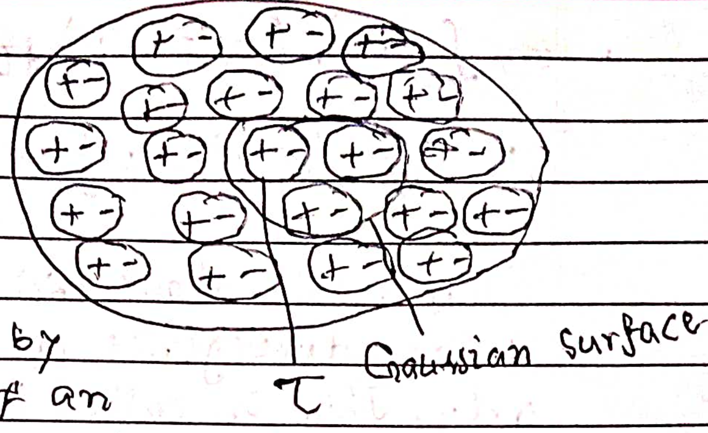
Relation between P, E and D :-



Every electric field is associated with an auxilliary vector whose flux across any closed surface is equal to only the free charge enclosed by the surface. Such vector of an electric field is called its displacement vector.

To introduce this vector, let us consider a polarized dielectric of any shape and size. Let P be the polarization of dielectric. Let us assume that there are also free charges embedded into it by introducing small conductors. If $\vec{\nabla}$ is the del operator with respect to a point in the dielectric, the density of polarised charge is given by $\rho_{pol} = -\vec{\nabla}\cdot\vec{P}$

Consider a point O inside the dielectric and draw a Gaussian Surface of volume τ and surface S inside the dielectric point O. No portion of the Gaussian Surface should lie outside the dielectric.

Obviously, total charged enclosed by the Gaussian Surface

$$\int_{\tau} (\rho_{free} - \vec{\nabla}\cdot\vec{P})\, d\tau$$

Where ρ_{free} is the density of free charge inside the dielectric. By Gauss's theorem

$$\oint \vec{E}\cdot\vec{ds} = \frac{1}{\epsilon_0}\int_{\tau} (\rho_{free} - \vec{\nabla}\cdot\vec{P})\, d\tau$$

Passing from the surface integral of the electric vector to volume integral of its divergence by Gauss's divergence theorem, we have

$$\int_\tau \vec{\nabla}\cdot\vec{E}\,d\tau = \frac{1}{\epsilon_0}\int_\tau (\rho_{free} - \vec{\nabla}\cdot\vec{P})\,d\tau$$

or, $$\int_\tau \vec{\nabla}\cdot(\epsilon_0\vec{E} + \vec{P})\,d\tau = \int_\tau \rho_{free}\,d\tau$$

$$\therefore \vec{\nabla}\cdot(\epsilon_0\vec{E} + \vec{P}) = \rho_{free}$$

This result shows that $\epsilon_0\vec{E} + \vec{P}$ is such a vector, whose divergence is equal to density of free charge only. This is called the displacement vector and generally is denoted by $\vec{D}$.

Thus,
$$\vec{D} = \epsilon_0\vec{E} + \vec{P}$$

which is required Condition.