Material	Resistivity (Ω-m)	Resistivity (sec)
Silver	1.6×10^{-8}	1.8×10^{-17}
Copper	1.7×10^{-8}	1.9×10^{-17}
Gold	2.4×10^{-8}	2.6×10^{-17}
Iron	1.0×10^{-7}	1.1×10^{-16}
Sea water	0.2	2.2×10^{-10}
Polyethylene	2.0×10^{11}	220
Glass	$\sim 10^{12}$	$\sim 10^{3}$
Fused quartz	7.5×10^{17}	8.3×10^{8}

As you can see, the resistivity of ordinary materials varies over an enormous range, reflecting the very different electronic properties of materials around us.

5.2 Electric fields and conductors

For the rest of this lecture, we will assume that conductors are materials that have an infinite supply of charges that are free to move around. (This of course just an idealization; but, it turns out to be an extremely good one. Real conductors in fact behave very similar to this limit.) From this, we can deduce a few important facts about conductors and electrostatic fields:

- **There is no electric field inside a conductor**. Why? Suppose we bring a plus charge near a conductor. For a very short moment, there will be an electric field inside the conductor. However, this field will act on and move the electrons, which are free to move about. The electrons will move close to the plus charge, leaving net positive charge behind. The conductor's charges will continue to move until the "external" $\vec{E}$-field is cancelled out — at that point there is no longer an $\vec{E}$-field to move them, so they stay still.

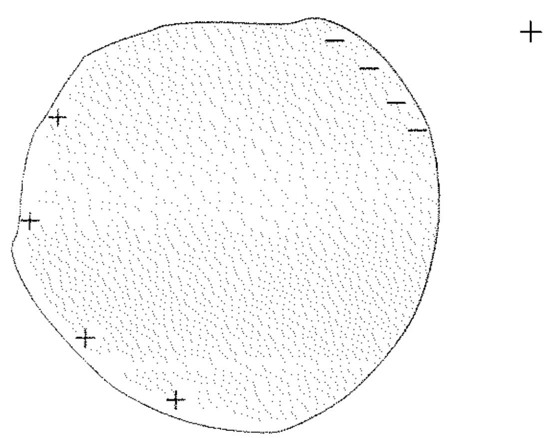

Figure 1: Conductor near an external charge. The charges in the conductor very quickly rearrange themselves to cancel out the external field.

A more accurate statement of this rule is "**After a very short time, there is no electric field inside a conductor**". How short a time is it? Recall that in cgs units, resistivity (which tells us how good/bad something conducts electricity) is measured in seconds. It turns out that the time it takes for the charges to rearrange themselves to cancel out the external $\vec{E}$-field is just about equal to this resistivity. For metals, this is a time that is something like $10^{-16} - 10^{-17}$ seconds. This is so short that we can hardly complain that the original statement isn't precise enough!

- **The electric potential within a conductor is constant.** Proof: the potential difference between any two points $\vec{a}$ and $\vec{b}$ inside the conductor is

$$\begin{aligned} \phi_b - \phi_a &= -\int_{\vec{a}}^{\vec{b}} \vec{E} \cdot d\vec{s} \\ &= 0 \end{aligned}$$

  since $\vec{E} = 0$ inside the conductor. Hence, for any two points $\vec{a}$ and $\vec{b}$ inside the conductor, $\phi_b = \phi_a$.

- **Net charge can only reside on the surface of a conductor.** This is easily proved with Gauss's law: make a little Gaussian surface that is totally contained inside the conductor. Since there is no $\vec{E}$-field inside the conductor, $\oint \vec{E} \cdot d\vec{A}$ is clearly zero for your surface. Since that is equal to the charge the surface contains, there can be no charge.

  We will discuss the charge on the conductor's surface in a moment.

- **Any external electric field lines are perpendicular to the surface.** Another way to put this is that there is no component of electric field that is tangent to the surface. We prove this by contradiction: suppose that a component of the $\vec{E}$-field *were* tangent to the surface. If that were the case, then charges would flow along the surface. They would continue to flow until there was no longer any tangential component to the $\vec{E}$-field. Hence, this situation cannot exist: even if it exists momentarily, it will rapidly (within 10^{-17} seconds or so) correct itself.

- **The conductor's surface is an equipotential.** This follows from the fact that the $\vec{E}$-field is perpendicular to the surface. We do a line integral of $\vec{E}$ on the surface; the path is perpendicular to the field; so the difference in potential between any two points on the surface is zero.

A few important corollaries follow from these rules.

- **Corollary 1**: Consider a conductor with a hollowed out region. If there is no charge in this hollow, then the potential ϕ there is constant. It follows that the electric field $-\vec{\nabla}\phi$ inside the hollow is zero.

  We will prove this carefully shortly. For now, we can motivate this proof by noting that the surface of the conductor must be an equipotential. Since there is no charge anywhere on the inside, the interior potential must obey Laplace's equation, $\nabla^2\phi = 0$. Solutions to Laplace's equation can have no local maxima or minima. The only solution that has some proscribed constant value on an exterior boundary *and* has no local maxima or minima is one that is constant.