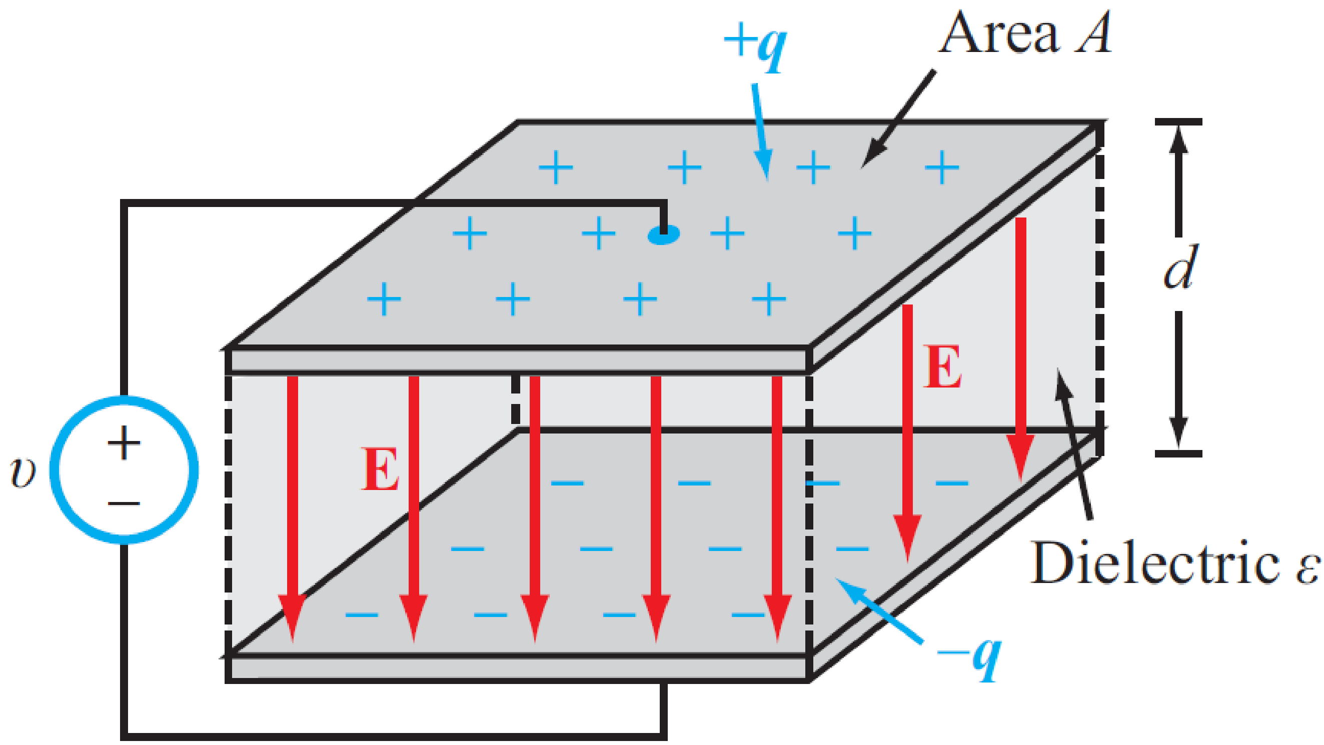
Capacitors

When separated by an insulating medium, any two conducting bodies (regardless of their shapes and sizes) form a *capacitor*.



The parallel-plate capacitor shown above represents a simple configuration in which two identical conducting plates (each of area A) are separated by a distance d containing an insulating (dielectric) material of electrical permittivity ε. If a voltage source is connected across the two plates, charge of equal and opposite polarity is transferred to the conducting surfaces. The plate connected to the (+) terminal of the voltage source will accumulate charge +q, and charge −q will accumulate on the other plate. The charges induce an electric field E in the dielectric medium, given by

$$E = \frac{q}{\varepsilon A}$$

with the direction of E being from the plate with +q to the plate with −q. In the specific case of a parallel plate capacitor, E, whose unit is V/m, is related to the voltage, v, through

$$E = \frac{\upsilon}{d} \qquad \text{(V/m)}$$

For any capacitor, its **capacitance, C**, measured in farads (F), is defined as the amount of charge q that its positive-polarity plate holds, normalized to the applied voltage responsible for that charge accumulation.

Given this, for any capacitor:

$$C = \frac{q}{\upsilon}$$

For the parallel plate capacitor specifically:

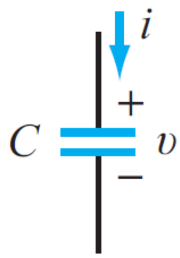
$$C = \frac{\varepsilon A}{d}$$

Although the specific equation will vary with capacitor geometry, some general trends hold true across the various geometrical configurations. In general, the capacitance C of any two-conductor system increases with the area of the conducting surfaces, decreases with the separation between them, and is directly proportional to ε of the insulating material.

Note that since q = Cv, it follows that:

$$i = \frac{dq}{dt} = C\,\frac{d\upsilon}{dt}$$

which relates the voltage across a capacitor to the current across it.



$$i = C\,\frac{d\upsilon}{dt}$$

What is permittivity, ε?

The permittivity of a material is usually referenced to that of free space, namely $\varepsilon_0 = 8.85\times10^{-12}$ farads/m (F/m). Hence, the relative permittivity of a material is defined as

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

When a dielectric material is subjected to an electric field, its atoms become partially polarized. The electric field E induced in the space between the conducting plates is the result of the voltage, v, applied across the plates. The electrical susceptibility χ_e of a material is a measure of how susceptible that material is to electrical polarization. The permittivity ε and susceptibility χ_e are related by

$$\varepsilon = \varepsilon_0(1 + \chi_e)$$

From which follows that:

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = 1 + \chi_e$$

Free space contains no atoms; hence, its $\chi_e = 0$ and $\varepsilon_r = 1$. For air at sea level, $\varepsilon_r = 1.0006$. The permittivity of common insulators is tabulated below.

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