② Silicon :-

- Available in most of the common rocks.
- Sand is silicon dioxide. Silicon dioxide is treated chemically and reduce to pure silicon.
- Its Atomic number is 14. It has 14 protons and 14 electrons.

first orbit has 2 electron
Second orbit has 8 electrons
third orbit has 4 electrons

- Silicon atom has four valence electrons ∴ it is known as tetravalent element.

* Why Silicon semiconductor devices are preferred over Germanium devices?

At room temperature, the number of electrons lifted to the conduction band are less than germanium.

It has high power ~~ra~~ holding, low leakage current, available in earth.

Effect of temperature on the conductivity of semiconductor

At absolute zero :- Semiconductor behaves as an inductor at this temperature due to empty conduction band.

Above Absolute zero:- When the temperature of semi-conductor is raised, its co-valent bonds break due to the thermal energy supplied to it. Thus some current will flow.

HOLE

Vacancy left in the valence band because of lifting of an electron from valence band to conduction band is known as Hole.

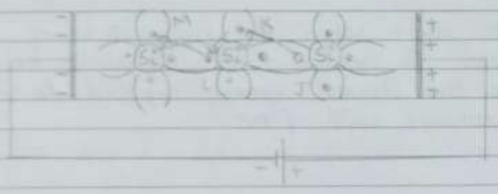
If only one electron is lifted to the conduction band, then one hole is created in the valence band. Thus, each time an electron-hole pair is formed.

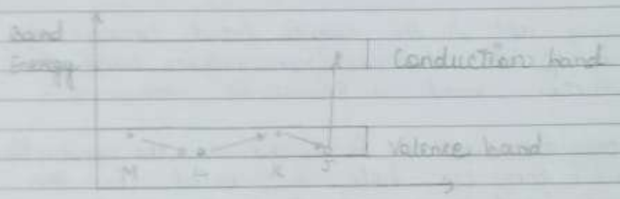
Holes acts as positive charge. It has strong tendency to attract the electrons from a nearby co-valent bonds.

The merging of a free electron and a hole is called Recombination

The average time between creation & disappearance of an electron-hole pair is known as lifetime.

The movement of hole (positively charged vacancy in the valence band) from positive terminal of the supply to the negative terminal through semiconductor constitutes hole-current.





The electron moves from one covalent band to the other to fill the hole in valence band, it is still known as hole-current. It is because the movement of electron is only due to existence of hole in the valence band causing current.

Semiconductors

Intrinsic Semiconductor	Extrinsic Semiconductor
Extremely pure semiconductor	Doped semiconductor having better current conducting properties

Drift current: The flow of current in the semiconductors, constituted by drift of free electrons available in the conduction band and holes available in the valence band, which are formed due to external (i.e. heat) energy supplied to them, is known as drift current.

Note :- In an intrinsic semiconductor, concentration of electrons and holes is equal, but nearly 2/3 of current flowing through it is constituted by the free electrons and the remaining one-third by holes. This is because the electrons are much more mobile than the holes.

Conductivity of semiconductors

Resultant conductivity of semiconductors depends upon:-
1. Concentration of mobile charge carriers (i.e. e^- & holes)
2. Mobility of charge carriers.

Bonds in Semiconductors

1. Co-valent bonds are formed by sharing of the valence electrons.

2. In the formation of co-valent bonds, each valence electron of a semiconductor atom forms direct bond with the valence electron of an adjacent atom. Therefore there are no free electrons to conduct current under ordinary conditions.

Note :- A silicon atom has 14 electrons. Two in the first orbit, 8 in the second and 4 in the third or last orbit.

A germanium atom has 32 electrons. Two in the first orbit, 8 in the second, 18 in the third and 4 in the fourth or last orbit.

Crystalline Structure of Semiconductors

↳ In semiconductors, the atoms are arranged in an orderly pattern to form a solid. This orderly pattern is known as Crystal.

↳ In semiconductors, the eight electrons do not belong exclusively to the central atom but they are shared by the four surrounding atoms. As the adjacent cores have a net positive charge, they attract the shared valence electrons and create equal & opposite forces. These pulling forces in the opposite dirⁿ acts as a glue that holds atoms together and form a covalent bond, consequently gives a crystalline structure of semiconductor.

Commonly used Semiconductor

Tetravalent materials :- Carbon in diamond state $\Delta E_g = 7$ ev (insulator)

Gray tin $\Delta E_g = 0.1$ ev (conductor)

Germanium $\Delta E_g = 0.72$ ev

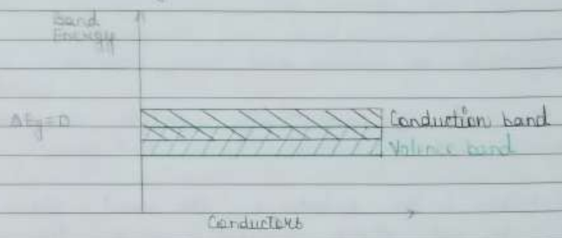
Silicon $\Delta E_g = 1.1$ ev

① Germanium

- Earth element recovered from ash of certain coals or from the flue dust of zinc smelters.
- Recovered Ge is Germanium dioxide powder.
- Then it reduced to pure germanium.
- It is used in electronics, because it can be purified relatively well and crystalline easily.
- Its Atomic number is 32. Therefore, 32 protons in nucleus and 32 electrons in four orbits.
  first orbit has $2e^-$
  second orbit has $8e^-$
  third orbit has $18e^-$
  fourth orbit has $4e^-$
  It has 4 valence e⁻s, so it is tetravalent element.

(2) Conductors :- The substances (like copper, aluminium, silver etc.) which allow the passage of current through them are known as Conductors.

Valence band overlap the conduction band, so slight potential difference applied across them causes a heavy flow of current.

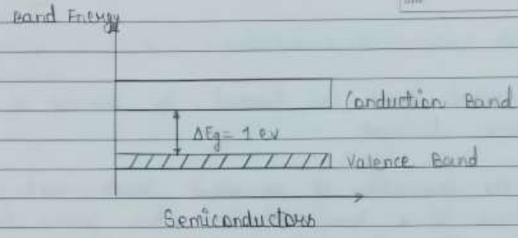


(3) Semiconductors :- The substances (like carbon, silicon, germanium etc.) whose electrical conductivity lies in between the conductors and insulators are known as Semiconductors.

Valence band - almost filled
Conduction band - almost empty
Forbidden Energy Gap = very small (1 ev)

At 0K (-273°C) Semiconductor behaves as Insulator
At 300K (27°C) Semiconductor behaves as Conductor

\# In semiconductor covalent bond is broken.
Moving of $e^{\ominus}$ from one place to another cannot create a hole, hole is created when covalent bond is broken.



Properties of Semiconductors

(1) Resistivity of semiconductors

Conductors < Semiconductors < Insulators
(10^{2} to 0.5 ohm-m)

(2) Semiconductors have negative temperature co-efficient of resistance

Temp. ↑ Resistance ↓

(behaves as insulators at very low Temperature and as conductors at very high temp.)

(3) When a suitable metallic impurity (like arsenic, gallium etc) is added to a semiconductor, it changes the current carrying properties of semiconductor appreciably.

Doping changes the current carrying/ conducting properties.

This band may be filled completely or partially.

The energy band which possess the valence electrons is called Valence Band.

② Conduction Band :- In metals, valence electrons are loosely attached to nucleus and can be detached very easily. These electrons are known as free electrons and are responsible for conduction of current. These electrons are also known as Conduction Electrons.

The energy band which possesses the conduction (or free) electrons is called Conduction Band.

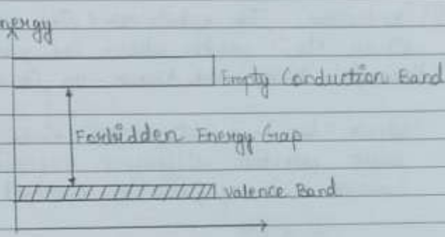
If a substance has empty conduction band, it means current conduction is not possible in that substance and is known as Insulator.

③ Forbidden Energy Gap :- The energy gap between the valence band and conduction band is known as Forbidden Energy Gap.

It is a region where no electron can stay as there is no allowed energy state.

Greater the forbidden energy gap, more tightly the valence electrons are bound to nucleus.

External energy (heat, light radiation etc.) equal to forbidden energy gap, lifts the electron from valence band to conduction band.

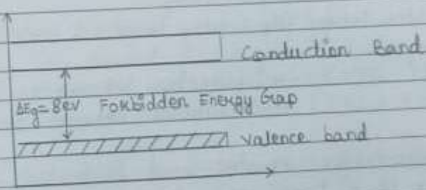


* Classification of Solids and Energy Bands

On the basis of conductivity, solids are classified as :-

① Insulators :- The substance (like wood, glass, mica etc.) do not allow current passage through them, are called Insulators.

Valence band - full
Conduction band - completely empty
Forbidden energy gap - Very large (15 eV nearly) (mostly 5 eV - 15 eV)



Insulators

INDUCTOR

↳ An electronic component (coil) which opposes the change of current in circuit is called Inductor.

↳ The ability of coil / inductor to opposes the change of current flowing through it, is called its inductance.

↳ OR Ability to produce induced vtg. when current varies through it.

↳ Unit :- Henry (named after Joseph Henry)

Fixed Inductor

Variable Inductor

↳ It offers High Impedance ⟶ A.C signal (block)
Low Impedance ⟶ DC signal (Pass)

↳ Variable Inductors are used in tuning circuits (for changing the resonant frequency) for radio frequencies.

↳ These are also used for impedance matching.

Types of Inductors

• Fixed Inductors

1. Filter Chokes

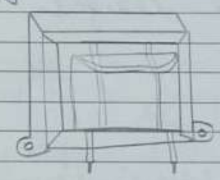
↳ Used in filter section of a d.c. power supply.

↳ Blocks AC signal but pass DC signal

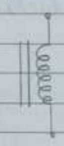
↳ It has many turns of wire wound on an iron core

↳ Two major ratings are — inductance
— current rating

↳ Most power supplies uses inductor of 1 H to 50 H capacity and current carrying capable upto 0.5A.



Filter Choke



Schematic diagram of filter choke.

2. Radio frequency Choke

↳ Smaller in size in comparision to filter chok
↳ Air-core coils are used for RF app^n having very small value of inductance

Troubles in Capacitors

→ Capacitor may be short-circuited (due to dielectric deterioration with age); partially short-circuited (leaky capacitor) and open-circuited (due to some open connections or electrolyte g dry up).

→ Normal capacitor :- High resistance (MΩ)
Short-ckt^d capacitor :- Zero ohm resistance
Leaky capacitor :- lower than normal.

→ Capacitor is checked with ohmmeter (or multimeter)

Procedure
1. Take discharged capacitor (for this short-circuited the terminals of capacitor)

2. Good capacitor shows meter pointer moving quickly towards low-resistance (zero-resistance) side of the scale and then slowly recedes back towards high (infinity) resistance side.

3. This is because as soon as leads of capacitor are connected, capacitor starts charging by the battery of ohmmeter itself.

4. Therefore, at first instant, max current flows and the pointer rises quickly towards zero resistance side.

5. Then the charging current decreases as the capacitor voltage increases towards applied vtg of battery of ohmmeter.

Hence needle recedes towards the infinity resistance side.

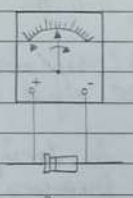
6. Both rise & fall of needle are due to charging of the capacitor.

Ohmmeter Reading indications :-

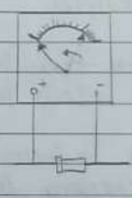
1. If needle of ohmmeter rises immediately to zero and stay there, capacitor is short-circuited since current flows through circuit continuously.

2. If the needle of ohmmeter rises quickly and then recedes back, but final resistance reading is appreciably less than infinity, then capacitor is leaky.

3. If the needles of ohmmeter doesnot rise and stays at infinity resistance value, the capacitor may be open. (So make sure that capacitor was discharged)



Capacitor starts charging

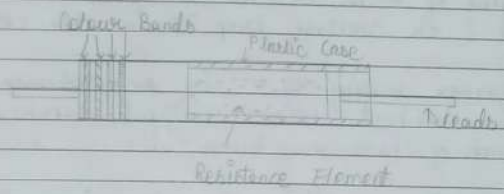


Capacitor is fully charged.

Fixed Resistors

① Carbon- Composition Resistors

↳ Made of mixture of carbon/graphite and clay.
↳ low power rating (2 W or less)
(Power rating :- max. amount of energy it can dissipate without failing or degrading)



↳ Resistance Element is enclosed in a plastic case for insulation and mechanical strength.

↳ Leads are made of tinned copper.

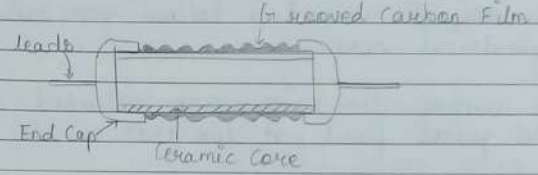
↳ Resistance : one ohm to 22 MΩ , tolerance range of 5 to 20 %.

↳ Power rating : 1/4 , 1/2 , 1 or 2 W.

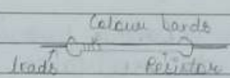
↳ Size ↑ carry more current , dissipates higher losses (heat losses.)

↳ Cheap in cost

Another variety of carbon composition resistor is "Film - type resistor".(or Precision Type Resistors)



Sectional view



Outer look

↳ A homogeneous film of pure carbon (or other metal) is deposited over a ceramic or other insulating core.

↳ To obtain the desired value, either layer is trimmed off or a helical groove of suitable pitch along its length is cut.

↳ Accurate (± 1 %) ∴ it is also known as Precision Type Resistor.

UNIT - 1

Electronic Components and Devices

Electronic Components

Electronic circuits are made to obtain a particular function. For this, a number of electronic components are suitably connected.

Passive Components	Active Components
They are not capable of amplifying / processing an electrical signal.	They are capable of amplifying / processing an electrical signal
Eg:- Resistor, Capacitor, Inductor	Eg:- Vacuum tubes, gas tubes & semiconductor devices.

* Active components cannot work alone without passive components. Eg:- transistor cannot be made to amplify signals without the aid of passive components. (resistor, capacitor & inductor)

1. Resistors

It is used to limit the amount of current or divide the voltage in an electronic circuit.

→ The ability of resistor to oppose the current is called Resistance.

→ Unit is ohm (Ω)

Types of Resistors

→ Characteristic of resistor → Resistance (Ω) ; → Power rating (watts)

→ The value of R is selected to obtain a desired current I or voltage drop IR in the ckt.

→ The power rating of R is selected so it can dissipate the heat losses without overheating itself. Too much of heat may burn it.

From operating condition pt. of view, it is of two types :-

1. Fixed Resistors
2. Variable Resistors

# Fixed Resistor	# Variable Resistor
→ It have fixed value of resistance.	→ To adjust (control) the values of I & V. Eg:- to change the volume of sound in T.V.
→ Carbon - Composition Resistor, Wire - Wound Resistor	→ Carbon - Composition & Wire - Wound Resistor.

ECE - 155A: BASIC ELECTRONICS

Electronic Components & Devices: Construction and characteristics of Carbon composition, wire wound & film resistors. Colour codes and ratings of resistors. Construction and characteristics of capacitors for electronic circuits. Air core, Iron core & Ferrite core magnetic components. Qualitative theory of PN junction. Characteristic & Ratings of junction diode, zener diode, LED, photo diode, BJT, FET & SCR.

Regulated Power Supply: Circuit configuration and analysis of full wave and half wave rectifiers. Various filter circuits. Elementary study shunt and series regulators.

Amplifiers:- Classification of Amplifiers. Concept of voltage and power amplifications. Qualitative study of different single stage audio and power amplifiers. Concept of Gain & frequency response and input & output impedance of amplifiers. Small signal equivalent circuit of BJT.

Concept of Positive & Negative Feedback: Qualitative study of Sine Wave Oscillators

Basic Electronic Instruments: Principales of general purpose CRO and its elementary applications. Characteristics of Electronic analog and digital Voltmeters. Concept of multimeters.

Basic Electronic Entertainment Systems: Concept of AM and FM Elementary block diagram of Super heterodyne receiver. AM transmitter. Basic principle of Television. Television transmission standards. Block diagram of Television transmitter and receiver.

BOOKS:-

1. Electronic Principles by Sahdev (Publication :- Dhanpat Rai & Co.)

2. Microelectronic Circuits - Adel S. Sedra, Kenneth C. Smith

3. Integrated Electronics - Jacob Millman, Christos Halkias, Chetan D. Parikh

4. Fundamentals of Electrical Engineering & Electronics by S. K. Sahdev.

Introduction to Electronics

The word Electronics is derived from "Electron Mechanics" which means the study of the behaviour of an electron under different conditions of externally applied fields.

The branch of science and engineering which deals with electronic devices and their utilization.

The branch of science and engineering which deals with the flow of electrons through vacuum or gas or semiconductor is known as Electronics.

Applications of Electronics

1. Communications and Entertainment (Mobile, T.V.)

2. Industrial Applications (specific machine design) ctrl of thickness of material

3. Defence Applications (SONAR) (RADAR)

4. Applications in Medical Sciences (X-Ray, ECG)

5. ~~Power~~ Applications in Automobiles

6. Digital Electronics

7. Instrumentation (CRO, fx Counter) Sig genr

The variable resistors are of two types :-

1. Carbon composition Resistors
2. Wire-wound Variable Resistors

1. Carbon composition Resistors

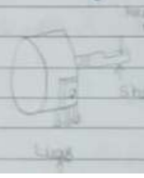
↳ A thin carbon coating on pressed paper or a moulded carbon disc make resistance element.

↳ The two ends of the disc are joined to external soldering lug terminals 1 and 3.

↳ The middle terminal is connected to the variable arm that contacts the resistor element by a metal spring wiper.

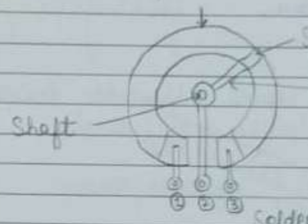
↳ As shaft of control is turned, variable arm moves the wiper to make contact at different points on resistor element which changes the value of resistance inserted in ckt.

↳ 1000 Ω to 5M Ω : Resistance
Power rating: ½ to 2W.



External View

Carbon Composition Resistance Element



Internal View of Carbon-Composition V.R.

2. Wire-Wound Variable Resistors

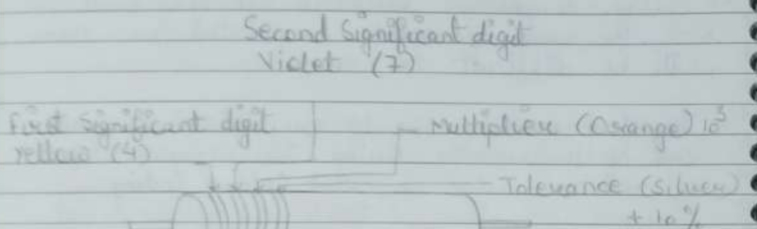
↳ A resistance wire is wound over dough-shaped core of bakellite or ceramic.

↳ The two ends of resistance wire are joined to the external soldering-lug terminals 1 & 3.

↳ The middle terminal is connected to the variable arm that contacts the resistor element

↳ As the shaft of the control is turned, the variable arm moves the wiper to make contact at different points on the resistor element which changes the value of resistance

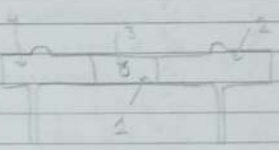
Wire-Wound Variable Resistor



↳ In wire wound resistors, first band is of double the width as compared to rest of bands.

↳ For moulded resistors with radial leads, the colour coding system is called body-end-dot system.

Wire - Wound Resistor



Moulded composite resistor with radial

Q.1. A resistor has a colour band sequence : green, blue, orange and gold. Find the range in which its value must lie depending upon the manufacturer's tolerance to suit a circuit.

Sol.

1st band	2nd band	3rd band	4th band
1st significant digit	2nd significant digit	Multiplier	tolerance
Green	Blue	Orange	Gold
5	6	10^3	$\pm 5\%$

Resistor's resistance $\Rightarrow 56 \times 10^3 = 56\ K\Omega$

Tolerance $= \pm 5\%$

Now, $\pm 5\%$ of $56 K\Omega \Rightarrow \frac{5}{100} \times 56 = 2.8\ K\Omega$

$\therefore$ The value of resistance of resistor is b/w $\Rightarrow$

$56 + 2.8 = 58.8\ K\Omega$

and $56 - 2.8 = 53.2\ K\Omega$ Ans

Variable Resistors

↳ Sometimes, we need to adjust (control) the values of currents and voltages.

↳ For eg:- To change the volume (loudness) of sound in transistor radio & T.V.

To adjust brightness and contrast of T.V. pictures.

② Wire - wound Resistors

↳ Resistance wire (Nichrome, tungsten or manganin) is wrapped around a hollow porcelain cylindrical core.

↳ The ends of the wire are attached to the metal pieces fixed at two ends of the core.

↳ This assembly is coated with an enamel containing powdered glass and is heated, then vitreous enamel is formed.

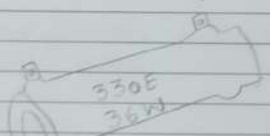
↳ This hard & smooth coating provides the mechanical protection to resistance wire. It also helps in dissipating heat away quickly.

↳ Value of resistance depends on the resistivity of material (ρ), dimension (length & area of cross-section) of resistance wire.

↳ Resistance range: 1 ohm to 100 KΩ and more

↳ Power rating: From 2W to 500W.

↳ Value of resistance is printed on body of resistor



Wire - Wound Resistor

Resistor Colour Coding

↳ Carbon composition resistors are very small in size. The value of resistance printed on them, will be difficult to read.

↳ Therefore, colour bands are printed on one end of the resistor casing. This representation of resistor value is called Colour Coding.

↳ The colour coding is standardized by Electronic Industries Association (AIE).

↳ Colour bands are always read left to right.

Colour Coding

Colour	Significant Digit	Multiplier	Tolerance
Black	0	$10^0 = 1$	–
Brown	1	$10^1 = 10$	–
Red	2	$10^2 = 100$	–
Orange	3	$10^3 = 1000$	–
Yellow	4	$10^4 = 10000$	–
Green	5	$10^5 = 100000$	–
Blue	6	$10^6 = 1000000$	–
Violet	7	$10^7 = 10000000$	–
Gray	8	$10^8 = 100000000$	–
White	9	$10^9 = 1000000000$	–
Gold	–	$10^{-1} = 0.1$	± 5%
Silver	–	$10^{-2} = 0.01$	± 10%
No colour	–	–	± 20%

Checking of Resistors

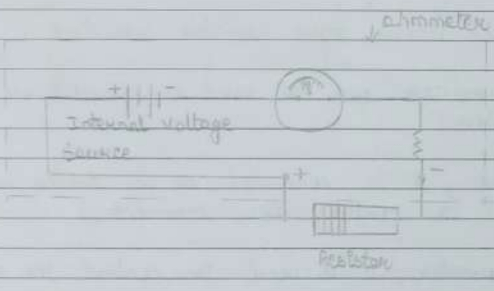
↳ This is done by an ohmmeter.

↳ Ohmmeter has its own vtg source, so no external power source is required.

↳ For defective (open) resistor, ohmmeter reads infinitely high ohm.

↳ Resistor cannot be short-circuited in itself.

↳ Proper range has to be selected while checking a resistor.



CAPACITORS

↳ The two conducting plates separated by an insulating material (dielectric) is called Capacitor.

↳ Purpose :- to store the charge.

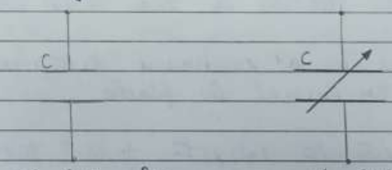
↳ The capacity of a capacitor to store charge per unit potential difference is called its capacitance

↳ Unit :- Farads (F)

↳ It offers low impedence to a.c. but a very impedance to d.c.

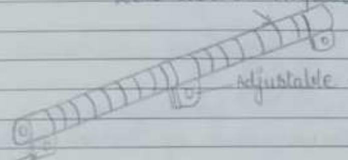
↳ Function :- To block d.c vtg. but pass a.c. vtg. by means of charging and discharging.

↳ Application :- Coupling, bypassing and filtering for a.c. signal.



Fixed Capacitor Variable Capacitor

↳ Adjustable wire-wound resistors are also available with adjustable slider.



Adjustable Wire-wound Resistor

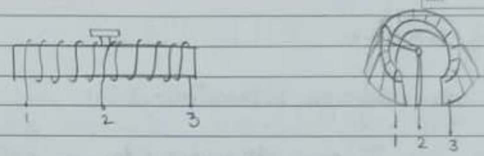
↳ The variable resistors can be linear or non linear.

Linear type variable resistor
↳ Wire is wound in uniform height.
↳ Resistance value varies linearly with the rotation (movement) of moving contact.

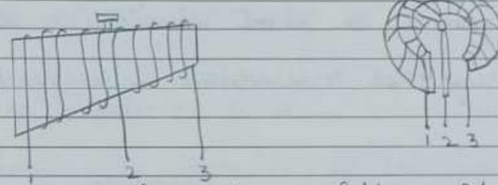
Non-linear type variable resistor
↳ wire is wound on non-uniform height
↳ Value of resistor varies non-linearly (logarithmic variation)
↳ Eg:-

↳ These resistors are mostly used as volume control in sound equipment.

↳



Linear type variable resistor



Non-linear type variable resistor

↳ Variable resistor can be used as Rheostat or potentiometer.

↳ As rheostat, it is connected ~~as~~ in series with loa
It is used to control the current.

↳ As potentiometer, it is used to control the o/p vtg

Trouble in Resistors
↳ It may OPEN.

↳ Carbon-composition resistors are partially opened resulting in much higher resistance than the colour coded value.

Types of Capacitors

Characteristics of capacitors are :-
1. Capacitance (C)
2. Operating Voltage

↳ Capacitors are classified on the basis of their dielectric

↳ There is no required polarity, since either side can be made positive plate, except for electrolytic capacitor.

1. Paper Capacitors

↳ Two metal foils (aluminium or ~~fo~~ tin) separated by paper impregnated with a dielectric material (eg wax, plastic or oil) are rolled into a compact cylinder.

↳ Connecting leads are attached to two metal plates.

↳ Cylinder is placed in a cardboard container coated with wax or encased in plastic.

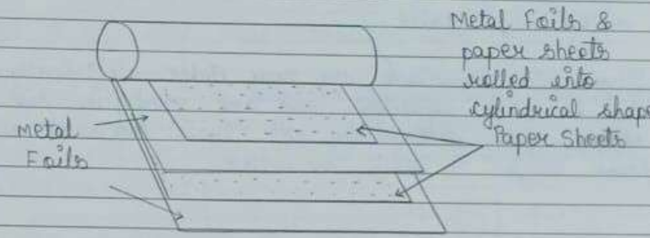
↳ Range :- 0·0001 µF to 1·0 µF ± 10% tolerance
200 to 10,000 volts and more.

Leakage Resistance :- 100 MΩ.

↳ These capacitors should <u>not</u> be used in radio-freq. tuned ckts. because they are not electrically stable.

↳ A black band at one end indicates lead connected to outside foil.

↳ This lead should be used for the ground or low potential side of ckt. to take ~~tolo~~ advantage of shielding by outside foil.



2. Mica Capacitor -

↳ Alternate thin sheets of metal (aluminium or tin) foils are separated by thin mica sheets.

↳ Alternate metal sheets are connected together and make as one terminal. Similarly on opposite side.

↳ The entire unit is encased in a plastic hou or moulded in bakellite case.

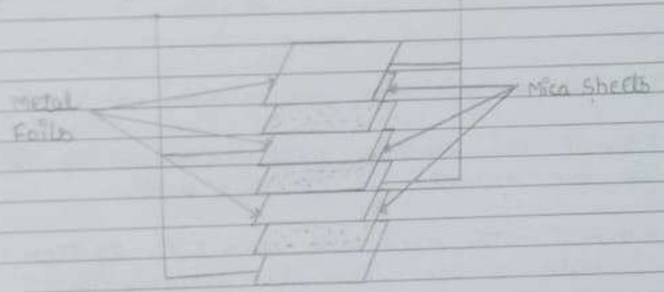
↳ In silver-mica capacitors, opposite faces of mi sheets are silver coated (which acts as the conducting material)

↳ Range :- 50 to 500 pF tolerance ± 2% to ± 20%
200 to 1000 V

↳ leakage Resistance :- 1000 MΩ (so leakage current is very small)

↳ Use :- In RF tuned ckts because they are ~~not~~ electrically stable.

• Silver-mica capacitors are more stable electrically than foil-type capacitors and are used in high stable freq determining ckt. Their tolerance is from ±5% to ±1% or better.



Internal Construction of Mica Capacitor

3. Ceramic Capacitors

↳ Ceramic is made from earth fired under extreme heat.

↳ Titanium oxide or other silicates are used to obtain high value of dielectric constt.

↳ It is of disc type / tubular type.

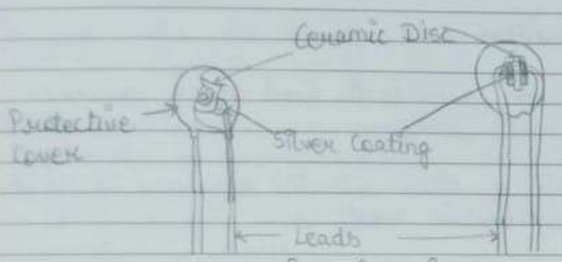
↳ In disc type, it is coated on two sides with metal (silver or copper). Leads are of tinned copper. Then the entire unit is encapsulated in protective coating (plastic).

↳ Disc capacitor :- Range : 47 pF to 0.05 µF
Tolerance : ± 2 to ± 20%
Voltage : 200 to 1000V.
Leakage Resistance : 1000 MΩ
(Small in size)

↳ In tubular ceramic capacitor, inner and ~~of~~ outer surfaces of hollow ceramic tube are coated with silver and form the two plates of the capacitor.

↳ Tubular Ceramic capacitor :- Range : 1 to 500 pF.

Use of ceramic capacitors :- Coupling and bypass portions of RF circuits. In resonant ckt also.



Ceramic Capacitor

4. Electrolytic Capacitors

↳ It contains two aluminium electrodes.

↳ Between the two electrodes absorbent gauze is present which soaks up electrolyte (borax, phosphate or carbonate)

↳ When d.c. vtg is applied, oxide film (a molecular thin layer of aluminium oxide) at +ve electrode is formed.

↳ This oxide film acts as an insulator and forms capacitance b/w +ve electrode & electrolyte in gauze separator.

↳ The -ve electrode provide connection to electrolyte

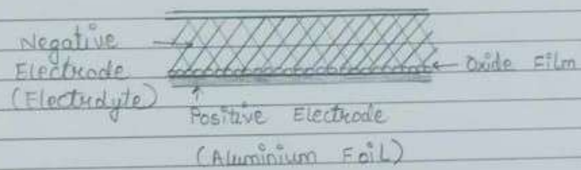
↳ Metal can itself acts as -ve terminal of capacitor.

↳ High capacitance - to - size ratio

↳ Range:- less than 1 μF to 10,000 μF or more
1 to 700 v
Leakage current → high 0.1 to 0.5 mA/μF

↳ Use: Filter section of d.c. power supplies and transistor circuits, Audio coupling capacitors in transistor amplifier.

↳ Must be connected as per polarity. If they are connected in opposite polarity, the reversed electrolysis forms gas in the capacitor. It becomes hot and may explode.



Electrolytic Capacitor

→ Non-polarized electrolytic capacitor contains two capacitors connected in series-opposing polarity. The total capacitance is $\frac{C}{2}$ but oxide film is maintained.

→ In new form of electrolytic capacitor, tantalum (T_a) or titanium (T_i) is used instead of Aluminium because :-
- It is compact
- high dielectric constant (25) {Al has 7 only}
- longer life
- less leakage current

* Variable Capacitors

↳ They are used where freq is to be changed (eg in tuning ckts)

↳ Air-gang capacitors are variable capacitors.

↳ They are available in single, dual and three-section units.

↳ Range : 10 pF to 365 pF.

↳ Capacitance depends upon common area between movable and fixed plates.

↳ Common area can be changed by rotating shaft to which movable plates are attached.

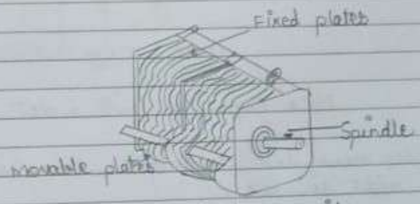
↳ ↑ Common area ↑ Capacitance

→ Another type of variable capacitor is Trimmer (padd

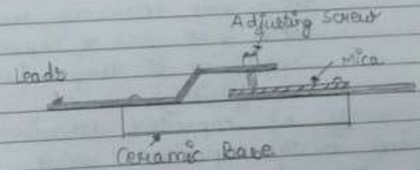
→ Used where variation of capacitance is not frequent.

→ It has two or more metal (aluminium) sheets separated by sheets of mica or ceramic

→ The metal sheets are under spring tension so that they are squeezed together by turning of an adjusting screw, their physical spacing and thus capacitance is varied.



Air-gang Variable Capacitor



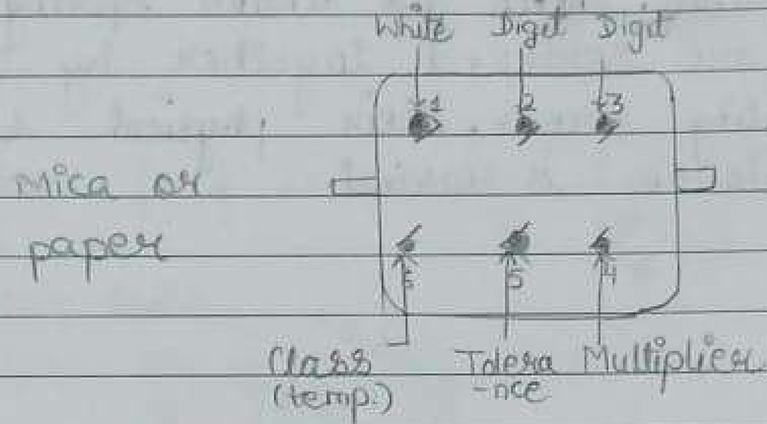
Trimmer

Capacitor Colour Coding

↳ Used for mica and tubular ceramic capacitors

↳ Usually in pF units ↳ Similar to resistance coding

↳ For mica – Six dot system is used.



Mica Capacitor with 6 dot colour coding

↳ Read from top row left to right, then bottom row from right to left.

↳ First dot → material of cap^r — White for mica
Silver for paper.

↳ Capacitance value – read from dots 2, 3 & 4.
dot 5 gives tolerance range.
dot 6 gives class of capacitor (specifying its temperature co-efficient)

* Temperature co-eff. of capacitor describes the maximum change in the capacitance value with a specified temperature range.

If a pentavalent impurity (having 5 valence electrons) are added to semiconductor ; free electrons will be increased.

If a trivalent impurity (having 3 valence electrons) are added to pure semiconductor no of holes will be increased.

Depending upon the type of impurity added, extrinsic semiconductor may be classified as

1. n-type semiconductor
2. p-type semiconductor

① n-type semiconductor

When a small amount of pentavalent impurity is added to a pure semiconductor providing a large number of free electrons in it, the extrinsic semiconductor thus formed is known as n-type semiconductor.

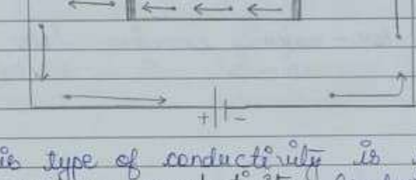
Eg:- Arsenic (At. no. 33) Donor
Antimony (At. no. 51) impurities

② p-type semiconductor

When a small amount of trivalent impurity is added to a pure semiconductor providing a large number of holes in it, the extrinsic semiconductor thus formed is known as p-type semiconductor.

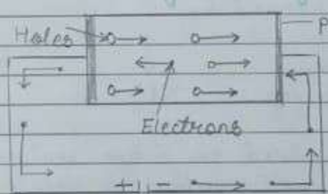
Eg:- Gallium (At. no. 31) Acceptor
Indium (At. no. 49) Impurities

Conduction through n-type semiconductor



This type of conductivity is called Negative or n-type conductivity. Conduction through n-type semiconductor is similar to that of conduction through metals like copper.

Conduction through p-type semiconductor



As the current flow through crystal is by holes (positive charge), this type of conductivity is called positive or p-type conductivity.

When an electric field of E volts / metre is applied the current densities contributed due to the motion of electrons and holes are :-

$J_n = e n V_n \quad A/m^2$

$J_p = e p V_p \quad A/m$

where e = charge of e^- (or hole)
$= 1.602 \times 10^{-19} C$

n = density of free e^-
(no of free e^-s $/m^3$)

p = density of holes
(no. of holes$/m^3$)

V_n = drift velocity of free electrons in m/s

V_p = drift velocity of holes in m/s

Conductivity due to electrons

$$\sigma_n = \frac{J_n}{E} = \frac{e n V_n}{E} = e n \mu_n$$

Conductivity due to holes

$$\sigma_p = \frac{J_p}{E} = \frac{e n V_p}{E} = e n \mu_p$$

where μ_n and μ_p = mobility of free electrons and holes respectively.
(It is the drift velocity of per unit field and is given b in m/s per V/m or m^2/Vs.

Total conductivity of a semiconductor

σ = conductivity due to electrons + conductivity due to holes

$$\sigma = \sigma_n + \sigma_p$$
$$= e n \mu_n + e p \mu_p$$
$$= e(n \mu_n + p \mu_p)$$

In an intrinsic semiconductor
$n_i = n = p$ so $\sigma_i = e n_i (\mu_n + \mu_p)$

where $n_i = n = p$ = intrinsic concentration

Extrinsic Semiconductor

Doping The process ~~of~~ by which an impurity is added to a semiconductor is known as Doping

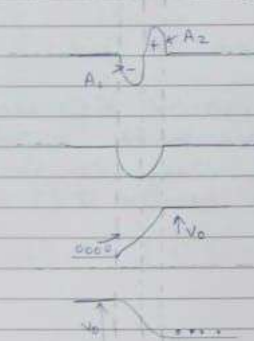
Extrinsic Semiconductor Semiconductor to which an impurity at controlled rate is added to make it conductive is known as an Extrinsic Semiconductor.

Width depletion Region (W) $\propto \frac{1}{\sqrt{doping}}$

The potential where diffusion stops Si $V_0 = 0.7V$
Ge $V_0 = 0.2V$

Fictious Battery :- The electric field intensity generated in the depletion layer having +ve and -ve ions.

We ~~don~~ cannot measure voltage across depletion layer practically using multimeter/voltmeter.



Charge density $A_1 = A_2$

Electric field intensity

$\boxed{E_0 = -\frac{dV_0}{dW}}$ V/m

$|E| \propto \frac{1}{W}$

Barrier for flow of holes

Barrier for flow of e^-s

A pn function will be created b/w p-type and n-type semiconductor only when a bonding force is created in b/w them.

Junction can also be between metal and Si and that is called Metal - Si junction.

Depletion layer is also called Space charge region or transition layer.

- Depletion layer is created due to the diffusion of majority carriers across the junction
- On the depletion layer mobile charge carriers are 0.
- The width of depletion layer $W \propto \frac{1}{\sqrt{doping}}$ and W is in the range of 0.1 μm to 1.0 μm, typical value of W = 0.5 μm.
- Depletion layer consists of ions and large no. of covalent bonds.
- Depletion layer consists of -ve and +ve charge (immobile) charges on either side of the junction.
- Depletion layer consists of -ve ions (acceptor ions on p-side) and +ve ions (donor ions on the n-side)
- Depletion layer opposes majority carriers in crossing the junction.

Note :- The conductivity of n-type semiconductor is nearly double to that of p-type semiconductor.

n-type as well as p-type semiconductors are electrically neural.

n-type semiconductor — majority carriers — Electrons
minority " — holes

p-type semiconductor — majority carriers — holes
minority " — Electrons

P-n Junction

When a p-type semiconductor is suitably joined to an n-type semiconductor, the contact surface so formed is called p-n junction.

p-n junction
formed by

Growing Alloying Diffusion

Alloying :- Indium is placed on n type semiconductor and heat it about 500°C. Indium is absorbed and produce p-region and hence p-n juction is formed.

Diffusion : p-type or n-type semiconductor wafer is placed in a vessel of oxide of impurity to be added. The combination is passed slowly through a furnace with temp. of 800°C to 1200°C. At high temperature, gas of impurity atoms diffuses into semiconductor.

(Movement of something from higher concentration to lower concentration)

Holes in p-type starts moving towards n-type
Electrons from n-type starts moving towards p-type

Properties of p-n junction

Recombination when an electron pairs up with a hole after moving to a certain distance.

Depletion layer The region of immobile charge ~~carr~~ carrier or the region around the junction from which the charge carriers are depleted.

- Width ↓↓ 0.1 μm to 1μm

Potential barrier A potential difference built up across the p-n junction which restricts the further movement of charge carriers across the junction. (or Junction Barrier V_0)

$W \propto \frac{1}{\sqrt{doping}}$ (for equal doping)

· Equation for contact potential of diode :-

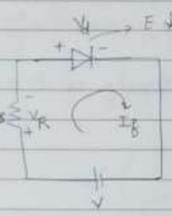
In open circuit diode, the contact potential

$$\boxed{V_0 = V_T \log_e \frac{N_A N_D}{n_i^2}}$$ logarithmic curve

Contact potential of diode depends on temperature, doping concentration, n_i.

Biasing :- When pn junction is connected across an electric supply. the junction is said to be biased.

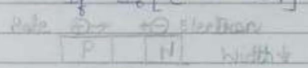
FORWARD BIASING :- When the positive terminal of a d.c. power source or battery is connect-ed to p-type and negative terminal is connected to n-type of p-n junction, the junction is said to be in forward biasing



Current limiting Resistance

$I_f = I_0\, e^{V_d/\eta V_T}$ Approx.

$I_f = I_0 \left[e^{V_d/\eta V_T} - 1 \right]$



$V = V_R + V_d$

$V = I_f R_S + I_f R_f$

$V_d < V$ E ↓ in depletion layer

The external voltage applied to a pn junction that cancels the potential barrier to constitute easy flow of current through it is called forward biasing.

When pn junction is in forward bias, the width of the depletion layer is decreased and also the barrier height decreases in a forward bias diode. This effect as barrier voltage on the majority carriers is reduced to zero.

Once the potential barrier is eliminated by the forward voltage, a conducting path is established for the flow of current, and current starts flowing. This is called forward current and it is due to majority charge carriers.

→ V_T is thermal voltage

→ V_d is forward voltage across the diode
(below 0.5 V for Ge diode)
(below 0.9 V for Si diode)

η = Recombination factor or utility factor or idealization factor ($\eta = 1$ for Ge / larger i)
($\eta = 2$ for Si / smaller i)

I_0 = reverse saturation current in amp.

Depletion layer will not oppose minority carrier.

Depletion layer will help the minority carrier in crossing the junction.

V_0 is called contact potential, barrier voltage, diffusion voltage or potential hill or built in voltage (V_{bi})

For Ge diode $V_0 = 0.1\,V$ to $0.5\,V$ typical value $= 0.2\,V$
~~fo~~ For Si diode $V_0 = 0.6\,V$ to $0.9\,V$ typical value $= 0.7\,V$

In ~~non~~ any p-type of p-n junction diode, field intensity is always maximum at the junction.

In normal diode, field intensity is maximum at the junction and it tappers on either side of the junction and it is zero outside the depletion layer.

Majority carriers has to climb-up barrier voltage hence there is a opposition by minority charge carriers will be falling down the barrier voltage and thereby there is no opposition.

Diode

The arrow marked on the diode symbol denotes the direction of the forward current (i_f)

Equation for the width of depletion layer in open circuit diode

$$W = \sqrt{\frac{2E}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_0}$$

$$E = E_0 E_r$$

Permitivity or Electrical permitivity	Permitivity of free space $8.854 \times 10^{-12}\,F/M$	Relative permitivity of medium $E_r = 11.7$ for Si, $E_r = 16$ for Ge

In open circuited p-n junction, width of the depletion layer depend on doping concentration, barrier voltage and relatively permitivity of the medium

Let $N_A = N_D$ i.e. equal doping of P and N region.

$$W = \sqrt{\frac{2E}{q}\left(\frac{2}{N_A \text{ or } N_D}\right)V_0}$$