

2.3: Permittivity

Permittivity describes the effect of material in determining the electric field in response to electric charge. For example, one can observe from laboratory experiments that a particle having charge q gives rise to the electric field

$$\mathbf{E} = \hat{\mathbf{R}} q \frac{1}{4\pi R^2} \frac{1}{\epsilon}$$

where R is distance from the charge, $\hat{\mathbf{R}}$ is a unit vector pointing away from the charge, and ϵ is a constant that depends on the material. Note that \mathbf{E} increases with q , which makes sense since electric charge is the source of \mathbf{E} . Also note that \mathbf{E} is inversely proportional to $4\pi R^2$, indicating that \mathbf{E} decreases in proportion to the area of a sphere surrounding the charge – a principle commonly known as the *inverse square law*. The remaining factor $1/\epsilon$ is the constant of proportionality, which captures the effect of material. Given units of V/m for \mathbf{E} and C for Q , we find that ϵ must have units of farads per meter (F/m). (To see this, note that $1 \text{ F} = 1 \text{ C/V}$.)

Permittivity

Permittivity (ϵ , F/m) describes the effect of material in determining the electric field intensity in response to charge.

In free space (that is, a perfect vacuum), we find that $\epsilon = \epsilon_0$ where:

$$\epsilon_0 \cong 8.854 \times 10^{-12} \text{ F/m}$$

The permittivity of air is only slightly greater, and usually can be assumed to be equal to that of free space. In most other materials, the permittivity is significantly greater; that is, the same charge results in a weaker electric field intensity.

It is common practice to describe the permittivity of materials relative to the permittivity of free space. This *relative permittivity* is given by:

$$\epsilon_r \triangleq \frac{\epsilon}{\epsilon_0}$$

Values of ϵ_r for a few representative materials is given in Appendix A1. Note that ϵ_r ranges from 1 (corresponding to a perfect vacuum) to about 60 or so in common engineering applications. Also note that relative permittivity is sometimes referred to as *dielectric constant*. This term is a bit misleading, however, since permittivity is a meaningful concept for many materials that are not dielectrics.

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