SEMICONDUCTOR ELECTRONICS MATERIALS, DEVICES AND SIMPLE CIRCUITS

Important Points:

1. In semiconductors Valence band is almost filled and the conduction band is almost empty. The energy gap is very small and it is about 1eV.

2. Energy gap for silicon = 1.12eV and for Germanium = 0.72eV.

3. Fermi Energy Level is the highest energy level which an electron can occupy at zero Kelvin.

4. **Intrinsic Semiconductor:**

The number of electrons in the conduction band and the number of holes in valence band are equal. Charge carries are both electrons and holes.

5. **Extrinsic Semiconductor:**

The conductivity of a pure semiconductor can be increased by adding impurities. Adding impurity to a pure semiconductor is called doping. Such a semiconductor is called Doped or Extrinsic Semiconductor.

6. **N-Type Extrinsic Semiconductor**:

Pentavalent substances like arsenic, phosphorus, antimony, bismuth are doped into a pure semiconductor.

7. **P-Type Extrinsic Semiconductor**:

Trivalent substances like boron, aluminium, gallium, indium etc are doped in a pure semiconductor.

8. Zener diode is the reverse biased p-n junction diode which can be used as a voltage regulator.

9. Transistors:

A transistor is formed by sandwiching a thin layer of a p-type semiconductor between two layers of n-type semiconductors or by sandwiching a thin layer of an n-type semiconductor between two layers of p-type semiconductors.

10. Emitter:

a) It is heavily doped to get more number of majority charge carriers.

b) Width of this region is slightly less than that of collector region.

c) Its function is to supply majority carriers to the base.

11. Base:

a) It is the middle section of the transistor.

b) It is slightly doped.

c) Width of this region is very thin (of the order of 10^{-6} m)

d) Its function is to inject majority carriers to the collector.

12. Collector:

a) It is moderately doped.

b) This is physically large of all regions to get large number of charge carriers.

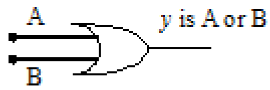
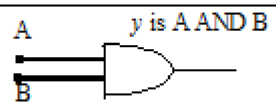
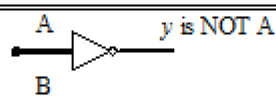
c) Its function is to collect majority carriers from the base.

13. The relation between emitter, base and collector currents is $I_E = I_B + I_C$.

14. C-E configuration transistors are widely used as amplifiers because of its higher efficiency over the other configurations.

15. A light emitting diode (LED) is a specially made forward biased P-N junction diode which emits visible light when energized.

16. A logic gate is an electronic circuit which performs a particular logical function.

Gate	Boolean Expression	Read as	Symbol
OR (+)	y = A + B	y is A OR B	
AND (•)	y = A.B	y is A AND B	
NOT (bar or complementation)	$y = \bar{A}$	y is NOT A	

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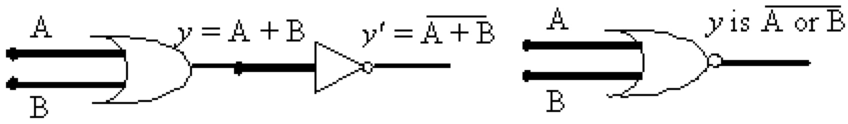
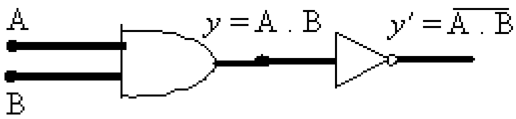
18. NOR Gate (NOT + OR)

This is the combination of NOT and OR gates.



19. NAND Gate

This is the combination of NOT and AND gates



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Very Short Answer Questions

1. What is an n-type semiconductor? What are the majority and minority charge carriers in it?

A. When pentavalent impurity is added to a pure semiconductor, then it is called n-type semiconductor.

In n-type semiconductor electrons are majority charge carriers and holes are minority charge carriers

2. What are intrinsic and extrinsic semiconductors?

A. Intrinsic semiconductors:

Pure semiconductors are called the intrinsic semiconductors.

Ex: Ge, Si etc.

Extrinsic semiconductors:

Doped semiconductors are called the extrinsic semiconductors.

Ex: P-type and n– type

3. What is a p-type semiconductor? What are the majority and minority charge carriers in it?

A. When trivalent impurity is added to a pure semiconductor, then it is called p-type semiconductor.

In p-type semiconductor holes are majority charge carriers and electrons are minority charge carriers

4. What is a p – n junction diode? Define depletion layer?

A. p – n Junction Diode:

When an intrinsic semiconductor is grown with one side doped with trivalent substance and other side with pentavalent substance, a junction is formed in the crystal called p – n junction diode.

Depletion Layer:

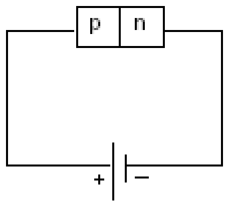
A region without any charge carriers is formed at p-n junction due to the recombination of electrons and holes is called depletion layer.

5. **How is battery connected to junction diode in**

1) Forward Bias **2) Reverse Bias**

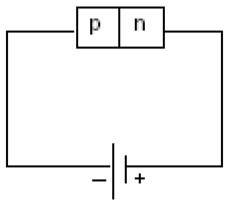
A. **1) Forward Bias:**

In the forward bias positive terminal of battery is connected to p-region and negative terminal of battery is connected to n-region.



Forward bias

2) Reverse Bias



Reverse bias

In reverse bias negative terminal of battery is connected to p-region and positive terminal of battery is connected to n-region.

6. **What is the maximum percentage of rectification in half wave and full wave rectifiers?**

A. 1) Efficiency of half- wave rectifier $= \dfrac{DC\ \ power\ ouput}{AC\ \ power\ \ input} = \dfrac{0.406 R_L}{R_L + r_f}$

Where r_f = forward resistance of diode. R_L- Load resistance.

Maximum efficiency of the half- wave rectifier is 40.6%.

2) Efficiency of the full-wave rectifier $= \dfrac{DC\ \ power\ ouput}{AC\ \ power\ \ input} = \dfrac{0.812 R_L}{r_f + R_L}$

Where r_f = forward resistance of diode. R_L- Load resistance.

Maximum efficiency of the full-wave rectifier is 81.2%.

7. What is zener voltage (V_Z) and how will a zener diode be connected in circuits generally?

A. The zener diode in reverse bias condition the voltage at which current rises suddenly is called zener voltage. Generally zener diode is connected in reverse bias condition.

8. Write the expressions for the efficiency of a full wave rectifier and a half wave rectifier?

A. (i) In half wave rectifier $\eta = \frac{0.406\, R_L}{r_f + R_L}$

(ii) In full wave rectifier $\eta = \frac{0.812\, R_L}{r_f + R_L}$

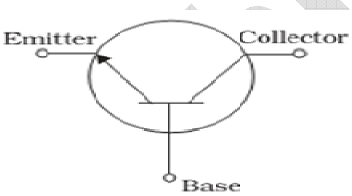
9. What happens to the width of the depletion layer in a p-n junction diode when it is 1) Forward biased and 2) Reverse Biased?

A. 1) In forward bias condition, width of the potential barrier decreases.

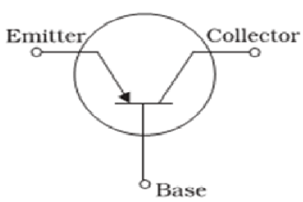
2) In reverse bias condition, width of the potential barrier increases.

10. Draw the circuit symbols for p-n-p and n-p-n transistors

A.



Circuit symbol for n-p-n



Circuit symbol for p-n-p

11. Define amplifier and amplification factor?

A. The process of raising the strength of a weak signal is known as amplification and the device which accomplishes this job is called an amplifier.

The ratio of output voltage (V_0) to input voltage (V_i) is called Amplification Factor (A)

Thus $A=\frac{V_0}{V_i}$

12. In which bias can a zener diode can be used as voltage regulator?

A. A device used to give constant output voltage even when the input voltage changes is called voltage regulator. Zener diode can be used as voltage regulator by operating it in the breakdown region in reverse bias condition.

13. Which gates are called universal gates?

A. NAND gate and NOR gate are known as the basic building blocks of logic gates or universal gates because any logic gate can be constructed by using only NAND gates or only NOR gates.

14. Write the truth table of NAND gate. How does it differ from AND gate?

A. Truth Table:

NAND Gate

Input		Output
A	B	$Y=\overline{A.B}$
0	0	1
1	0	1
0	1	1
1	1	0

AND Gate

Input		Output
A	B	Y=A.B
0	0	0
1	0	0
0	1	0
1	1	1

NAND gate differ from AND gate, the output of a NAND gate is an inversion of an AND gate.

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Short Answer Questions

1. What are n- type and p- type semiconductors? How is a semiconductor junction formed?

A. The conductivity of a pure semi-conductor can be increased by adding impurities. Adding impurity to a pure semiconductor is called doping. Such a semiconductor is called an extrinsic semi-conductor.

Extrinsic semiconductors are classified into 2 types, namely N - type and P - type

N-type Extrinsic Semiconductor:

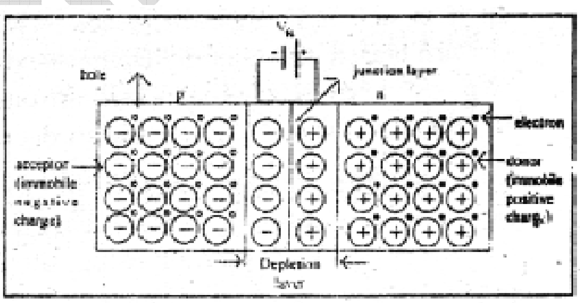
Pentavalent substances like arsenic, phosphorus, antimony, bismuth are doped in a pure semiconductor. Arsenic is called donor impurity. Majority charge carries are electrons and minority charge carries are holes. Hence it is called N-type semiconductor. Fermi energy level is nearer to the conduction band.

P-type Extrinsic Semiconductor:

Trivalent substances like boron, aluminium, gallium, indium etc are doped in a pure semi-conductor. Boron is called acceptor impurity. Majority charge carries are holes and minority charge carries are electrons and hence it is called p-type semi-conductor. Fermi energy level is nearer to the valence band.

p – n Junction:

A p-n junction is formed by doping n-type on one side and p-type on the other side of a pure semi conductor. p-side of semiconductor contains excess holes and n-side of semi conductor contains excess of electrons.



Junction Barrier:

In p-n junction electrons from n-side diffuse across the junction into p-side and combine with holes there. Similarly, holes from p-side diffuse across the junction into n side and combine with electrons there. Due to diffusion, positive ions are left over in n-region and negative ions are left over in p-region, near the junction. These ions are immobile. Due to the immobile ions on either side of the junction an internal electric field is formed at the junction which is directed from n to p. At p-n junction a neutral region where there are no charge carriers is formed and it is called depletion layer. The thickness of the depletion layer is of the order of 10^{-6} m. The potential difference across the barrier prevents diffusion of charge carriers through the junction and it is called potential barrier. The potential barrier depends on the nature of semiconductor, doping concentration and temperature of the junction. There is no current in the p-n junction diode in the absence of any external battery.

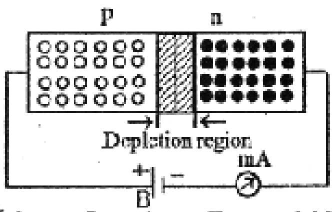
2. Discuss the behavior of a p-n junction. How does a potential barrier develop at the junction?

A. When p-n junction is formed the free electrons on n-side diffuse over to p-side, combine with holes and become neutral. Similarly the holes on p-side diffuse over to n-side, combine with electrons and become neutral. “This results in the formation of a narrow region on either side of the junction, which becomes free from charge carriers. This region is called depletion layer.

The loss of electrons from the n-region and the gain of electron by the p-region cause a difference of potential across the junction of the two regions. The polarity of this potential is such as to oppose further flow of carriers so that a condition of equilibrium exists. The n-material has lost electrons, and p material has acquired electrons. The n material is thus positive relative to the p material. Since this potential tends to prevent the movement of electron from the n region into the p region, it is often called a barrier potential.

3. Draw and explain the current – voltage (I-V) characteristic curves of a junction diode in forward and reverse bias?

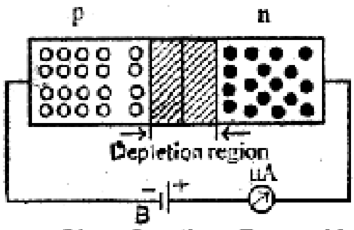
A. Forward Bias:



(a) p-n Junction - Forward bias

In a p-n junction diode, p-region is connected to positive terminal of a battery and n-region is connected to negative terminal of a battery .Then it is called forward bias. The width of depletion layer and barrier potential decrease. In forward biased condition, the flow of current is mainly due to the diffusion of charge carriers. The direction of current is from p to n .The voltage of at which the current starts is called knee voltage. The current will be of order of few mill amperes.

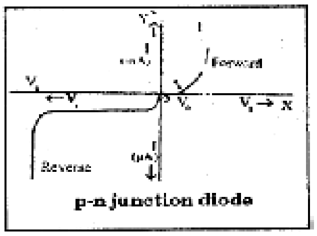
Reverse Bias:



(b) p-n Junction - Reverse bias

In a p-n junction diode, p-region is connected to negative terminal of a battery and n-region is connected to a positive terminal of the battery. Then it is called reverse bias. The width of the depletion layer and barrier potential increase. In reverse biased condition a small current flow through the junction due to the drift of minority charge carriers. This is called leakage current .This is of order of few micro amperes .The direction of current in it is from n to p during reverse bias.

I-V Characteristics:



p-n junction diode

Current - voltage (I-V) characteristic curves of junction diode in forward and reverse bias modes are shown. The reverse voltage applied to junction diode at which sudden rise of reverse current due to breakage of covalent bonds in semi-conductor and creates large number of electron-hole pair, is called breakdown voltage.

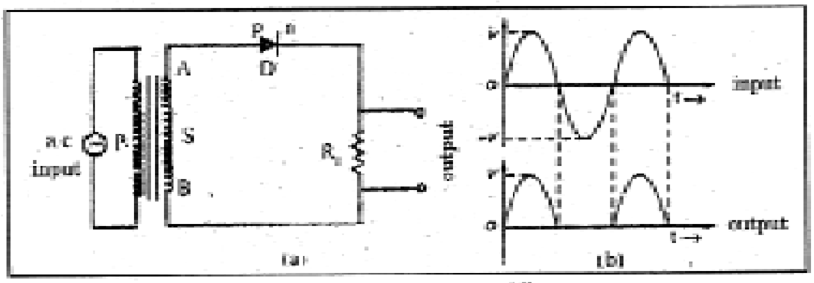
4. Describe how a semi -conductor diode is used as a half wave rectifier?

A. Rectifier:

Conversion of AC voltage into DC voltage is called rectification. A p-n junction diode is used as a rectifier.

Half wave rectifier:

In a half wave rectifier a single diode is used. The AC from the secondary of the transformer AB is applied to the diode and a load resistance R_L in series. During the positive half cycle, the diode is forward biased and current flows though the diode and the load resistance. During the negative half cycle, the diode is reverse biased and current does not flow through the diode. Thus current flows during the positive half cycle only. The output across the load resistance contains rectified voltage which is a variable DC.



p-n diode - half wave rectifier

Efficiency of half- wave rectifier $= \frac{DC\ \ power\ \ ouput}{AC\ \ power\ \ input} = \frac{0.406 R_L}{R_L + r_f}$

Where r_f = forward resistance of diode. R_L - Load resistance.

Maximum efficiency of the half- wave rectifier is 40.6%.

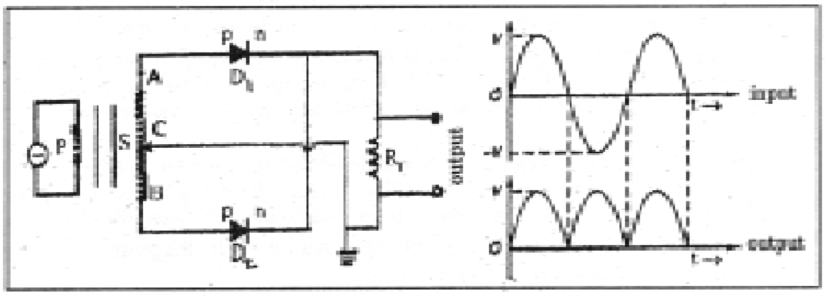
5. What is rectification? Explain the working of a full wave rectifier?

A. Rectifier:

Conversion of AC voltage into DC voltage is called rectification. A p-n junction diode is used as a rectifier.

Full – Wave Rectifier:

In a full wave rectifier two diodes are used. The secondary of the transformer AB is centre tapped between diodes D_1 and D_2 as shown. Across the common point of n-ends and the central tap C a load resistance R_L is connected. During the positive half cycle of AC diode D_1 is forward biased and D_2 is reverse biased. During the negative half cycle of AC diode D_2 is forward biased and D_1 is reverse biased. Hence current flows through the load resistance R_L during the full cycle of AC. Thus, a full wave of AC is rectified.



p-n diode - full wave rectifier

Efficiency of the full-wave rectifier = $\frac{DC\ power\ output}{AC\ power\ input} = \frac{0.812R_L}{r_f + R_L}$

Where r_f = forward resistance of diode. R_L- Load resistance.

Maximum efficiency of the full- wave rectifier is 81.2%.

6. Distinguish between the half- wave and full – wave rectifiers.

A.

Half Wave Rectifier	Full – Wave Rectifier
1. Every positive half cycle of AC is rectified.	1. Both positive and negative half cycles of AC are rectified.
2. One diode rectifies one half- cycle only.	2. The two diodes rectify the two half cycles separately.
3. Efficiency is low (40.6%)	3. Efficiency is high (81.2%)

7. Distinguish between Zener breakdown and avalanche breakdown.

A.

Zener Break Down	Avalanche Break Down
1) The diode is heavily doped.	1) The diode is lightly doped.
2) It occurs at low reverse bias voltages.	2) It occurs at high reverse bias voltages.
3) Rupture of covalent bonds takes place because of strong electric field at the junction.	3) Thermally generated electrons and holes acquire sufficient energy from applied potential to produce new carriers.

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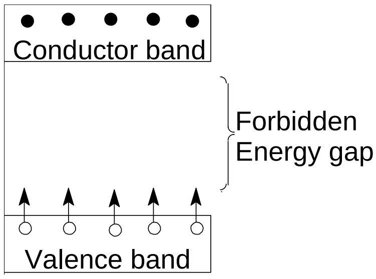
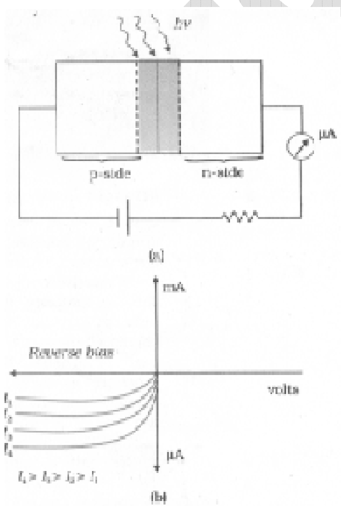
8. Explain hole conduction in intrinsic semiconductors?

A. According to band theory the silicon crystal contains four electrons in the outer most shell of each atom form four identical covalent bonds the corresponding energy level form the valence band. The conduction band is separated from it by about 1.1 eV forbidden energy gap. At higher temperature, due to collisions some electrons absorb energy and rise to the conduction band. Then in their places in the valence band holes are formed.



Due to doping in a pure intrinsic semiconductor, the density of charge carries increases. Hence conductivity increases.

9. What is photodiode? Explain its working with a circuit diagram and draw its I-V characteristics.



A. A photodiode is a reverse biased p-n Junction diode, provided with a transparent window to allow light to fall on it. When the photodiode is illuminated with light with energy greater than the energy gap (E_g) of the semiconductor, then electron-hole pairs are generated. The diode is fabricated such that the generation of e-h pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. The magnitude of the photocurrent depends on the intensity if incident light. A diode can be used as a photo-detector to detect optical signals. A typical I-V characteristics are shown in the diagram.

10. Explain the working of LED and what are its advantages over conventional incandescent low power lamps?

A. LED (Light Emitting Diode) is a heavily doped p-n junction which under forward bias emits spontaneous reaction. The diode is encapsulated with a transparent cover so that emitted light can come out.

When the diode is forward biased, electrons are sent from $n \to p$ (Where they are minority carriers) and holes are sent form $p \to n$ (Where they are minority carriers). At the junction boundary the concentration of minority carriers increases compared to the equilibrium concentration (i.e. when there is no bias). Thus at the junction boundary on either side of the junction, excess minority carriers are there which recombine with majority carriers near the junction. On recombination, the energy is released in the form of photons. Photons with energy equal to or slightly less than the band gap are emitted. When forward current of the diode is small, the intensity of light emitted is small. As the forward current increases, intensity of light increases and reaches a maximum. Further increase in the forward current results in decrease of light intensity. LEDs are biased such that the light emitting efficiently is maximum.

Advantages of LEDs over conventional incandescent low power lamps:

i) Low operational voltage and less power.

ii) Fast action and no warm-up time required.

iii) It is nearly (but not exactly) monochromatic

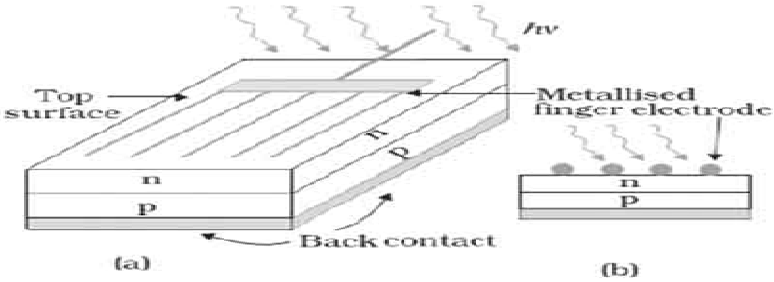
iv) Long life and ruggedness.

v) Fast on-off switching capability.

11. Explain the working of a solar cell and draw its I-V characteristics?

A. A solar cell is a p-n junction which generates emf when solar radiation falls on it.

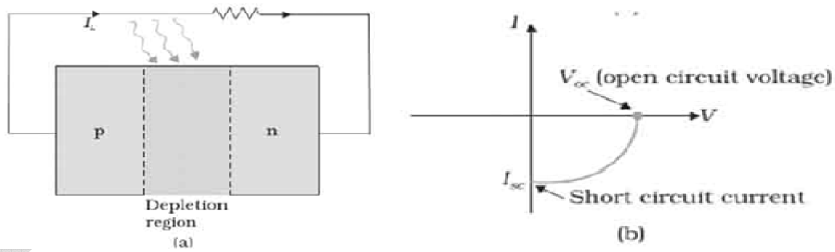
A simple p-n junction solar cell is shown in figure



A p-Si wafer of about 300 μm is taken over which a thin layer of n-Si is grown on one-side by diffusion process. The other side of p-Si is coated with a metal (back contact). On the top of n-Si layer, metal finger electrode (or metallic grid) is deposited. This acts as a front contact. The metallic grid occupies only a very small fraction of the cell area (<15%) so that light can be incident on the cell from the top.

The generation of emf by a solar cell is due to (i) generation of e-h pairs due to light close to the junction (ii) Separation of electrons and holes due to electric field of the depletion region. (iii) The electrons reaching the n-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photo voltage.

A typical I-V characteristic of a solar cell is shown in the figure.



This is drawn in the fourth quadrant of the coordinate axes, because a solar cell does not draw current but supplies the same to the load.

Solar cells are used to power electronic devices in satellites and space vehicle and also as power supply to calculators.

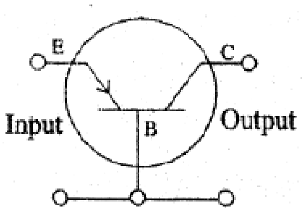
12. Explain different transistor configurations with diagrams.

A. There are 3 configurations for either n-p-n or p-n-p transistor namely

1. Common base (CB) 2. Common Emitter 3. Common collector (CC)

1. Common Base Configuration:

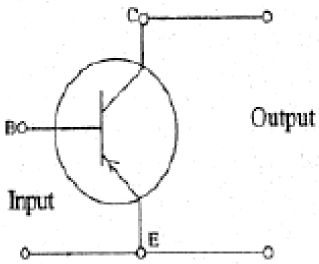
In this configuration base is common to both input and output. Input is given across base-emitter and output is taken across base-collector.



Circuit Symbol

2. Common Emitter Configuration:

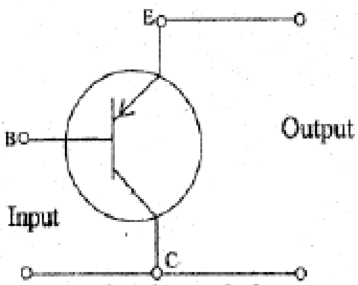
In this configuration emitter is common to both input and output. Input is given across base-Emitter and output is taken across collector-emitter.



Circuit symbol

3. Common Collector Configuration:

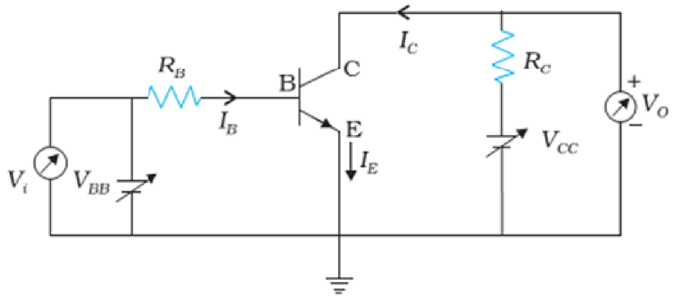
In this configuration collector is common to both input and output. Input is given across base-collector and output is taken across emitter- collector.



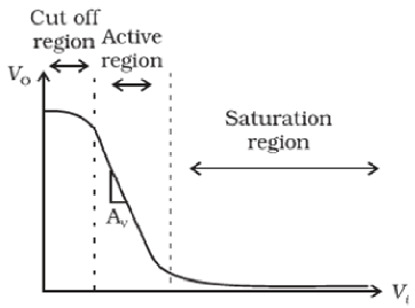
circuit symbol

13. Explain how transistor can be used as a switch?

A. Transistor as a switch:



(a)



(b)

Transistor as a switch can be analyzed by the behavior of the base - biased transistor in CE configuration as shown in fig.

Applying Kirchhoff's Voltage rule to the circuit we get

$V_{BB} = I_B R_B + V_{BE}$ and

$V_{CE} = V_{CC} - I_C R_C$

Consider

V_{BB} As the dc input voltage V_i and

V_{CE} As the dc output voltage V_0

$\therefore V_i = I_B R_B + V_{BE}$ And

$V_0 = V_{CC} - I_C R_C$

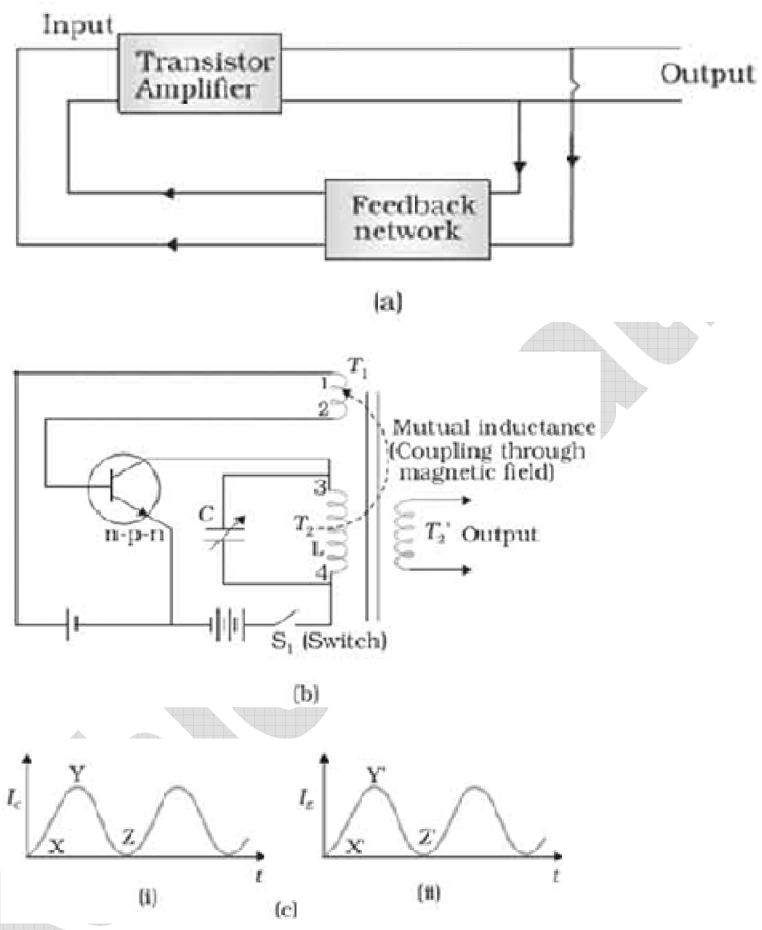
As long V_i is low and unable to forward-bias the transistor. V_0 is high (at V_{CC}). If high enough to drive the transistor into saturation, then V_0 is low. very near to zero. When the transistor is not responding it is said to be switched off and when it is driven into saturation it is said to be switched on.

This shows that a low input switches the transistor is off and a high input switches it is on. (Or) we can say that a low input to the transistor. Gives a high output and a high input gives a low output.

The switching circuits are designed in such a way that the transistor does not remain in active state. Thus transistor can be operated as a switch.

14. Explain how transistor can be used as an oscillator?

A. Transistor as an Oscillator.



The function of an oscillator circuit is to produce an alternating voltage of desired frequency when only DC batteries are available. The basic parts in the circuit are (a) an amplifier and (b) an LC network.

The amplifier section is just a transistor used in common emitter mode. The LC network consists of an inductor and a capacitance. This network resonates at a frequency.

$$\upsilon_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

Batteries are used to bias the transistor and no external input signal is fed to the amplifying section.

A part of the output signal is feed back to the input section after going through the LC network.

The feedback is accomplished by inductive coupling from one coil winding (T_1) to another coil winding (T_2). The inductive coupling between coil T_2 and coil T_1 causes a current to flow in emitter circuit. As a result Transistor becomes saturated and a part is again feed back to its input section. Thus it is a self sustaining device frequency υ_0 gets resonantly amplified and the output acts a source of AC of that frequency which can be varied by varying L or C.

15. Define NAND and NOR gates. Give their truth tables.

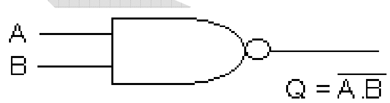
A. NAND Gate:

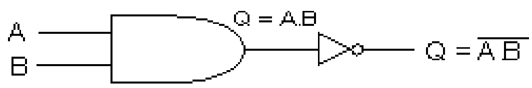
It has two input terminal and output terminal. The output of a NAND gate is an inversion of the output of an AND gate. If A and B are the inputs of the NAND gate its output is not (A and B)

Truth Table of NAND gate

Input		Output	Input		Output
A	B	Q	A	B	Q
Low	low	high	0	0	1
High	low	high	1	0	1
Low	high	high	0	1	1
High	high	low	1	1	0

The logical function shown by the truth table is written as A NAND B. The output Q=A.B and the symbol used for the logic gate is





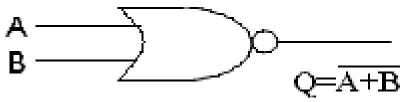
NOR Gate:

It has two input terminals and one output terminal. If A and B are the input of NOR gate its output is NOT (A or B).

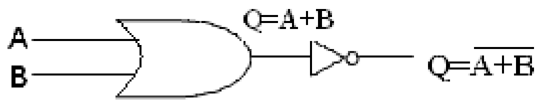
Truth table of NOR gate.

Input		Output	Input		Output
A	B	Q	A	B	Q
Low	low	high	0	0	1
High	low	low	1	0	0
Low	high	low	0	1	0
High	high	low	1	1	0

NOR Gate:



NOR Gate is inversion of OR gate and diagram in terms of OR gate is



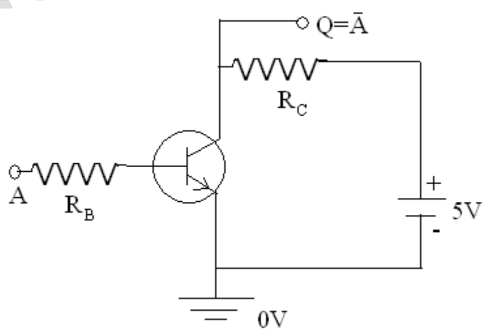
NOR gate = OR gate + NOT gate

16. Explain the operation of a NOT gate and give its truth table

A. NOT Gate:

It has one input terminal and one output terminal, when the input is low the output is high and when the input is high, the output is low.

Operation:



This can be implemented with transistor if A = 0 the emitter base junction is open and there is no current through the transistor the current through the resistor $R_c = 0$ and 0 becomes equal to a potential of 5V i.e. Q = 1. When A = 1, the emitter base junction is forward biased as the potential at A is 5V the current through the transistor is large. When such a large current flows through the potential at Q. becomes approximately 'o' volts i.e. Q = 0 thus the output is same as that of a not gate.

Input A	**Output B**	**Input A**	**Output B**
Low	High	0	1
High	Low	1	0

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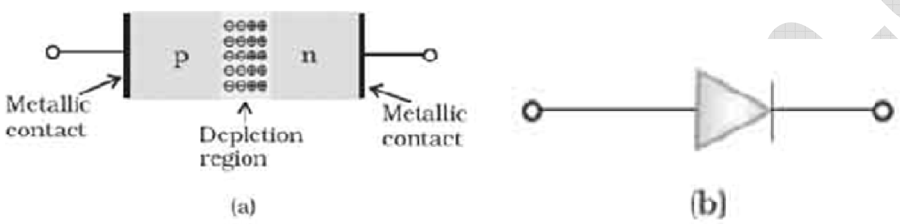
Long Answer Questions

1. What is a junction diode? Explain the formation of depletion region at the junction. Explain the variation of depletion region in forward and reverse-biased condition.

A. **Junction Diode:**

A p-n junction diode is a two terminal device. When a semiconductor material of silicon or germanium is doped in such a way that one side of it becomes a p-type and other side becomes n-type we get p-n junction diode.



Formation of Depletion Layer:

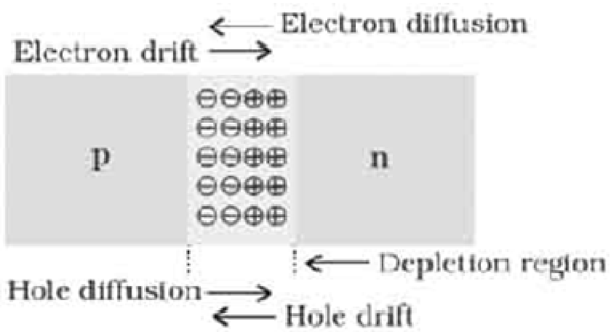
When a p-n junction is formed the free e^- diffuses form $n \rightarrow p$ combine with holes a layer of positive charge on n side of the junction is developed similarly when a hole diffuses form $p \rightarrow n$ a layer of negative charge on the p-side of the junction is developed.

The thickness of depletion region is of the order of one-tenth of a micrometer.

Near the n- type the junction becomes positively charged and near the p-type, the junction becomes negatively charged.

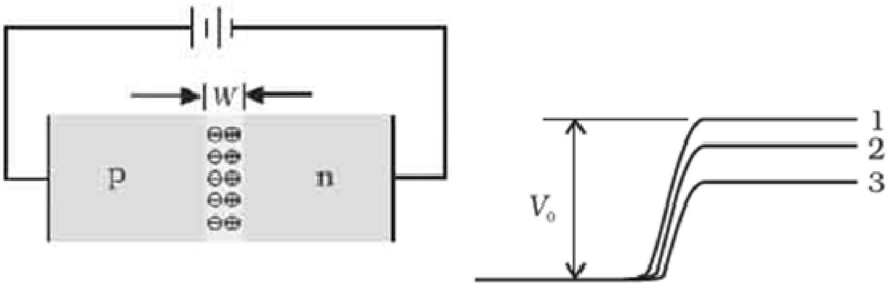
This creates an electric field about the junction due to this field motion of charge carriers across the junction created and it is called drift.

Thus drift current is opposite to the diffusion current.



Forward Bias:

When an external voltage V is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and n -side to the negative terminal of the battery is then said to be forward biased.

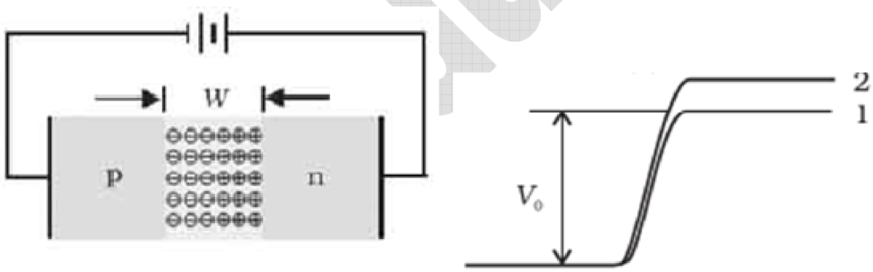


(a) (b)

The holes on p-side repelled by the positive terminal of the battery and moves towards the junction at same time e^- on n-side repelled by the negative terminal of the battery and move towards the junction.

As a result the width of the depletion layer decreases. Therefore number of charge carriers slow across the junction. The resistance of the diode in it is low.

Reverse Bias:- When an external voltage V is applied across the diode such that n-side is positive and p-side is negative. It is said to be reverse biased.

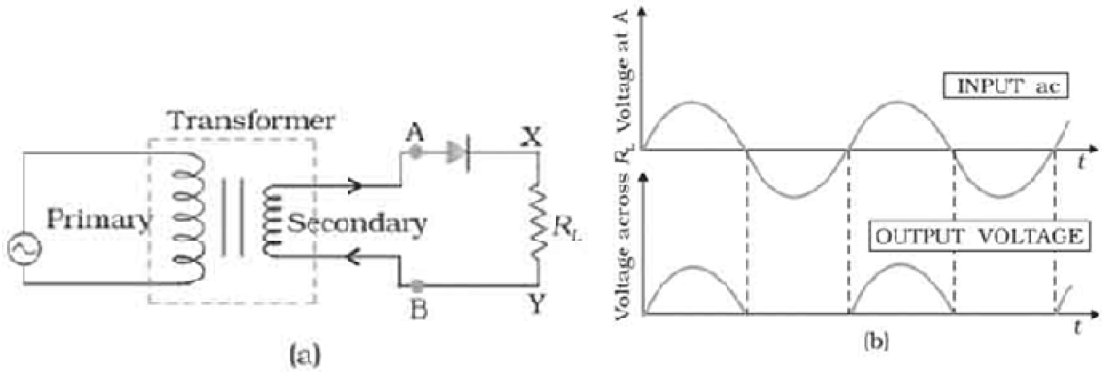


(a) (b)

The holes on p-side are attracted by the negative terminal of the battery and move away from the junction similarly the e^- on n-side are attracted by the positive terminal of the battery and move away from the junction as a result width of the depletion layer increases. The diode will not allow current through it. In reverse bias the resistance is high.

2. What is a rectifier? Explain the working of half wave and full wave rectifiers with diagrams?

A. The process of converting an alternating current (AC) into a direct current (DC) is called Rectification. The device used for this purpose is called Rectifier.



Half Wave Rectifier:

i) If an alternating voltage is applied across a diode in series with a load, a pulsating voltage will appear across the load only during the half cycles of the ac input during which the diode is forward biased.

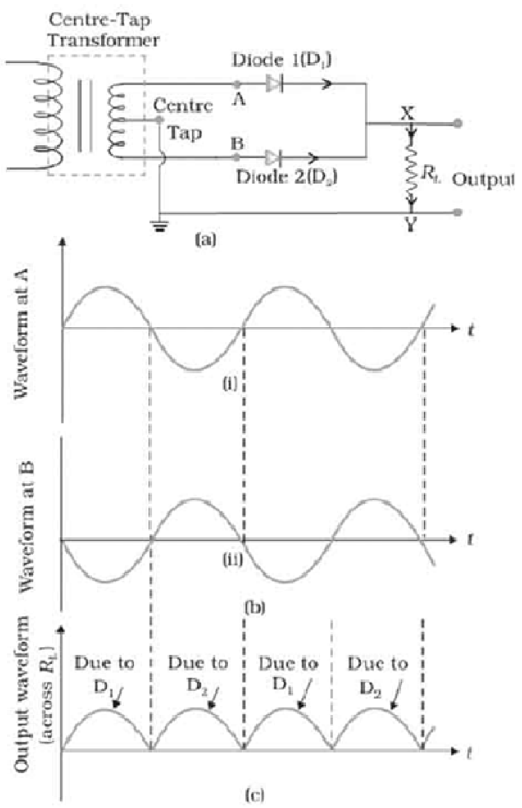
ii) The secondary of a transformer supplies the desired ac voltage across terminals A and B. When the voltage at A is positive, the diode is forward biased and it conducts. When A is negative, the diode is reverse-biased and it does not conduct.

iii) The reverse saturation current of a diode is negligible and can be considered equal to zero for practical purposes.

iv) In the positive half-cycle of ac there is a current through the load resistor R_L and we get an output voltage, whereas there is no current in the negative half-cycle.

v) In the next positive half-cycle, again we get the output voltage. Thus, the output voltage, though still varying, is restricted to only one direction and is said to be rectified. Since the rectified output of this circuit is only for half of the input ac wave it is called as half-wave rectifier. Efficiency of half wave rectifier is defined as the ratio of DC output power to the AC input power.

Efficiency of half wave rectifier $(\eta) = \dfrac{0.406\, R_L}{r_f + R_L}$



Full Wave Rectifier:

1) The circuit using two diodes gives output rectified voltage corresponding to both the positive and negative half of the AC cycle.

2) The p-side of the two diodes are connected to the ends of the secondary of the transformer

3) The n-side of the diodes are connected together and the output is taken between this common point of diodes and the midpoint of the secondary of the transformer.

Hence for a Full-wave rectifier the secondary of the transformer is provided with a centre tapping and so it is called centre tap transformer.

4) The voltage rectified by each diode is only half the total secondary voltage but the two do so for alternate half cycles. Therefore, the output between their common terminals and the centre tap of the transformer becomes a full-wave rectifier output

5) Suppose the input voltage to A with respect to the centre tap at any instant is positive. At that instant, voltage at B which is out of phase will be negative so, diode D_1 which is forward biased conducts and D_2 which is reverse biased do not conduct.

6) When the voltage at A becomes negative with respect to the centre tap, the voltage at B would be positive. So, diode D_1 which is reverse biased do not conduct but D_2 conducts giving an output current and output voltage during the negative half cycle of the input a.c.

Hence we get output voltage during both the positive as well as the negative half of the cycle.

Efficiency of full wave rectifier is defined as the ratio of DC output power to AC input power.

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{0.812\,R_L}{r_f + R_L}$$

Where R_L is the load resistance and r_f is forward resistance.

In full wave rectifier maximum efficiency is 81.2%.

3. What is a Zener diode? Explain how it is used as voltage regulator?

A. Zener Diode:

It is a heavily doped p-n junction diode which is operated in the breakdown region in reverse bias mode. Zener diode has a sharp breakdown voltage in the reverse bias due to heavy doping. This voltage is called Zener Voltage (V_Z). In forward bias, zener diode act like an ordinary p-n junction diode.

Zener diode-voltage regulator:

Zener diode is used as a voltage regulator. If the input voltage increases, more current passes through the zener and more potential is dropped across R. The potential V across the zener remains same. When R_L is less, more current passes through it and p.d across R is less. Hence the p.d across zener remains constant. Thus the output voltage is regulated.

Output voltage (V_O) = Zener voltage (V_Z)

Current through load resistance $\frac{V_Z}{R_L}$

Voltage across series resistance (V) = input voltage – zener voltage.

Current through zener diode (I_Z) = $I - I_L$.

4. Describe a transistor and explain its working?

A. Transistor:

Transistor is a device which transfers a signal towards a high resistance side.

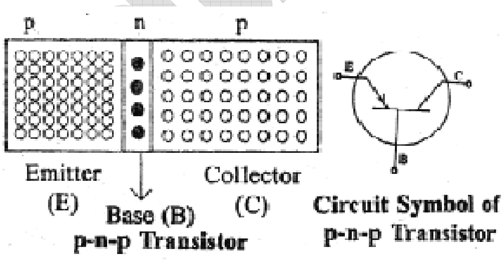
Construction:

When a silicon or germanium crystal is doped with acceptor impurity and donor impurity so that three layers are formed. These are named as emitter, base and collector. Emitter region is heavily doped and collector region is moderately doped and the base region is lightly doped.

Working:

p – n – p Transistor:

The figure shows p-n-p transistor with forward bias to the emitter- base junction and reverse bias to the collector- base junction. The forward bias causes the holes in the p-type emitter to flow towards the base. This is called emitter current I_E. As the holes flow through the n type base, they tend to recombine will the electrons. As the base is lightly doped, very few holes (less than, 5%) combine with electrons which constitute base current I_B. The remaining holes (more than 95%) reach the collector region to constitute collector current I_{-C}.

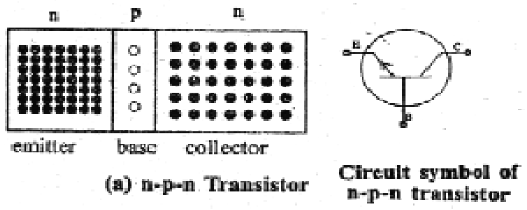


Therefore, $I_E = I_B + I_C$.

The current in the p-n-p transistor is mainly due to the majority holes and outside the circuit electron flow is present.

n-p-n Transistor:

The figure shows n-p-n transistor with forward bias to the emitter - base junction and reverse bias to the collector – base junction. The forward bias causes the electrons in the n-type emitter to flow towards the base. This is called emitter current I_E.As these electrons flow through the p-type base, they tend to recombine with the sides. As the base is lightly doped, very few electrons (less than 5%) combine with the holes which constitutes base current I_B.The remaining electrons (more than 95%) reach the collector region to constitute collector current I_C.



Therefore, $I_E = I_B + I_C$

The current in the n-p-n transistor is mainly due to the electrons.

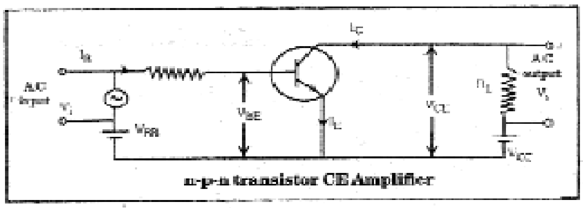
5. What is amplification? Explain the working of a common emitter amplifier with necessary diagram?

A. **Amplification:**

The process of raising the strength of weak signal is called amplification and the device used for this is called amplifier. Amplification is of two types namely

1) Power Amplification and 2) Voltage amplification.

Figure shows an amplifier circuit using n-p-n transistor in common emitter mode. The battery V_{BE} is connected in the input circuit in addition to the signal voltage. This DC voltage keeps base-emitter junction forward biased .During positive half cycle of the signal, the forward bias across the emitter - base junction is increased. Hence more electrons flow from the emitter to the collector through the base. This causes an increase in the collector current produces a greater voltage drop across the collector load resistance the R_L. During negative half cycle of the signal, the forward bias across the emitter - base junction is decreased. Due to this, collector current decreases which results in decreased output voltage in the opposite direction. Hence an amplified output is obtained across the load.



n-p-n transistor CE Amplifier

$$(\beta_{ac}) = \frac{Change\ in\ collector\ current}{Change\ in\ base\ current} = \frac{\Delta I_C}{\Delta I_B}$$

Voltage gain $A_V = \dfrac{Change\ in\ collector\ voltage}{Change\ in\ base\ voltage} = \dfrac{\Delta V_{CE}}{\Delta V_{BE}}$

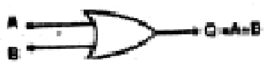
Power gain = Current gain x Voltage gain = $\beta_{ac} A_V$

6. Draw an OR gate using two diodes and explain its operation. Write the truth table and logic symbol of OR gate.

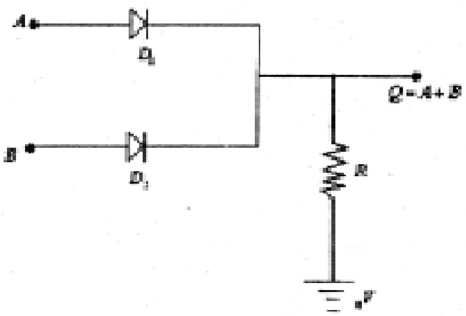
A. **OR GATE:**

It has two input terminals and one output terminal. When both the inputs are low the output is low. When one of the input is high or when both the inputs are high then the output is high.

Input		Output
A	B	Q
0	0	0
1	0	1
1	1	1



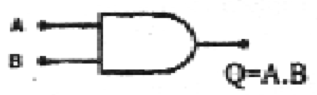
OR gate using diodes :



Truth table:

Input		Output
A	B	Q
0	0	0
1	0	1
0	1	1
1	1	1

Explanation:



Input		Output
A	B	Q = A.B
0	0	0
1	0	0
0	1	0
1	1	1

Let D_1 and D_2 represent two diodes. A potential of 5V represents high and the logical value '1' and a potential of '0' V represents low and the logical value zero. When A = 0, B = 0 and the diodes are reverse biased and they behave like open switches and there is no current through the resistance. So the potential at Q is zero i.e. Q = 0 When A = 0 or B = 0 and the other equal to a potential of 5V, then that diode is forward biased, and there is a current flow through the resistance. So the output potential then become 5V i.e. Q = 1

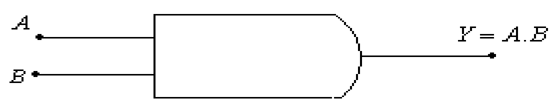
7. **Sketch a basic AND circuit with two diodes and explain its operation. Explain how doping increases the conductivity in semiconductors.**

A. **AND Gate:**

An AND gate has two inputs high only when both the inputs are high.

Truth Table of AND gate **Logic symbol for AND gate**

Input		Output
A	B	Y= A.B
0	0	0
0	1	0
1	0	0
1	1	1



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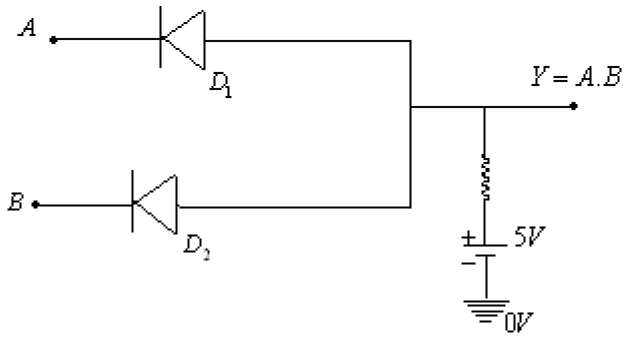
Implementation of AND gate using diodes:



Let D_1 and D_2 represent two diodes. A potential of 5V represents the logical value 1 and 0V represents the logical value 0.

When A = 0, B = 0, both diodes are forward biased and they behave like closed switches. Output is y = 0.

When A = 0 (or) B = 0 the diode D_1 or D_2 is forward biased output $Y = 0$.

When A = 1, B = 1; both diodes are reverse biased and they behave like open switches.

The output is Y = 1 and it is same as that of AND gate.

The deliberate addition of a desirable impurity to a semiconductor substance is called doping and the impurity atoms are called dopants. Such a material is called doped semi conductor. Doping changes the number of charge carriers and hence the conductivity of semiconductor. due to doping in a pure intrinsic semiconductor the density of charge carrier increases. Hence conductivity increases in either N type or P type semi conductor. The semiconductor's energy band structures affected by doping.

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PROBLEMS

1. In a half wave rectifier, a p –n Junction diode with internal resistance 20 ohm is used. If the load resistance of 2 ohm is used in the circuit, then find the efficiency of this half wave rectifier?

Sol: $r_f = 2\Omega,\ R_L = 200\Omega$

$$\mu = \frac{0.406 R_L}{\left(r_f + R_L\right)} \times 100$$

$$= \frac{0.406(200)}{(2+200)} \times 100$$

$= 40.2\%$

2. A full wave p-n junction diode rectifier uses a load resistance of 1300 ohm. The internal resistance of each diode is 9 ohm. Find the efficiency of this full wave rectifier?

Sol: $R_L = 1300\Omega$

$.\, r_f = 9\Omega$

$$\mu = \frac{0.812 R_L}{\left(r_f + R_L\right)} \times 100$$

$$= \frac{0.8812(1300)}{(1300+9)} \times 100 = 80.64\%$$

3. Calculate the current amplification factor (beta) when change in collector current is 1mA and change in base current is 20 μ A?

Sol: $\Delta I_C = 1mA = 10^{-3} A$

$\Delta I_B = 20\mu\, A = 20 \times 10^{-6} A$

$$\therefore \beta = \frac{\Delta I_C}{\Delta I_B} = \frac{10^{-3}}{20 \times 10^{-6}} = \frac{1000}{20} = 50$$

4. For a transistor amplifier, the collector load resistance $R_L = 2k$ ohm and the input resistance R_1= 1K ohm. If the current gain is 50, calculate voltage gain of the amplifier?

Sol: $R_L = 2k\ \Omega = 2000\Omega$

$R_i = 1k\Omega = 1000\Omega$

$\beta = 50$

$$A_V = \frac{V_o}{V_i} = \left(\frac{I_o}{I_i}\right)\left(\frac{R_o}{R_i}\right)$$

$$A_v = \beta\left(\frac{R_L}{R_i}\right) = 50\left(\frac{2000}{1000}\right) = 100$$

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