RELAXATION TIME:

The medium is called <u>homogeneous</u> when the physical characteristics of the medium donot vary from point to point but remain same everywhere throughout the medium.

If the characteristics vary from point to point, the medium is called <u>hetrogeneous</u> (or) <u>non-homogeneous</u>.

While the medium is called <u>linear</u> with respect to the electric field if the flux density $\vec{D}$ is directly proportional to the electric field $\vec{E}$. The relationship is through the permittivity of the medium

If $\vec{D}$ is not directly proportional to $\vec{E}$, the material is called <u>non-linear</u>

Considering a conducting material which is linear and homogeneous. The current density for such a material is,

$$\vec{J} = \sigma \vec{E} \quad \text{where } \sigma \rightarrow \text{conductivity} \quad \text{---(1)}$$

But W.K.T $\vec{D} = \varepsilon \vec{E}$ ---(2)

$$\therefore \quad \vec{E} = \frac{\vec{D}}{\varepsilon} \quad \text{---(3)}$$

Sub (3) in (1) we get

$$\vec{J} = \sigma \frac{\vec{D}}{\varepsilon} = \frac{\sigma}{\varepsilon} \vec{D} \quad \text{---(4)}$$

The point form of continuity equation states that,

$$\nabla \cdot \vec{J} = -\frac{\partial \rho_v}{\partial t} \quad \text{---(5)}$$

Sub (4) in (5)

$$\nabla \cdot \left(\frac{\sigma \vec{D}}{\varepsilon}\right) = -\frac{\partial \rho_v}{\partial t}$$

$$\frac{\sigma}{\varepsilon} \nabla \cdot \vec{D} = -\frac{\partial \rho_v}{\partial t} \quad \text{---(6)}$$

But W.K.T } $\nabla \cdot \vec{D} = \rho_v$ ---(7) → Point form of Gauss's law Page No: 18 (unit II)

$\therefore$ Sub (7) in (6) we get

$$\frac{\sigma}{\varepsilon} \rho_v = -\frac{\partial \rho_v}{\partial t} \Rightarrow \frac{\partial \rho_v}{\partial t} + \frac{\sigma}{\varepsilon} \rho_v = 0 \quad \text{---(8)}$$

$$\frac{\partial \rho_v}{\partial t} + \frac{\sigma}{\varepsilon}\rho_v = 0 \quad \text{--- (8)}$$

The above equation is of the form

$$\frac{\partial x}{\partial t} + a x = 0$$

solution of this equation is $x = x_0 e^{-at}$

where $x_0 \rightarrow$ Initial condition

III^ly solution of Equation (8) is

$$\rho_v = \rho_0 e^{-\sigma/\varepsilon \, t}$$

$$\boxed{\rho_v = \rho_0 e^{-t/\tau}}$$ where ρ_0 = charge density at $t=0$.

--- (9)

This shows that if there is a temporary imbalance of electrons inside the given material, the charge density decays exponentially with time constant $\tau = \varepsilon/\sigma$ sec. This time is called relaxation time.

The relaxation time (τ) is defined as the time required by the charge density to decay to 36.8% of its initial value

τ = Relaxation time = $\frac{\varepsilon}{\sigma}$ sec.

DIELECTRIC MATERIALS:-

→ It is seen that the conductors have large number of free electrons while insulators and dielectric materials do not have free charges.

→ The charges in dielectrics are bound by the finite forces and hence called bound charges. As they are bound & not free, they cannot contribute to the conduction process.

→ But if subjected to an Electric field $\vec{E}$, they shift their relative positions, against the normal molecular and atomic forces. This shift in the relative positions of bound charges, allows the dielectric to store the energy.

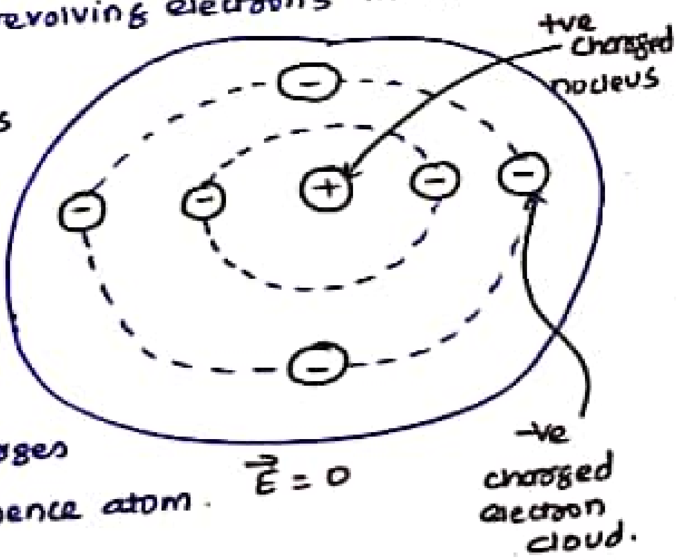
The shifts in positive and negative charges are in opposite directions and under the influence of an applied electric field $\vec{E}$ such charges act like small electric dipoles.

→ These electric dipoles produce an electric field which opposes the externally applied Electric field. <u>This Process, due to which seperation of bound charges results to produce electric dipoles, under the influence of electric field $\vec{E_r}$ is called POLARIZATION.</u>

POLARIZATION:

→ consider an atom of a dielectric

→ This consists of a nucleus with +ve charge and -ve charge in the form of revolving electrons in the orbits.



→ The negative charge is thus considered to be in the form of cloud of electrons. as shown in figure.

Note that $\vec{E}$ applied is zero. The number of +ve charges is same as -ve charges and hence atom is electrically neutral.

Due to symmetry, both +ve and -ve charges can be assumed to be point charges q equal amount, coinciding at the centre. Hence there cannot exists an electric dipole. This is called unpolarized atom.

When electric field $\vec{E}$ is applied, the symmetrical distribution of charges gets disturbed. The +ve charge experience a force $\vec{F} = Q\vec{E}$ while the -ve charge experience a force $\vec{F} = -Q\vec{E}$ in the opposite direction.