Assignment 6

Due date: Friday, October 8

Electrical resistance between concentric cylinders

Two concentric metal cylinders are placed in an electrolyte solution. When a potential difference V is applied to the two cylinders with a battery, a current I flows from one cylinder to the other. Calculate the resistance $R = V/I$ in terms of the resistivity ρ of the electrolyte and the geometry of the cylinders. Model the cylinders as thin sheets with length L along their common axis and radius a (inner) and b (outer). You may assume that $L \gg b > a$ so that "end effects" can be neglected (the electric field and potential can be approximated by a model with $L = \infty$). Also assume that the resistivity of the metal sheets is so small (compared with the electrolyte) that the electric potential is a constant on each cylinder.

Hints: A potential function with cylindrical symmetry is $\varphi(r) = A \log r$, where A is a constant and r is the distance from the cylinder axis. Check this fact by working out the corresponding electric field and comparing with the electric field produced by uniform charge along a line. Use the function $\varphi(r)$ to find the potential difference V. From the corresponding electric field at $r = a$ and $r = b$ find the current I that flows into one cylinder and out of the other (they better be the same!).

A compound resistor

Two cylinders of different semiconducting materials are joined end-to-end to form a compound resistor. Both cylinders have the same cross sectional shape and area A. However, the cylinders have different lengths and resistivities: L_1, ρ_1 and L_2, ρ_2. The following parts are *not* meant to be done in a particular order:

- Find the ratio of electric fields in the two semiconductors, E_1/E_2, when a potential difference is applied between the ends of the compound resistor.
- Find the ratio of potential differences between the ends of the individual semiconductors, V_1/V_2, when a potential difference is applied between the ends of the compound resistor.
- Find the current I that flows along the compound resistor when the potential difference between its ends is V.
- Explain why in general a surface charge density σ forms where the cylinders are joined and there is a nonzero potential V between the ends of the compound resistor. Calculate the value of σ.