

SURFACE AND VOLUME CURRENT IN A WIRE

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Reference: Griffiths, David J. (2007) Introduction to Electrodynamics, 3rd Edition; Prentice Hall - Problem 5.5.

A couple of examples of surface and volume current.

If we have a wire of radius a which carries a current I , what is the surface current K if the current in the wire is spread uniformly over the surface of the wire?

Since K is defined as the charge per unit width per unit time, we need the width over which the surface current is spread. This is just the circumference of the wire, so

$$K = \frac{I}{2\pi a} \quad (1)$$

Now suppose the current is distributed in the volume of the wire such that volume current density is inversely proportional to the distance from the axis. That is,

$$J = \frac{A}{r} \quad (2)$$

for some constant A . We need the total flow across the cross-sectional area of the wire to be the total current I , so we must have, using cylindrical coordinates:

$$I = \int_0^a \int_0^{2\pi} J d\phi r dr \quad (3)$$

$$= 2\pi A a \quad (4)$$

$$A = \frac{I}{2\pi a} \quad (5)$$

Thus the volume current density is

$$J = \frac{I}{2\pi ar} \quad (6)$$