reference source that supplies only a low current (much lower than I_Z) to the output.



Resistor R_1 in fig. limits the Zener diode current to the desired level.

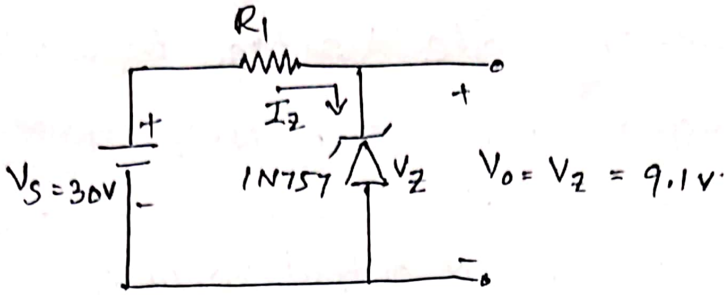
$$I_Z = \frac{V_S - V_Z}{R_1}$$

The Zener current may be just greater than the diode knee current I_{ZK}. However, for the most stable reference voltage, I_Z should be selected I_{ZT}.

Ex: A 9 V reference source is to be designed using a series connected Zener diode and resistor connected to a 30 V supply. Select suitable components and calculate the circuit current when the supply voltage drops to 27 V.

Soln: from data sheet 1N757 Zener diode has.

$$V_Z = 9.1\,V \quad , \quad I_{ZT} = 20\,mA.$$



with $V_S = 30V$

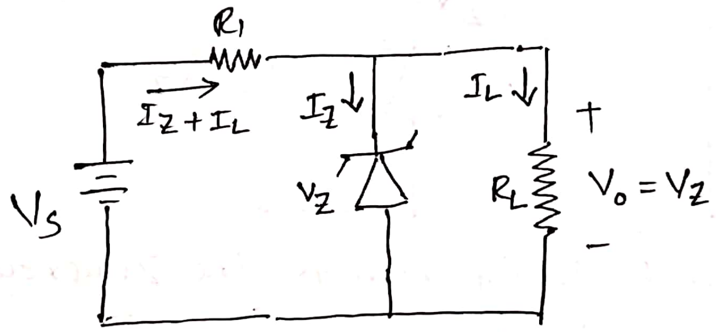
$$R_1 = \frac{V_S - V_Z}{I_Z} = \frac{30 - 9.1}{20 \times 10^{-3}}$$

$$= 1.05 k\Omega \simeq 1k\Omega.$$

when $V_S = 27V$

$$I_Z = \frac{27 - 9.1}{1 \times 10^3} = 17.9 mA.$$

— Regulator circuit with load



when a zener diode regulator has to supply a load current I_L as shown in fig, the total supply current through R_1 is the sum of I_L and I_Z. care must taken to ensure that the minimum zener diode current large enough to keep the diode in reverse breakdown

Typically $I_{Z(min)} = 5 mA$ for a zener diode with $I_{ZT} = 20 mA$.. The circuit current equation is

$$I_Z + I_L = \frac{V_S - V_Z}{R_1}$$

In some cases, the load current in the ckt shown may be reduced to zero. Because the voltage drop across R_1 remains constant, the supply current remains constant at.

$$I_{R_1} = I_Z + I_L$$

All of this current flows through the zener diode when R_L is disconnected. The circuit design must ensure that the total current does not exceed the maximum zener current I_{ZM}.

* Voltage regulator performance.

The performance of a zener diode voltage regulator may be expressed in terms of source and load effect and line and load regulation.

$$\text{Source effect} = \Delta V_o \text{ for } 10\% \text{ change in } V_s$$

$$\text{Line Regulation} = \frac{\text{source effect} \times 100\%}{V_o}$$

regulator output voltage is also affected by changes in load current I_L

$$\text{Load effect} = \Delta V_o \text{ for } \Delta I_{L\,max}$$

$$\text{Load regulation} = \frac{\text{Load effect} \times 100\%}{V_o}$$

- Ripple rejection ratio

It is the ratio of output to input ripple amplitudes.

$$\frac{V_{ro}}{V_{ri}} = \frac{Z_Z}{R_1 + Z_Z} \quad \text{regulator with no load}$$

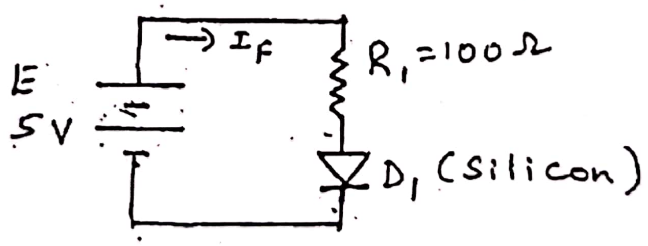
$$= \frac{Z_Z \| R_L}{R_1 + Z_Z \| R_L} \quad \text{regulator with load.}$$

QUESTION BANK

Module – 1

Semiconductor Diodes

1. Explain the operation of pn junction diode under forward and reverse bias conditions with the help of V-I characteristics curve.
2. Explain the forward and reverse characteristics of a silicon diode.
3. Draw and explain the V-I characteristics of a Ge (Germanium) diode.
4. Define following diode parameters: (i) Static resistance (ii) Dynamic resistance
   (iii) Knee voltage (iv) Forward voltage drop (v) Maximum forward current (vi) Reverse saturation current (vii) Reverse breakdown voltage (viii) Peak inverse voltage (PIV)
   (ix) Maximum power rating
5. Explain the different diode approximation with neat figures.
6. Construct the piecewise linear characteristic for a silicon diode which has a 0.25 Ω dynamicresistance and a 200 mA maximum forward current.
7. With appropriate circuit diagram, explain the DC load line analysis of semiconductor diode.
8. For the circuit shown in the figure, draw the DC load line and locate Q-point.



Diode Applications

1. What is a rectifier?
2. Explain positive half wave rectifier with input and output waveforms.
3. Explain the working of full wave bridge rectifier with neat circuit diagram and waveforms.
4. With a neat circuit diagram and waveforms, explain the working of centre-tapped full waverectifier
5. What is the need for a capacitive filter? Explain.

6. Describe the working of a capacitor filter for a half wave rectifier with a neat circuit diagramand necessary waveforms.

7. With a neat diagram and waveforms, explain the full-wave rectifier with a capacitive filter

8. Explain the operation of RC π-filter using full wave rectifier.

9. The input voltage to a half wave rectifier is V = 200 sin 50t. If R_L = 1 kΩ and forwardresistance of the diode is 50 Ω, find:

   i) The dc current through the diode
   ii) The ac or rms value of current through the circuit
   iii) The dc output voltage

10. A diode with V_F = 0.7 V is connected as a half wave rectifier. The load resistance is 500 Ω and the secondary RMS voltage is 22 V. Determine the peak output voltage and the peak load current.

Zener Diodes

1. Name the junction breakdowns in diodes. Explain them briefly.
2. Write down the characteristic of Zener diode.
3. What is Zener diode? With neat circuit diagram, explain the operation of voltage regulatorwith and without load.
4. Explain the performance of Zener diode voltage regulator in terms of source and load effects.
5. Discuss the load and line regulation using Zener diode with neat circuit diagram and appropriate expressions.