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 F $=1$ 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:

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

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.