Definitions for Current and Resistance

AVERAGE CURRENT

The AVERAGE CURRENT (I_{av}) through any area A is the total charge ΔQ that passes through that area in time Δt, divided by Δt.

In Symbols: $$I_{av} \equiv \frac{\Delta Q}{\Delta t}$$ in Units of C/s = Amperes (A)

INSTANTANEOUS CURRENT

The INSTANTANEOUS CURRENT ($I(t)$) is the limit as Δt goes to zero of the average current.

In Symbols: $$I(t) \equiv \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$ in Units of C/s = Amperes (A)

CURRENT DENSITY

The CURRENT DENSITY ($\vec{J}(\vec{r})$) at location $\vec{r}$ is the time rate of charge flow per unit area through an infinitesimal area located at $\vec{r}$; the direction of current density is the direction of <u>positive</u> charge flow.

In Symbols: <u>IF</u> $\vec{J}(\vec{r})$ is constant over some area A $$|\vec{J}| \equiv \frac{|I|}{A}$$ in Units of A/m^2

in general for area A $$I_A \equiv \int_A \vec{J}(\vec{r}) \cdot d\vec{A}.$$

This last equation is often used as the definition of current. Note that current density is a VECTOR while current is a signed scalar.

RESISTANCE

The RESISTANCE (R) between any two points on a conducting <u>object</u> is

$$R \equiv \frac{V}{I} \qquad \text{in Units of V/A = Ohms } (\Omega)$$

where V is the absolute value of the applied potential difference between those two points, and

I is the absolute value of the resulting current.

CONDUCTIVITY

The CONDUCTIVITY (σ) of a <u>material</u> is the ratio of the magnitude of the current density at some point in the material to the electric field strength that produces that current density.

In Symbols: $\sigma \equiv \dfrac{J}{E}$ in Units of $(\text{A/m}^2)/(\text{V/m}) = 1/\Omega\cdot\text{m}$

or in vector form: $\vec{J} = \sigma \vec{E}$ (1)

RESISTIVITY

The RESISTIVITY (ρ) of a <u>material</u> is the reciprocal of the conductivity.

In Symbols: $\rho \equiv \dfrac{1}{\sigma}$ in Units of $\Omega\cdot\text{m}$

which allows us to write (1) as $\vec{E} = \rho \vec{J}$.