Guide to: Electric resistance: current conduction in a metal.

Applications: Electric circuits. Loading of electric networks.

Basic idea: A model for electric conduction in a metal: an electric field accelerates charges; a constant current implies a constant drift velocity; a drag force is counter-acting the electric field. Resistance depends on geometry (proportional to length, inversely proportional to cross section), and on the material. Material properties that matter: density of free charge carriers.

Derivations: Cylindrical wire (Fig. 19.6): a volume defined by cross section A and length $v_d \Delta t$ drift speed time a chosen time step) contains charge carriers that will move across the cross section within time Δt. The total number of these charge carriers depends on their volume density n: $N = nAv_d\Delta t$. The amount of charge that corresponds to N electrons: $\Delta q = N(-e) = -neAv_d\Delta t$.

The electric current $I = \dfrac{\Delta q}{\Delta t} = -neAv_d$ is proportional to the drift speed and cross section A. The drift speed is proportional to the electric field applied, which is proportional to the voltage drop. Ohm's law expresses the current-voltage relation as: $\Delta V = -R\ I$, the resistance R absorbs the free (conduction) electron density and lattice material property into the resistivity (specific resistance), and the geometric dependence (L=length of cylindrical wire): $R = \rho \dfrac{L}{A}$. The resistivity increases with temperature. Some semi-conductor materials have a reversed temperature dependence.

Equations: The unit of resistance is the ohm = volt/ampere, and is denoted by a Greek capital omega: Ω.

For parallel resistors: $\dfrac{1}{R_{\mathrm{eq}}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$ Current branches, same voltage drop across each R.

The voltage drop (Ohm's law) $\Delta V = -R\ I$ contains a minus sign to show that it falls along the nominal direction of current flow (from plus to minus, or from high potential to low potential).

The drift speed is calculated from $v_d = -\dfrac{I}{neA}$.

Problems: 19.1-5; 19.9-21, and circuit problems 19.22-47 ; 19.74-77, 84, 87, 88-89, 98.
Understand the derivation of the parallel-resistor formula.
A 1-mm diameter copper wire carries a current of 1 Ampere: what is the drift speed? Table 19.1 states that $\rho_{\mathrm{Cu}} = 1.7 \times 10^{-8}\ \Omega\mathrm{m}$, but you need the free-electron density, $n_{\mathrm{Cu}} \approx 2 \times 10^{26}\ \mathrm{m}^{-3}$.