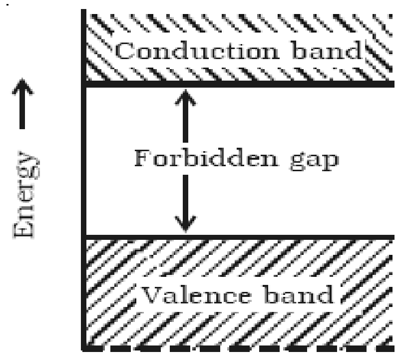
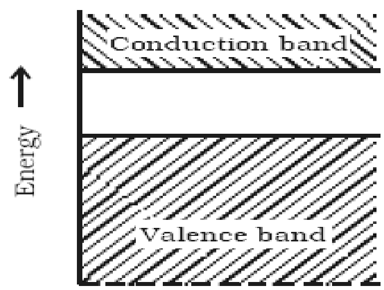
Solids and Semiconductor devices

1. Draw energy band diagram for a) insulator eg.diamond b)semiconductor $n_e = n_h$ eg. Si, Ge. C) conductor



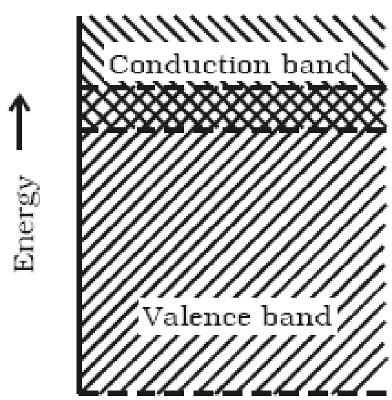

(a) Insulator

Energy gap > 3eV




(b) Semiconductor

Energy gap < 2eV. For Si 1.1 eV, Ge 0.7 eV

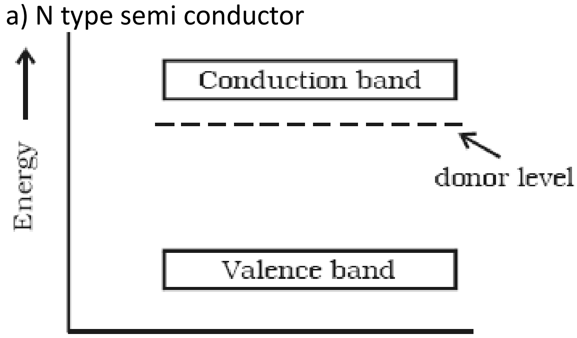



(c) Conductor

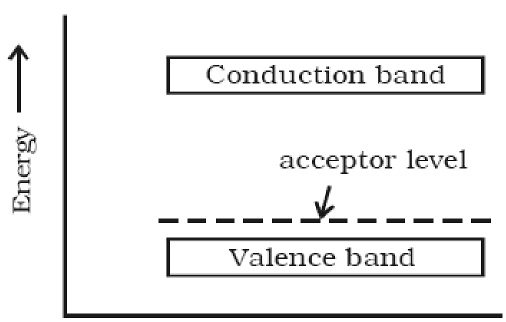
No energy gap conduction band and valance band over lap.

2.What is doping?
Deliberate addition of very small amount of desirable impurity into an intrinsic semiconductor is called **doping**. The impurity atoms are called dopants.
3. What are the characteristics of dopant atoms ?
i. The dopant atom not must distort the original pure semiconductor lattice.
ii. The sizes of the dopant and the semiconductor atoms should be nearly the same.
iii. The dopant atoms must fit the place of few intrinsic atoms.

4. What is the relation between the concentrations of electrons and holes in a semi conductor at thermal equilibrium?
The electron and hole concentration in a semiconductor in thermal equilibrium is given by $\mathbf{n_e n_h = n_i^2}$ where $\mathbf{n_i}$ is known as intrinsic carrier concentration.
5. Draw energy band diagram for semiconductor in which a) $\mathbf{n_e > n_h}$
b) $\mathbf{n_e < n_h}$
a) N type semi conductor




b) P type semi conductor



6. ***A pure Si crystal has $5 \times 10^{28}$ atoms $m^{-3}$.***
***It is doped by 1 ppm concentration of pentavalent As. Calculate the number of electrons and holes. Given that $n_i = 1.5 \times 10^{16}$ $m^{-3}$.***

$n_e \approx N_D$

$\mathbf{n_e} = 5 \times 10^{28} / 10^{6} = 5 \times 10^{22}$

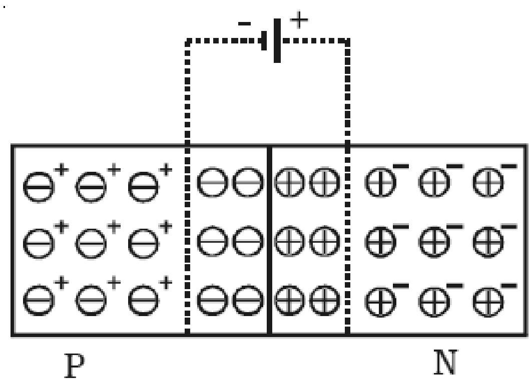
$\mathbf{n_e n_h = n_i^2}$

$n_h = (2.25 \times 10^{32})/(5 \times 10^{22})$

$\sim 4.5 \times 10^{9}\ \mathrm{m^{-3}}$

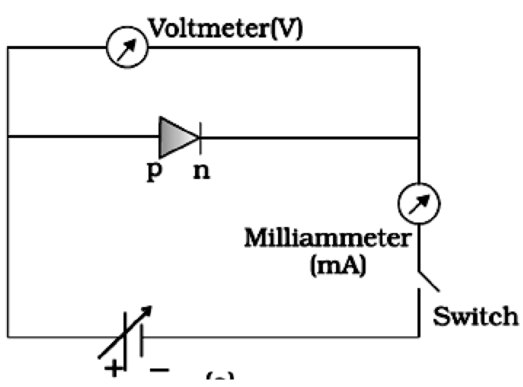
It will become N type semiconductor.

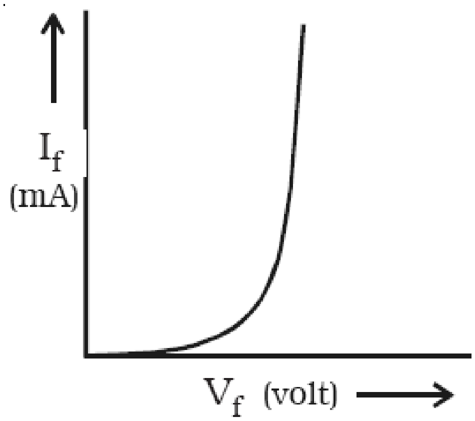
7. Draw diagram to show depletion layer and internal potential barrier in a PN junction Diode
And define them.




When a PN junction Diode is formed ,region near the junction is depleted of majority carriers and have only minority carriers called as depletion layer.
The potential due to minority carrier near the junction is known as internal potential barrier.

8. Explain the working of PN unction diode in forward bias .





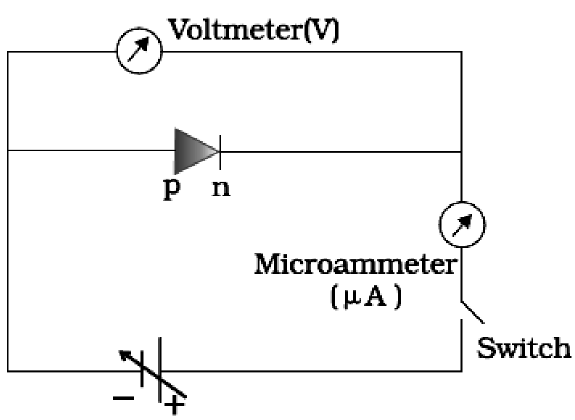

When the positive terminal of the battery is connected to P-side and negative terminal to the N-side , thePN junction diode is said to be forward biased.

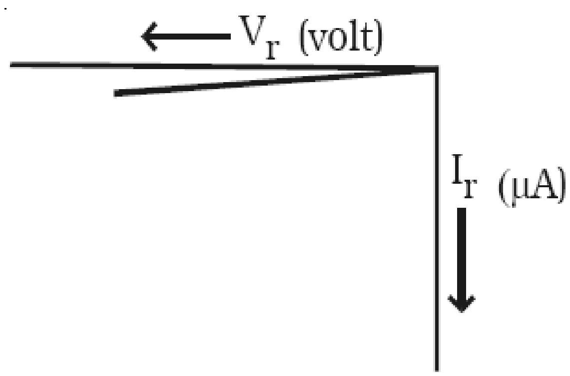
Above a particular value of applied voltage, called knee voltage, the majority carriers are repelled by the battery . As they cross the junction they neutralize the minority carriers at the depletion layer and , the **depletion region disappears** and the **potential barrier** also **disappears.** Hence, during FB, the majority charge carriers flow across the junction in opposite direction and constitute current flow in the forward direction.

9. Explain the working of PN unction diode in reverse bias .

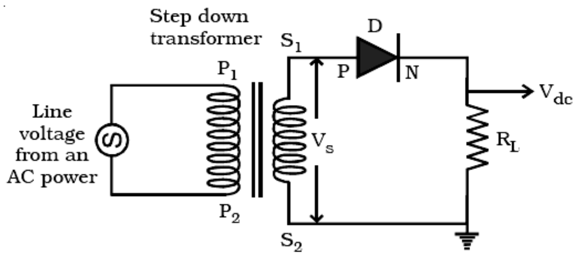
When the positive terminal of the battery is connected to N-side and negative terminal to the P-side , thePN junction diode is said to be reverse biased. The majority carriers are attracted away from the junction leaving more minority carriers at the depletion layer. The width of **depletion region increases** and the **potential barrier** also **increases .**

There is no flow of current due to majority carriers and a small current of micro amperes flow due to minority carriers.

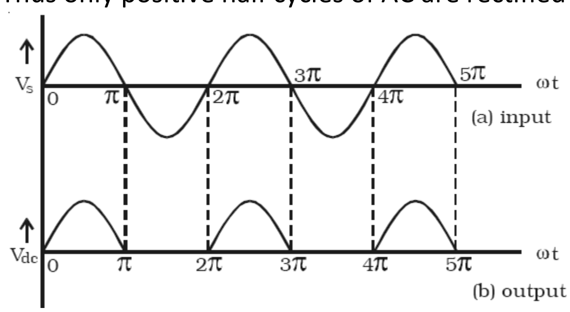





9. Explain the working of a half wave rectifier.

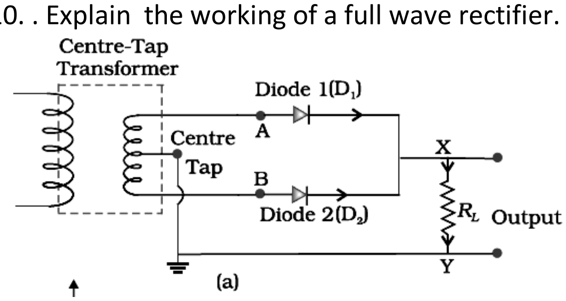



Rectification is the process in which alternating emf or current is changed into direct emf or current.
Diode is used as a rectifier.
The circuit shows a half wave rectifier. During positive half cycles of stepped down AC voltage the diode D is forward biased and conducts. The forward bias current produces a pd across the load resistor $R_L$.
During negative half cycles
of AC the diode D is reverse biased and does not conduct.
Thus only positive half cycles of AC are rectified and the arrangement is known as half wave rectifier.

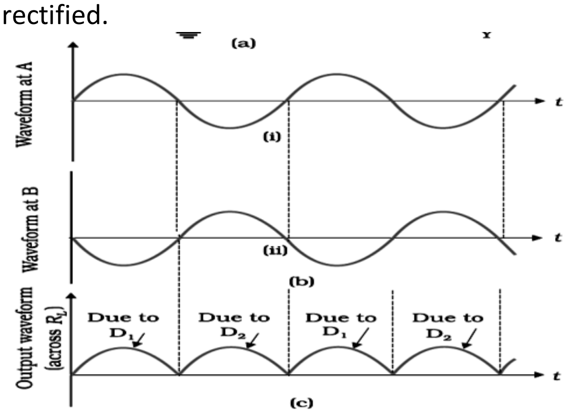



Efficiency of a half wave rectifier is 40.6%

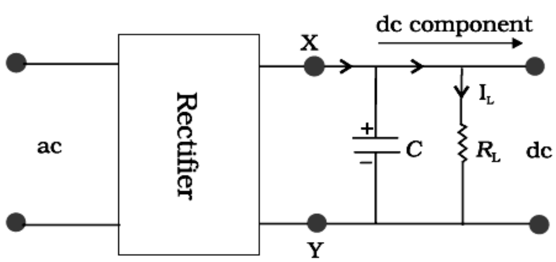
10. . Explain the working of a full wave rectifier.



The step down transformer is centre tapped and a bridge of two diodes D1 and D2 are used in a full wave rectifier.
During positive half cycles the diode D1 is forward biased and conducts but the diode D2 is reverse biased and does not conduct.
During negative half cycles the diode D2 is forward biased and conducts but the diode D1is reverse biased and does not conduct.
Thus during both the half cycles there is a dc out put across the load resistor. Thus the full wave of AC is rectified.

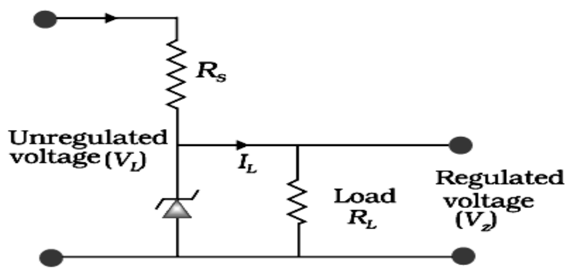



To get a steady dc a filter circuit is used . capacitor of the filter circuit filters out the ac ripple part and steady dc output is available across $R_L$

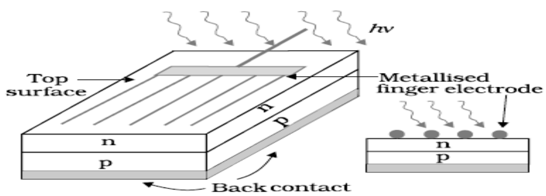



Efficiency of a full wave rectifier is 81.2%

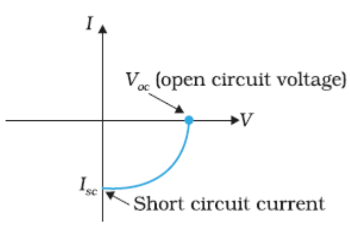
11. Explain the working of a zener diode as a voltage regulator.
Zener diode is designed to operate under reverse bias in the breakdown region and used as a voltage regulator, it is heavily doped.
To get a constant dc voltage from the dc unregulated input, we use a Zener diode.
The unregulated dc voltage is connected to the Zener diode through a series resistance $R_s$ such that the Zener diode is reverse biased.
When the input voltage increases, the current through $R_s$ and Zener diode also increases. This increases the voltage drop across $R_s$ without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes.
When the input voltage decreases, the current through $R_s$ and Zener diode also decreases. The voltage drop across Rs decreases without any change in the voltage across the Zener diode. Thus any increase/decrease in the input voltage does not produce any change in voltage across the Zener diode.

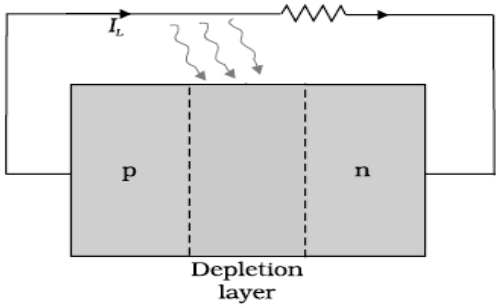



12. Explain the working of solar cell .




In a solar cell **the junction area** is kept **much larger** for more solar radiation to be incident to get more power.
The generation of emf by a solar cell, when light falls on, it is due to the following **three basic processes: generation, separation and collection—**
(i) generation of e-h pairs due to light (with hv > $E_g$) close to the junction;
(ii) separation of electrons and holes due to electric field of the depletion region. Electrons are swept to n-side and holes to p-side;
(iii) the electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back contact. Thus p-side becomes positive and n-side becomes negative giving rise to photo voltage.



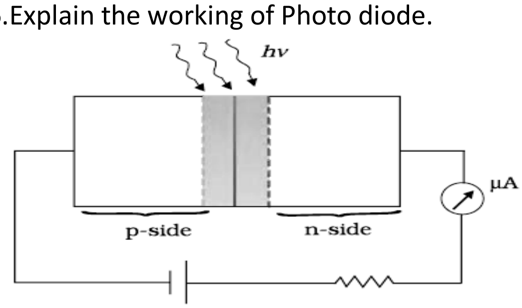



13.Mention the Uses of solar cell
i) in calculators and watches
ii) an array of solar cells is called as solar panel
which can be used in artificial satellites, and houses to generate electricity.
14. Explain the working of LED (Light Emitting Diode)
When a junction diode is forward biased, electrons from N-side and holes from P-side move towards the depletion region and recombination takes place. When an electron in the conduction band recombines with a hole in the valence band, energy is released.
If the semiconductor material is transluscent, light is emitted and the junction becomes a light source. By using **gallium arsenide phosphide** and **gallium phosphide**, a manufacturer can produce LEDs that radiate **red, green, yellow and orange. GaAs (Eg ~ 1.4 eV) is used for making infrared LED.**

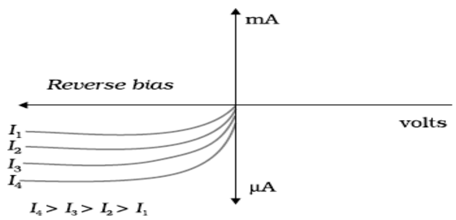
15.Mention uses of LED
LEDs are used for instrument displays, calculators and digital watches. remote controls, burglar alarm systems,
optical communication,
they replace incandescent lamps
used in LED televisions

16. Mention the advantages of LED over incandescent lamps.
(i) Low operational voltage and less power.
(ii) Fast action and no warm-up time required.
(iii) The bandwidth of emitted light is 100 Å to 500 Å or in other words it is nearly (but not exactly) monochromatic.
(iv) Long life and ruggedness.
(v) Fast on-off switching capability.

16.Explain the working of Photo diode.



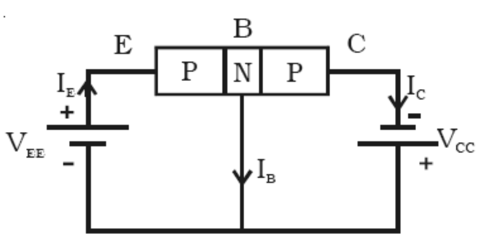
A Photodiode is again a special purpose p-n junction diode fabricated with a transparent window to allow light to fall on the diode. It is operated under reverse bias.
When the photodiode is illuminated with light (photons) with energy greater than the energy gap (Eg) of the semiconductor, then electron-hole pairs are generated due to the absorption of photons.
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.
The direction of the electric field is such that electrons reach n-side and holes reach p-side.
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 of incident light falls on the diode.




17. Why a photodiode is always operated under reverse bias.
It is easier to observe the change in the current
with change in the light intensity, if a reverse bias is applied , so detection of optical signals is easy.
18.Even though energy gap for GaAs is more than that of Si GaAs is better than Si to make solar cell why?
GaAs is better Si because of its relatively higher light absorption coefficient.

19. Compare the size and level of doping in the components of a transistor.
Base is lightly doped and thin in size .
Emitter region is heavily doped and moderate in size.
Collector is is moderately doped. Since it has to accept majority charge. carriers, it is physically larger in size.

20. explain the working of a PNP transistor.



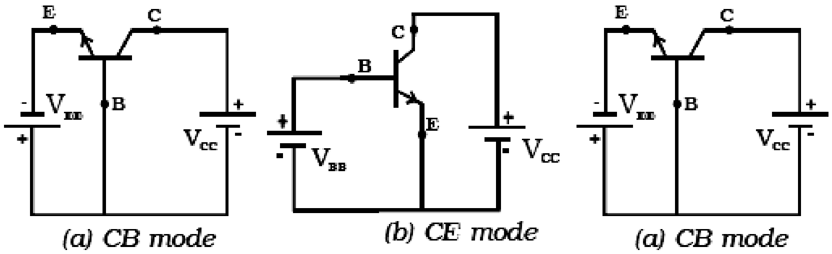

When the two junctions are properly biased,
Few holes from emitter move to the base to combine with electrons in the base region. This flow causes $I_E$ Since the base is lightly doped and thin majority of holes enter collector to produce $I_C$ . The minority carriers electrons flow to produce $I_B$ at the base .By Kirchoff's law
$\mathbf{I_E = I_B + I_C}$.

**21 .State the biasing rules used in a transistor.**

(i) The emitter-base junction is forward biased, so that majority charge carriers are repelled from the emitter and the junction offers very low resistance to the current.

(ii) The collector-base junction is reverse biased, so that it attracts majority charge carriers and this junction offers a high resistance to the current.

22. Draw circuit diagrams for a NPN transistor in CB mode ,CE mode,CC mode.




22. Define curren gains α and β .

The current amplification factor or current gain of a transistor is the ratio of output current to the input current. If the transistor is connected in common base mode, the current gain

$$\alpha = \frac{I_C}{I_E}$$

and if the transistor is connected in common emitter mode, the current gain

$$\beta = \frac{I_C}{I_B}$$

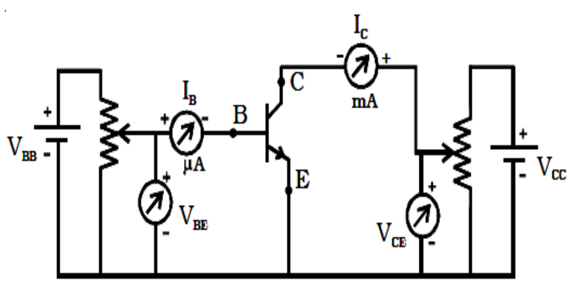
23.Derive the relation between α and β .

$$\alpha = \frac{I_C}{I_E} = \frac{I_c}{I_B + I_C} \quad (\because\ I_E = I_B + I_C) \qquad \frac{1}{\alpha} = \frac{I_B + I_C}{I_C} = \frac{I_B}{I_C} + 1$$

$$\frac{1}{\alpha} - 1 = \frac{1}{\beta}$$

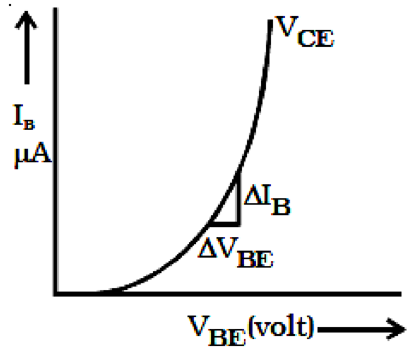
$$\beta = \frac{\alpha}{1-\alpha}$$

25. With a neat circuit diagram explain how will you Plot i) Input ii) output iii)transfer characteristics of an NPN transistor in CE mode.




Input characteristics

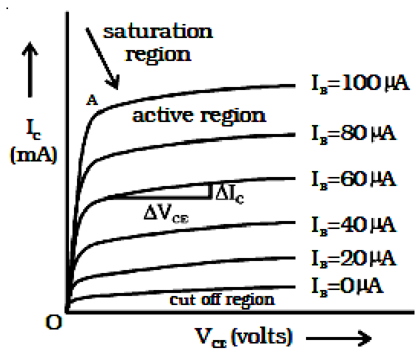
Input characteristic curve is drawn between the base current ($I_B$) and voltage between base and emitter ($V_{BE}$), when the voltage between collector and emitter ($V_{CE}$) is kept constant at a particular value.




The **input impedance** of the transistor is defined as the ratio of small change in base – emitter voltage to the corresponding change in base current at a given $V_{CE}$.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

ii) Output characteristic curves are drawn between IC and $V_{CE}$, when $I_B$ is kept constant at a particular value.



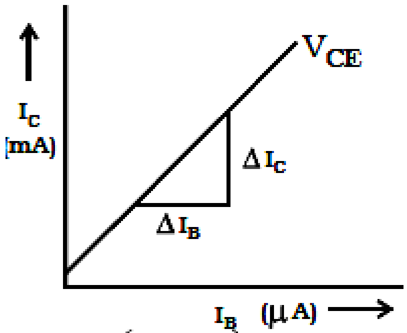

The **output impedance** $r_o$ is defined as the ratio of variation in the collector emitter voltage to the corresponding variation in the collector current at a constant base current in the active region of the transistor characteristic Curves.

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

The **current gain** is defined as the ratio of a small change in the collector current to the corresponding change in the base current at a
constant $_{VCE}$

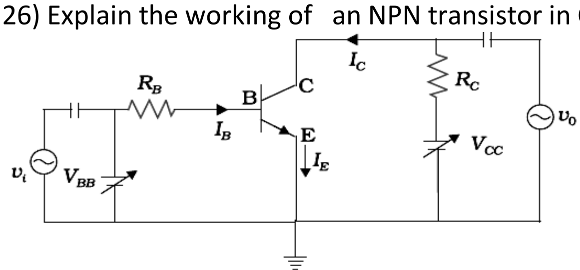
$$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

iii) The transfer characteric curve is drawn between $I_C$ and $I_B$, when $V_{CE}$ is kept constant at a particular value.




$$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

26) Explain the working of an NPN transistor in CE mode used as an amplifier.




The circuit is connected as shown in the figure.

The input voltage without signal voltage is

$V_i = V_{BE}$ ( 1 ) The input voltage with signal voltage .

$V_i' = I_B R_B + V_{BE}$ ( 2)

Change in input voltage $\Delta Vi = \Delta I_B R_B$ ( 3)

The out put voltage without signal voltage

$Vo = V_{CE} = V_{cc}$ (4)

The out put voltage with signal voltage

$Vo' = V_{cc} - I_c R_c$ (5)

Change in output voltage

$\Delta Vo = -\Delta I_c R_c$ (6)

Voltage gain =

Av = Change in output voltage/ Change in input voltage

$= -\Delta I_c R_c \quad / \Delta I_B R_B$

$= -\beta R_{c}/R_B$

- sign means that amplified out put has a phase difference of 180◦ with input

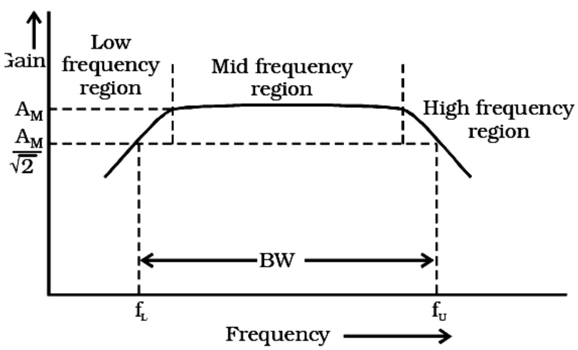
$Av = -\ gm \times R_c$

where gm is known as trans conductance it is the ratio of change in output current to the corresponding change in input voltage.

Power gain = Voltage gain x current gain

$= \beta^2 \times R_c/R_B$

27 . Draw frequency response curve for a transistor amplifier . Define band width.




Bandwidth is defined as the frequency interval between lower cut off and upper cut off frequencies
**Band width = $f_u - f_L$**

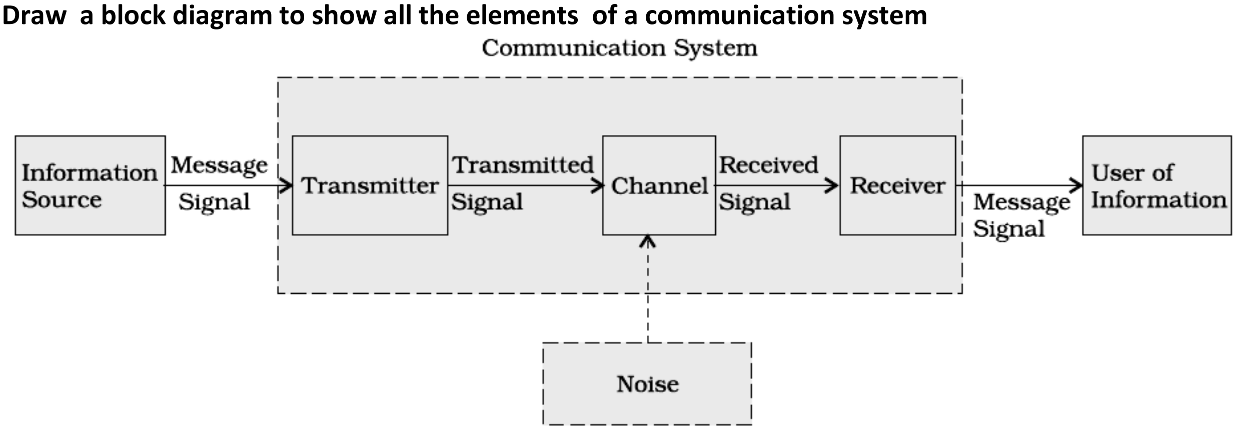
## Communication Systems

Definitions

- **Transmitter:** It is a device that transmits a message/signal over a communication channel to the receiver.

- **Signal:** Information converted in electrical form and suitable for transmission is called a signal. Signals can be either analog or digital. Analog signals are continuous variations of voltage or current.
- **Communication channel:** It is the medium that links transmitter and receiver with each other eg.optical fibre, coaxial cables (guided media) ,space, earth's surface, sky (unguided media).
- **Receiver:** It receives the transmitted signal and reconstruct for processing the signal
- **Range:** It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.
- **Bandwidth:** Bandwidth refers to the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.
- **Modulation:** Variation in any of the following characteristics viz. frequency , amplitude and phase of carrier wave, in accordance with intensity of signal wave is modulation
- **Transducer :** It is a device which converts one form of energy to another.eg. Microphone converts sound to electrical energy and loud speaker converts electrical to sound energy.
- **Amplifier:** It is device used to increase or amplify the strength and power of signal to be transmitted and the received signal also. Amplification is necessary to compensate for the attenuation of the signal in communication systems
- **Demodulation or Detection:** It is the extraction or retrieval of signal from the carrier wave at the receiver end.
- **Transponder:** It is a device in a satellite which receives the signal from a TV channel at a particular frequency(up link ) and retransmits the signal at a different frequency (down link)to avoid loss of signal by destructive interference of transmitted and received signal.
-

**Draw a block diagram to show all the elements of a communication system**



**What are the two basic modes of communication?**

- In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver. Eg : Telephony
- In contrast, in the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Eg: Radio and television.
- **What is the BANDWIDTH OF SIGNALS** in the following cases
  i) speech ii) music iii) video iv) television
  **Therefore speech signal requires a bandwidth of 2800 Hz (3100 Hz– 300 Hz)**
  **To transmit music, an approximate bandwidth of 20 kHz is required because of the high frequencies produced by the musical instruments**

**Video signals for transmission of pictures require about 4.2 MHz of bandwidth. A TV signal contains both voice and picture and is usually allocated 6 MHz of bandwidth for transmission.**

| Service | Frequency bands | Comments |
|---|---|---|
| Standard AM broadcast | 540-1600 kHz | |
| FM broadcast | 88-108 MHz | |
| Television | 54-72 MHz<br>76-88 MHz<br>174-216 MHz<br>420-890 MHz | VHF (very high frequencies)<br>TV<br>UHF (ultra high frequencies)<br>TV |
| Cellular Mobile Radio | 896-901 MHz<br>840-935 MHz | Mobile to base station<br>Base station to mobile |
| Satellite Communication | 5.925-6.425 GHz<br>3.7-4.2 GHz | Uplink<br>Downlink |

***1.What are ground waves ? why the frequency of ground waves can not exceed 1.5 MHz?***

The wave which glides over the surface of the earth. Ground wave induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the earth.

The attenuation of surface waves increases very rapidly with increase in frequency. Therefore, the frequency of ground waves can not exceed 1.5 MHz

Used for short distance radio communication.eg . walkie-talkie

**2.What are sky waves ? Give the frequency range of Sky waves.**

These waves are transmitted by a transmitter towards sky and reflected by the ionosphere to the multiple receivers (radio sets)

*3 to 30 MHz*

*Used for long distance radio broadcast in Short wave and medium wave band.*

**3.Why waves of frequency above 30 MHz can not be propagated as skywaves?**

*Waves of frequency above 30 MHz are not reflected by the ionosphere but they pass through the ionosphere and lost in space.*

**4.What are space waves? Mention the frequency range of space waves?**

**Space waves travel in a straight line from transmitting antenna to the receiving antenna in space both by line-of-sight (LOS) communication as well as satellite communication.**

**At frequencies above 40 MHz.**

*Used for FM radio and TV transmission*

**5.State three reasons which make modulation of signal wave essential.**

*With out modulation*

*i) due to large wavelength λ the size of antenna required is impossible to construct as* $h = \lambda/4$,

*ii) Power P radiated is very less due to large wavelength λ . as* $P \alpha 1/\lambda$. *Signal is attenuated at short distances.*

*iii) Mixing of number of message signals which results in confusion.*

**6. What are the types of commonly used Modulation?**

*Frequency modulation (FM)- frequency of carrier wave is changed according to the intensity of signal wave to superimpose signal wave on it.*

*Amplitude modulation( AM) - amplitude of carrier wave is changed according to the intensity of signal wave to superimpose signal wave on it.*

**7. Advantages of FM over AM**

*1. Noiseless reception of signal always.*

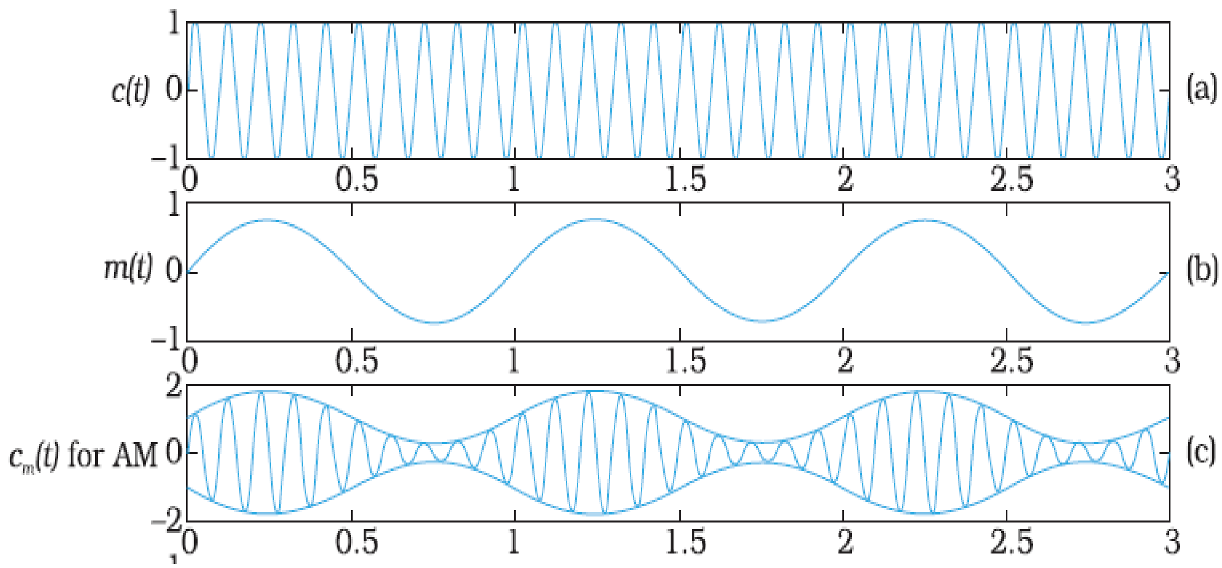
*2. Range of transmission is longer*

**8.Disadvantages of FM over AM**

*1.Complex and expensive equipments are required for transmission*

*2. a much wider channel is required by FM.*

*9.Draw the wave forms of carrier wave message signal, and AM wave.*




***9.Define modulation index. Why it must be less than 1 or 100%?***

*It is the ratio of amplitude of signal wave to the amplitude of carrier wave. $\mu = Am/Ac$ .*

*$\mu$ must be less than 1 or 100% to prevent distortion of the signal.*

**10.Message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 volts. Determine (a) modulation index, (b) frequency the side bands produced.**

*(a) Modulation index =10/20 = 0.5*

*(b) The side bands are at (1000+10 kHz)=1010 kHz and*

*(1000 –10 kHz) = 990 kHz.*

***11. A carrier wave of peak voltage 12V is used to transmit a messagesignal. What should be the peak voltage of the modulating signal in order to have a modulation index of 75%?***

*μ = Am/Ac . μ =75%  Ac= 12V Am = 9V*

***12.Discuss the theory of amplitude modulation and arrive at the equation for AM wave with the three components of it.***

Let $c(t) = A_c \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal where, $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal can be written as

$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

$$= A_c \left(1 + \frac{A_m}{A_c} \sin\omega_m t\right) \sin\omega_c t$$

the modulated signal now contains the message signal.

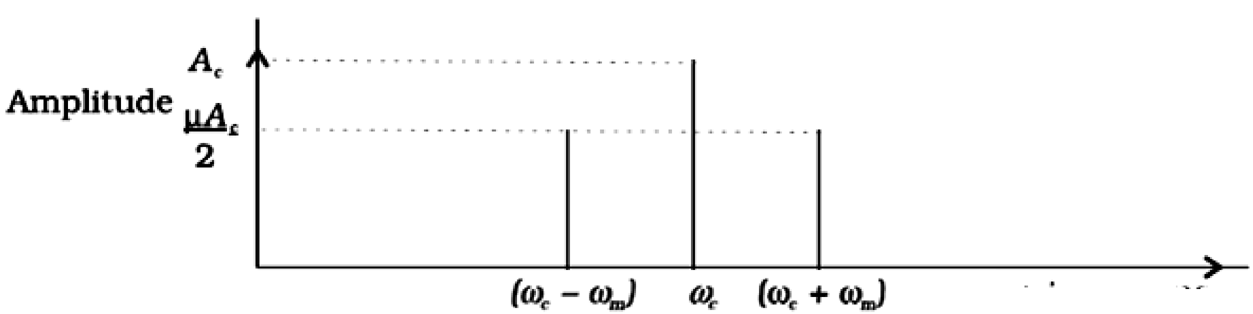
$$c_m(t) = A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t$$

$\mu = A_m/A_c$ is the modulation index, in practice,μ is kept $\leq 1$ to avoid distortion.

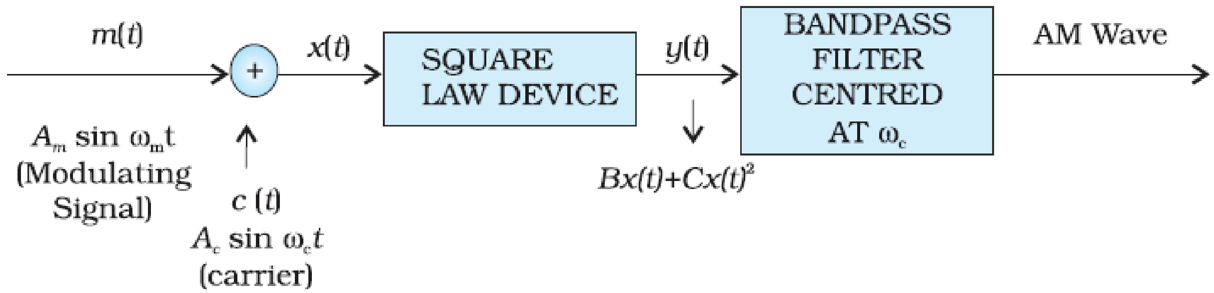
Using the trignomatric relation sinA sinB = ½ (cos(A – B) – cos (A + B), we can write $c_m(t) = A_c \sin\omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)\, t - \frac{\mu A_c}{2} \cos(\omega_c + \omega_m) t$

- *Here,* $\omega_c - \omega_m$ *and* $\omega_c + \omega_m$ *are respectively called the lower side and upper side band frequencies. The modulated signal now consists of the carrier wave of frequency* $\omega_c$ *and two sinusoidal waves each with a frequency slightly different from, known as side bands.*

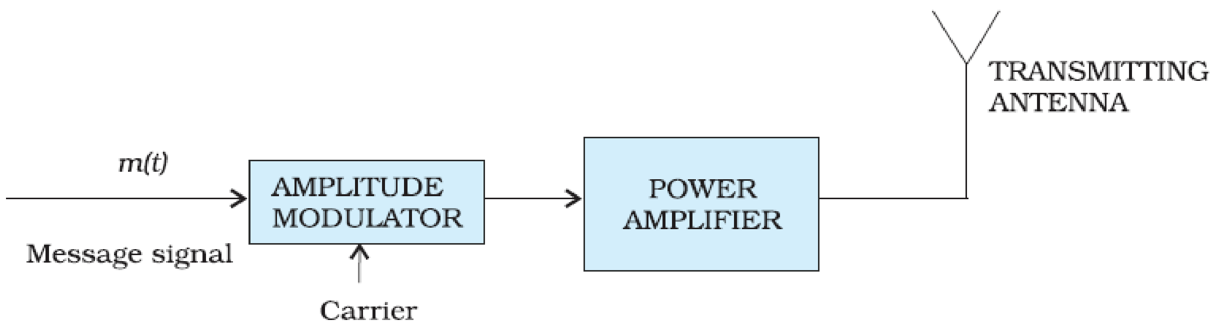
***13. Draw a graph between angular frequency and amplitude of carrier wave , LSB and USB .***



14.Draw block diagram to show AM taking place in square law device.



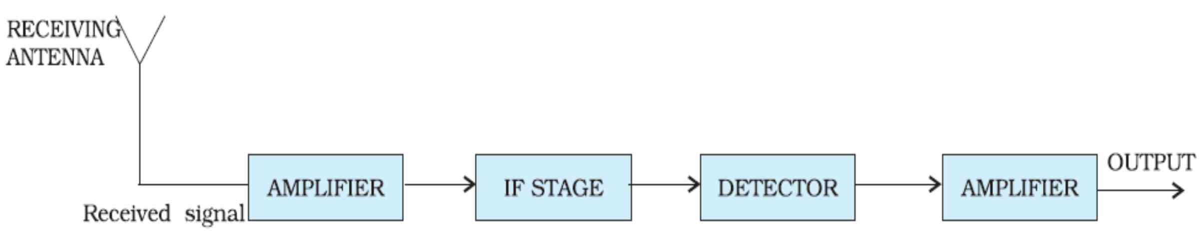

15.Draw block diagram to show Amplitude modulation and transmission of message signal.



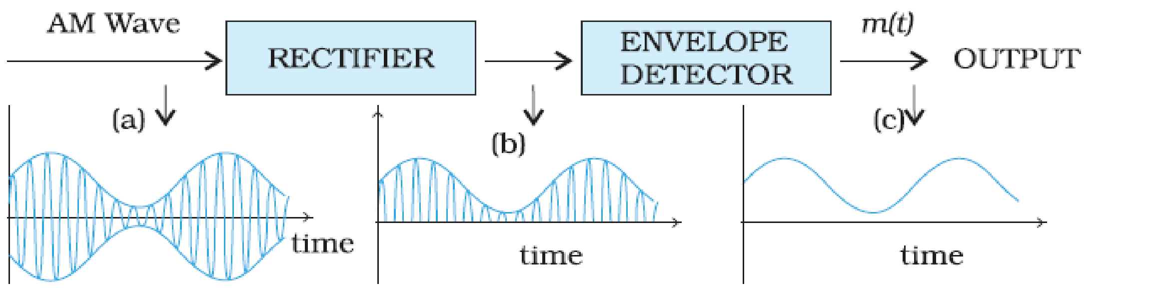

**16.Define detection or Demodulation.**

It is the process of retrieval / extraction of signal from modulated wave at the receiver.

17. **Draw a block diagram showing reception and detection of AM wave at the receiver.**




**18.Draw a diagram to explain the detection taking place in a detector.**




AM input wave    Rectified wave    Output (without RF component)

Rectifier rectifies half wave of the AM wave. Envelope detector separates the radio frequency carrier wave from the signal.

**19.Why satellite communication is preferred over LOS communication for space waves?**
The radio horizon distance requires construction of very large number of repeaters to cover the entire world as it is very expensive satellite communication is preferred over LOS communication for space waves for global coomunication.

**20.Is it necessary for the height of transmitting and receiving antenna to be equal?**
Not necessarily as long as a receiver receives the signal from the transmitter.