"Electrical Engineering Materials

Module 1 :

* Importance of materials.

Use of materials is very much indispensible required for development of engg. & Technology. Materials is used for manufacturing, fabrication, operations & constructions etc. these materials are of diffnt natures viz R.C.C (reinforced cement concrete), steel & iron, copper & aluminium, mica, rubber, alloy & glass etc.

Depending upon the area in which they are used, the materials may be known as

1. Civil engg materials,
2. Electrical engg materials.
3. Mechanical "
4. Electronic "
5. Nuclear "
6. Computer "

As an illustration, we take ex of aluminium. Aluminium generally a mechanical engg material but it is used in electrical engg material as a conductor. However conventionally we call (RCC) as civil engg material, insulator (MICA) as electrical engg material, metal as mechanical engg materials & Uranium as nuclear engg materials etc.

Advancement of any engg discipline is not possible without the development of materials suitable for appropriate use.

Rapid advancement in electron-based computers, revolutionary changes in electronic engg from vacuum valves to VLSI, development of conducting polymers, ferroelectric as a modern breed of dielectrics & ferrite as super magnetic material are some illustration which are outcome of development in electrical engg.

*Classification of Electrical & Electronic materials :

Electrical engg materials can be classified as

1. Conductors
   a. High vg & low vg conductors.
   a. High & low temp^r conductors
   b. High temp^r & low temp^r conductors.
   c. bared & insulated Conductors.

2. Semi conductors
   a. Intrinsic (or element type)
   b. Extrinsic (compound & alloy type)
      i. n-type
      ii. p-type

3. Dielectrics [Insulators]
   i) solid
   ii) liquid
   iii) Gaseous
   iv) Ceramic
   v) polymeric
   vi) Fibrous

4. Superconductors.
   i) Metalic ii) Ceramic iii) Ideal & hard type
   iv) Low & high temp^r types.
   v) Magnetic & non magnetic type

5. Magnetic materials

   i) Dia, Para, ferro, antiferro, ferrimagnetics.

6. Ferroelectric
   a) zirconates   c) titanates
   b) hafnates   d) PLZT → peizoelectric lanthanum zirconate titanate

7. Piezoelectric
   a) Natural (as rochelle salt)
   b) Artificial (as tourmaline, metaniobate)

8. Perovskites (or mixed oxides)

9. spinels, Garnets & magnetoplumbites
   a) Normal spinel
   b) Inverse spinel
   c) metallic garnet
   d) rare earth garnet.

Scope of Electrical & Electronics materials

scope of application of electrical materials is very vast. Applications like machines, equipments, devices ~~etc~~ . and also, components, circuits & other auxiliaries related to electronics, cpu & instrument fields. Their importance is also realized in cable networking, wireless networking, satellites, optical devices etc..

Scope of electrical materials in numerous applications:

In Consumer Items

- Bulb filament
- Heaters, Micro waves ovens
- Remote Control
- Radio
- switches
- Iron press
- Television
- Domestic wiring

In electrical Engineering

- Contacts
- Cables
- Magnets
- Bus bars
- conductor
- Insulator
- Tfr & alternator
- capacitor etc

In Electronics:

- Amplifier
- IC
- Antena
- Printed circuits etc
- Filters
- Satellite
- Transistor, Modulator

In Robotics:

- sensors
- controls
- Grippers etc
- Actuators
- Processors

Computer Engg :

- Hardware
- Monitor
- Floppy, CD's
- ~~xxxx~~ printers
- Memory device
- Hard disc
- ~~Mouse~~, cpuete

Instrumentation :

- Tranducers
- signal generator
- CRO
- MP
- Recorders
- Energy meter

Information Technology

- Networking cables
- Web cam
- cam recorder
- Routers
- optical fibres etc

Mechanical Engg :

- Furnace
- Thermocouples
- X-ray system etc
- Arc welding set
- Metal

Loss angle : Ratio of active power to the absolute value of reactive power. [Dissipation factor]

Decay constant : It is the inverse of the mean life time [avg life time of radioactive particle before decay] then

Requirements of Engg materials

Material technology does not mean just knowing physics and chemistry of materials, their behavior and properties.

It is also essential to know how a material can be suitably & economically put to practical use.

An electrical engg material is used in one or all the following areas.

- Machines (as motor, alternator, robots etc)
- Structures (as tfr, CRT, antenna etc)
- Devices (as strain gauge, IC, control switch, thermistor etc)
- Instruments (as multimeter, transducers etc)

→ Requirements of Electrical Engg materials are resistivity, conductivity, dielectric constant, dielectric strength, relaxation time, loss angle, power factor.

→ Requirement of magnetic materials

Hysteresis, retentivity, Permeability, susceptibility, coercive force, reluctivity

→ Req — electronic:

semi-conduction, drift, diffusion

Thermal fatigue: Failure mechanism which occurs due to repetitive fluctuation of the temp of mechanism concentration, energy gap, Fermi energy

→ **Requirement of Optical material**

Reflection, refraction, transmission, lustre, luminescence.
(soft glow)

→ **Requirement of physical material**

density, melting pt, colour, shape, size, finish, porosity.

→ **Thermal** :- Expansion, conductivity, specific heat, thermal fatigue, thermal stress, thermal shock, etc.

→ **Mechanical** : creep (slow steady movement), toughness, hardness, ductility (without breaking length can be stretched), malleability (without breaking shape).

→ **chemical** : corrosion, resistance, passivity, atomic number, molecular weight, acidity (Measure of presence of H+ ion → Hydrogen +ve charge), alkalinity.

surface : Friction, abrasion, wear, erosion.

Nuclear : Radiation absorption, Half-life period, decay constant

(Alkalinity : Measure of water's buffering capacity to neutralize

→ Structural : strength, stiffness, elasticity & plasticity.

Operational Requirements of Electrical & Electronics materials :

Electrical material have to satisfy widely varying needs of diff^nt operational parameters.

These parameters are vg, current, temp^r, freq^ncy, polarization, remanance resistivity, emission etc.

Accordingly, these materials have to be suitable for meeting the following requirements.

- High & low vg applications.
- " Conduction application
- " temp^r services.
- " freq services
- " resistivity devices
- " emission app^n etc.
- "

Half life period :- It is time req^d for quantity to reduce to half its initial value.

acid)

Equipment	Materials
Overhead line cond^r →	ACSR [Aluminium cond^r reinforced with steel]
UG cables ⟷	Nitrogen gas filled pressure cables in conjunction with oil-treated paper insulation.
Insulators →	Highly purified benzene, hexane, silicon oil, mica, vacuum, ferroelectrics.
High freq coils →	Powdered metals
circuit breakers →	~~Pd~~-Rh and W-pt contacts, Petroleum oil as insulation
low-loss cap^r :	Ferroelectrics, Vacuum as insulation.

Product	Working Principle	Material
• LVDT (linear variable differential tfr core).	High permeability magnetic effect	supermalloy, permalloy, si-iron.
• Antenna rod	Conductivity	Al, Cu,
• Phototube pulse pick-up microphone	piezo electricity	Carbon, quartz, Rochelle salt

Electronic Product	Working Principle	Materials
• Sound recording in films	Magnetism	Metallic glass
• Accelerometer	Piezoelectric	Quartz
• Stroboscope disks	Flashing light called stroboton (electro optics)	Opto-electronic polymers
• Solar Cells	Photovoltaic action	Compound semi-cond^rs
• Cinematography	Photocell effect	Se, Cds, $PbSO_4$ semi conductor
• Automatic door opener	photo conductivity	Cdse, Cds, CdTe semi cond^r
• Computer memory device	soft magnetism	magnetic bubbles
• Wheel-less train magnets	super conductivity	Ceramic
• Oscillographic recorder	Electromagnetic	FeCoNi alloys $Gd_3Fe_5O_{12}$
• Capacitive transducers	Capacitance	saline impregn-ated papers.
• Cold cathode glow transfer tube	Gas ionization	Neon (lamp)

Cds – cadmium sulphide, $PbSO_4$ → lead sulphate, CdTe → cadmium Telluride
Se → selenium
Gd_3 → ganglioside, Penta coobolyn iron, Ni → Nickel, Fe → iron, Co → carbon monox

Different types of Engg materials

Materials are broadly classified in diffnt categories as shown below

1) **Metals** are elemental substances capable of changing their shapes permanently.

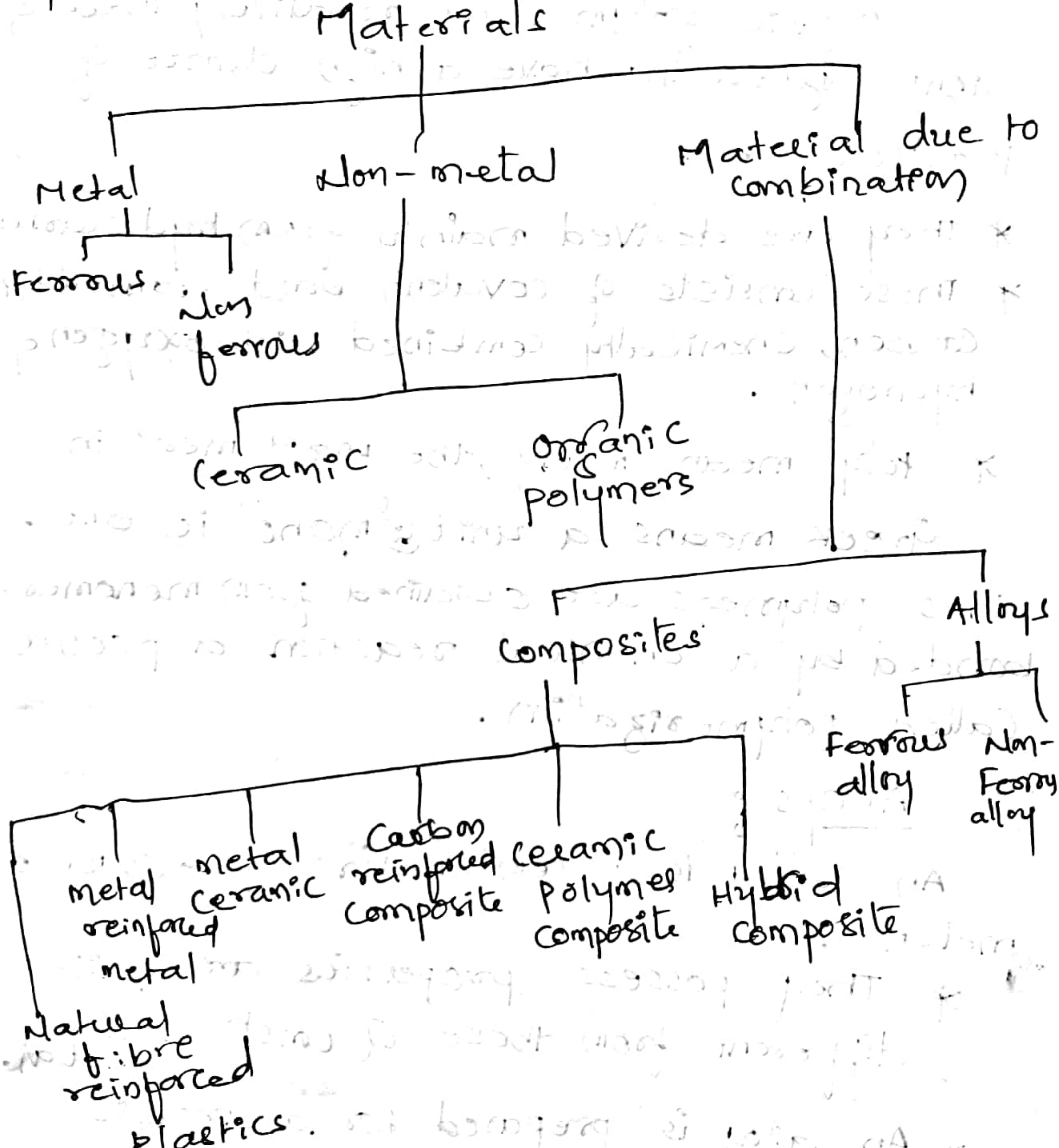
* They are good condr of heat & electricity
* These may be ferrous or non ferrous type.
* Behaviour & properties of ferrous metals depend on the percentage & the form of carbon present.

2) **Non - Ferrous metal** : They do not contain Fe (iron) & C (carbon) as their constituents. Aluminium, Copper, silver, nickel, zinc, tin, chromium etc.

* Al, Cu, Ag & Au are good condr of electricity
* (silver) Ag is most maleable
* (Gold) Au is ductile
* chromium is corrosion resistance
* zinc is used in metal plating
* Tin is used in bushes.
* Nickel imparts strength & creep resistance

3) Ceramics :* generally metallic (or) non metallic oxide.

*



* Rocks, glass, fireclay & firebricks, cements & limes are ceramics.
* Ferrites, garnets, ferroelectric and ceramic superconductors are latest development

4) Organic polymers :- lack in strength or ability to mon

Organic polymer are relatively inert & light, generally have a high degree of plasticity.

* They are derived mainly from hydrocarbons
* These consists of covalent bond formed by carbon, chemically combined with oxygen & hydrogen.
* poly mean many, the word 'mer' in Greek means a unit or 'mono' ie one.

Thus polymers are obtained from monomer's bonded by a chemical reaction a process called polymerization.

5) Alloys :-

An alloy is a combination of 2 or more metals.

* They possess properties are quite different from those of constituent metal.
* An alloy is prepared for a specific purpose to meet the particular requirement of an app^{n}.

Composites : It may be inorganic or organic.

* They have 2 or more constituents of dissimilar properties.
* The 2 major constituents may be metals & ceramic, or metals & polymers, or ceramic & polymers or other combinations.
* Alloys may also be used instead of metals to make composites.
* One of the constituent may be in particulate form, fibrous form or flake form.

II Different Levels of Materials structure :

It is possible to study the internal structure of a material at diff^nt level of observation.

* By the use of naked eye, we can see some details of its structure & to see finer details, we take the help of microscope.

Depending on whether we observe the material with naked eye (or) under a low magnification by optical scope or, under a microscope of high magnification, there are 2 broad levels of structure

1) Macro - structure
2) Micro - structure

Macro - structure : It can be observed with naked eye (or) with a low magnification using an optical microscope.

* Etched & polished crystals of cast brass can be directly seen with naked eyes.
* Etched [metal, glass (or) stone] by coating it with a protective layer, drawing on it with a needle.

Micro
* The human eye is capable of distinguishing 2 lines as separate lines only when their separation is more than 0.1 mm. This is known as limit of resolution of the human eye. It means that if the separation b/w 2 lines is less than 0.1 mm, the human eye will see them as one line.

Micro structural levels may further be classified as below

1. sub - structure
2. Crystal - structure
3. Electron structure
4. Nuclear structure

structure level	Dimensional range (order in mtr)	Example	Magnification
• Macro	10^{-1} to 10^{-3}	Fractured pieces of metals, internal symmetry of quartz	Naked eye 10x
• Micro	10^{-4} to 10^{-6}	Crystals	200x to 1500 x
• sub	10^{-6} to 10^{-8}	crystal imperfection	10000x to 100,000 x
• Crystal	10^{-8} to 10^{-10}	unit cells	x-ray diffraction
• Electronic	10^{-10}	Electron in outermost shell of atom	spectroscopic technique
• Nuclear	still smaller	Proton and neutron	Nuclear magnetic resonance (NMR) technique

Spintronics (The Electronics of Tomorrow) and spintronic materials :

The development of electronics has spread in many specialized branches such as bio-electronics, molecular electronics, spintronics, rubber electronics, polymer electronics, nano electronic etc.

Amongst these, spintronic is one of the fast emerging field.

Spintronics = spin-based electronics

The spintronics devices stores information by spining action ie, moving up and down orientation which are then attached to mobile electronc to carry them along a wire, to be read at a terminal.

Several kind of spintronic devices are in the stage of development.

There are some bipolar devices such as spin diodes, spin transistors, spin polarized solar cells, magnetic diodes etc

These devices are attractive for the purpose of magnetic sensor and memory storage applications.

Working principle of spintronics devices

On application of magnetic field in normal metals, there is a change in their resistance & this change is normally in order of 1% of mag field of 1 tesla (T). In some ferromagnetic material, the direction of magnetic field reversed when magnetic field of order 0.0001 tesla is applied. This results in a phenomenon called Magneto-resistance (MR) which is utilized in commercial production of small magnetic read heads. They can sense very small magnetic fields in written information on hard discs. This causes considerable decrease in space req^d for storing the bits of information. Thus the storage capacity of hard disc increases.

Some major field of current spintronic research

1. Development of spin based devices such as p-n junctions & amplifiers.
2. Spin relaxation behavior in metals & semi cond^rs.
3. Spin based quantum computing.
4. Quantum computer hardware.

Left Handed (LH) Material

LH material characterized by negative Permittivity (ε) and negative permeability (μ)

ie, $\boxed{\varepsilon < 0}$ & $\boxed{\mu < 0}$

Permittivity: Ability of a substance to store electrical energy in an electric field.

Permeability: Degree to which the material is capable of being magnetised.

Unusual properties are that

i) the light rays incident on a convex lens will diverge instead of converging, as happens in conventional ie, right handed (RH) materials.

ii) it will support waves with antiparallel group and phase velocities, known as backward waves.

iii) in a left-handed medium, the light propagates in opposite direction to the direction of energy flow.

Left Handed Material are just opposite to ~~that~~ of R.H material [$\varepsilon > 0$ & $\mu > 0$]

: Conductors :

All metal & alloys fall in category of conductors.

These conductor are used in various application

* Electricity transmission & distribution
* Electrical Contacts viz. relay, switches etc
* Resistors &
* Heating elements.

Gold is best condr for electricity followed by silver, cu, alumi.

Keeping in view the cost factor, cu, al are natural choices. Although silver is used for contacts in aircrafts.

Characteristics of good conductor

* High electrical & thermal conductivity
* High melting point.
* good oxidation resistance.
* low cost.
* Good wear & ~~abrasion~~ abrasion resistance
* Better mechanical property.

Factors Affecting conductivity (and Resistivity) of metals

i) Temperature: The electrical resistance of most metals increases with increase of temperature but in semiconductors and electrolytes decreases with increase of temp^r.

Variation of resistance with temp^r in a material can be expressed as

$$R_{T2} = R_{T1}(1 \pm \alpha dT)$$

ii) Alloying: A solid solution has a less regular structure than a pure metal. Consequently, the electrical conductivity of a solid solution alloy drops off rapidly with increased alloy content.

In other words, addition of small amount of impurities leads to considerable increase in resistivity.

3) Effect of plastic deformation & cold working :

When a metal is cold worked this effect induce scattering of electrons, decrease in mean free path & hence an increase in resistivity of the materials.

Continuation of temperature

$$R_{T_2} = R_{T_1} (1 \pm \alpha \, dT)$$

where R_{T_2} & R_{T_1} are the resistance of materials at temp^r T_2 & T_1 respectively.

$dT = T_2 - T_1$ is the change in temp^r.

α is temp co-efficient of resistance of material

$+\alpha \rightarrow$ pure metals

$-\alpha \rightarrow$ electrolyte & insulators

Problems

* Resistance of a 200 meter long copper wire is 21 Ω. Its diameter is 0.44 mm. Determine its specific resistance.

Given: $l = 200$ mtr, $d = 0.44\,mm = 0.44 \times 10^{-3}$
$= 0.44 \times 10^{-2}\,m$

$R = 21\,\Omega$

$$\boxed{R = \rho \frac{l}{A}} \Rightarrow \rho = \frac{RA}{l}$$

$$21 = \rho \frac{200}{A}$$

where $A = \frac{\pi d^2}{4} = \frac{\pi (0.44 \times 10^{-3})^2}{4}$

$$A = \frac{\pi (0.44 \times 10^{-3})^2}{4}$$

$$\rho = \frac{(21)\{\pi (0.44 \times 10^{-3})^2}{4 \times 200}$$

$$= 1.597 \times 10^{-8}\,\Omega m$$

Heating effect of electric current

When an electric current flows through a metal (ie conductor), the metal becomes hot after some time.

It is due to collision of free electrons moving in random manner through the latice of metals. During their movement (drift), they collide with atoms in the latice of metals.

As a result of such collisions, the electrons lose some of their kinetic energy & manifests as vibrational energy of latice. This results in generation of heat, & hence the phenomenon is termed as 'heating effect of electric current'.

Heat produced is measured in the unit of calorie (or) kilo calorie and may be expressed by Joule's work.

Joule's Law of Electric heating

According to joules law, if a current 'I' flows through a conductor of resistance R ohm for 't' second, then the amount of work required [W.D] to maintain the current flow will be given by

$$W.D = I^2Rt \text{ joule}$$

$$= I^2 \cdot Rt \text{ joules} = I^2 \cdot \frac{V}{I} t \text{ joule}$$

$$= VIt \text{ joule as } R = \frac{V}{I}$$

$$= Pt \text{ joules as power } P = V \times I$$

$$= \frac{V^2 t}{R} \text{ as } I = \frac{V}{R}$$

Heat equivalent of this work may be expressed as

$$H = \frac{W.D}{J}$$

where J = Mechanical equivalent of heat whose value is 4186 joule/Kcal

≈ 4200 joule/Kcal

Applications of Heating effect

1. Electric furnace heating in metallurgical industry.
2. Heating of electric kettle, heater, boiler, immersion heater etc.
3. Heating of filament of incandescent lamp, arc lamp etc.
4. In calorimetry.
5. In Fuses for protection against excessive current.
6. In hot wire ammeter for measuring alternating current.

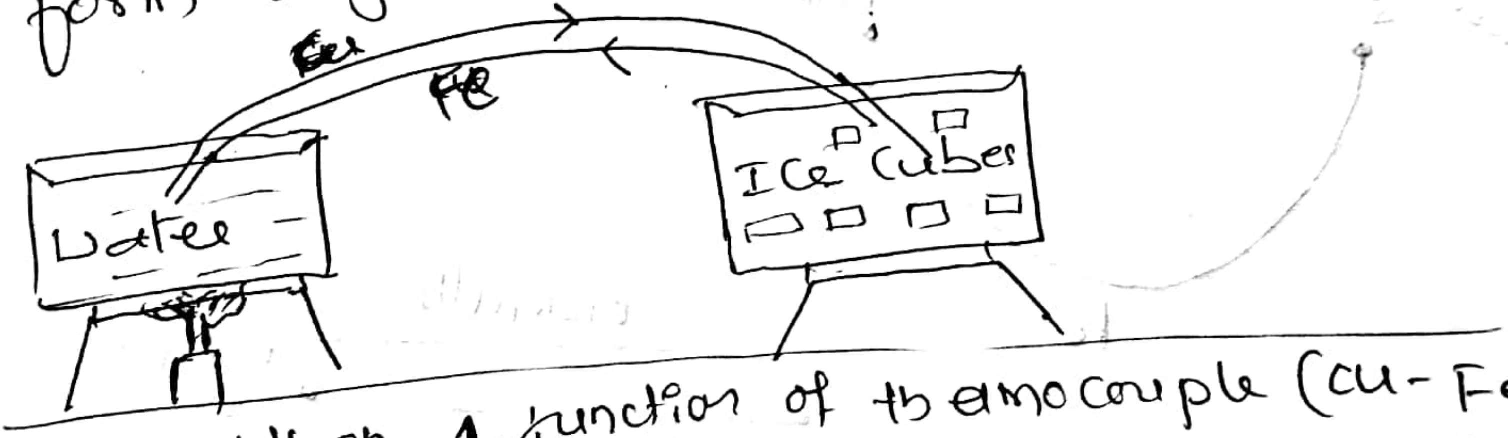
Thermoelectric Effect

It is a well-known fact that electrical energy can be converted into heat energy and heating effect of electric current is irreversible [unalterable (or) irreparable] similarly, the heat energy can also be converted into electrical energy but this is a reversible effect & is known as thermoelectric effect.

Thermoelectric effects are the phenomenon occuring in metals in which flow of electrons begins on app^n of thermal potential difference.
This flow of current is different from the flow of current in metals when an electrical potential difference (gradient) is applied.
The term thermoelectric implied that the flow of electricity is caused due to thermal effect, which can be expressed in a general way as follows

seeback effect :

In 1821 seebeck found that A current flows in a circuit consisting of 2 dissimilar metals, when 1 junction is kept cold is heated, while other junction is kept cold
Two dissimilar metals connected to form 2 junction is called Theemo couple.



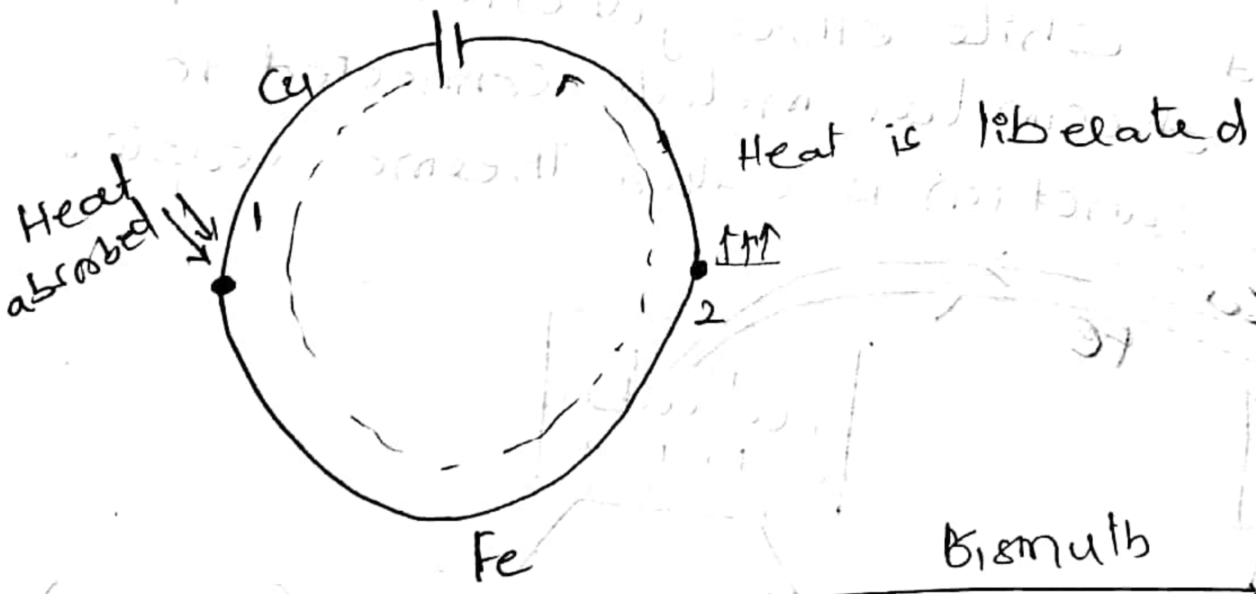
When 1 junction of thermocouple (Cu-Fe) is kept at Ice Cubes (0°) another junction is kept at boiling water. A current will flow through the circuit indicated by the galvanometer
A cold junction current flow from (Fe) to (Cu

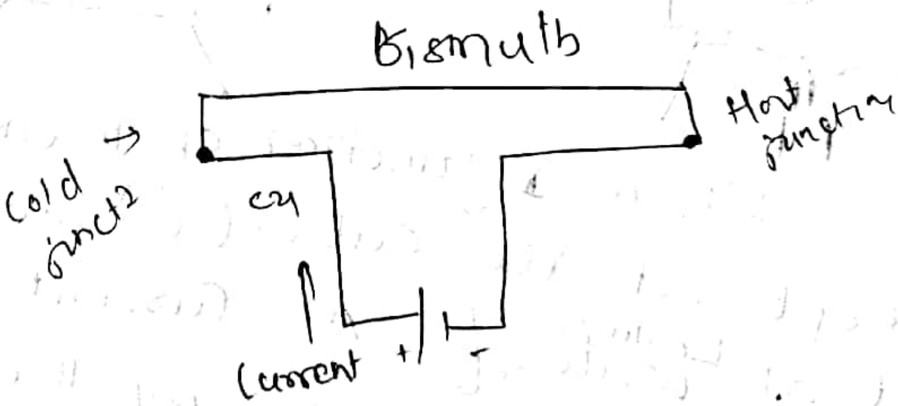
A hot junction current flows from (Cu) 28 to iron.

The emf produced is called as thermo emf.

Peltier effect

In 1834, Peltier discovered that when electric current is passed through a circuit consisting of 2 dissimilar metal. Heat is evolved at 1 junction and absorbed at the other junction

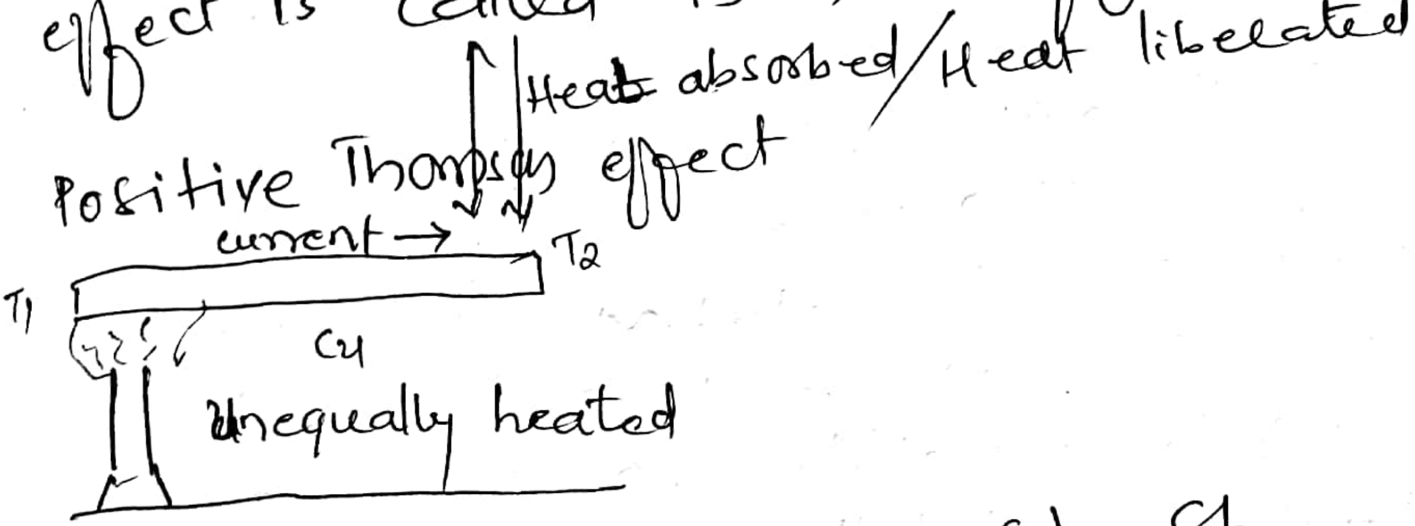




Thomson effect

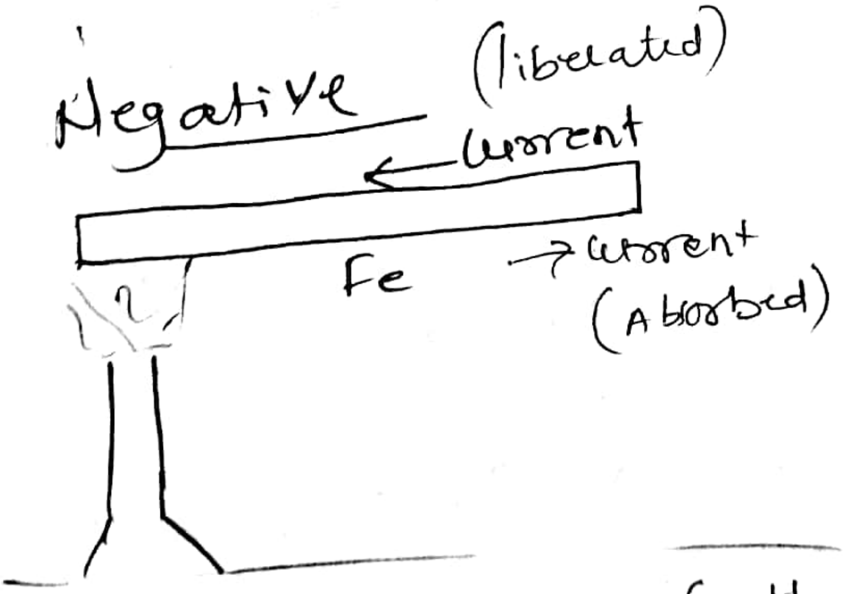
In 1851 Thomson suggested that when current flows through an unequally heated conductor, heat is evolved (or) absorbed through out the body of conductor. This effect is called thomson effect.

Positive Thomson effect



Eg : Sn, Au, Ag, Zn, Cd, Sb.

Negative



Eg : Bi, Ni, Pt, Co, Hg

Ceramics

* Ceramic materials are inorganic, non-metallic materials made from compounds of a metal & non-metal.

A simple manufacturing process for ceramics involves mixing finely ground clay & metal oxide, with water just sufficient to make a paste which is shaped according to requirements & then it is dried & fired at a temp ranging will be in 1200°c & 1700°c.
Other materials used with clay in order to have different types of ceramics are alumina, quartz, talc, magnesite, feldspar.

Ex: insulator porcelain : clay + quartz + feldspar.

* The main features or properties

- Hard, strong & dense [thick or heavy]
- Stronger in compression than in tension.
- Not affected by chemical action except with strong acids and alkalies.
- Completely stable at high temperatures.
- Excellent dielectric properties.
- Weak in impact strength.

Tension [state of being stretched tightly]
Impact strength [capability of the material to withstand a sudden applied load]

* Applications of ceramics

1) Porcelain insulators:

Porcelain materials are used for making different types of insulators, like transformer, bushing-pins, suspension insulators for transmission and distribution lines, disconnecting switches, fuse holders, etc.

2) Line insulators:

Porcelain is widely used in line insulators. Rain & dirt affect its surface resistivity. But the proper design of the line insulator helps in overcoming the problem of reduced surface resistivity and flash over due to rain & accumulation of dirt.

3) Other ceramic materials:

clay + talc dried & adding other materials like feldspar, magnesite

a) Steatite: It is used in making equipments for high frequency systems, also where thermal shock resistance is desired.

(compressive, low moisture absorption and electrical property)

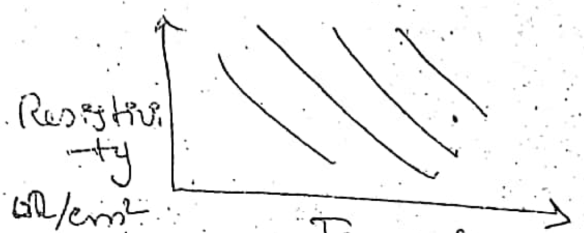
b) Alumina: It is primary made of aluminium oxide. It posses extremely high firing temp (1750°C), less water absorption and high compressive strength. It is used in high temperature appliances like furnaces.

c) Titanate ceramic: It possesses (has) high dielectric constant. This high value of dielectric constant offers big advantage in capacitor designing & application.

d) Oxide free ceramics: They consist of nitrides, sulphides, carbides etc. They possesses (has) good heat resisting property. It is used in manufacturing synthetic mica & metal crystals for making transistors.

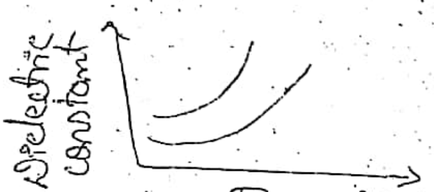
* Factors affecting the ceramics

1) Temperature



Electrical resistance of ceramics decreases very rapidly with rise in temperature.

2) Moisture



In order to reduce the penetration of moisture, ceramic insulators are glazed.
Glazing also prevents dirt & dust from accumulating on surface of insulators.

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* Classifications of ceramic materials.

1) Clay products 2) Refractories 3) Glasses
4) Cements.

1) Clay products :

Clay is one of most widely used ceramic raw material. It is [redacted] abundant and popular, ~~because of ease with which products are made~~. Clay products are mainly two kinds. - structural products (bricks, tiles, etc) & white-wares (porcelain, pottery, etc) & chemical wares are clay products.

2) Refractories:

These are described by their capacity to withstand high temp without melting or decomposing [redacted] in diff. industrial processes & ops without breaking & suffering permanent deformation. ~~resistance in severe environments~~. Thermal insulation is [redacted] important functionality of refractories..

3) Glasses:

Glasses are a familiar group of ceramics - container windows, mirrors, etc. They are non-crystalline silicates containing other oxides. Typical property of glasses that is important in engineering applications is its response to heating.

4) Cements:

cement, plaster of paris come under this group of ceramics. The characteristic property of these materials is that when they are mixed with water, they form slurry which sets subsequently and hardness finally. Thus it is possible to form virtually any shape. They are also used as bonding phase.

* Types of ceramic capacitors

1) For General electronic devices → General purpose.

General purpose → operating vtg 4 Vdc to 630 Vdc
- capacitance 0.1pF to 100μF.

2)

Special purpose
- → High freq low loss.
- → Low ESL capacitor.
- → Microchip capacitor
- → Medium voltage.
- → Array capacitor.
- → Trimmer capacitor.

→ High freq low loss

Designed for high freq ckts & used in communication system.

→ Microchip capacitors

These capacitors are developed for embeding in IC's or other packages in high speed wireless communication ckts & optical communication devices.

size is 0.25 mm square.

ESL – aluminium electrolytic single ended 4 capr

→ Low ESL capacitor

These capacitors are designed with small valued series inductance capacitor & are developed to enable high speed charging & discharging in high freq ckts & used in CPU's & other devices.

→ Array type capacitors

These arrays are developed in order to improve the packing density & to reduce mounting cost.

→ Medium voltage capacitor

These capacitors ~~used~~ use a high break down voltage ceramic dielectric substance & special internal electrode structure to achieve rated vtg in KV units.

→ Trimmer capacitor.

These are developed to enable continuous variability ~~persability of~~ of capacitance in capacitor & these are used for freq control.

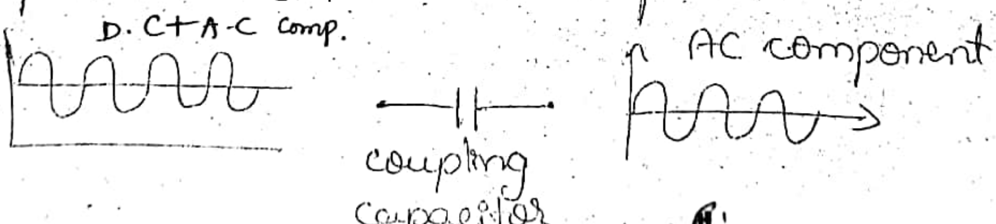
* Applications of ceramic capacitor

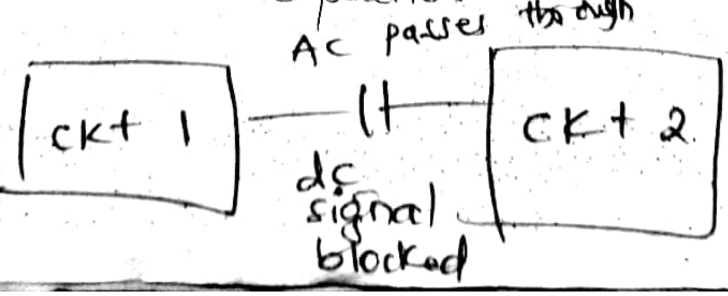
There are 4 " " applications,

1) Coupling capacitor
2) Decoupling capacitor
3) Smoothing capacitor.
4) Filtering capacitor.

1) Coupling capacitors

Coupling capacitors are used to extract ac components from DC+AC components





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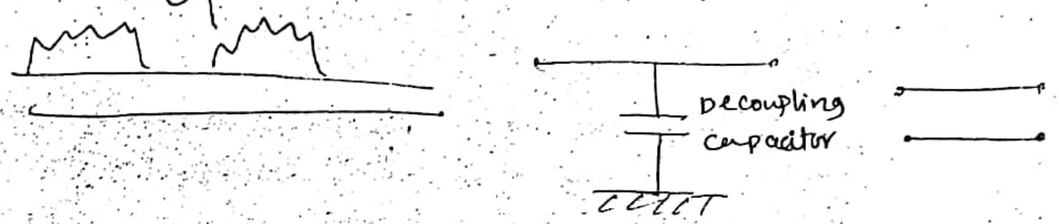
8) Decoupling capacitors

Decoupling capacitors are used to pass noise coming from the power source to the ground terminal which also helps to supply continuously a stabilised current. Unwanted noise superimposed on the line can be passed through the ground terminal through decoupling capacitor as shown below.



3) Smoothing capacitors

Smoothing capacitors supress repels that are generated even after rectification with the power ckt to smooth out signals so that they approach direct current [when smoothing capacitors are considered after rectification, excess vtg is stored in capacitor sharing during high vtg period & released during low vtg period, there by eliminating fluation in period.]

4) Filtering capacitors :

Filtering capacitors are combined with resistors & inductors to create filters that only transmit signals of a particular freq. Different filters can be used depending on the frequencies to be transmitted including low pass filter, that filters low freq components & high pass filters, that filters high freq components.

Plastics

- Natural
- Synthetic.
  - Thermoplastic
    1. Cellulose ~~dielectrics~~ derivatives
    2. Polyhydro-Carbons
    3. Vinyl polymers
    4. PolyCarbonate resins
    5. Linear Polyester resins
  - Thermosetting plastics (Thermosets)

1) Cellulose derivates:- ex:- Cellulose Acetate, cellulose nitrate, cellulose ether, cellulose propinate
2) polyhydro Carbons:- ex:- poly ethelene, ~~polytetra~~ polytetra-flouroethylene (P.T.F.E) or Teflon, polysterene e.t.c. (thin film Capacitor)
3) vinyl polymers:- ex:- (PVC) polyvinyl chloride, polymides.

Thermosetting plastics.

- Formoldhyde Resins (phenol formaldehyde, urea formaldehyde, melamine resins)
- Polyester Resins
- EPoxy Resins
- silicon resins
- poly-urethane resins

Differen betwn Thermosettings & thermoplastics.

Imp Thermosetting plastics:- very hard, less flexibility, reshape

Thermoplastics:- less hard as compared to thermosettings. u give any shape

oxidation- Reduction
Impregnated → To fill throughout

Cellulose derivatives :-
i) cellulose acetate (Bakelite).
Properties :-
* Good mouldability
* Low Softening temp.
* Low inflammability
* Hard & tough
* Good electrical property
Disadvantages :-
* shrinkage due to ageing
* Low softning temp.
* oxidation high temp.
applications :-
* used as insulating material in low voltage Capacitors
* As Coatings for wire & Cables
* used to make switches & instrument mountings
* used as impregnated material.

Cellulose nitrate :- (celluloid)
i) good impact strength, good mouldability, Poor elect[cal] property, High inflammability
Polyhydrocarbons :- (normally Communication System used)
1) * polyethylene] melting point 110°c
2) * polysterene]
* very good electrical properties
* less hygroscopic
* Solubility is poor
* Good mechanical property.
* very low dielectric loss.
* high resistance to moisture.
* Good ageing stability.

organic solvents :- Benzene, chloroform
Acetic acid
Venegar

Polyethelene - polysterene :-
applications used in Capacitor & thin film.
up to 300°c

10/2/15

Vinyl polymers :-

i) ★ PVC. (poly vinyl chloride).
Hydrogen chloride + acetylene. → 50°c
operating temp → 60°c to 90°C

Properties :-
★ Hard ★ operating temp (60-90°c)
★ Less flexible
★ Insoluble in water + organic solvants.
★ Dielectric strength 20kv/mm.

properties like mechanical strength, porosity, mouldability, electrical ~~properties~~ are affected by adding different types of ~~materials~~

Additives :-
1) Fillers 2) Stabilizers.
3) Plastisizers 4) supplementary additives.

1) Fillers ⇒ mica powder, wood flour (grinded grains, seeds),
glass fibre → used to make end product cheap
2) Stabilizers ⇒ calcium oxide, metal
soaps, calcuim carbonate etc
3) plasticizers :- ~~...~~ phosphate, butyl phthalate. tricresyl
4) supplementary additives :- coloring agents, Lubricants.

ii) Polyamide resins (nylon)
★ temp 132-150°c
★ dielectric strength is about 20 kv/mm
★ Good wear & tear resistance.

stabilizers are used to protect from degradation.
↓ reduction in quality.

plasticizers — used control the flexibility of insulating materials.

* High thermal stability.

<u>Used</u>:

Insulation for Cables & wires.

Poly Carbonate

* High input strength
* excellent structured stability
* low hygroscopic
* Satisfactory electrical properties.
* Good temperature resistance.

Linear poly siloxane resins

* High melting point
* low solubility
* excellent insulating property.
* Good stability against temp. & moisture.

Varnishes :— It is a liquid. When applied to [redacted] surface it dries by either evaporation or chemical action, results in hard shining coating. Resistance to air or water, cause the corrosion.

<u>property</u>

1) liquid insulating material.
2) which also gives mechanical strength.
3) Good electrical property.

<u>Need of varnishes</u>

1) To improve the insulating property.
2) Increase the mechanical property.
3) Reduce degradation caused by [redacted] oxidation corrosion.
4) protecting from atmospheric [redacted].
5) giving fire retarding finish.

Types of varnishes :—

* Coating varnishes.
* Impregnating varnish.
* Adhesive varnish.

(1) To protect device from oxidation, Corrosion, solvent attack also increases mechanical strength.
(2) used for insulating paper, glass-cotton to increase dielectric strength, resistance to moisture, to reduce oxidation & thermal ageing).
(3). used as binder/ binding material for mica & glass to give good adhesive electrical property).

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Materials used in varnish Manufacture:-

* Raw → (oils, resigns, solvants, thinners, & dryers).
* Oils → (tung oil, castor, olive, Linseed oil, rosin oil).
* Resins:- Animal & vegetable resins (shelloc, gum, amber)
* solvents thinners:- turpentine oil, benzene, toluene, Acetone, Carbon tetra chloride.
* dryer :- Lead acetate, Manganese dioxide.

Gaseous Insulator : air, Nitrogen, SF6 [sulphar hexaflouride]

→ cheap, easily available, non explosive & inflammability

SF6 [sulphur hexa-flouride]

Properties:- * High dielectric strength

Nitrogen:- * In High vg app^n air is replaced by nitrogen to prevent oxidation of other insulating material & reduce the rate of deterioration.
* In certain type of cap^r, it is used as dielectric under pressure.

castor - kaiye nhe, haralerke

* non inflammability
* better cooling property.
* high degree of chemical stability.
* operating temp :100°c

Thermosetting plastics (Thermosets).

I) For-maldehyde resins.
i * phenol formaldehyde — * used in solid + liquid form, * used as moulding
ii * urea formaldehyde. * requires high pressure $230-250 kg/cm^2$
iii * Melamine " * Temp 150 − 190°C
(Good electrical property, good resistance to heat)

II) polyester resins :- used as insulating coatings + varnishes; insulating laminates as moulding for diff^nt insulating material.

III) Epoxy resin :- * good electrical & mechanical property.
* less shrinkage
* High resistant to chemical solvants.
* Good structural stability.
* Good adhesive property.

ii) Urea formaldehyde :-> good electrical property
* High resistance to heat & light
* used as moulding & adhesive coating

iii) Melamine resins :- * good electrical property
* Easy to mould.

II) polyester resins :- * good electrical property
* good resistance to heat

Disadv : ~~Decompose when comes in~~ contact with moisture used as insulating coatings.

Sludge:- Formation of mud at the bottom layer due to oxidation.

12/2/14

Liquid Insulating materials:-

arc extinguishing media, heat distribution media, used as good insulator.

affects:- temp, impurities increase moisture decreases, dielectric strength.

Transformer oil:- (Mineral oil)

Property:- Non-inflammable, non-sludging (which blocks the passage of oil)

* High permittivity
* perfectly free form.

Imp There are 4 types transformer oil (Tests):-

Tests on transformer oil

1) Moisture test
2) Sludge test
3) Acidity test.
4) Electric strength test

(1) Moisture test:-

In which the oil will be cooled at temp 15 to 25°c, It could be good in glass. The oil should be put 12.5mm, 250 mm, upto the boiling point, Here no cracking takes place there moisture test is used.

(2) Sludge test:-

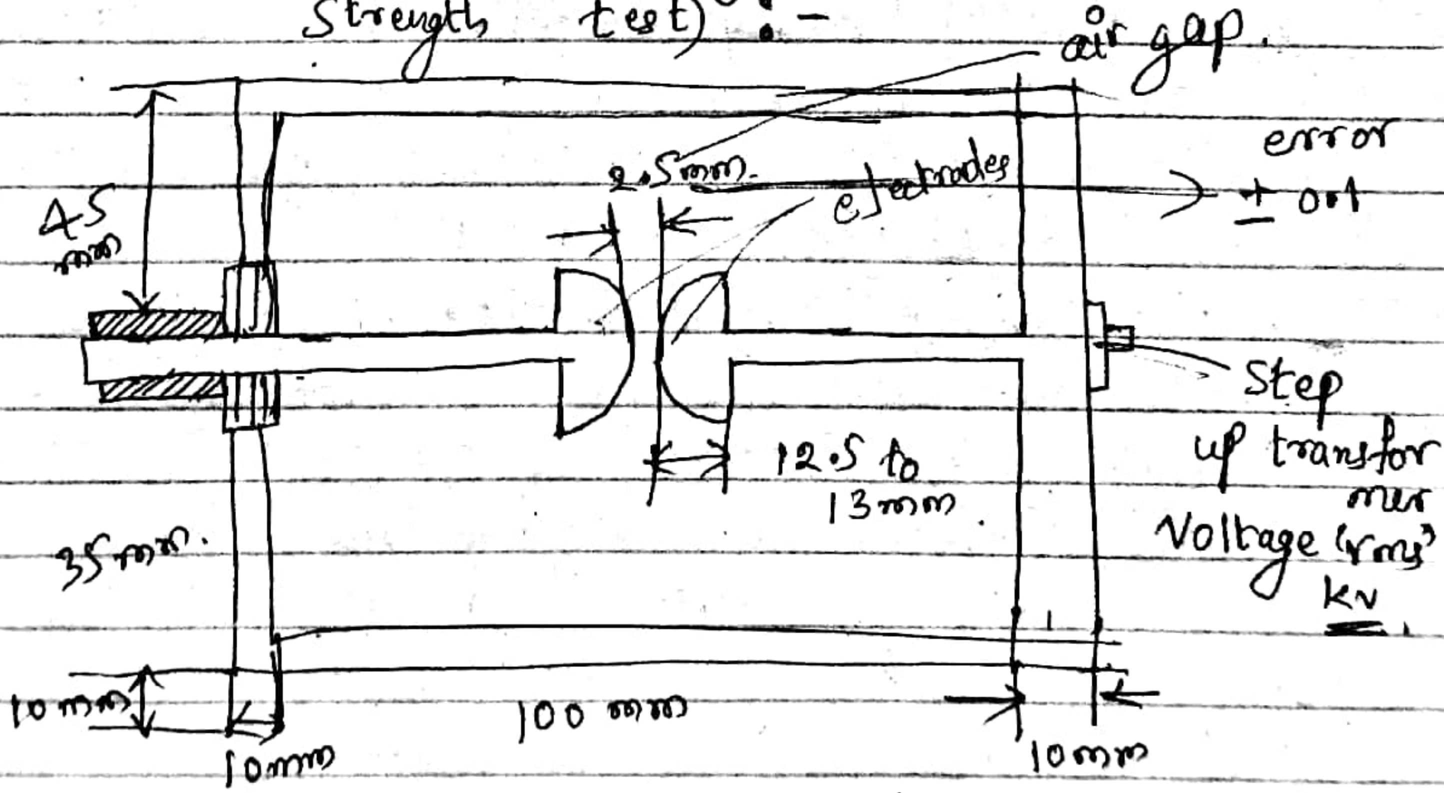
temp 120°c, normaly takes place 30 to 40 days. Here Copper Catalyst is used there will be formation of sludge.

3) Acidity test :-

- 10gm of oil sample in 250cc flask.
- Add 1cc phenolpthaline soln to 50cc alcohol
- Heat the soln 40 to 50°c
- add & add KOH.
- ~~Neut~~ Nutralised soln to oil & heat to boiling pt for 5 minute.
- add 1cc phenopthaline & cool for 40 to 50°c & titrate with KOH.

Here $\left[SG\text{-}1 \ \frac{NV}{W} \right]$ KOH will require.

④ Electric strength test:- (Breakdown voltage test or electric strength test):-



Container ⇒ non absorbant, transferant.
apply voltage 2kv/sec ⇒ breakdown voltage

* used in Tfs, rheostat.
* used to improve insulats' propery
* It good heat dissipation media — used for cooling of wdgs
* used for extinguishing arc in ckt breaker

3) Liquid insulating materials :-

* liquid insulating materials are widely used in transformers, switches, ckt breaker, reactor, rheostat e.t.c. & liquid insulating materials also improve the insulating property of other solid materials by eleminating air & gaseous and
* also acts as good heat & dissipation media & which helps in cooling of the windings. * liquid insulating materials used for extinguishing arc in certain ckt breaker.

Factors affecting liquid insulating material

1) oxidation :- when oxidisied the insulating oil has a greater capacity to absorb water which affects the dielectric strength. to overcome the oxidation the oxidation should be prevented or the oxidised part should be removed periodicaly.

2) moisture :- Increase in moisture decrease the dielectric strength of insulating oil & moisture should be removed from the oil before it is used.

3) temp :- Increase in temp increases oxidation which affects the insulating property.

Transformer oil :-

* It is the mineral insulating oil which is perfectly free from moisture
* which is non flamable.
* Non sludging
* ~~It has high permivity.~~
* presence of even a drop of water in a transformer oil reduces its insulating strengt considerably.
* The transformer oil mainly serves the two purposes.
  1) It transfers heat from windings & core to the cooling surfaces.
  2) It maintains the insulation of windings

Suldge formation :-

Suldge formation is accelerated by the contact with air & temp.

Effects of suldge -

1) Rate of heat transfer is reduced.
2) operating temp increases
3) ducts are closed.

14/2/15

Test on transformer oil :-

1) Moisture test :-

* In this test oil sample is cooled in closed vessel upto 15° to 25°c.
* A dry test tube 12.5 mm diameter and 125 mm long is taken and an adequate quantity of oil is put into it.
* The tube containing the oil is heated

rapidaly with the help of an electric heater. till the oil begins to boil. during this process oil should not produce cracking.

2) <u>Sludge resistance test</u>:-

* In sludge accumulation test. the rate at which the sludge is found. at 120°c. (that time) under the definate Conditions of oxidation is determined.
* generally test is completed within 35 to 40 days but by the addition of Copper which acts as catalyst. reduces the test duration to 14 days.

3) <u>acidity test</u>:-

* 10 gm of test oil is taken and put it in a 250 cc Conical vessel.
* add 1 cc of phenopthaline soln & 250 cc of alcohol.
* heat the mixture upto 240 to 250°c and neutrialize with a soln of pottasium hydroxide. (KOH) soln
* Add the neutralised alcohol to the oil sample.
* heat the sample to boiling point and boil for 5 minutes.
* add again 1cc of phenopthalene and cool it to 14 to 15°c and titrate with pottasium hydroxide. soln quickly.
* Then acidity of pottasium hydroxide soln in milli grams. required to neutrilise the acidity. 1 gm of sample. is given by $\left[56 \cdot \frac{1\,N\,V}{W}\right]$

KOH – Potassium hydroxi-

where N → normality of KOH soln.
V → volume of KOH soln in mm^3.
W → ~~wait~~ weight of the sample in gms.

4) Electric strength test :-
(breakdown strength of transformer).

* The dielectric strength of any ~~equi~~ liquid insulant is tested in a special equipment Consisting of a cell made up off glass or plastic. That is the cell material should be transparant & non absorbant.
* Two polished [electrodes made up off copper, brass, bronze or stainless steel are used
* This electrodes are normaly spherical in shape with 12.5mm to 13 mm diameter]
* The electrodes are arranged horizontaly & the gap betwn betwn them is aqurately (accurately) adjusted to 2.5 ± 0.1 mm. 4mm to 0.02 mm
* A variable high voltage ~~to~~ through a step up transformer Connected to the electrodes.
* [A voltmeter will indicate the breakdown voltage and which gives rms value of voltage in kV.]
* The test consist of Increasing the test voltage at a uniform rate of 2kV/sec. from zero up to the value producing breakdown.
* The Breakdown voltage is the voltage reached during the test at the time of the first spark occurs betwn the electrodes.
* The test is carried out 6 times on the same cell filling the oil & the arithmatic mean of 6 breakdown voltages is taken to be the breakdown voltage of the oil.

* In order to get the accurate & reliable results. Care should be taken for the following facts.

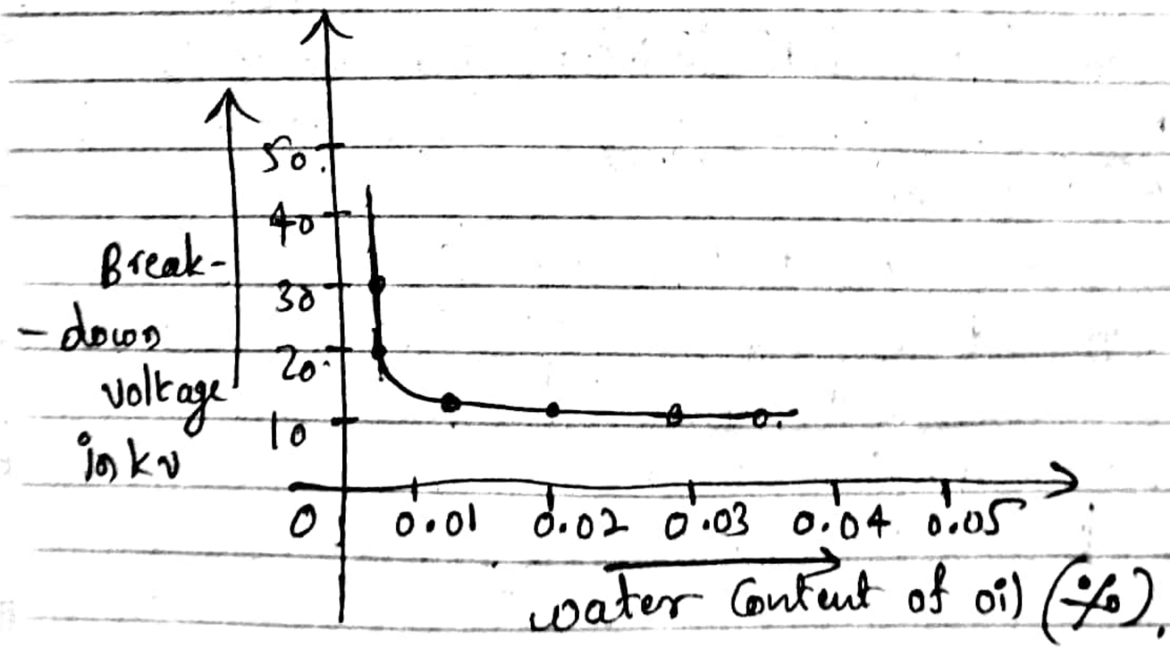
1) Resistance ~~gap~~ betwn the end faces of the two electrodes should be accurately set.

2) The electrodes should be cleaned with clean dry oil. ~~or to be dryed with the a thermostat~~.

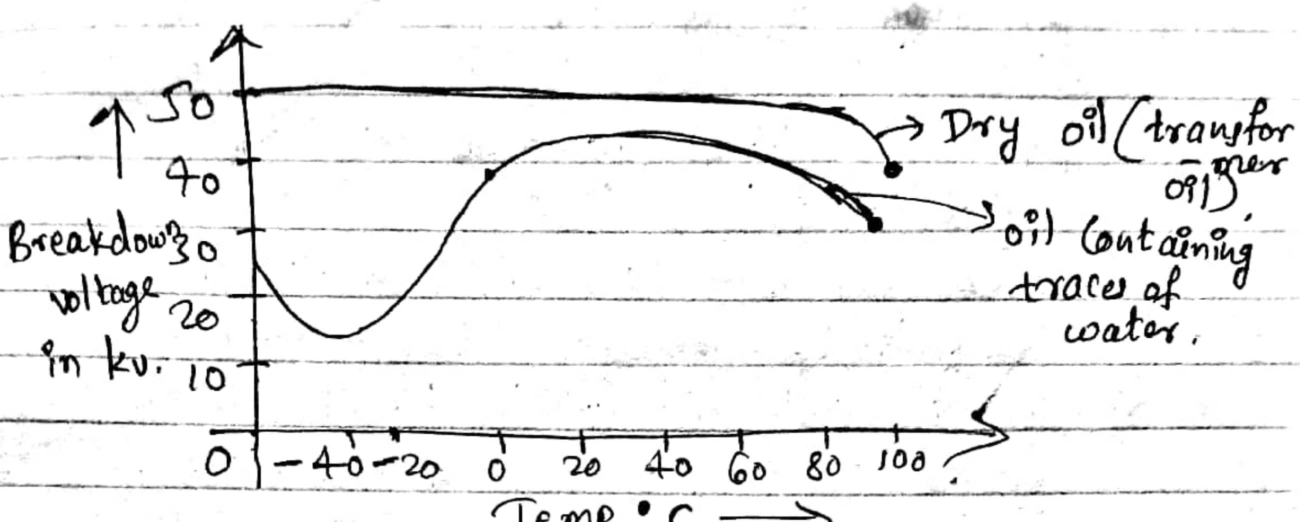
3) write before the test the jark containing the oil to be slowly turned ~~of~~ upside down several times to ~~fix~~ mix the oil properly. and their should not be any air bubbles.

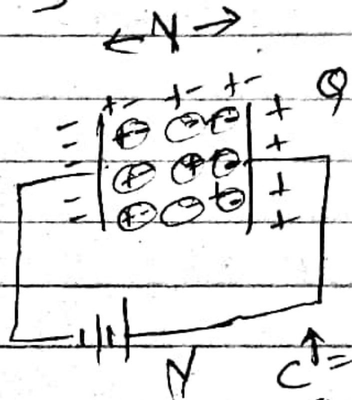
4) After each test the oil should be properly mixed with the help of a clean dry glass stick.

Breakdown voltage v/s water Content of oil :-



Temperature Depedence of breakdown voltage of transformer oil :-





19/2/15.

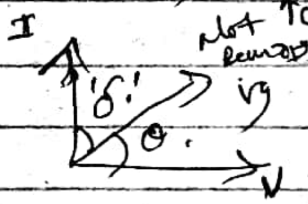
Dielectrics :—

store electric energy. $Q \propto V$.

$C\uparrow = \frac{Q}{V\downarrow}$

Removing vg

$\uparrow C = \frac{Q}{V}$ Not Removed vg



$P = VI\cos\theta$

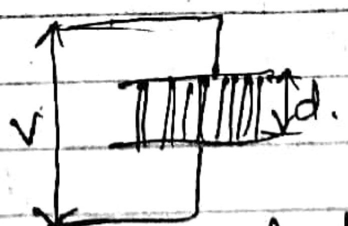
$= V \times \frac{V}{X_C}\cos\theta$

$P = \frac{V^2}{X_C}\cos\theta$

$P = V^2 2\pi f C\cos\theta$

$P = V^2 2\pi f C\tan\delta.$

Electric force/electric field strength/ field intensity 'E'.



$E = \frac{V}{d}$ volts/m

electric flux :- shifting of charge (electrons) takes place

electric flux density :- $\frac{flux}{area} \Rightarrow \frac{\psi}{A} \Rightarrow B$

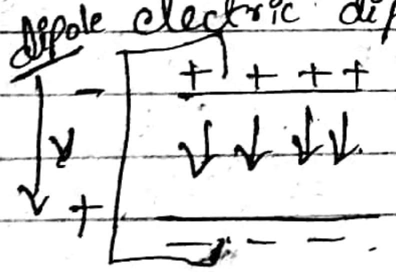
Applications of dielectrics :-

1) Type of capacitor depends on the type of dielectrics.
Mica, glass are the solid dielectric material.
Capacitor with mineral oil ⇒ liquid dielectric materials.
Oil integrated capacitors ⇒ solid as well as liquid insulating material.

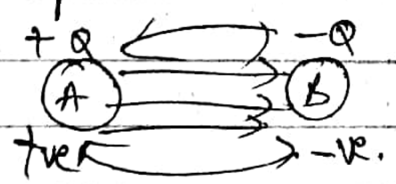
Polarization of Dielectrics :-

dipole moment = 'Qd'

electric dipole ⇒ It is always oppose the applied electric field.



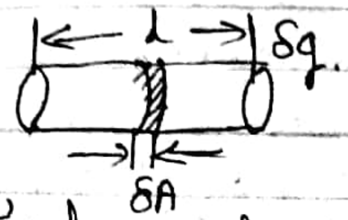
* Permanent dipoles :- Presents of dipoles.
* dipolar polarization or orientation of dipoles ⇒

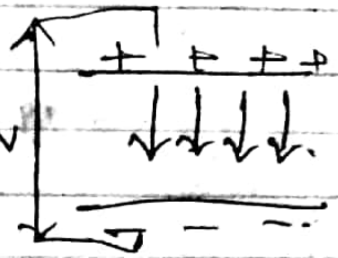


* dipole moment $M = Qd.$

* Ionic polarization of dielectric material. :- Shifting of Ions or Shifting of free electrons.

Imp
expression for polarization :-





'σ' → charge density

$$\sigma = \frac{\delta q}{\delta A} = \frac{l \times \delta q}{l \times \delta A} = \frac{m}{\delta V}$$

$$\boxed{\sigma = \frac{m}{\delta v}}$$

m → dipole moment
δV → volume of dielectric material.

No of dipoles per unit volume 'N'

$$N = \frac{1}{\delta v}$$

$$\sigma = Nm \quad (\because N = 1/\delta v)$$

$$\boxed{P = Nm}$$

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Dielectrics :-

A dielectric material are electrical insulator that can be polarise by an applied electric field.

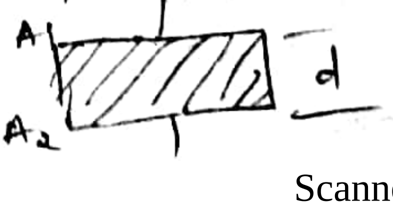
The dielectric materials are used to store energy.

Electric force or field strength or field intensity in dielectrics :-

Electric force or field strength is the pottential drop per unit length of dielectric material.

$$E = \frac{V}{d} \text{ volts/m.}$$

If the Potential diff of V volts is maintained across the 2 metal plates say A_1 & A_2, held 'd' int



It is assumed that 1 line of electric flux comes out from a +ve charge of 1 coulomb & enters a -ve charge. Hence flux emanating from unity charge of one coulomb = its strength in coulomb

Electric flux in dielectrics :-

The electric flux is the moment of positive charge of one coloumb to negative charge of one coloumb.

'ψ' denotes the electric flux
ψ = charge 'Q' measured in coulomb

Electric flux density :-

It is defined as the charge per unit area of the dielectrics.

Electric flux density $D = \frac{Q}{A}$ Coulomb/m^2

Applications of dielectrics :-

* The main function of dielectric is to store energy. * Capacitors is the most common example in which use of dielectric is [illegible] to store the energy.

* Types of capacitors used depending upon the type of dielectric used.

Types :-

(1) Capacitor that uses vaccum, air or other gasses as dielectrics.

* These are used where the energy loss required must be small & the value of capacitance required is not very large.

That is why dielectric losses in this type of capacitors are very small.

* These are used in radio frequency ckts & low frequency measuring ckt

(2) Capacitors that uses the mineral oil as the dielectrics.

Scanned by CamScanner

* This type of Capacitors are used where a large value of Capacitance is required & the only small amount of loss is allowed.

(3) Capacitor which gives the Combination of solid & liquid dielectrics.

* Normaly this type of capacitors uses oil impreganated papers & this type of Capacitors have large value of capacitance with small size. and these are used for power factor correction in power system.

(4) Capacitor that use solid dielectric (glass, mica e.t.c).

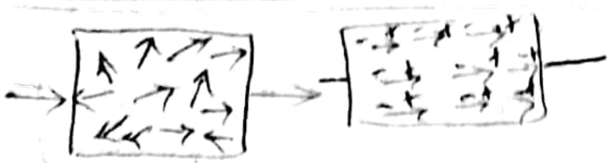
* This type of capacitors are used in laboratories as std capacitance.

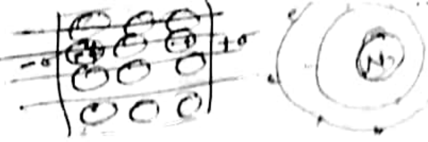
* Mica is commanly used dielectrics in capacitors. because of losses are small, high value of dielectric constant, high insulation resistance and the properties doesnot change with the temp.

Polarization:-

"It is defined as the definite orientation of electric dipoles in the material due to an applied electric field" is denoted as polarization of dielectric material.

or which is also defined as it is the displacement of the charge by electromotive intensity.





Process :-

Imp — when their is ~~no~~ external field then electrons are distributed symmetrically around the nucleus. & when an electric field is applied, the moment of electrons is in ~~all direction~~ opposite direction to the applied field, ~~takes place~~ this moment is opposed by the attractive force betwn the nuclei & electrons. The resultant effect is to separate the '+ve' & '−ve' charges in each molecule so that they behave like electric dipoles.

The strength of each dipole is given by dipole moment, which consists of two equal point charges of opposite sign. ($\pm Q$) separated by a distance 'd', then the dipole moment has the magnitude

$$\text{dipole moment} = Q \cdot d$$

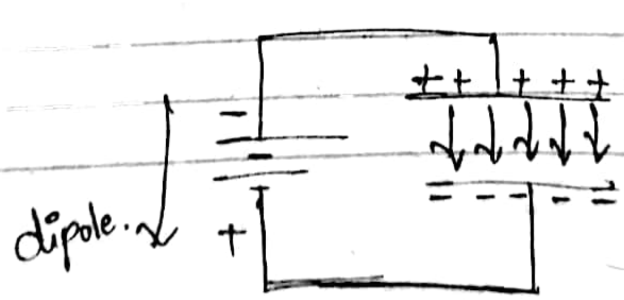
Generally the direction of dipole moment is parallel to the direction of applied field.

Dipole moment is expressed in terms of 'Debye',

$$1 \text{ Debye} = 3.336 \times 10^{-30} \text{ coloumb/m}$$

When dipoles are created the dielectric material is said to be polarized.

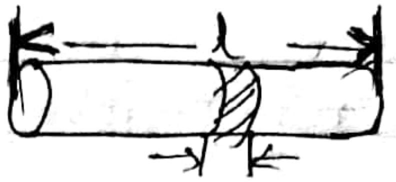
Or it is the state of polarization.



There is an induced -ve charge on the surface of dielectric near the +ve plate. ||ly induced +ve charge on the surface near the -ve plate

Consider the dielectric cylinder each of length of 'L' & cross section. δA.

Imp.



Let an uniform electric field of strength 'E' be applied normal to the plates. this polarizes the dielectric material. (cylinder). and charges δq appear on either end of the cylinder.

(sigma)

The charge density 'σ' on the surface (δA) of the cylinder is given by

$$\sigma = \frac{\delta q}{\delta A} \; c/m^2$$

The dielectric cylinders having length 'l'. Therefore 'σ' can be written as.

$$\sigma = \frac{l \times \delta q}{l \times \delta A} = \frac{m}{\delta v} \quad (\because l\delta q = \text{dipole moment} = m)$$

$$\boxed{\sigma \Rightarrow \frac{\text{dipole moment}}{\text{Volume of elementary dielectric cylinder}}}$$

($l\delta A$ = volume of dielectric material) = δv)

if the no. of dipoles per unit Volume 'N'

i.e $\boxed{N = \frac{1}{\delta v}}$ $\Rightarrow \sigma = m \times 1/\delta v$

$\therefore \sigma = Nm \quad (\because N = 1/\delta v)$

$$\boxed{P = Nm}$$ #

P = Polarization

This product 'Nm' is called the polarization of dielectric material.

∴ Polarization $\boxed{P = Nm}$ ✱

Ionic polarization :-

The ionic polarization takes place when ~~the some~~ some of atoms in a molecule have an excess positive or negative charges.

When an external field is applied this applied electric field will tend to shift the positive ion related ~~near~~ to the the '-ve' ions.

Therefore the ionic polarization measures the shift of ions related to each other.

Dipolar polarization or orientation polarization

Consider two different atoms ~~other~~ one with more balance electron ~~that~~ then the other. Suppose take 'A' & 'B' atoms. 'A' is having more balance electrons then 'B'. & 'A' has a tendency to give the balance electrons to atom 'B'. Then the 'A' will be more electropositive then 'B' and their will be more electrons around the nucleus of atom 'B'. Then their will be bond betw A & B that can be called as Ionic bond. Therefore the molecule A & B carries an electric dipole. and the dipole moment even in the absense

A $\xrightarrow{BE}$ B

A has tendency $\xrightarrow{BE}$ B

A $\xrightarrow{\text{more EP}}$ B so more electrons around the nucleus of B

Then there will bond b/w A & B called Ionic

When an external field 'E' is applied to a molecule carrying a permanent dipole moment then the dipole moment will tend to align along the direction of an external applied field 'E'. The contribution of orientation of the permanent dipole to the polarization 'P' is called the Orientational or dipolar polarization.

The orientational polarization may be written as follows.

$$\text{Orientational polarization or dipolar polarization} = \frac{m^2}{3kT}$$

where m is the permanent dipole moment

$k \rightarrow$ boltzman's constant.

and $T \rightarrow$ Absolute temp

A dipolar the polarised unity is thus the universaly propotional to the absolute temp. Hence the dielectric constant of gases or gaseous dielectric depends on temp even if the no of molecules per volume or/m3 is kept constant.

The total polarizability may be written as

Total polarizability = ionic + electronic + dipolar polarizibility.

$$\alpha_{(static)} = \alpha_0 + \frac{m^2}{3kT}$$

$$\alpha_0 = \alpha_{electronic} + \alpha_{ionic}$$

$$P = Nm.$$

$$P = N\left(\alpha_0 + \frac{m^2}{3kT}\right)E$$

$$\because (m \propto E)$$

Dielectric Strength:-

Factors affecting the dielectric strength

1) ↑ Temp ↓ dielectric strength
2) Resistance "
3) Voltage applied. "
4) ↑ thickness ↑ dielectric strength.
5) ↑ frequency ↓.

Dielectric loss:-

$P = VI\cos\phi$

$= V \times \frac{V}{X_C} \cos\phi$

$P = V^2 2\pi f \cos\phi$

Factors affecting the Capacitor material

1) Plate Area: greater plate area gives greater capacitance

1) Parallel plate Capacitor

2) Plate spacing:
→ more space give less cap
→ Less space - More capacitance.
3) Greater permittivity of dielectric gives greater capc.
→ less
→

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

$Q \propto V$

$Q = CV$

$$C = \frac{Q}{V}$$

electric field density (electric flux density)

$D = \frac{Q}{A}$

$D = \varepsilon_0 E$

$E = \frac{D}{\varepsilon_0}$

$E = \frac{Q}{A\varepsilon_0}$ $E = \frac{V}{d}$

$V = Ed$

$Q = CV$

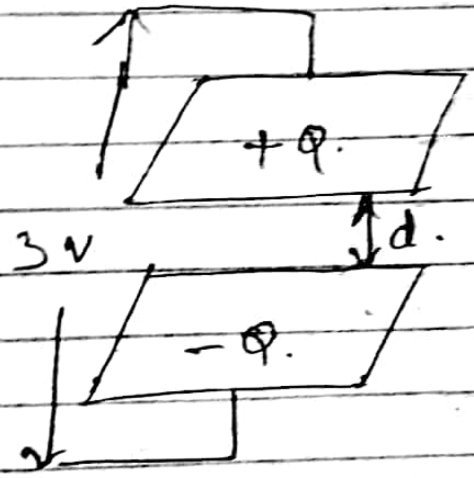
$C = Q/V = \frac{Q}{Ed} = \frac{Q}{\frac{Q}{A\varepsilon_0} \times d}$

$$C = \frac{A \epsilon_0}{d}$$ ★

Separation is $\propto$ capacity of the capacitor.

A capacitor is a device for storing electric charge. basically consists of 2 metal plates separated by an insulator, the insulator is called as dielectric.

✓ Parallel plate capacitor :-



ce.

Let us consider two large plane parallel plates separated by a distance 'd' m. and a potential difference of 3V maintain betwn the plates. then the plates will become charged positively & negatively with charges $\pm Q_0$. and a uniform electric field with intensity $E = \frac{V}{d}$ will be created betwn the plates.

The magnitude of the charge accumulated on each plate is proportional to the applied potential differen that is $Q_0 \propto V$.

$Q_0 = C.V.$ $\boxed{C = \frac{Q_0}{V}}$

where C = Capacitance of capacitor

The electric flux density 'D' is given by $D = \frac{Q}{A}$ *

The relation betwn the field strength 'E' & flux density 'D' may be written as

$D = \varepsilon_0 E$

∴ D can be written as

$E = \frac{D}{\varepsilon_0}$.

put the value of 'D' in above eqn.

$E = \frac{D}{\varepsilon_0}$.

$E = \frac{Q}{A\varepsilon_0}$. *

we have $E = \frac{V}{d}$

∴ $V = Ed$.

$V = \frac{Q}{A\varepsilon_0} * d \quad \left(\because E = \frac{Q}{A\varepsilon_0}\right)$

Therefore the capacitance can be given by

$\because C = \frac{Q_0}{V}$ $\quad C = \frac{Q_0}{\frac{Q}{A\varepsilon_0} * d} = A\varepsilon_0 / d$.

$$\boxed{C = \frac{A\varepsilon_0}{d}}$$

$$\boxed{C = \frac{A\varepsilon_0}{d}} \text{ farad/m.}$$

where $\varepsilon_0 \Rightarrow$ permivity of ~~f~~ air or free space

$\varepsilon_0 \Rightarrow 8.854 \times 10^{-12}$ F/m

The Capacitance of area of free space is given by

$$C = \frac{\epsilon_0 A}{d}$$

$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

ϵ_r => relative permitivity of air of the Capacitance.

Problems

1) Determine the Capacitance of the Capacitor Consisting of 2 parallel metal plates 0.30 x 0.30m surface area, separated by 5 mm in air.
2) The Capacity of parallel plate capacitor is 0.2 μF the potential difference betwn the plates is 2V. Calculate the energy stored by the charged capacitor.
3) A pottential difference of 15kV is applied across the terminals of the Capacitor Consisting of 2 circular metal plate each having an area of 200 cm^2 & separated by 1 mm thickness of dielectric. The Capacitance of the Capacitor is 4.5×10^{-4} μF. Calculate the dielectric Constant & the electric flux density assume permitivity as 8.854×10^{-12}
4) An air Condensor of Capacitance 0.005 μF is Connected to d.c supply of 500V, it is then dis Connected from the supply & invoved in Oil. with the dielectric Constant of 2.5 find the energy Stored in the Condensor before & and after immersion.

Im

5) Calculate the capacitance of the condensor which has plates of 0.2 m^2 in area separated by a distance of 2.5×10^{-5} m the dielectric having a permitivity of 5

8M

(b) also ~~sketch the electrica field.~~

1) Given :- $d = 5$ mm $\quad A = 0.30 \times 0.30$

$$C = \frac{\epsilon A}{d}$$

$\epsilon \Rightarrow$ dielectric constant $\Rightarrow 8.854 \times 10^{-12}$

$\epsilon = \epsilon_0 \epsilon_r$.

energy stored in a Capacitor $= \frac{1}{2} CV^2$

$$C = \frac{8.854 \times 10^{-12} \times 0.30 \times 0.30}{5 \times 10^{-3}}$$

C: = ~~[illegible]~~ F/m.

$C = 159.372 \times 10^{-12}$ F/m

2) Given :-

$C = 0.2 \mu F$.

$V = 2v$.

energy stored $= \frac{1}{2} CV^2$

$= \frac{1}{2} \times 0.2 \times 10^{-6} \times (2)^2$

$= 0.4 \times 10^{-6}$ F

energy stored in a Capacitor $= 0.4 \times 10^{-6}$ F

3) Given :-

$V = 15\,kw$ $\quad d = 1\,mm$ $\quad Q = C \times V$

$A = 200\,cm^2$ $\quad C = 4.5 \times 10^{-4}$ $\quad = 4.5 \times 10^{-4} \times 15$

$Q = 6.75 \times 10^{-3}$

$C = \frac{\varepsilon A}{d}$ $\quad D = \frac{Q}{A} = \frac{6.75 \times 10^{-3}}{200 \times 10^{-4}}$

$E = 1.5 \times 10^{6}\,V/m$

$4.5 \times 10^{-4} = \frac{\varepsilon \times 200 \times 10^{-4}}{1 \times 10^{-6}}$ $\quad D = 0.3375$

$D = \varepsilon_0 E$

wrong $8.854 \times 10^{-12} \times 15 \times 10^{6}$

$D = 1.3281 \times 10^{-4}\,C/m^2$

$\varepsilon = 0.0225\,\mu$ $\quad$ (or) $22.5 \times 10^{-12}\,F/m.$

~~$D = \varepsilon_0 E$~~

~~$= 0.0225 \times 10^{-6} \times 15$~~

~~$D = 0.3375\,\mu F$~~

$E = \frac{V}{d} = \frac{15k}{1m}$

$E = 15 \times 10^{6}\,V/m$

4) Given :-

$C = 0.005\,\mu F$ $\quad$ air conductor

$V = 500V$ $\quad$ 2.5 ⇒ dielectric constant

Energy stored $= \frac{1}{2} CV^2$ $\quad C = ?$

$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$ ⇒ air

$0.005\,\mu = \frac{\varepsilon_0 \times 1 \times A}{d}$

$C = \frac{\varepsilon_0 \times 2.5 \times A}{d}$ ⇒ dielectric constant

equate the both equations.

$0.005\,\mu = \frac{\varepsilon_0 \times 1 \times A}{d}$ $\quad E = \frac{1}{2} CV^2$

$C = \frac{\varepsilon_0 \times 2.5 \times A}{d}$ $\quad = \frac{1}{2} \times 500 \times 10^{-6} \times (500)^2$

$C = 500 \times 10^{-6}$ $\quad E = 0.625$

Dielectric strength

5/3/15 Complex dielectric constant.

Lorentz field.

$$E_i(t) = E(t) + \frac{P(t)}{3\epsilon_0} \quad \text{--- (1)}$$

α_e^* & α_i^*

$$P(t) = N \, Re[(\alpha_e^* + \alpha_p^*) E_0 \, e^{j\omega t}] \quad \text{--- (2)}$$

Complex conjugate of internal material.

$$E(t) = P(t) = \epsilon_0 \, Re[(\epsilon_r^* - 1) E_0 \, e^{j\omega t}] \quad \text{--- (3)}$$

$$E_0 e^{j\omega t} \rightarrow (E_0 \cos\omega t + j \sin E_0 \cos t)$$

$$\boxed{\frac{\epsilon_r^* - 1}{\epsilon_r^* + 2} = \frac{N(\alpha_e^* + \alpha_p^*)}{3\epsilon_0}} \; *$$

$$\epsilon_r^* = \epsilon_r' + j\epsilon_r''$$

ϵ_r'' → Imaginary parts responsible for dielectric loss

Dielectric losses :-

'ω' 'ϵ_r' 'A' 'd'

$$\vec{Y} \Rightarrow G + jB$$

Impedence Conductance + j susceptance

$$\vec{Y} = G + j\omega C$$

$$C = \epsilon_r' \frac{A}{d}$$ (Capacitance of capacitor)

$$G = \sigma \frac{A}{d}$$

σ = effective conductivity

$$\vec{Y} = G + j\omega C$$

$$\vec{Y} = \frac{\sigma A}{d} + j\omega C$$

$$\vec{Y} = \frac{\sigma A}{d} + j\omega \epsilon_r' \frac{A}{d}$$

$$\vec{Y} = (\sigma + j\omega \epsilon_r')$$

$$\vec{Y} = \frac{A}{d} j\omega \epsilon_r^*$$

$$\therefore \quad j\omega \epsilon_r^* = \sigma + j\omega \epsilon_r'$$

$$\epsilon_r^* = \frac{\sigma}{j\omega} + \epsilon_r'$$

$$\epsilon_r^* = \epsilon_r' - j\frac{\sigma}{\omega} = |\epsilon_r^*| \angle \delta$$

$$\epsilon_r' - j\epsilon_r'' = $$

$$\boxed{\epsilon_r'' = \frac{\sigma}{\omega}}$$

$$\epsilon_r^* = |\epsilon_r^*| \angle \delta$$

$$\boxed{\tan\delta = \frac{\epsilon_r''}{\epsilon_r'}}$$ Loss tangent of the dielectric material.

Complex dielectric constant

The internal field of a non polar solid dielectric material is given by Lorentz field.

i.e $E_i(t) = E(t) + \frac{P(t)}{3\epsilon_0}$ — (1)

Let ~~It is~~ us consider the solid contains 'N' no of units per m^3. and each unit is characterised by electronic & ionic polarization.

Therefore, the total polarisiblity is given by

$P(t) = N Re[(\alpha_e^* + \alpha_i^*) E_{oi}^* e^{j\omega t}]$ — (2).

where α_e^* & α_i^* are electronic & ionic polarisibility.

& $E_{oi}^* \Rightarrow$ Complex amplitude of the internal field.

For an alternating field the polarizibility $P(t)$ can be written as

$P(t) = \epsilon_0 Re[(\epsilon_r^* - 1) E_0 e^{j\omega t}]$ — (3).

where E_0 is the applied voltage and its magnitude will be $E_0 \cos(\omega t)$.

Finally using eqn (1), (2) & (3) will get

$$\frac{\epsilon_r^* - 1}{\epsilon_r^* + 2} = \frac{N(\alpha_e^* + \alpha_i^*)}{3\epsilon_0}.$$

where ε_r^* (Complex) is called as Complex permitivity or Complex dielectric constant.
& which is $\varepsilon_r^* = \varepsilon_r' - j\varepsilon_r''$

$\varepsilon_r' \rightarrow$
$\varepsilon_r'' \rightarrow$ relative.

Dielectric losses:-

Consider a parallel plate Condensor filled with a dielectric material characterised by ε_r'.

Let the electrode area be 'A' & the plate separation be 'd'. The admittance of the capacitor for any angular frequency 'ω' is given by

$$\vec{Y} = G + jB.$$

where G & B are the Conductance & Susceptance of material.

⇒ admittance $\vec{Y} = G + j\omega C$.

Can be written as where $C \rightarrow$ Capacitance $= \varepsilon_r' \frac{A}{d}$.

The Conductance $G = \frac{\sigma A}{d}$.

where σ is an effective Conductivity at the angular frequency 'ω'.

Thus Y Can be written as

$$\vec{Y} = \frac{A}{d}(\sigma + \varepsilon_r' j\omega)$$

$$\vec{Y} = \frac{A}{d} j\omega \varepsilon_r^*$$

the

$\therefore j\omega \epsilon_r^* = \sigma + j\omega \epsilon_r'$

$$\epsilon_r^* = \frac{\sigma}{j\omega} + \epsilon_r'.$$

$$\epsilon_r^* = \epsilon_r' - j\frac{\sigma}{\omega}.$$

$$= \epsilon_r' - j\epsilon_r'' = |\epsilon^*| \angle\delta.$$

$$\boxed{\epsilon_r'' = \frac{\sigma}{\omega}}$$

Thus the absorption of energy by the material in an alternating field is proportional to the imaginary part of the dielectric constant. The dielectric is said to have losses which are characterised by the loss tangent.

$$\boxed{\tan\delta = \frac{\epsilon_r''}{\epsilon_r'}}$$ *

7/3/15

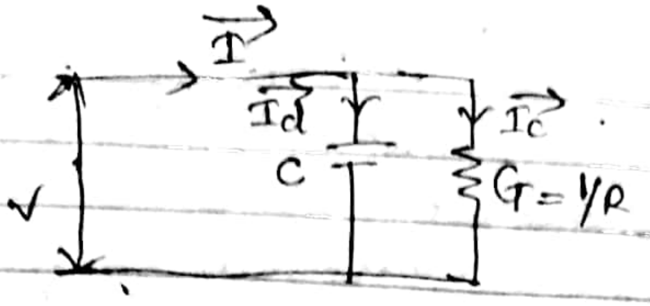
Loss tangent $= \tan\delta = \epsilon_r''/\epsilon_r'$

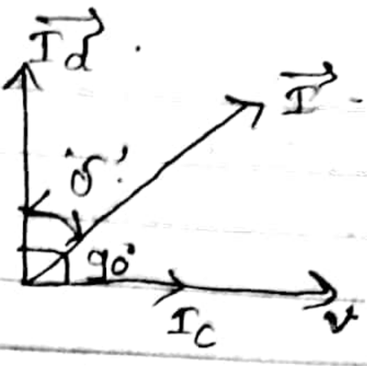
$$\epsilon_r'' / \epsilon_r' = \frac{\sigma}{\omega\epsilon_r'} \quad \left(\epsilon_r'' = \frac{\sigma}{\omega}\right)$$

$$= \frac{G}{B}.$$

$$\frac{\epsilon_r''}{\epsilon_r'} = \tan\delta = \frac{G}{\omega C} = 1/\omega CR.$$

Thus we can represent a condensor containing a lossy dielectric by an equivalent ckt which consist of a pure capacitance & a parallel resistance.



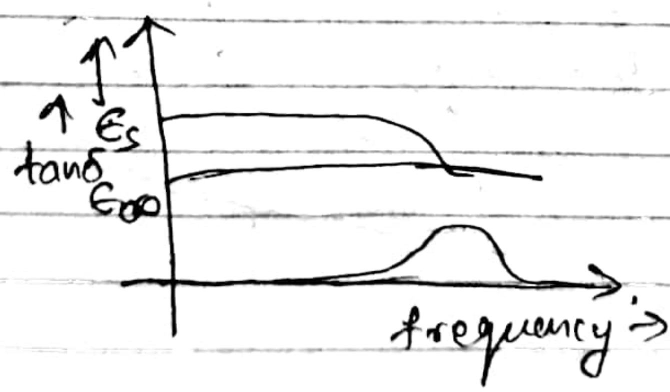


In this ckt vector 'I_C' is the conduction current which is responsible for the dielectric losses and is in phase with the applied voltage. The vector Id is displacement c/n which is in quadrature with the applied voltage. & 'I' is the phasor sum of vector I_C & vector I_d.

If there are no losses $\varepsilon_r'' = 0$. and the current 'i' leads the applied voltage by an angle of 90°.

Significance of the Loss tangent :—

The variation of tanδ with frequency will show a normal resonance behaviour this is shown as below.



The curve of tanδ has the largest values in the reagion of frequencies where their is sharp change in the dielectric Constant. In Case of ionic resonance the change in the dielectric constant occurs from microwave to infrad reagions of frequencies, the dielectric losses associated with ionic vibrations are normaly refered to infrad absorption. Similarly the losses in the optical reagion of frequencies are associated with electronic vibration & are refered to as optical absorption.

Hence it is possible to predict whether the dielectric properties are due to ionic or electronic polarization.

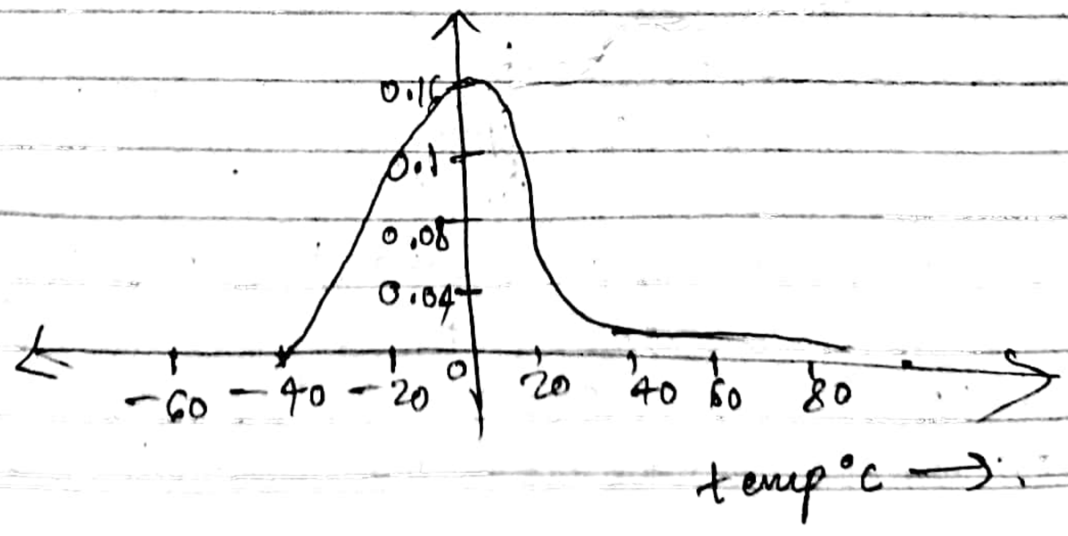
The occurance of absorption in the optical reagion is the source of colour in some materials.

~~Problem~~:-

ex:-

Nacl is transferent in the visible reagion which means that their is negligible absorption for the corresponding frequency. as it turns yellow, brown under x-rays

Dependance of loss tangent on temp & frequency:-



EEM Unit-2

Magnetic Materials :

(Q) Imp — **Magnetostriction** : "The change of length of a ferromagnetic material, when it is magnetised" is known as magnetostriction.

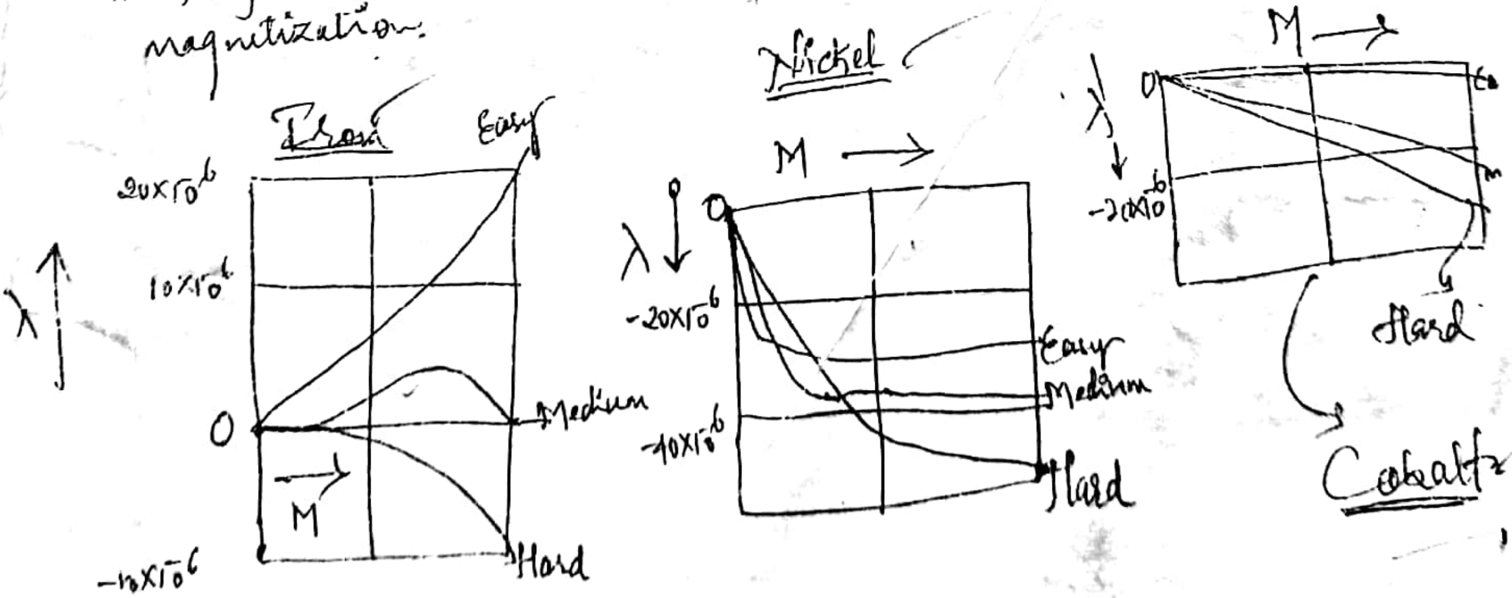
(or) When a ferromagnetic substance is magnetised there are small changes in its dimension, this phenomenon is called as magnetostriction.

The magnetostriction coefficient 'λ' is defined as " The increase in length per unit length of the crystal in the direction of magnetisation".

i.e. $\delta l / l$

(or) "The fractional change in length, $\delta l/l$ associated with the change in magnetisation from '0' to saturation."

* Negative value of 'λ' shows contraction in the direction of magnetization.



Magnetic Materials:

30 * Materials which can be magnetised are called magnetic materials. When magnetized they produce a magnetic field around them.

According to atomic theory { Origin of forming magnetic dipoles

→ Materials are made up of atoms, & atoms consist of a nucleus & a number of electrons revolving around the nucleus in orbits.

→ All the electrons around the nucleus do not revolve in the same orbit but revolve in different orbits.

→ Since current is the flow electrons, the rotation of electrons in the orbits is therefore equivalent to circulating currents.

→ It is clear that when current flows through a coil it creates m.m.f. Thus the circulating electrons in material also develop m.m.f.

→ In most of the materials the direction of motion of electrons in various orbits is such that they develop m.m.fs in opposite directions thus cancelling each other.

→ However in magnetic materials such as iron & steel there are a number of unneutralized orbits which produce a resultant m.m.f creating magnetic poles called magnetic dipoles.

→ In an unmagnetised material the dipoles are scattered at random. & In a magnetised material the dipoles line up parallel with exciting m.m.f

(56) Permeability or Magnetic permeability:

The property of a material by virtue of which it allows itself to be magnetised is called permeability.

The permeability of free space is denoted by μ_0 & is equal to $4\pi \times 10^{-7}$. & the permeability of air is almost same as for free space.

For magnetic materials permeability 'μ' is given

$$\mu = \mu_0 \times \mu_r \text{, where}$$

$\mu_r \rightarrow$ relative permeability.

The value of 'μ_r' depends on the degree to which the material is capable of being magnetised.

It may have a high value as 2500.

Classification of Magnetic Materials :

Imp

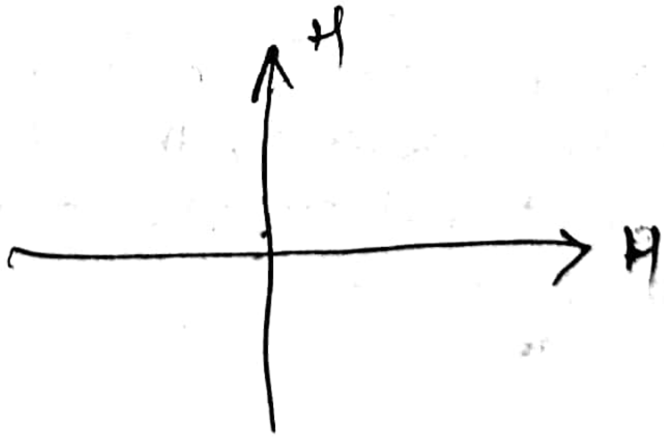
Magnetic Materials
- Non-magnetic
  - Diamagnetic
  - Paramagnetic
- Magnetic
  - Ferromagnetic
    - Hard
    - Soft

(57) * Diamagnetic Materials : Materials which lack permanent magnetic dipoles are called 'diamagnetic' materials.

If an external magnetic field is applied to a diamagnetic material it induces a magnetization 'M' in opposite direction to the applied field intensity 'H'.

This means that the relative permeability 'μr' of a diamagnetic material is negative.

This makes diamagnetism unimportant for electrical engineering applications.

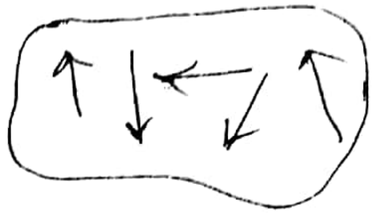


* (5) Paramagnetic materials | Paramagnetism:

magnetization

→ Materials having small ↑ but positive relative permeability are called paramagnetic materials.

— In paramagnetic materials the individual atomic dipoles are oriented in a random fashion as shown in the figure.



→ The resultant magnetic field is thus negligible.

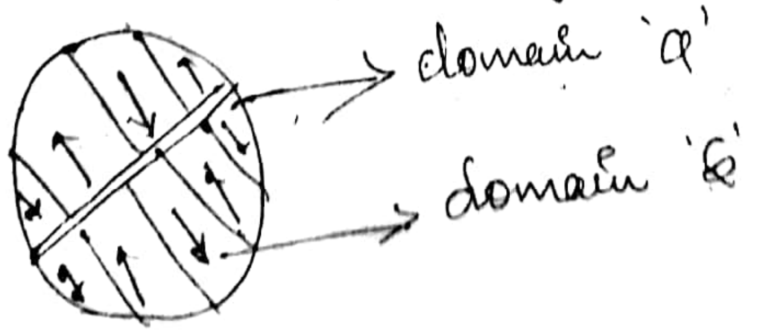
→ On application of an external magnetic field the permanent magnetic dipoles orient themselves parallel to the applied magnetic field & give rise to a positive magnetisation "M". But it is not complete. ∴ the magnetization "M" is small. Thus paramagnetic materials have negligible application in the field of electrical engineering.

* A ferromagnetic Substance contains ~~[illegible]~~ permanent atomic magnetic dipoles that are spontaneously oriented parallel to one another even in the absence of an external field.

* In ferromagnetic material χ_m may attain values as high as $10^5 - 10^6$ but it is not constant and varies with applied magnetic field strength 'H'.

* Ferromagnetic elements: Iron, nickel, cobalt, dysprosium and gadolinium.

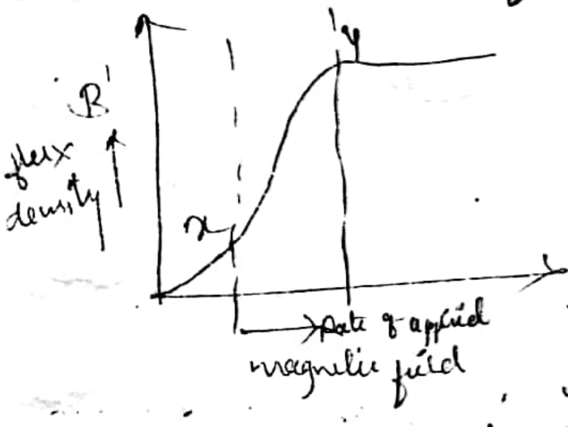
* Ferromagnetic materials are characterised in that they have a crystal structure divided into magnetic domains usually of microscopic size, in each of which the magnetic moments of the atoms are aligned. The alignment direction differs from one domain to another.
& a single crystal may contain many domains.



when the externally applied magnetic field is increased, a stage is reached when although it is still weak, the domains will start orienting themselves such that their resultant magnetic field coincides with the externally applied magnetic field & the material will develop strong magnetic field of its own.

There are some domains whose original magnetic orientation greatly diverges from that of the applied magnetic field & require a stronger external field to orient their magnetisation in the same direction as the applied field.

* Increase in the applied magnetic field ultimately gives rise to a state of magnetic saturation as explained below



* With very weak external field it is upto the point 'x' the domains do not orient themselves parallel to applied field.

* If the external field H is increased beyond the point 'x' there is sharp increase in the flux density & is strong enough to orient parallel to the applied magnetic field

When point 'y' reached the increase in 'B' is slow with the further increase in the external magnetic field & the permeability of the material, after that point starts decreasing & the material is said to start saturating.

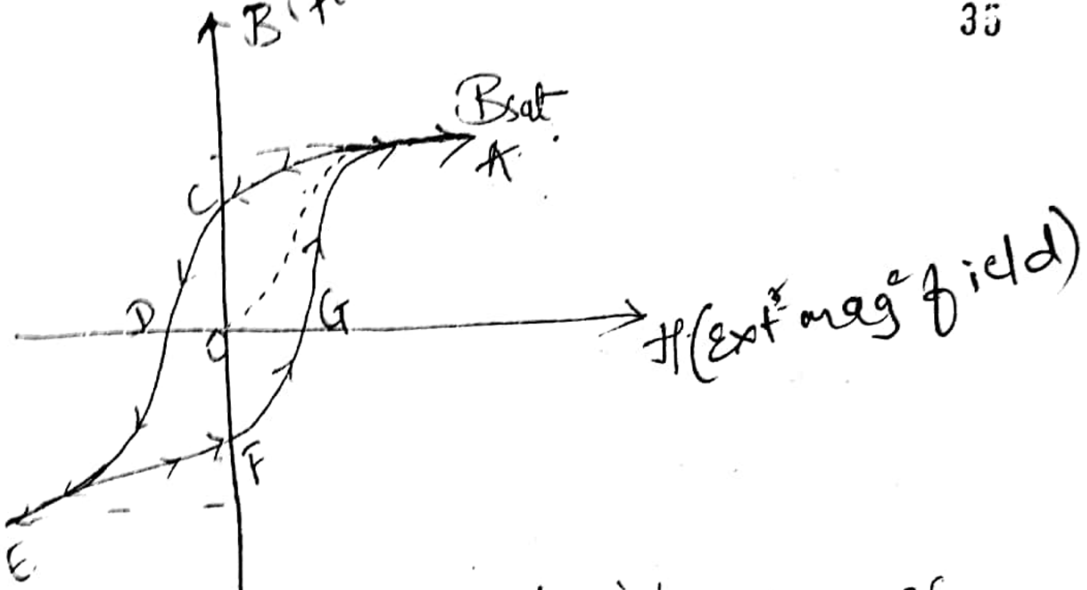
Ferromagnetism

* Ferromagnetic material are generally crystalline solids. (present as the strongest groups called domains)
* The permanent atomic dipoles are aligned parallel to each other with
* Each domain is therefore at all times completely magnetized.
* To give the material a net magnetization, 1 direction must predominate in the domains of the material.
* When a week external magnetic field is applied, it is not enough to cause any change in the orientation of the domains.
* When the external applied mag^c field is increased, a stage is reached when although it is still weak, the domains will start orienting themselves such that their resultant mag^c field coincides with the externally applied magnetic field & material will develop strong magnetic field of its own.
* However, there are some domains whose original magnetic orientation greatly (diverge) from that of applied field & require a stronger external field to be able to orient their magnetisation in the same direction as the applied field.
* This means that those domains whose original direction of magnetization is less divergent from that of applied field, will be aligned by a comparatively weak external field & external field will have to be made stronger & stronger in order to align the domains whose direction of magnetisation is more divergent from that of applied field.
* As a result the rate of strengthening of internal mag^c field decreases with increase in applied magnetic field & ultimately give rise to a state of mag^c saturation.

(52)

Hysteresis Loop:

Imp



→ In Ferromagnetic materials the flux density 'B' increases when external magnetic field applied to it is increased.

→ When the material reaches saturation state, the increase in 'B' almost ceases even though 'H' is increased.

Let us consider,
At 'H' equals to zero the material is still magnetised & the flux density has the value 'OC' in the figure shown above. This is called the 'remnant flux' or the 'residual magnetism'. (remanent)

→ In order to demagnetize the material the external magnetic field 'H' must be reversed & when it reaches the value 'OD' in the reverse direction, the 'B' becomes zero.

→ The applied magnetizing force 'H' in the reverse direction which causes 'B' to be zero is called 'Coercive force'.

→ Further increase of 'H' in the reverse direction will increase 'B' in the reverse direction & again at 'E' Saturation occurs.

→ 3G The residual magnetism in the reverse direction is represented by OF & to neutralise this, H must be increased to the value OG' in the positive or original direction.

→ Further increase in 'H' in the original direction will again magnetise the material in this +ve direction & saturation occurs at 'A'.

→ The loop ACDEFGA is called Hysteresis Loop.

→ The energy required in taking a material through one complete cycle of magnetisation is proportional to the area enclosed by the hysteresis loop.

→ The shape & area of the loop depend on the details of the internal structure & composition of the ferromagnetic substance.

→ Hysteresis loss depends upon flux density & frequency of variation of flux & is given by

$$\text{Hysteresis Loss} = K \cdot B_m^{1.6} f V_c \text{ Watt, where}$$

$K \rightarrow$ a constant

$B_m \rightarrow$ max flux density of the magnetic field in which core is placed.

$f \rightarrow$ frequency of variation of flux

$V_c \rightarrow$ Volume of the core material in m^3.

Eddy currents: (C1)

→ When a magnetic material is placed in an alternating magnetic field, the eddy currents are induced.

→ This is because the material is subjected to rate of change of flux linkages.

→ According to Faraday's laws of electromagnetic induction emfs are induced in the material due to the change in flux linkages hence causing currents, called '<u>eddy currents</u>'.

→ These currents cause loss of energy.

Eddy current loss $= K \cdot B_m^2 f^2 t^2 V_c$ Watts.

K → constant.

B_m → max flux density of the field

f → frequency of variation of flux

t → Thickness of the core laminations

V_c → Volume of the core material.

(8) Curie point (temperature)

→ It is a critical temperature called 'Curie point' above which the ferromagnetic materials lose their magnetic properties.

→ This temperature of magnetic material differs from material to material.

→ Above curie point or temperature the domains of ferromagnetic materials lose their alignment & become arranged in random manner. & thus the material loses its ferromagnetic property.

Permeability: Ability with which the mag^c material forces the mag^c flux through given medium

Ferromagnetic materials can be divided into two groups

1. Soft or permeable magnetic materials
2. Hard or permanent magnetic materials

Imp Soft magnetic materials :

The soft magnetic materials have high permeability and low coercive force i.e. narrow hysteresis loop and small energy losses during cyclic magnetization.

* They are magnetised & demagnetised easily.

Soft magnetic materials are used for the construction of cores for electric machines, transformers or electromagnets, reactors and relays.

The material used for above applications should have

→ high saturation value of flux density
→ high permeability to keep the magnetising current within reasonable low limits.
→ Material should produce small hysteresis & eddy current losses i.e core must be made of laminations

Hard Magnetic Materials.

Magnetic materials which are having gradually rising magnetization curve, large hysteresis loop area and large energy losses for each cycle of magnetization are called hard magnetic materials.

Hard magnetic materials are used for making permanent magnets.

Ex. Carbon steel, Cobalt steel, tungsten steel, ALNICO etc.

Material used for making permanent magnets should have

→ High Saturation value.

→ High coercive force

→ High residual magnetism.

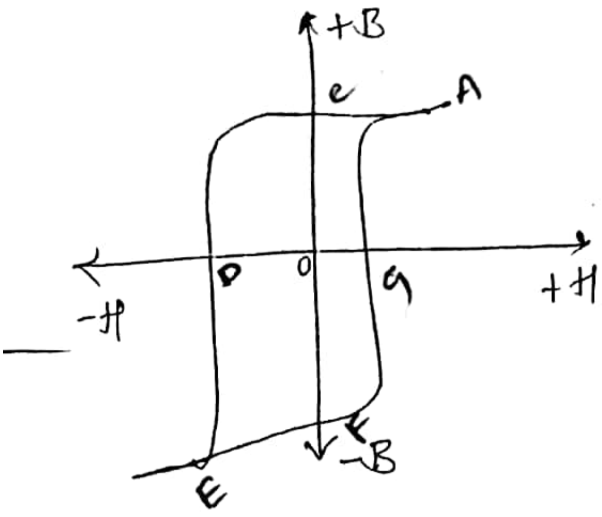
Differences Between Hard & Soft magnetic Materials

Imp

Hard Magnetic Materials

- Can not be magnetised easily
- High coercive force
- High residual magnetism
- Large hysteresis loop
- Large energy losses during magnetization

Ex : Carbon steel, cobalt steel etc



Large Hysteresis loop

H → Magnetic field strength or intensity

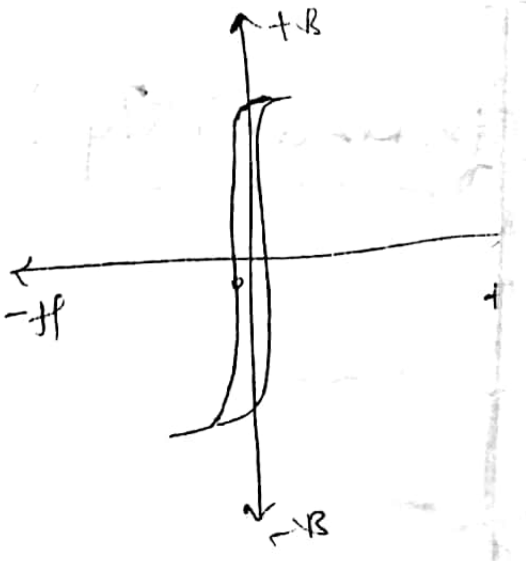
B → Magnetic flux density

* Used in making permanent magnets.

Soft Magnetic Materials

* Can be magnetised easily
* Low coercive force
* Low residual magnetism
* Small hysteresis loop
* Small energy losses during magnetisation
* Ex. pure iron, iron-silicon a...

*



Narrow Hysteresis loop

* Used in electric transformer machines as core.

Soft magnetic materials :

Examples :

- Pure Iron : (Ferrous material with an extra low carbon content).

* It has high magnetic permeability.

* Low Coercive force

The pure Iron is widely used in electrical apparatus & instruments as magnetic material core for electromagnets.

And the components for relay electrical instruments.

* Iron + Silicon alloys : { Silicon Steel }

0.5 to 5%

-> The good magnetic properties are obtained by adding silicon about 0.5 to 5 percent to Iron.

-> Iron - silicon - alloy is normally called as Silicon Steel.

-> Silicon steel is suitable for strong alternating magnetic fields.

-> Addition of silicon to iron reduces the eddy current losses and hysteresis losses.

→ It increases the permeability at low & moderate
34 } x densities.

→ The magnetostriction effect is also reduced in iron - silicon alloy. i.e silicon steel.

→ Addition of silicon is facilitates the steel making process.

* Grain Oriented Sheet Steel :

→ sheet steel which has been rolled such as to give easy direction to all its crystals is called grain - Oriented steel.

→ The grain orientation of silicon steel is obtain by a special technique called cold rolling.

→ The sheet steel obtained as a result of such process is called 'Cold Rolled Grain Oriented Silicon Steel' i.e (CRGO) silicon steel.

* CRGO - silicon steel is widely used for making transformers cores.

* With CRGO the magnetising current required by the transformer is less & hysteresis loss is also reduced.

* Nickel Iron alloys.

→ A group of iron alloys containing nickel between 30 to 80 percent with the possible addition of molybdenum & chromium, give very high permeabilities at low flux densities. & low losses. & are used in instrument transformers and relays. etc.

Important alloys:

Permalloy (Nickel + Iron)

- used in sensitive relays.
- curie temperature (b/n 420 - 580°C)
- Initial permeability b/n 2500 to 800
- Maximum permeability 100,000,

Supermalloy

- Iron nickel alloy + copper & molybdenum
- * High initial permeability 100,000
- * used in manufacturing of components of radio engg, telephony, telemetering instruments

Mumetal

- iron nickel a + copper & chromium
- * instrument X^r & miniature X^r
- * curie temp 430°C
- * initial permeability 20,000
- * maximum permeability is 110,000

Hard magnetic materials

* Carbon steel, tungsten steel, cobalt steel.

→ When carbon is added to soft magnetic materials its hysteresis loop area is increased. That is why carbon steel is used for permanent magnets.

→ But carbon steel loses its magnetic property under the influence of vibrations.

→ When materials like tungsten, chromium or cobalt are added to carbon steel, its magnetic properties are improved.

* ALNICO (Aluminium - nickel - Iron - Cobalt)

→ ALNICO alloys are most important of hard magnetic materials

→ Have good magnetic property & are cheaper.

→ ∴ most of permanent magnetic materials used ~~are~~ ALNICO alloys.

* Hard Ferrites. Hard magnetic ferrites are used for the manufacture of light weight permanent magnets.

Module 3

Insulating Material

Def?:—

It doesn't allow current to flow through it.

General properties:—

i) Electrical property

The various electric property are given as—

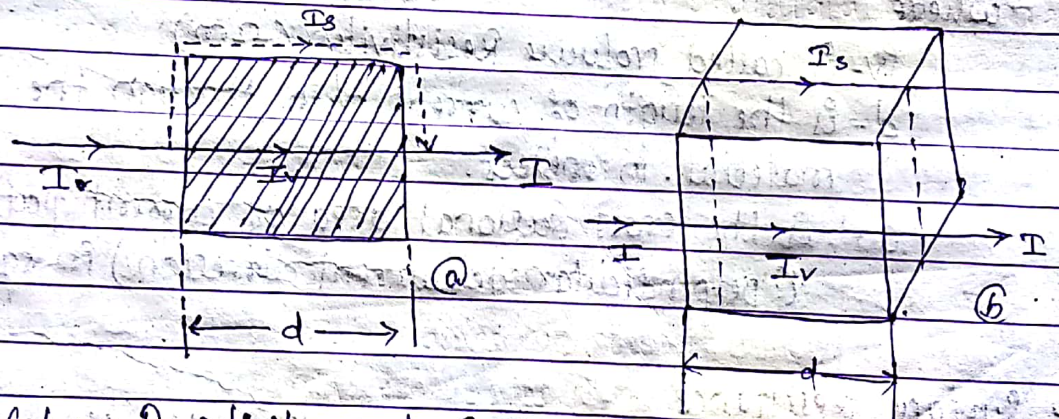
i) Insulation resistance

This is the property by virtue of which the material Resist the flow of current and insulate to which V applied with have small current I flowing through it the insulation resistance are (R) is given by

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

There are two types of insulation resistance

1) Volume Resistance
2) Surface "



Volume Resistivity and Surface resistivity of a piece of insulating material

fig(b) shown a piece of insulating material in isometric view, the same view is shown in cross section fig@

If a potential difference (V) is applied across the faces @ and b the current will flow.

The current likely to take to path straight through the material and around the material over the surface.
The current flows right through the material is denoted by Iv (I_v) and the current that flows over the surface of the material is denoted as I_s.
The possibility of current flowing over the surface of the surface of the material. that is due to presence of moisture. or atmospheric or surrounding impurities.

1) Volume Resistance:—
The resistance offered to current I_v which flows through the material is called volume resistance.
for a cube of unit dimensions this is called volume resistivity
unit is ohm meter (Ωm)
The volume resistance of insulating materials may be expressed as

$$R_v = \rho_v \frac{d}{a}$$

where
ρ_v - is called volume Resistivity (Ωm)
d - is the length of current path through the material. in meters.
a - is the cross sectional area of current path (perpendicular to current direction) in sq.m.

2) Surface Resistance
The resistance offered by the current I_s which flows over the surface of the material. is called surface resistance.
Surface resistivity depends upon humidity.

✓ Dielectric strength :—

Every electrical aparatus. designed to operate within a defined range of voltage. if the operating voltage increased gradually then the it is logical to think that at some value voltage break-down will occur.

Thus spoiling of insulating property permanently, in solid ins solid insulating material. but not necessorily in liquid and gaseous material.

vg / thickness ⟹ kV/cm

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General propertilies

1. Electrical property
2. Mechanical property
3. Thermal property
4. Visual property
5. Chemical property.

1. Electrical property
- Insulation resistance
- Dielectric strength
- Dielectric constant
- ~~Dielectric loss~~

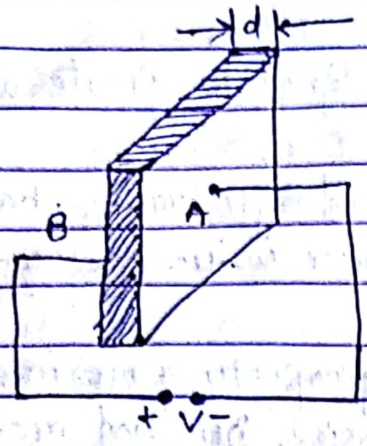
✓ Dielectric Constant :—

Every insulating material has got basic property of storing charge Q when the voltage is applied across it Q ∝ V

$Q = CV$

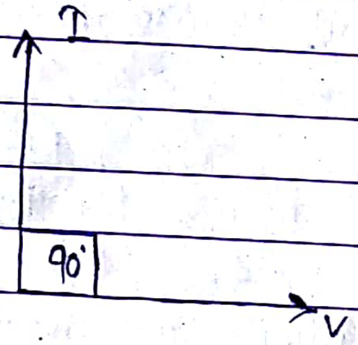
where

C - is the capacity or capacitance of the insulating material when voltage applied across it.



dielectric loss :-

when a perfect insulation is subjected to alternating voltage it is like applying alternating voltage to a perfect capacitor.
In such cases there is no consumption of power only vacuum and purified gaseous (approach this perfection)
In such cases charging current would lead the applied voltage by 90° (exactly as shown in fig a)



fig(a)

This would may means that there is no power loss in insulation.
In most insulating material i.e not the case there is definite amount of dissipation of energy when an insulator is subjected to alternating voltage. So This dissipation of energy is called dielectric loss"

* factors affecting dielectric constant
1) Temperature — T↑ effect the area
2) Area

Mechanical property
1) mechanical strength
2) Viscosity
3) porosity
4) Solubility
5) Machinability
6) portability

* mechanical strength depends upon no of factors
1) Temperature
2) Humidity

• Temperature :- if temperature rised as a result of heat generation in the conductor and dielectric loss in the insulator.
High temperature adversely effect mechanical strength of insulating material.

• Climatic effect :- Humidity can also adversely effect the mechanical strength of the insulating material.

2) Viscosity :- Thickness of oil (liquid dieletric)
It a liquid dielctric that affects the manufacturing process called viscosity
ex. in paper insulated cables. the temperature at which oil will penetrate through the paper.
This method is used to purify the insulating oil used in transformer and other applications depends on the viscosity of the oil.

3) porosity :- (
high porosity insulating material will increase the moisture holding the capacity consequently adversely effect electric component property

Therefore normally it is not desired to have dielectric of high porosity.
But in some application porosity advantages.
Ex. when paper is impregnated with oil.

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* Solubility :-
In certain applications insulation can be applied only when it is dissolved in some solvents.
Ex:- varnish with acetone it comes toluene
toluene is used as solvent that is present in paints thinners, nailpolish remover glues.

* Machinability and Mouldability :-
This properties are imp from the point of view of economic mass production.

— Thermal properties :-

* melting point :-
- it should be high in solid insulating material.

* Thermal conductivity :-
- heat generated due to I^2R losses and dielectric losses will be desipiated through the insulator itself.
- How affectively this flow of heat takes place the depends on thermal conductivity of insulator, and insulator with better thermal conductivity will not allow the temp rise because of affective heat transfer to through it to the atmosphere.

* Thermal expansion of contraction :-
It should be less [wide-null and cancelled]

* Heat resistance :-
Heat resistance capacity of insulator should be good.

* Visual property :-
These propertities do not have significant importance of in engineering point of view.
However factor like appearance, colour, bright, smooth to mat surface. count some extent towards the customer selection of insulating material.
1) colour :-
External appearance should be good.
Crystalallity (hard and tolerance) of the material.

2) In-organic insulating material
porcelain, mica, glass. asbestos.

* propertities :- (Porcelain)
1) Good mechanical strength
2) capacity to withstand high temperature
3) Immunity against moisture.
4) Not affected by chemical action.
5) Good compressive strength.

* Applications :-

1) Line insulator, transmission and distribution type Insulator (pin & suspension type insulator)

✣ GLASS

✓ • propertities
1) Transparent.
2) Brittle (which can be break easily) & hard
3) Good mechanical strength.
4) Insoluble in water & other solve
5) Low dielectric loss.
6) Low aging. (durable for long period)

• oxides used to make glass are silicon, magnesium, calcium, zinc, lead, boron, phosphorous, sodium, potassium, etc

• most commonly used glass is silicon oxide.

Application

1) used as insulator, fuse body.

2) used as dielectric for capacitor. electric lamp, radio television etc.

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* Types of glass :-

Glass is Inorganic material (Ceramic) made by mixing different metallic oxides.

This mixed product is cooled to a conditioned in which crystallisation do not occur.

1) Silica Glass [fused Quartz

2) Borosilicate glass (pyrex)

3) fibre glass

4) Epoxy glass

1) Silica glass

properties.

low co-efficient of expansion, of high resistivity & high melting point.

high chemical durability.

2) Borosilicate glass :-

properties

it consist of 28% Boron oxide

its having good electrical property.

Resistance to chemical & moisture content

Thermal resistivity.

3) fibre glass
* withstand very high temperature
* less hygroscopic, good electrical & mechanical property.

4) Epoxy glass :-
* It is obtained by mixing glass fibre with thermo setting material. (plastics)
* It is non absorbant of water and acids.
* used in circuit boards and PCB //

5) Mica :-
Mica is an inorganic material which is used as large amount 80% requirement to India. which is in the form of mineral.
They are two types of Mica.
i) Muscovite Mica ($KH_2 \cdot Al_3(SiO_4))_3$
ii) phlogopite Mica ($KH(MgF))_2 Mg Al (SiO_2)_3$.

property	Muscovite Mica	phlogophite Mica
1) Moisture Absorbation	low	low
2) Resistivity (Ω-cm)	$15^{15} - 10^{15}$	$10^{12} - 10^{14}$
3) Dielectric const	6-7	5-6
4) Dielectric strength	upto 80	upto 60
5) maximum operating temp	500-600°C	800-900°C
6) power factor	1-3	50

* Muscovite Mica :-
1) Good mechanical property (strong, tough, less flexible).
2) Available in colour less, yellow, silver, or green in colour
3) Good insulating property
4) abrasion resistance is high (resistance against the continous)

* phlogopite Mica :-
1) Good thermal stability
2) Good structure stability available in amber, yellow green or grey.
3) insulating property is poorer than Muscovite.

Mica Product :-
1) Glass bonded mica
2) High dielectric strength, low dielectric loss, can be mould and machine very accurately.
Ratio between mica and glass 40/60 to 60/40 as th

Synthetic mica :-
1) Good structural stability
2) High temperature resistance
3) good electrical insulation

Mica paper :-
1) Good moisture resistance
2) Low cost
3) high temperature stability
4) Good mechanical strength
5) Good arc resistance (thickness 0.005 mm to 0.1 mm)
6) ~~thickness~~ thickness (0.005 mm - 0.1 mm)

Manufactured mica
when mica flex are held together with adhesive. the product is called manufactured mica.

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* Rubber :-

Rubber material has high elasticity perfect resistance to moisture and gas
Many rubber

Types of Rubber :-
i) Natural Rubber
ii) Valcanised Rubber
iii) Butyle Rubber
iv) chloroprene rubber (Neoprene)
v) Butadiene rubber
vi) Ebonite
vii) Silicon Rubber.

1) Natural Rubber - it is obtained from 100 of different plants and trees especially from Rubber tree. 50°c of temperature it comes soft and stricky. at low temp it becomes brittle. Natural Rubber disolve in liquid hydrocarbon and carbon disulphide.

* Applications :-
The solution of Rubber is called Rubber glew. is used for joining pieces of Rubber.
Natural Rubber is rarely used for insulation purpose due to low head resistance.

2) Valcanised Rubber :-
For improving the insulation qualities natural rubber the valcanisation is done. natural rubber with

Sulphur is heated. The rubber with sulphur become thermosetting substance.

By valconisation the rubber becomes temperature and solvent resistive in the insulation and become mechanically strong. this process of valcanisation is done with 1%-8% of sulphur content. in the natural rubber & heated under pressure. Thus the rubber becomes elastic and soft.

Valconised Rubber is moisture repulant and has good insulating propetities low permeability for gas and water it has satisfactory mechanical propeetties

Applications :-

1) widely used for insulating wires in certain types of cables

2) Used for making protective clothings like glous and Boots etc.

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3) Isobutyle Rubber.

This rubber is manufactured through polymerisation of isobutylene hydrocarbon together with a small amount of isoprene or butadiene. it is not very Elastic but retains elasticity even at temperature below 70°c this rubber is expecially forst resistant material. chloro

4) chloroprene rubber :-

It is obtained through polymerisation of chloroprene hydrocarbons. its structure is unsymmetrical due to chlorine present in the composition and its insulation propetities are rather poor.

Applications
1) Used for making cable sheaths.
2) Used as oil resistant spacers in electrical apparatus.

5] Butadiene rubber :-
Is the most wide spread synthetic rubber. it is obtained through polymerisation of gaseous butadiene hydrocarbon.

6] Ebonite Rubber :-
In the valcanisation of rubber. if 30-35% of sulphur is added then the coutaint of sulphur makes ebonite rather material.
Ebonite is manufactured for electrical apparatus. Such as boards, sticks, tubes. and also used for making insulation articals.

7] Silicon rubber :-
They are highly heat resistant upto 250°C and satisfactory forst resistant. They remain flexible at temp down to 70°C and some rubbers upto 100°C
These rubbers are very costly mechanically weak and less resistant to solvents.

CERAMIC
It is a inorganic material, non-metallic material but it is made from compounds of metal and non. metal.
A simple manufacturing process for ceramics involves mixing findly powerederd ground clay and metal oxide with water just sufficient to make a paste which is shaked accordingly to requirements. and then it is drived and fiered at a temperature ranging from 1200°c - 1700°c.

other materials used with clay inorder to have diff types of ceramics are alumina, quartz, talc magnesite and feld spear.