Date:- 20/02/2022

Assignment Sheet :- 01 (BEC-101)

Unit :- 01

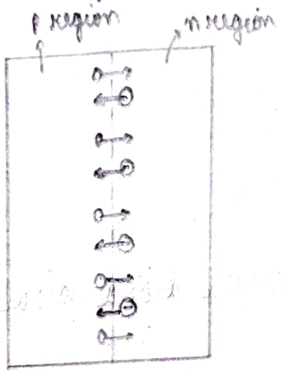
Ques.1 Explain the behavior of unbiased pn junction.

Ans When unbiased pn junction is not doped perfectly. Then at some place there is accumulation of charge is there where as in some place the concentration of charge is less.

In order to balance out the charge, the charge start moving from high concentration region to the region of charge is less.

This process is known as diffusion.

The current generated by this process known as diffusion current.



Unbiased pn junction.

Ques.2 What is depletion layer and junction in an unbiased pn junction

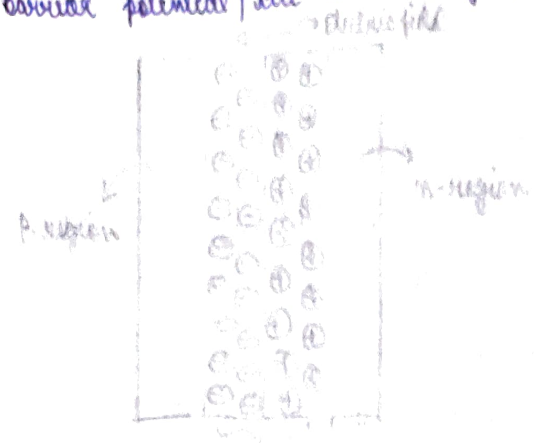
Ans:- As holes from p side move towards the n region. They find the no. of donor atom. The process of recombination occurs. This creates the negative ion with positive charge which is immobile. This creates a wall of positive immobile at the junction in the region.

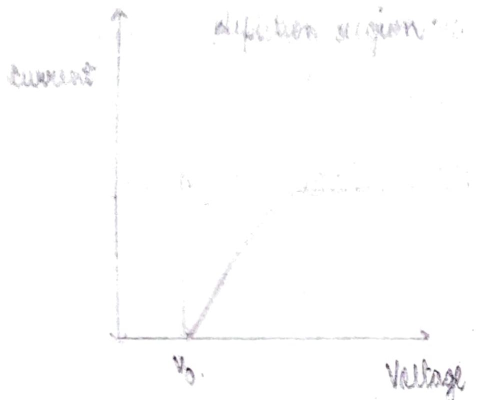
Same process occurs at p region.

Thus the region is formed which is free from free charge carriers or which is depleted from free charge carriers. This region is known as depletion region.

As the positive ion and negative ion get accumulated across the junction.

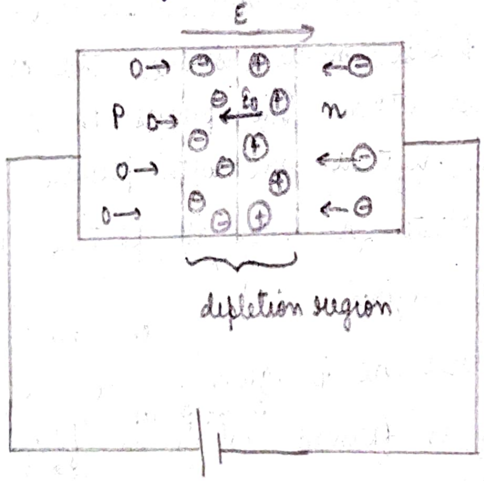
This creates the electric field across the junction. This electric field causes the potential across the junction. This causes the barrier potential | cut in voltage | built-in potential.





Ques3:- Explain the behavior of forward biased diode. Draw forward characteristics of diode.

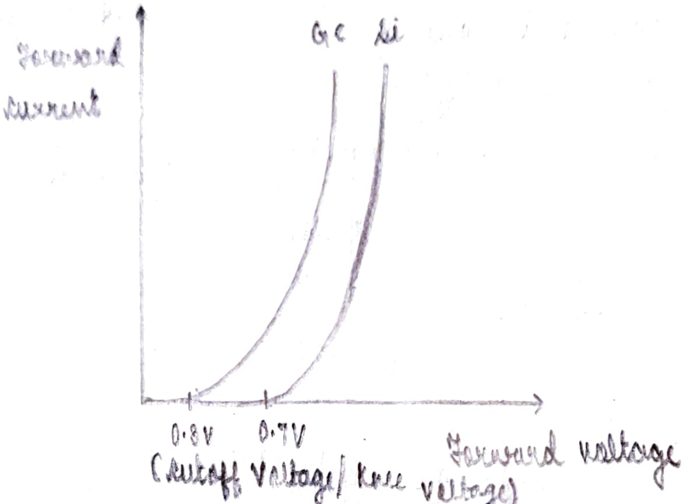
Ans:- When p side of the diode is connected with positive terminal and n side of diode is connected with negative terminal of the battery is known as forward biased.



Forward biased

In this,
the positive terminal of the battery attr repels the holes from the p region to n region.
Similarly the negative terminal of battery repels the electron from n side to p region.

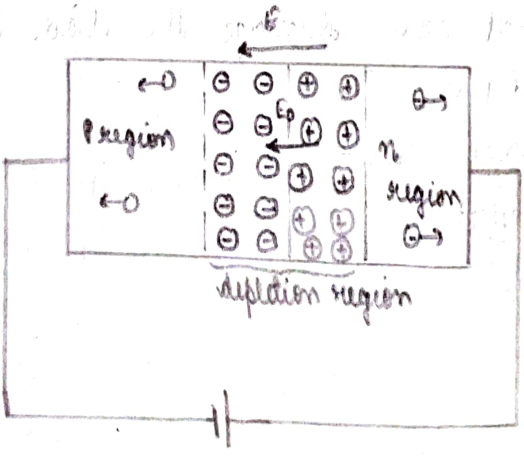
This causes the flow of charge carriers across the junction which reduces the depletion region across the junction. Hence the external voltage overcome the potential barrier.



Forward VI characteristics

Ques 4:- Explain the behavior of reverse biased diode. Draw reverse character-istics of diode.

Ans:- When the p side of the diode is connected with negative term-inal and n side of the diode is connected with positive terminal of the battery, The diode is said to be in reverse biased.



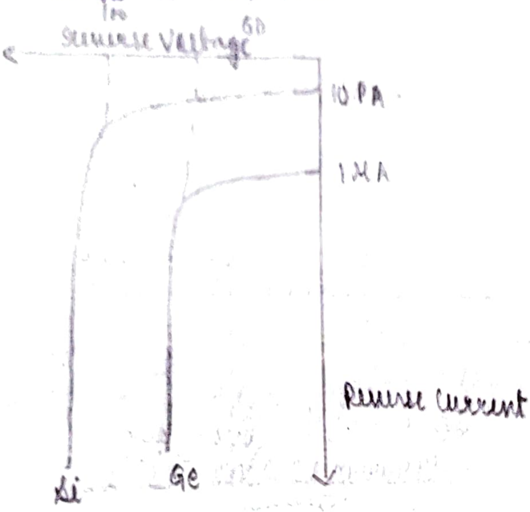
The operations are-

The positive terminal of the battery attracts the holes from the region away from the junction similary the negative Terminal of the battery attracts the free electrons from n region from the junction

This results the width of depletion region increment.

Here the charge carrier does not move.

Since the reverse voltage does not depends upon reverse current so but on minority charge carriers since the minority charge carriers are less so current is also less.



Reverse VI Characteristics

Ques-5:- What is reverse breakdown? Explain two breakdown mechanism.

Ans:- Although the reverse saturation current does not depends upon the reverse voltage. But when the reverse voltage is increased at the certain limit. The reverse current becomes too large. That can damage the diode too, known as reverse breakdown.

The two mechanisms are-

a) Avalanche effect

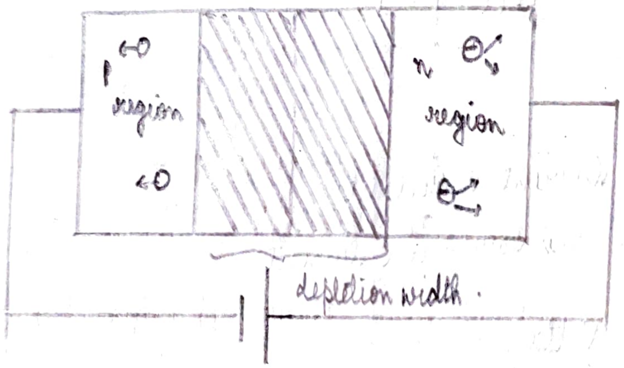
b) Zener effect.

a) Avalanche effect →

The reverse current is not dependent upon the reverse voltage. when the reverse voltage is increased up to a certain limit, the velocity of minority charge carriers increased. This causes the increment in the kinetic energy of the minority charge carriers. Due to high K.E these minority charge carriers collide with the atoms and make the electron free.

These free electron move under high reverse voltage and generate more minority charge carriers known as carrier multiplication.

+ These large no. of charge carriers move under the high reverse voltage generating more electrons large current. This effect is known as avalanche effect. The voltage at which breakdown occurs known as reverse breakdown voltage.



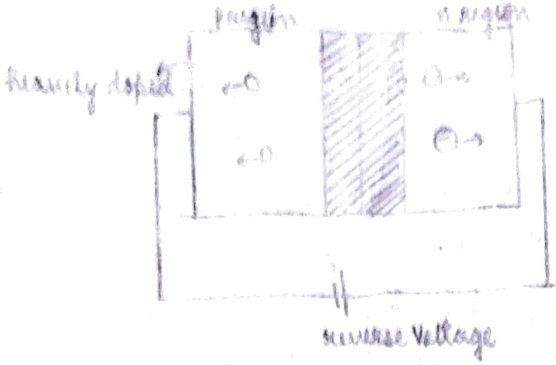
b) Zener effect:-

When the diode is heavily doped. Then the depletion region is very narrow. and from-

$$\uparrow E = \frac{V}{d\downarrow}$$

The Electric field is very intense. and such intense electric field is enough to pull the electron out of the valence shell. This creates a large number of free charge carriers. and causes the large current in the diode.

This effect is known as zener effect.



Ques 6:- Write the diode equation and explain the significance of various terms.

Ans:- The diode equation is the relation between the current and the voltage. It states how the current varies exponentially with the voltage.

$$I = I_0 \left(e^{V/\eta V_T} - 1\right)$$

where,

I: Current resultant.

I_0 = ~~rev~~ Saturation Current

V = Voltage.

V_T = Voltage equivalent of Temperature.

$V_T = \frac{T}{11600}$ where T is in Kelvin

at 300 K, the V_T = 26 mV.

and

Value of η is -

1 for ~~Ge~~ germanium

2 for Silicon.

Ques 6 :- Explain the VI characteristics of diode. Explain the effect of temperature of pn junction. Define forward and reverse dynamic and static resistance of diode

Ans :- The VI characteristics is the graph drawn between the voltage and current.

In forward biased condition,

till the external voltage is less than cut off voltage the conduction is zero

when the external voltage is greater than the cut off voltage, then the charge carries cross the junction as they overcome the barrier potential.

This causes the exponential increase in current, known as forward current.

a) Static resistance :-

The resistance offered by the diode when they are connected across the dc voltage.

$$r_s = \frac{V}{I}$$

b) Dynamic resistance :-

The resistance offered by the diode when they are connected across the ac voltage.

$$r_d = \frac{\Delta V}{\Delta I}.$$

In reverse biased condition,

The positive terminal of the battery attracts the holes from p region away from junction and similarly negative terminal electron away from junction.

No. charge carrier can cross the junction.

The reverse current is not dependent upon reverse voltage but on minority charge carriers. Since, the charge carrier is less so the reverse current is also very less.

But when the reverse voltage is increased upto a certain limit, the current increased suddenly.

$$= 0.01 = 6\times10^{-8}\left(e^{\frac{V\times1000}{52}}-1\right)$$

$$= e^{\frac{V\times1000}{52}}-1 = \frac{10^{8}}{6\times10^{2}}$$

$$= e^{\frac{V\times1000}{52}}-1 = \frac{10^{6}}{6}$$

$$e^{\frac{1000V}{52}} = 166666.67+1$$

$$e^{\frac{1000V}{52}} = 166667.67$$

$$\frac{1000V}{52} = \log(166667.67)$$

$$\frac{1000V}{52} = 5.22$$

$$V = 0.27\text{ V} \quad \underline{\text{Ans}}$$

Ques. 10 :- For a silicon diode with reverse saturation current of 0.1 μA. Calculate dynamic forward and reverse resistance of voltage 0.62 and -0.62 V respectively, applied across the room temperature of 26°C.

Solution:- for dynamic forward resistance.

$I_0 = 0.1\ \mu A.$

$V = 0.62\ V$

$\eta = 2$

$V_T = 26\ mV$

$$r_f = \frac{\eta V_T}{I_0\, e^{V/\eta V_T}}$$

$$r_f = \frac{2\times26\ mV}{0.01\ \mu A\ e^{620/52}}$$

$$r_f = \frac{2\times26\times10^{6}\times100}{10^{3}\times e^{620/52}}$$

$= r_f = \dfrac{52 \times 10^5}{e^{620/52}}$

$r_f = \dfrac{52 \times 10^5}{147266.6}$

$35.3\ \Omega$.

for dynamic reverse resistance -

$I_0 = 0.1\ \mu A$.

$V = -0.62\ V$

$\eta = 2$

$V_T = 26\,mV$

$r_r = \dfrac{\eta V_T}{I_0 e^{V/\eta V_T}}$

$r_r = \dfrac{2 \times 26\,mV}{0.01\ \mu A\ e^{-620/52}}$

$r_r = \dfrac{52 \times 10^5}{e^{-620/52}}$

$r_r = \dfrac{52 \times 10^5}{6.8}$

$r_r = 7.64 \times 10^5\ \Omega$

Thus the resistances are -

a) forward resistance

$35.3\ \Omega$

b) Reversed resistance

$7.64 \times 10^5\ \Omega$.

Ques. 11:- Calculate the dynamic forward and reverse resistance of a pn junction when applied to a voltage of 0.26V at 300 k. given $I_0 = 2\mu A$ $Si = 0.7V$ and $Ge = 0.3V$.

Solution:- In case of Silicon.

a) Forward resistance.

$I_0 = 2\mu A$

$\eta = 2$

$V_T = 26\,mV$

$V = 0.7V$

$$I = I_0(e^{V/\eta V_T} - 1)$$

$$r_f = \frac{\eta V_T}{I_0 e^{V/\eta V_T}}$$

$$r_f = \frac{2 \times 26 \times 10^{6}}{2 \times 10^{3} \times e^{0.7 \times 1000/52}}$$

$$r_f = \frac{26000}{e^{700/52}}$$

$$r_f = \frac{26000}{660003.2}$$

$$r_f = 0.039\ \Omega$$

b) reverse resistance-

$I_0 = 2\mu A$

$\eta = 2$

$V = -0.7V$

$$r_r = \frac{\eta V_T}{I_0 e^{V/\eta V_T}}$$

Similarly; $$r_r = \frac{26000}{e^{-700/52}} = \frac{26000}{1.5} = 17333.3\ \Omega.$$

· In case of germanium.

a) Forward resistance -

$I_0 = 2\mu A$

$V_T = 26mV$

$\eta = 1$

$V = 0.3V$

$$r_f = \frac{\eta V_T}{I_0 e^{V/\eta V_T}}$$

$$r_f = \frac{1 \times 26mV}{2 \times 10^{-6} \times e^{0.3 \times 1000/52}}$$

$$r_f = \frac{13000}{e^{300/52}}$$

$$r_f = \frac{13000}{298.9}$$

$43.4\,\Omega$

b) reverse resistance :-

$I_0 = 2\mu A$

$V_T = 26mV$

$\eta = 1$

$V = -0.3V$

$$r_r = \frac{\eta V_T}{I_0 e^{V/\eta V_T}}$$

$$r_r = \frac{1 \times 26mV}{2 \times 10^{-6}\, e^{-300/52}}$$

so; $$r_r = \frac{13000}{e^{-5.7}}$$

$$r_r = \frac{13000}{0.003}$$

$4333333.3\,\Omega$

Ques. 12:- Write in detail about two type of capacitances associated with diodes. State its practical significances.

Ans:- There are two types of capacitances on the basis of the biasing of the pn junction -

a) When the diode is forward biased the capacitance offered is known as diffusion capacitance.

b) When the diode is reverse biased, the capacitance offered is known as transition capacitance.

• Transition capacitance:-

Transition capacitance is defined as change in charge per change in voltage.

$$C_T = \frac{dq}{dV}$$

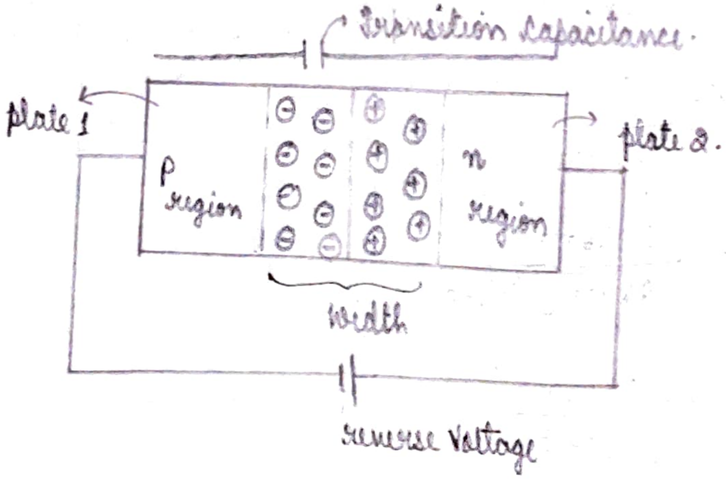
The transition capacitance is also known as-

a) Junction capacitance.

b) Space charge capacitance.

c) Barrier capacitance.

d) Depletion region capacitance.



$$C_T = \frac{\varepsilon A}{W}$$

where ε (permittivity of semiconductor) $= \varepsilon_0 \varepsilon_r$.

ε_0 = permitivity of free space.

ε_r = relative permitivity of semiconductor.

A: Area of capacitor.

W = Width of capacitor.

• Diffusion Capacitance-

The capacitance that happens due to transport of charge carriers between the two terminals of the diode.

During forward biasing the depletion width decreases, then holes diffuses from p to n and electrons from n to p side.

$$C_D = \frac{\tau I}{\eta V_T}$$

τ = Mean life time

I = Current

V_T = Voltage equivalent of Temperature.

Both of these capacitances will limit the performance of switching speed of Pn junction

In case of junction capacitance one can normally increase current based on $I = C' \frac{dv}{dt}$ to improve switching speed.

In case of diffusion capacitance, it is not as simple. The problem with diffusion capacitance is that amount of charge carriers is proportional to current.

Therefore higher the current, the higher the capacitance.

Ques:-13:- What is rectifier? What are important characteristics of rectifier circuit? Explain why diode is used as a rectifier?

Ans:- The rectifier is the device which converts the ac signal into the dc signal.

There are three types of rectifier -

a) Half-wave rectifier.

b) Full wave rectifier.

c) Bridge-rectifier.

The important characteristics of rectifier circuit are-

a) Efficiency -

The efficiency is defined as ratio of the output dc power to the input ac power.

$$\text{efficiency} = \frac{I^2_{dc} \times R_L}{I^2_{ac}(R_L + R_f)}$$

b) Ripple factor -

The ripple factor is defined as amount of ac component in the dc current.

$$\text{ripple factor} = \frac{\sqrt{I^2_{rms} - I^2_{dc}}}{I_{dc}}$$

c) Peak Inverse voltage:-

It is defined as maximum voltage that a diode can with stand in reverse biased.

The diode in forward biased condition allows the current to pass through it and in reverse biased condition it behaves as short circuit and blocks the ac signal. Thus allows positive cycle allows and in negative half cycle it blocks, This process is known as rectification.

Ques 14:- Draw the circuit diagram of half wave, full wave and bridge rectifier and explain its operation with proper expressions.

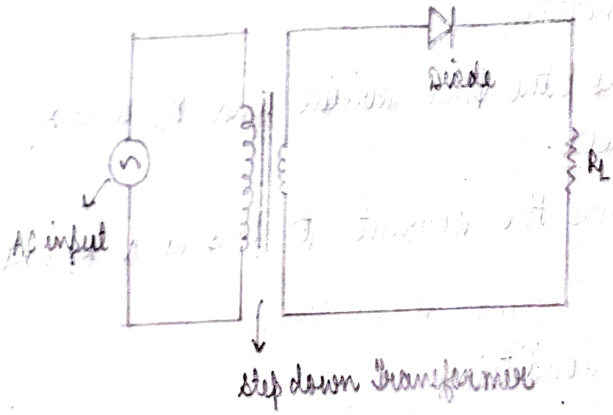
Ans:- Half wave rectifier:

The rectifier is the device that converts the ac signal into the dc one. The rectifier that converts the half cycle of input signal into dc one and blocks the other half cycle known as half wave rectifier.

In half wave rectifier,

The diode allows the current to pass through it in forward biased condition, as it behaves as the short circuit.

In reverse biased condition, the diode behaves as the open circuit and does not allowed the current to pass through it.



• Full wave rectifier:

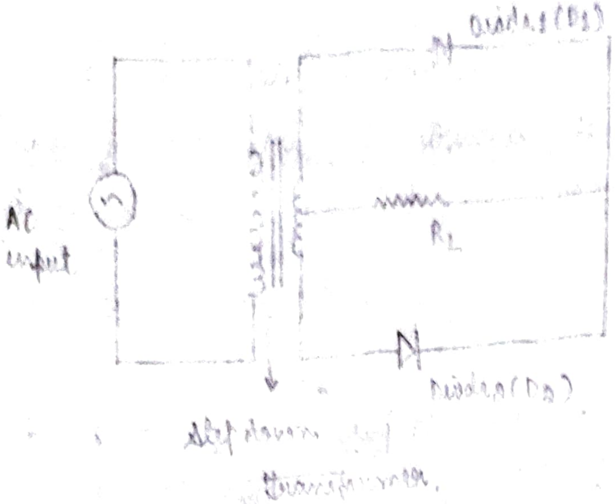
The rectifier that converts both cycles of input ac signal into dc signal.

In full wave rectifier,

In ~~forward biased circuit~~ positive half cycle, D_1 is forward biased and D_2 is reverse biased. So, D_1 act as short circuit and D_2 as open circuit. Thus D_1 allows the current to pass and D_2 blocks the current.

In negative half cycle, D_1 is reverse biased and D_2 is forward biased. So D_1 act as open circuit and D_2 act as reverse biased.

Thus it converts the both cycle of ac input into dc output.



c) Bridge rectifier-

The rectifier that converts both the input ac cycle into output one.

In forward biased condition,

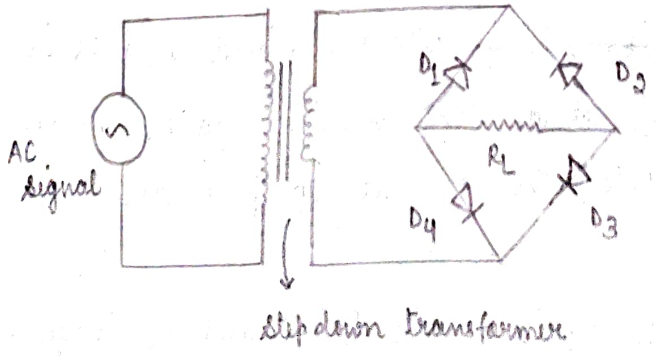
D_1 and D_3 behaves as the shot circuit and D_2 and D_4 behaves as the reverse biased.

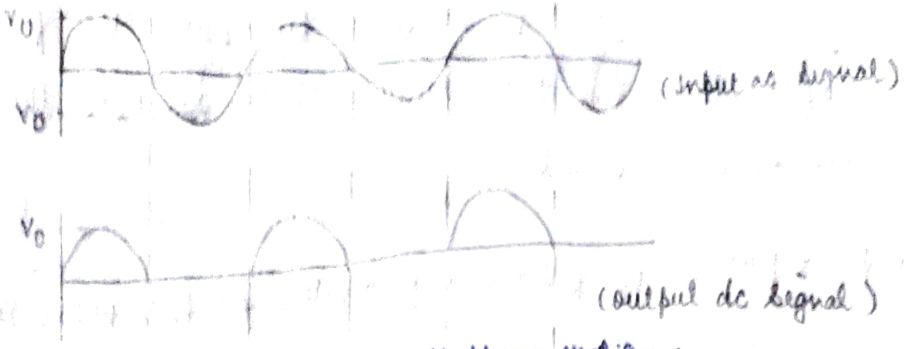
Thus D_1 and D_3 allows the current to pass and D_2 and D_4 doesn't.

In reverse biased condition,

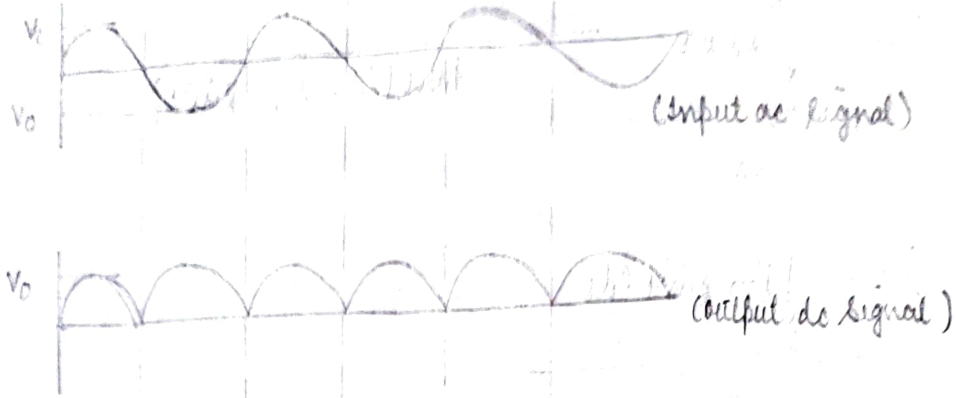
D_2 and D_4 behaves as the ~~open~~ shot circuit and D_1 and D_3 act as open ~~shot~~ circuit.

Thus, D_2 and D_4 allows the current to pass and D_1 and D_3 doesn't.





Half wave rectifier.



Full wave rectifier.

Ques.15:- Define the ripple factor and rectifier efficiency. What is requirement of the rectifier in terms of ripple factor? How is it achieved?

Ans:- The ripple factor is defined as the amount of ac component present in dc component output of the rectifier.

The rectifier efficiency is defined as the ratio of the output power to the input power.

The requirement of rectifier in terms of ripple factor is that we should use the full wave rectifier.

The full wave rectifier's ripple factor is 0.482, where as in case of half wave rectifier is 1.21.

Thus we should use the full wave rectifier. in case of half wave rectifier the ripples of ac is more than full wave rectifier.

The ripple factor can also be reduced by using the filter circuit, the filter circuit is the circuit that removes the ripples of ac from dc output.

Ques-6 Derive the expression of following parameters for half wave rectifier.

a) Average dc current:-

$$I_{dc} = \frac{\int_0^{\pi} i_d \, d\theta}{2\pi} \qquad \text{here } (i_d = i_m^2 \sin^2\theta)$$

$$I_{dc} = \frac{\int_0^{\pi} i_m^2 \sin^2\theta \cdot d\theta}{2\pi}$$

$$I_{dc} = \frac{i_m^2 \int_0^{\pi} \sin^2\theta \cdot d\theta}{2\pi}$$

$$I_{dc} = \frac{1}{4\pi} \times i_m^2 \int_0^{\pi} (1-\cos 2\theta) \, d\theta$$

$$I_{dc} = \frac{i_m^2}{4\pi} \left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

On solving $= \frac{I_m}{\pi}$

b) Average dc voltage:-

$$V_{dc} = \frac{\int_0^{\pi} V_d \cdot d\theta}{2\pi}$$ here $(V_d = V^2_m \sin^2\theta)$

$$V_{dc} = \frac{\int_0^{\pi} V^2_m \sin^2\theta \cdot d\theta}{2\pi}$$

$$V_{dc} = \frac{V^2m}{4\pi} \int_0^{\pi} (1-\cos 2\theta) \cdot d\theta$$

$$V_{dc} = \frac{V^2m}{4\pi} \left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

$$V_{dc} = \frac{V_m}{\pi}$$

c) RMS value of current:

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2_d \cdot d\theta}$$

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2_m \sin^2\theta \cdot d\theta}$$

$$I_{rms} = \sqrt{\frac{1}{2\pi}\left(\int_0^{\pi} i^2_m \sin^2\theta \cdot d\theta + \int_0^{\pi} 0 \cdot d\theta\right)}$$

so; $I_{rms} = \frac{I_m}{2}$

d) RMS value of Voltage:-

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} V^2_d \cdot d\theta}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} V^2_m \sin^2\theta \cdot d\theta}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi}\left(\int_0^{\pi} V_m^2 \cdot \sin^2\theta \cdot d\theta + \int_0^{\pi} 0 \cdot d\theta\right.}$$

$$V_{rms} = \frac{V_m}{2}$$

c) ripple factor (η) and ripple efficiency -

$$\text{ripple factor} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{I_m}{2} \times \frac{\pi}{I_m}\right) - 1}$$

$$= \sqrt{\frac{\pi^2}{4} - 1} \qquad = 1.21.$$

$$\text{ripple efficiency} = \frac{\text{output power}}{\text{Input power}}$$

$$= \frac{I_{dc}^2 \times R_L}{I_{rms}^2 (R_L + R_f)}$$

$$= \frac{\cancel{I_m^2} \times \pi^2}{4 \times \cancel{I_m^2}\left(1 + \frac{R_f}{R_L}\right)}$$

since R_f is very small

so $\frac{R_f}{R_L} \to 0$

$$= \frac{\pi^2}{4} = 0.406$$

or 40.6%