Module - 1

* Gas Discharge Tubes :

Disadvantages :

- Higher response time.
- Lower discharge capacity.
- Lower lifespan.

* Vaccum Tubes :

Disadvantages :

- Bulky, hence less suitable for portable products.
- Higher operating voltages generally required.
- High power consumption ; needs heater supply that generates waste heat and yields lower efficiency, notably for small-signal circuits.

* After the development of vaccum tubes, electronics has gone through 3 major stages of development.

- Stage 1 : 1920 - 1950 Vaccum tubes ruled the world of electronics.
- Stage 2 : 1950 - 1960 Invention of Transistors.
- Stage 3 : 1960 - present Invention of Integrated Circuits.

* Transistors :

- Electrons flow through solid instead of vaccum - Solid State Devices.

- Semiconductor Device.
- Initially made of Germanium.
- Silicon almost entirely replaced Germanium
  - Easily available
  - Available in sand and rock.

Disadvantages:
- Cost is high
- Low performance.

★ <u>Integrated Circuits (IC chips):</u>

Advantages:
- Extremely small in size.
- Low power consumption.
- Reliability
- Reduced cost
- Very small weight
- Easy replacement.

★ It contains 100s or 1000s of transistors.

★ <u>Nanoelectronics:</u>

- Nanotechnology
- Special attention to transistors.
- Design is different from traditional transist

Limitations:
- High cost.
- Cannot be used for heavy loads.

* **Different fields in nanoelectronics**

* **Nanofabrication**

To design arrays or layers of nanoelectronic devices.

* **Nanomaterials electronics**

* Dielectric property - high
Dielectric : It is an electrical insulator than can be polarized by an applied electric field.

* Electron or hole characteristics - high.

* Moore's Law : The law states that the number of transistors in a dense integrated circuit doubles about every two years.

* Josephson Effect : Flow of electric current between two pieces of superconducting material seperated by a thin layer of insulating material.

* Superconductivity : Below a certain temperature, materials enter a superconducting state and offer no resistance to the passage of electrical current.

* Quantum mechanic property : Science dealing with the behaviour of matter and light on the atomic and subatomic scale. These properties include the interactions of the particles with one

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another and with electromagnetic radiation. (i.e, light, X-rays, and gamma rays).

- Nanolithography

It is the science of etching, writing or printing to modify a material surface with structures under 100 nm.

★ Applications of Nanoelectronics

- Nanoradio
- Nanocomputers.

★ Energy production

- Solar cells
- Bio-nano generators - work like a fuel cell. (converting glucose into energy artificially).

★ Applications

- Entertainment and Communication
- Control and Instrumentation
- Applications in medical science
- Applications in defence

★ Electronic Components

- Resistor
- passive element : elements which do not generate power.

- Unit : ohm, kilo ohm, mega ohm

*) mega ohm is used for very high resistances.
eg: Insulation, earth resistance etc.

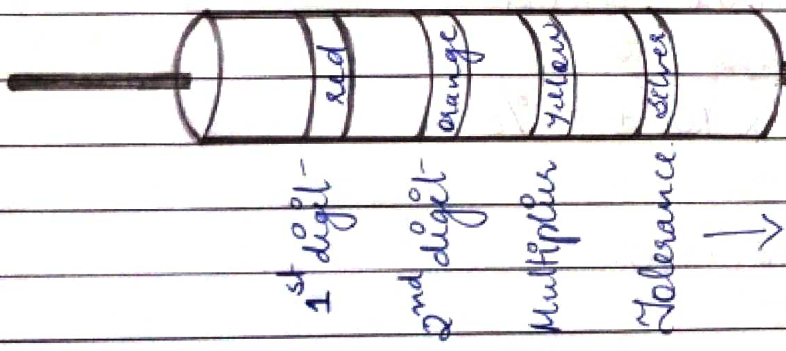
*) Device used to measure very high resistance is known as megger.

* Specifications of resistor

- Resistance value
- Tolerance (error) : permissible plus or minus resistance deviation.
- Wattage rating (max power) : Maximum power in Watts.
- Voltage rating : $\frac{V^2}{R} = P$; $V = \sqrt{P.R}$
- Temperature coefficient of resistance : Rate of change of nominal resistance as a function of temperature.

*) Nominal resistance : The average of the minimum and the maximum allowed values.

* Colour coding of Resistor



→ Gold : 5%
Silver : 10%
None : 20%

Color	Digit	Multiplier	Tolerance(%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

Q1) Find the resistance from the following colour combination :

1) red, red, yellow, gold.

$22 \times 10^4 \pm 5\ \%$

2) blue green orange silver

$65 \times 10^3 \pm 10\%$

3) black violet green

$7 \times 10^5 \pm 20\%$

* Fixed Resistors

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- Wire-Wound Resistors

*) a ceramic-core wound with a drawn wire having accurately-controlled characteristics

*) Coils are made of alloys of Copper and Chromium.

*) Materials must have high thermal stability, tensile strength and capacity to withstand high temperature.

*) Insulating material used is nylon or baked enamel - coated with entire wire.

*) Exit terminals are made of Cu.

*) The material should have high resistance and resistivity.

*) The wounding should be perfect.

* Advantages

- Can withstand large power.
- Used in high temperature situation
- Carries very high current
- Can with stand mechanical shock and vibration.
- Can be used in high voltage circuits.

* Disadvantages

- Not suitable for high frequency applications.
- Cost is high.
- Large size and weight.

* Carbon Composition Resistors

* Two types of construction :

- Slug : Carbon granules are mixed with an organic binder and molded into a pellet-shape around the terminal leads.

- Second type : Carbon resistive material is deposited on a glass tube attached to the terminal leads by a conductive cement

- A thick organic resin case is molded around the assembly.

* Advantages :

- Small in size
- Cheap
- Wide resistance range

* Disadvantages :

- Not useful for above 5W applications
- Resistance vary with aging
- Resistors easily get heated.

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* Carbon Film Resistors

- Depositing very thin film of carbon on to a substrate by vacuum sputtering.

*) vaccum sputtering :

- Thin and thick film resistors.

* Advantages

- Available for all resistive values
- Good frequency properties
- Available in every miniature size
- Can replace wire wound resistors in high voltag applications.

* Disadvantages

- Cannot withstand high temp.
- Chemically reactive and unstable.
- Have higher inherent inductance.

* Variable resistors

* Volume Control Type Potentiometer :

- Made of carbon
- Long Handle

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* Advantages

- Size is comparatively small
- Low weight
- Wide resistance range

* Trimmer Potentiometer

- Shorty trimpot
- Central moving arm is spring loaded.

* Advantages

- Small size and weight
- Low cost
- Available for all resistance values.

* Rheostat

- Wire wound type

* Advantages

- Large current carrying capacity.
- Capable of handling high voltages
- Rheostats are precision resistors with low tolerance.

* Disadvantages

- Costly
- Bulky, weight is more

* Maintenance required - wires can easily be broken.

* Harmonics

A harmonics of such a wave is a wave with a frequency that is a positive integer multiple of the frequency of the original wave, known as the fundamental frequency. The original wave is called the 1st harmonic, the following harmonics are known as higher harmonics.

* Capacitor

A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a capacitor is known as capacitance.

- Fixed capacitor
- Variable capacitor

* Capacitance

Capacitance is the ratio of the amount of electric charge stored on a conductor to a difference in electrical potential. There are two closely related notions of capacitance.

- That are:
- Self Capacitance
- Mutual Capacitance

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Any object that can be electrically charged exhibits self capacitance.

•> SI unit : Farad (F)
{Practical capacitors are in microfarads or pico-farads}.

★ Fixed Capacitor

• Capacitance doesn't vary with external factors.
• Capacitor that ~~shows~~ stores fixed amount of electric charge.
• There are 4 types of fixed capacitors :
•> Paper capacitors
•> Mica capacitors
•> Ceramic capacitors
•> Electrolytic capacitors.

★ Paper Capacitors

• Paper capacitor is a capacitor that ~~was~~ uses paper as the dielectric to store electric charge.
• Tissue or cellulose paper called craft paper.
• Craft paper is sandwiched between 2 aluminium foils.
• The entire unit is rolled to form a cylinder.
• The paper sheet is covered or soaked with oil or wax to protect from outside harmful environment.

- Used in the high voltage and high current applications.

Mica capacitors

- Mica is used as dielectric material.
- Muscovite mica is most frequently used for constructing the dielectric of mica capacitors.
- It consists of plates of aluminium foil separated by sheet of mica.

Advantages

- Good mechanical strength.
- Can be used for high temperature.
- High voltage and high frequency applications.
- High insulation resistance.

Disadvantages

- Chance of unavailability
- Silver migration occurs at high DC voltages, high temperature and high humidity.

Ceramic Capacitors

- Ceramic materials is used to construct the dielectric and conductive metals are used to construct the electrodes.
- Ceramic disc is coated on 2 sides with a metal, such as Cu or Ag.
- Tinned wire is placed as leads.

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- The entire unit is coated with plastic and marked with capacitor value.

* Advantages

- Wide range of capacitance
- Cheap
- Light weight
- highly reliable

* Disadvantages

- High voltage capacitors are not available.
- High capacitors (capacitance) are not available.

* Electrolytic capacitors

- Consists of aluminium foil electrode which has an aluminium oxide film covering on one side.
- Aluminium plate serves as positive plate. aluminium oxide acts as dielectric.

* Advantages

- High capacity in small volume.
- Lower cost per microfarad.

* Disadvantages

- Large leakage resistance
- Will work only in DC.

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* Variable capacitors

- Used for tunning

eg: Air gang capacitor
- Trimmer capacitor.

* Tantalum capacitors

- Another type of electrolytic capacitors.
- Tantalum is used instead of aluminium.
- Larger C in small size.
- Less leakage current.

* Inductors

- Long wires wound on insulating former.
- Fixed and Variable.

* Fixed

- Give constant inductance.
- No of turns do not change.

* Variable

- Inductance can be changed over a specified range.
- Inductance varied by changing the position of core.

* Transformers

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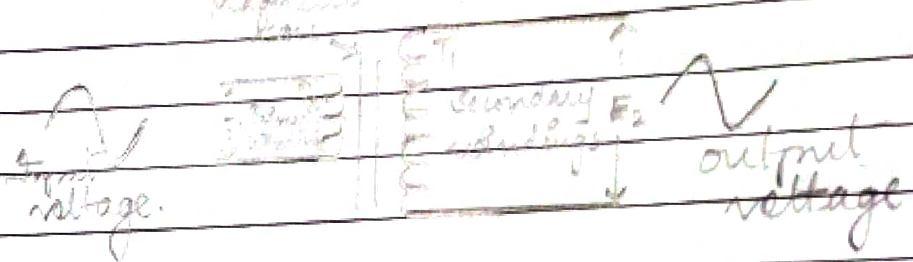
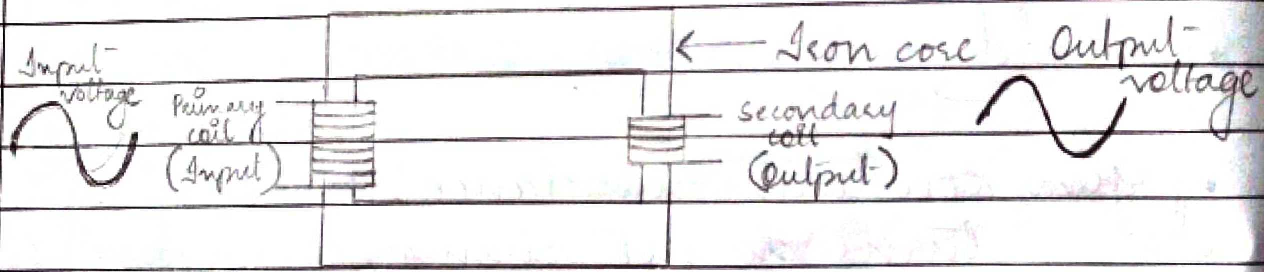
- Two inductors having same core.
- One is primary, the other is secondary
- It transforms one or more electrical parameters from one circuit to another.
- There are 2 types of transformers :
  - Step up transformer
  - Step down transformer

★ Step up transformer



★ Step down transformer



★ Classification of Transformers

- Based on their current capacity and frequency range:
  - Power Transformers.
  - Audio frequency Transformers
  - Impedance transformers
  - Pulse Transformers.

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* Power transformers

• Operating frequency 50 Hz or 60 Hz
• Handle large powers.

* Audio Frequency Transformers

• Transform electrical signals in audio frequency range.
• Application : Audio Amplifier.

* Impedance Transformers

• Transform impedance level
• Transform the output impedance of one circuit in such a way that is matches input impedance of another circuit.

* Pulse Transformers

• Transform pulses.
• Transform pulses may have change in amplitude or polarity.
• Uses

→ Pulse generating circuit
→ Pulse amplifiers.

• Small leakage current and capacitance.
• K greater than 99%.

Semiconductors

* **Energy band diagram**

- Energy band : The range of energies possessed by electrons in a solid.

- Valance band : ⇒ Electrons have least binding energy, more orbital energy.
⇒ The range of energy possessed by valance electrons called valance band.

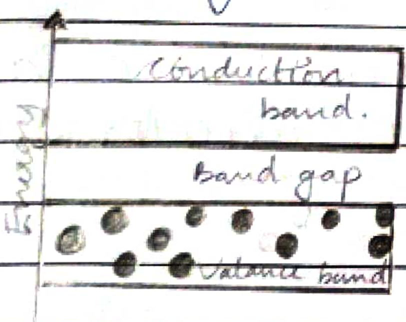
- Conduction band : ⇒ When certain energy is applied to valance electrons, they will become conduction electrons.
⇒ The range of energy possessed by free electrons is called conduction band.

- Forbidden band or gap : ⇒ The separation between valance and conduction band in energy band diagram.
⇒ The energy required to lift the electron from valance to conduction band should

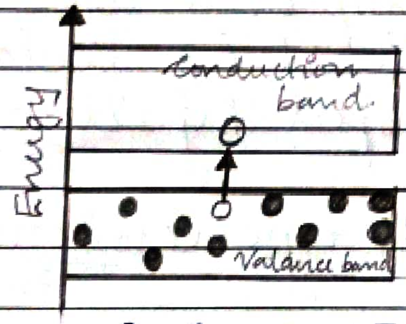
: be greater than the energy gap E_0.

* Classification of materials

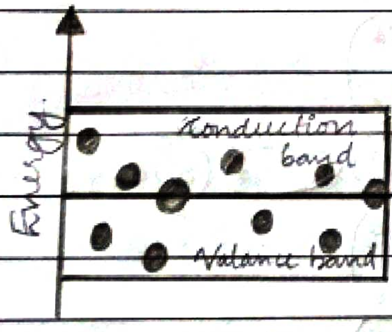
• According to energy band diagram



Insulator



Semiconductor

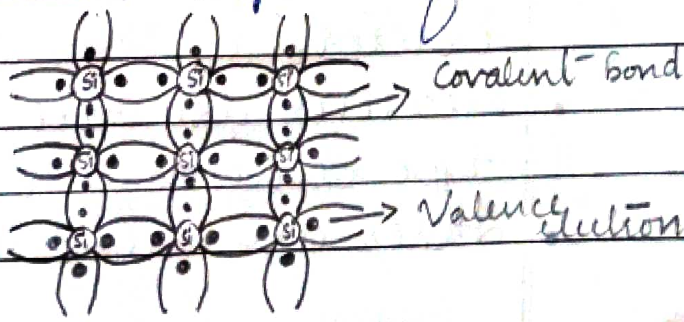


Conductor.

* Classification of semiconductors

• Intrinsic semiconductor :

•) Pure form of semiconductor.
•) Impurity should be less than one part impurity in 100 million ($1/10^8$) parts of semiconductors.



★ Extrinsic Semiconductor

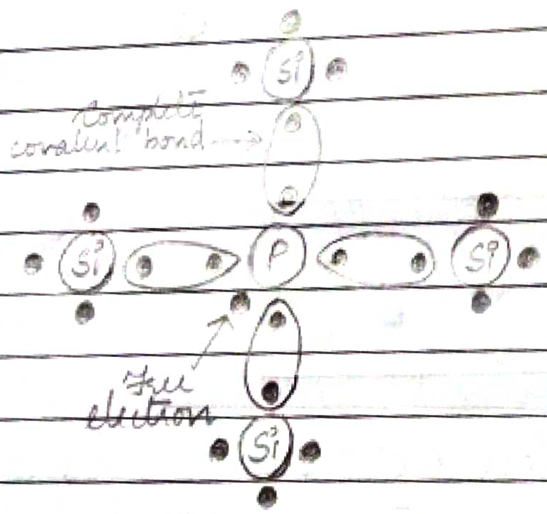
- Impure form of semiconductor.
- Doping

→ Conduction of semiconductor material is improved by doping.

→ Doped by pentavalent atom - donor doping

→ Doped by trivalent atom - acceptor doping

★ N-type Semiconductor



- The pentavalent atoms are Sb, P, Bi and As.
- These materials include five electrons in their outer shell.
- The four electrons will make covalent bonds using the adjacent atoms and the fifth electron will be accessible like a current carrier.
- Electrons are the majority carriers in N type semiconductor.
- Holes are minority carriers.

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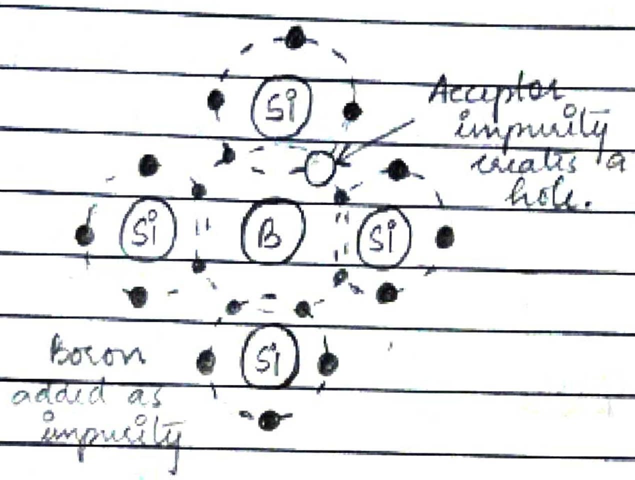
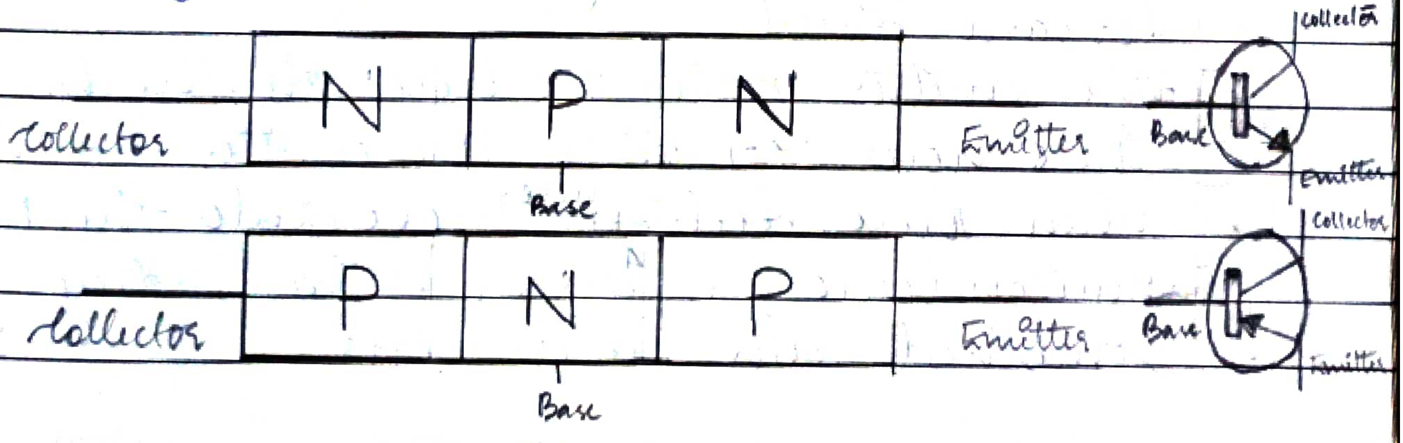
* P-type Semiconductors



- When a trivalent impurity is added to a pure semiconductor a large number of holes are created in it.
- trivalent impurities are boron, aluminium, thallium, Gallium and Indium.
- Major current carriers are holes.
- Minor current carriers are electrones.

★ Bipolar Junction Transistors (BJT)

- 3 doped semiconductor regions - Emitter, base, collector - provided with terminals.
- 2 pn junctions
- Base emitter junction and base collector
- Npn & pnp.



★ Emitter

- Heavily doped
- Supply majority carriers to the base
- Always forward biased with respect to base.

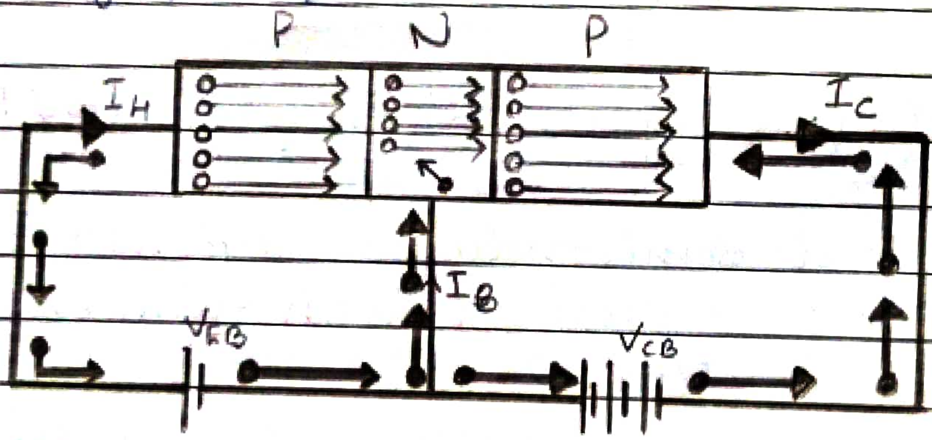
★ Base

- Lightly doped
- Very thin

★ Collector

- Moderately doped
- Always reverse biased with respect to base.

★ Working of PNP transistor



- The emitter - base junction is connected in forward biased.
- The emitter push the holes in the base region
- These holes constitute the emitter current.
- When these ~~electrons~~ holes move into the N-type semiconductor material or base, they get combined with the electrons.

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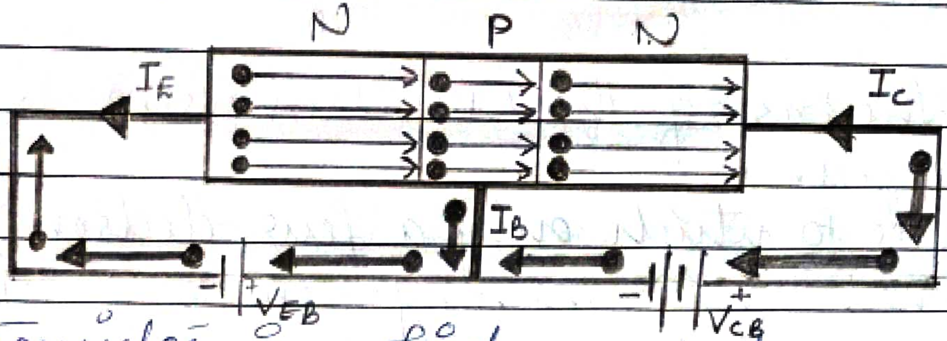
- The collector base region is connected in reverse biased.
- The holes which collect around the depletion region when coming under the impact of negative polarity collected or attracted by the collector. This develops the collector current.

* Working of NPN transistor



- The transistor in which one p-type material is placed between two n-type materials is known as NPN transistor.
- The NPN transistor amplifies the weak signal enter into the base and produces strong amplify signals at the collector end.
- In NPN transistor, the direction of movement of an electron is from the emitter to collector region due to which the current constitutes in the transistor.
- Such type of transistor is mostly used in the circuit because their majority charge carriers are electrons which have high mobility as compared to holes.

- The forward biased voltage ~~V_{EB}~~ is applied across the emitter-base junction, and the reversed biased voltage is applied across the collector-

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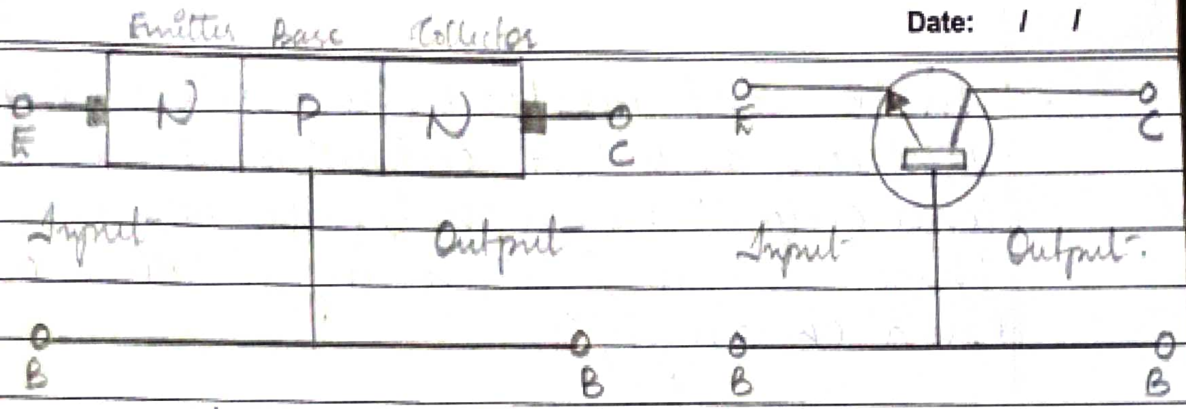
base junction.

- The forward biased voltage V_{EB} is small as compared to the reverse bias voltage V_{CB}.
- When the forward bias is applied across the emitter, the majority charge carriers move towards the base.
- This causes the emitter current I_E. The electrons enter into the P-type material and combine with the holes.

- The base of the NPN transistor is lightly doped.
- Due to which only a few electrons are combined and remaining constitutes the base current I_B.
- This base current enters into the collector region. The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction.
- Thus attract or collect the electrons at the collector.
- The whole of the emitter current is entered into the base. Thus, we can say that the emitter current is the sum of the collector & the base current.

* Transistor Configurations

- Common Base Configuration



- The input is applied between the base and emitter terminals and the corresponding output signal is taken between the base and collector terminals with the base terminal grounded.
- The input parameters are V_{EB} and I_E and the output parameters are V_{CB} and I_C.
- The input current flowing into the emitter terminal must be higher than the base current and collector current to operate the transistor.

$$\text{current gain } (\alpha) = \frac{\text{output current}}{\text{input current}} = \frac{I_C}{I_E}$$

α is the common base current gain.
It is also known as amplification factor
Its value is less than 1 (around 0.98).

$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{input voltage}} = \frac{V_{CB}}{V_{EB}}$$

therefore the output collector current is less than the input emitter current.

- The current gain is equal or less than unity.

- In CB configuration, a positive input produces a positive output and hence input and output are in phase. So, there is no phase reversal between input and output in a CB amplifier.

- If CB configuration is considered for amplification, it has low input impedance and high output impedance.

- The input and output signals are in-phase in this configuration.

- The amplifier circuit configuration of this type is called as non-inverting amplifier circuit.

- The construction of this configuration circuit is difficult because this type has high voltage gain values.

Characteristics

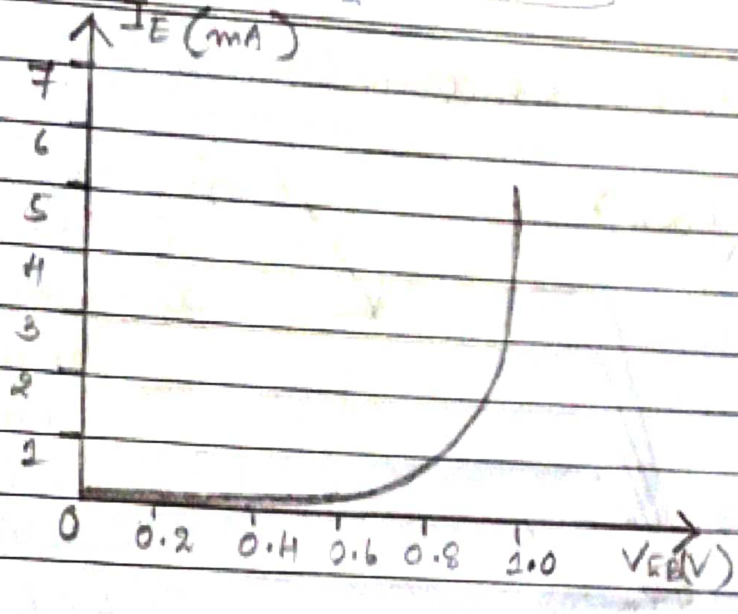
Input characteristics:

Between input current (I_E) and input voltage (V_{EB}) for different output voltage.

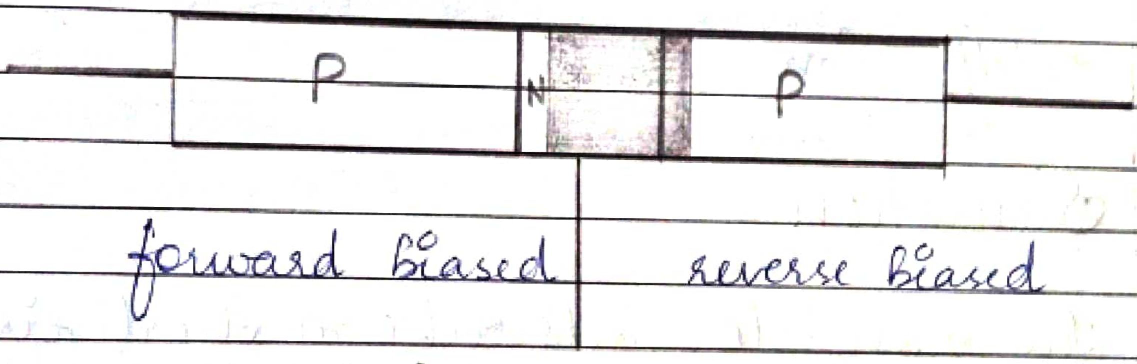
Output characteristics:

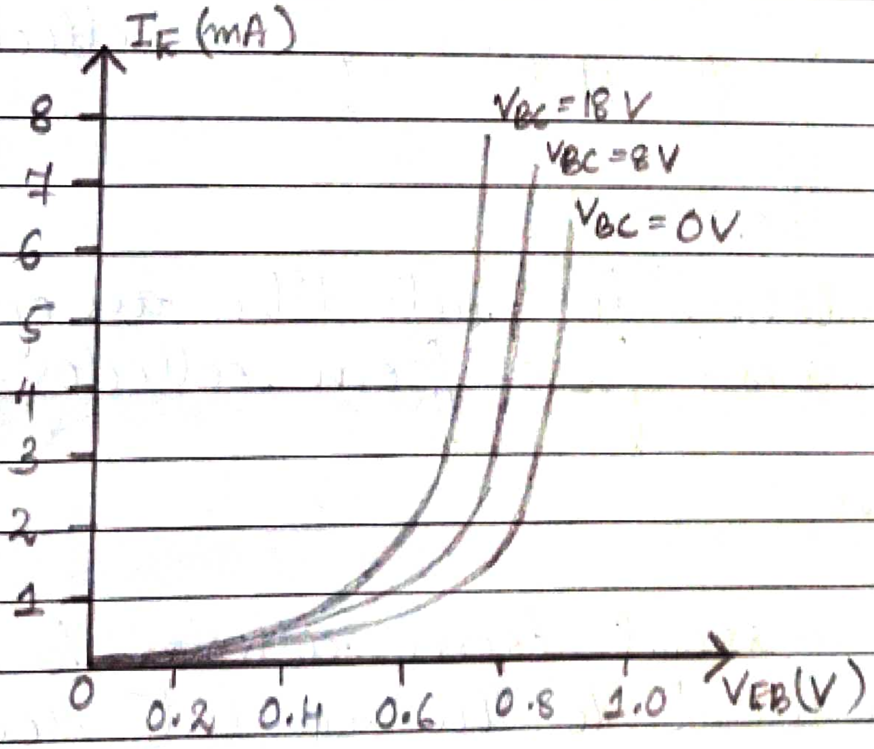
Between output current (I_C) and output voltage (V_{CB}) for different input currents.

Input Characteristics

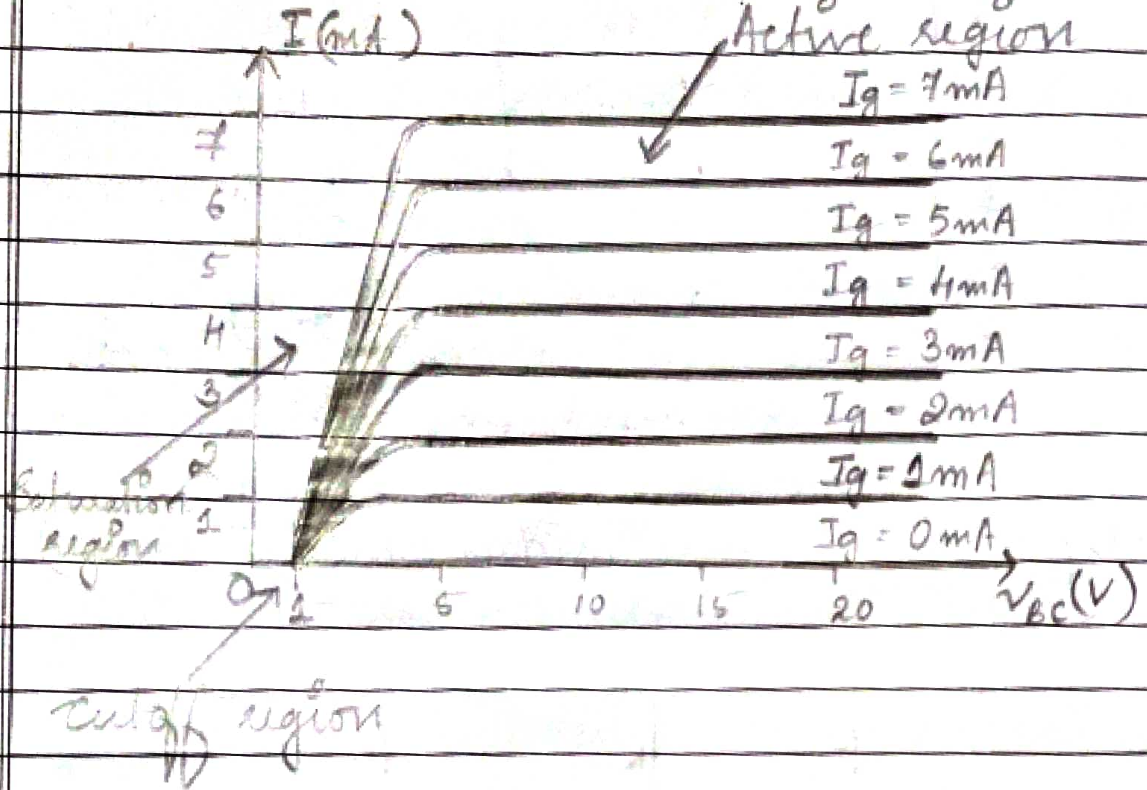


Early Effect (Base width modulation)





Output Characteristics



Saturation :

The transistor acts like a short circuit. Current freely flows from collector to emitter.

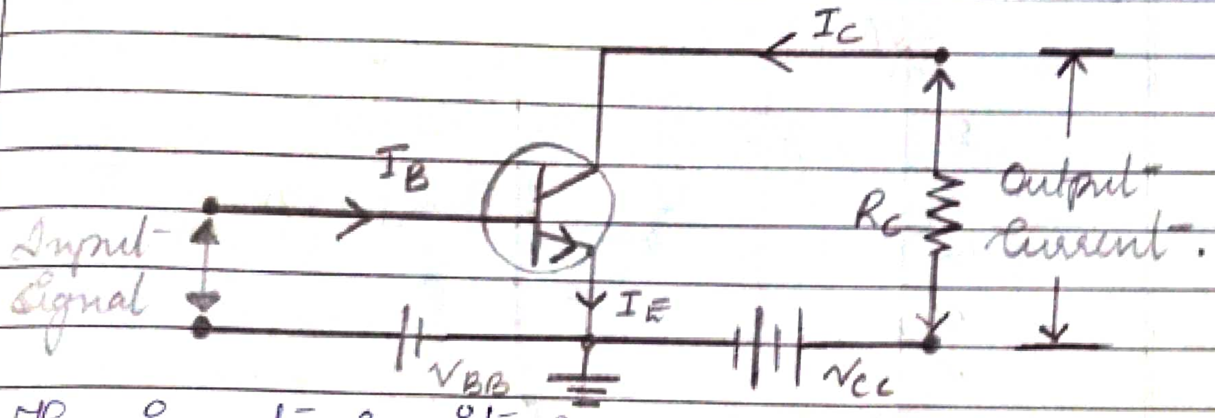
Cut - off :

The transistor acts like an open circuit. No current flows from collector to emitter.

Active :

The current from collector to emitter is proportional to the current flowing into the base.

• Common Emitter Configuration



* The input circuit is connected between emitter and base, and the output circuit is taken from the collector and emitter.

* Common Emitter Current gain (β)

Base current amplification factor is defined as the ratio of the output and input current in a common emitter configuration.

$$\beta = \frac{I_C}{I_B} \quad -①$$

$$\alpha = \frac{I_C}{I_E} \quad -②$$

$$\begin{Bmatrix} I_E = I_b + I_C \\ I_B = I_E - I_C \end{Bmatrix}$$

from ① & ②

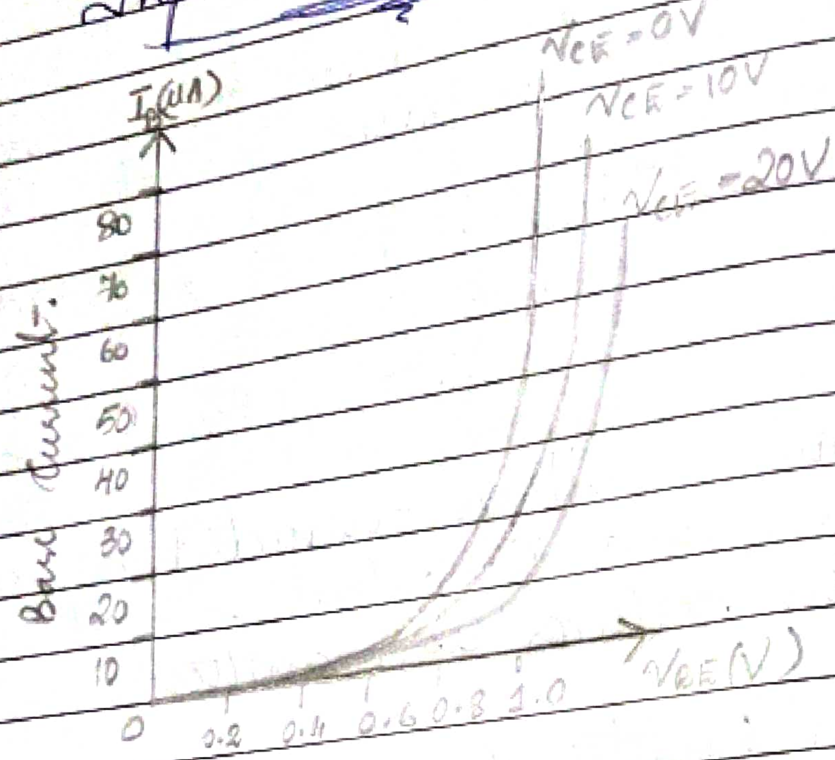
$$\beta = \frac{I_C}{I_E - I_C}$$

$$\frac{1}{\beta} = \frac{I_E}{I_C} - \frac{I_C}{I_C}$$

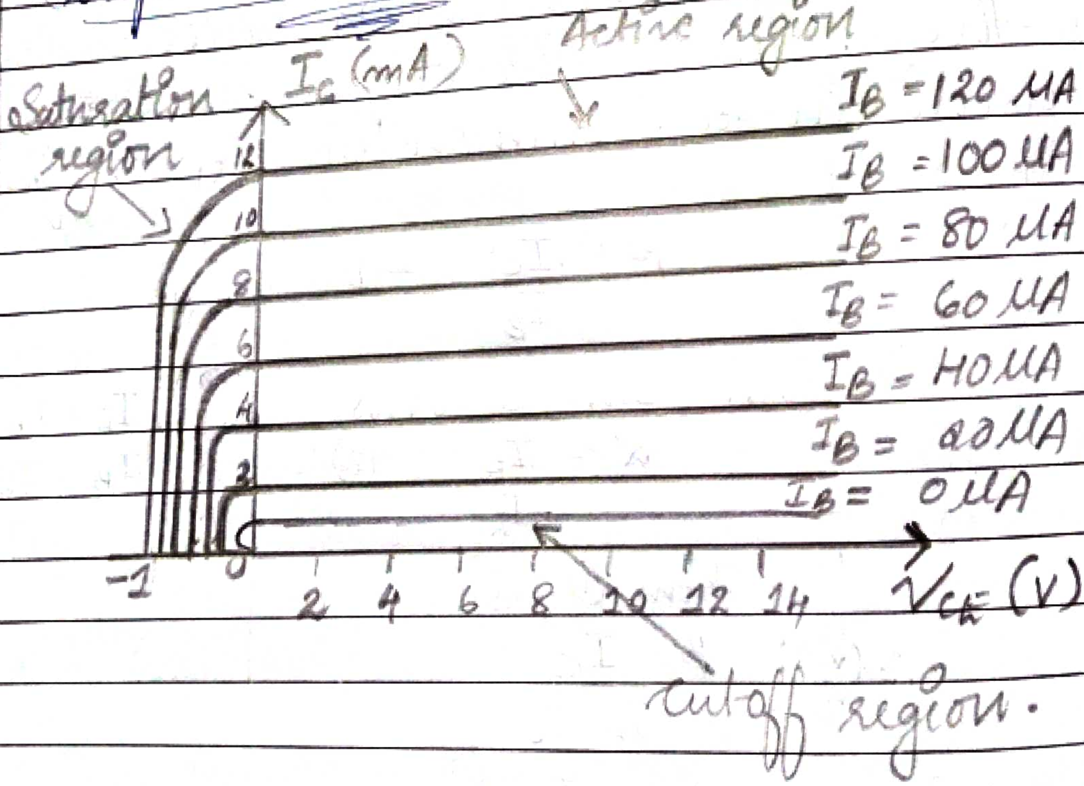
$$\frac{1}{\beta} = \frac{1}{\alpha} - 1$$

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

Input Characteristics

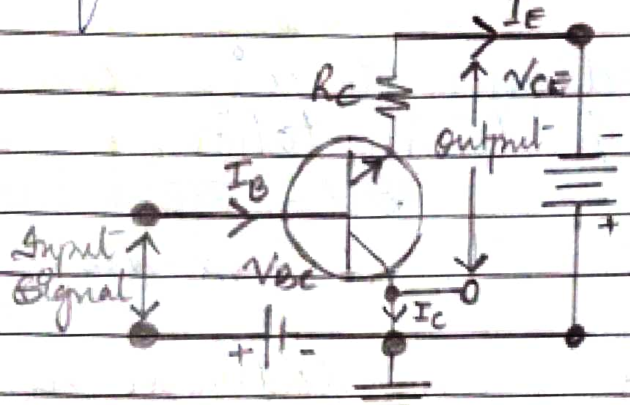


Output Characteristics



Common Collector Configuration

- Input circuit is connected between emitter and base and the output is taken from the collector and emitter.



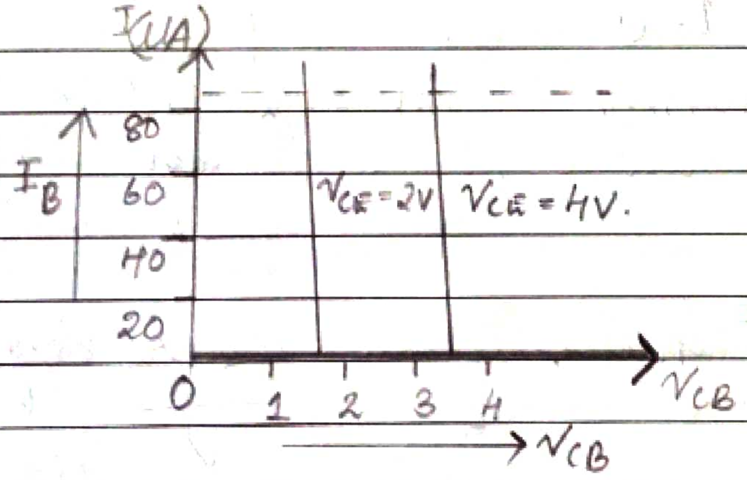
Current Gain:

$$\gamma = \frac{I_E}{I_B}$$

$$I_B = I_E - I_C$$

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

Input Characteristics



Output Characteristics