

PH 422: Day 4

25 Currents

How do we measure current? By counting the charges which go past. So use a stopwatch, and count. What are the units? Coulombs per second. What answer do we get? That depends on the charge density λ and the velocity \vec{v} . At any point in a wire, the *current* is given by

$$\vec{I} = \lambda \vec{v}$$

and the number of charges which go past per unit time is clearly just the magnitude, $I = |\vec{I}|$. Since the direction of the current is obvious in a wire, both I and \vec{I} are called the current.

Similarly, the *surface current density* \vec{K} and the (*volume*) *current density* \vec{J} , given respectively by

$$\vec{K} = \sigma \vec{v} \tag{5.41}$$

$$\vec{J} = \rho \vec{v} \tag{5.42}$$

Be very careful with the dimensions here, current densities do not have the dimensions of current per unit area or volume, respectively, but rather the dimensions of charge density times speed.

But what is the total current in these cases? The key idea is that one must insert a (1- or 2-dimensional) “gate”, and count the charges which cross the gate per unit time. But only the motion of the charges perpendicular to the gate is relevant. This is (2- and 3-dimensional) flux; the total current is given respectively by

$$I = \int \vec{K} \cdot \hat{n} ds \tag{5.43}$$

$$I = \int \vec{J} \cdot \hat{n} dA = \int \vec{J} \cdot d\vec{A} \tag{5.44}$$