Chapter E3: Fields and Currents

E3.2 Field of a Charged Disk

The field due to a disk of radius $R$, charge density $\sigma$, a distance $z$ above the disk along its central axis is given by:

$$E_z = 2\pi k \sigma \left[1 - \frac{1}{\sqrt{1 + \left(\frac{R}{z}\right)^2}}\right]$$  \hspace{1cm} (1)

Important limiting case: in the infinite disk limit. If the disk is infinitely wide, the field above the disk is constant.

E3.3 Field of a Charged Spherical Shell

Field due to a spherical shell with charge $Q$:

$$E_z = \frac{kQ}{r^2}$$  \hspace{1cm} (2)

Note that this doesn’t depend on the size of the shell.

E3.4 Introduction to Current

Current is defined as the amount of charge flowing per unit time:

$$I = \left| \frac{\Delta Q}{\Delta t} \right|.$$  \hspace{1cm} (3)

The direction of conventional current assumes that the charge carriers are positive.

The SI unit of current is the Amp:

$$1\text{A} \equiv 1\text{C/s}.$$  \hspace{1cm} (4)
E3.5 A Microscopic Model

Fields cause electrons to move in a metal. The conduction electrons undergo lots of collisions with the underlying lattice. The average speed at which electrons drift is given by:

\[ v_d = neAv_d . \] (5)

I think the key to understanding this equation is Fig. E3.7.

E3.6 Current Density

The current density is defined as the current per unit area:

\[ \vec{J} \equiv \lim_{A \to 0} \frac{\vec{I}}{A} = nq\vec{v}_d . \] (6)

The current density is proportional to the applied electric field:

\[ \vec{J} = \sigma \vec{E} . \] (7)

Where \( \sigma \) is the conductivity, a constant (like density or “hardness”) that varies from material to material.
Practice:

1. In class we found that the field due to the a wire of charge $Q$ and length $L$, a distance from the wire along its axis is given by:

$$\frac{kQ}{D(D + L)}$$

(a) What is the behavior of the field in the limit that $D \gg L$? Does this make sense?
(b) What is the behavior of the field in the limit that $L \gg D$? Does this make sense?
(c) Let $L = 1$ meter and $Q = 1 nC$. If I put a charge of $-3 nC$ at a point a distance $D = .5 meters$ from the wire’s end, what is the direction and magnitude of the force on the charge?