Electrical resistivity

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PRAECEPTOR

Electrical resistivity is a quantity which, in conjunction with the dimensions, determines the particular resistance of a sample. In general the resistance r is found to be proportional to the length l of a uniform sample of material and inversely proportional to the area of cross section A. Thus we usually write $r \propto l/A$ and the resistivity ρ is introduced as a constant of proportionality so that $r = \rho l/A$. For certain small specimens of conductors the measured resistivity near the absolute zero of temperature is found to be a function of the specimen size. This phenomenon is met when the wavelength λ associated with the moving electron (defined by $E = hc/\lambda$, where E is its energy, h is Plank's constant and c is the speed of light) is comparable with the linear dimensions of the specimen. The units of ρ are those appropriate to the function rA/l, viz. ohm cm or ohm metre. Electrical conductivity σ is defined to be equal to $1/\rho$ and its units are $ohm^{-1}\ cm^{-1}$ or $ohm^{-1}\ m^{-1}$. The practice of some writers of referring to such incorrect units as, for example, 'international ohms per centimetre cube' is to be deprecated. Such units and implied definitions are not only meaningless but can mislead the student when interpreting the results of measurements in the laboratory.

> **Why is this unanswerable?**
>
> *Advanced level*, 1960
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> Explain what is meant by the term 'work function' in relation to electron emitters.
>
> Calculate the work function in electron volts of a metal for which the photo-electric threshold wavelength is 2×10^{-5} cm.
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> The work function of tungsten is 4·5 v, whereas that of molybdenum is 4·2 v. Calculate the ratio of the thermionic emission from 1 cm^2 of molybdenum at the same temperature, assuming that Richardson's equation for thermionic emission applies.
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> *Answer on page* 61

The resistivity of a body determines its intrinsic resistance between its contacting surfaces, but when practical measurements of resistance are made, there is a danger that the additional resistance existing at the contacts between the specimen and its leads may give a falsely large value. Thus for the accurate measurement of resistance and hence resistivity, it is necessary to use four leads to the specimen. The two outermost should carry the current and the innermost leads should be potential probes. The measurement of the potential difference between these 'probes' by a potentiometric method, involving only infinitesimally small current flow along them when balance is achieved, is not then dependent on contact resistance, which merely acts to affect the sensitivity of balance.

For metals the resistivity tends to increase at a moderate rate with increasing temperature and the variation is often expressed in linear or quadratic form. For alloys the variation is in general somewhat slower. The resistivity of solid materials other than metals and simple alloys which have a metal-like behaviour decreases rapidly as the temperature is raised and in many cases this variation may be represented by a simple exponential function over wide ranges of temperature. However, the introduction of certain impurities into non-metallic solids can modify (*a*) the resistivity, and (*b*) the variation of resistivity with temperature. In some cases the introduction of such impurities can even give rise to some temperature ranges to a positive temperature coefficient of resistance which would normally be characteristic of a metal.

Typical values of the room temperature resistivity of solid materials are given in the following table, together with the class of solid to which they belong.

Material	Resistivity (ohm cm)	Type of material
Copper	$1{\cdot}5 \times 10^{-6}$	Metal
Germanium (doped for transistor manufacture)	1	Impurity semi-conductor
Germanium (pure)	50	Intrinsic semi-conductor
Quartz	2×10^{14}	Ionic crystal (insulator)