10.1: Permittivity of Some Common Materials

The values below are relative permittivity $\epsilon_r \triangleq \epsilon/\epsilon_0$ for a few materials that are commonly encountered in electrical engineering applications, and for which permittivity emerges as a consideration. Note that "relative permittivity" is sometimes referred to as *dielectric constant*.

Here we consider only the physical (real-valued) permittivity, which is the real part of the complex permittivity (typically indicated as ϵ' or ϵ_r') for materials exhibiting significant loss.

Permittivity varies significantly as a function of frequency. The values below are representative of frequencies from a few kHz to about 1 GHz. The values given are also representative of optical frequencies for materials such as silica that are used in optical applications. Permittivity also varies as a function of temperature. In applications where precision better than about 10% is required, primary references accounting for frequency and temperature should be consulted. The values presented here are gathered from a variety of references, including those indicated in "Additional References."

Free Space (vacuum): $\epsilon_r \triangleq 1$

Table 10.1.1: Solid Dielectrics:

Material	ϵ_r	Common uses
Styrofoam[1]	1.1	
Teflon[2]	2.1	
Polyethylene	2.3	coaxial cable
Polypropylene	2.3	
Silica	2.4	optical fiber[3]
Polystyrene	2.6	
Polycarbonate	2.8	
Rogers RO3003	3.0	PCB substrate
FR4 (glass epoxy laminate)	4.5	PCB substrate

[1] Properly known as *extruded polystyrene foam* (XPS).
[2] Properly known as *polytetrafluoroethylene* (PTFE).
[3] Typically doped with small amounts of other materials to slightly raise or lower the index of refraction ($= \sqrt{\epsilon_r}$).

Non-conducting spacing materials used in discrete capacitors exhibit ϵ_r ranging from about 5 to 50.

- **Semiconductors** commonly appearing in electronics – including carbon, silicon, geranium, indium phosphide, and so on – typically exhibit ϵ_r in the range 5–15.
- **Glass** exhibits ϵ_r in the range 4–10, depending on composition.
- **Gasses**, including air, typically exhibit $\epsilon_r \cong 1$ to within a tiny fraction of a percent.
- **Liquid water** typically exhibits ϵ_r in the range 72–81. Distilled water exhibits $\epsilon_r \approx 81$ at room temperature, whereas sea water tends to be at the lower end of the range.
- **Other liquids** typically exhibit ϵ_r in the range 10–90, with considerable variation as a function of temperature and frequency. Animal flesh and blood consists primarily of liquid matter and so also exhibits permittivity in this range.
- **Soil** typically exhibits ϵ_r in the range 2.5–3.5 when dry and higher when wet. The permittivity of soil varies considerably depending on composition.