Therefore one may say that the agreement of the radiation frequency of the "neutron" here proposed and the experimental frequencies is perfect. However, this neutron faces two serious difficulties. In the first place, the classical radiation reaction, roughly estimated, indicates that such an oscillator would be overdamped and hence would not oscillate. Secondly, it is not big enough to oscillate with one quantum of energy without going to pieces so that a quantum picture cannot be invoked in its support. The discussion given indicates, however, that the geometrical conditions of the experiment have an important effect on the value of μ inferred from the observations and this should not be neglected.

[1] Millikan, *Proc. Nat. Acad. Sci.*, **12**, 48 (1926).

[2] Myssowsky and Tuwim, *Zeits. Physik*, **35**, 299 (1925).

[3] McLennan and Burton, *Physic. Rev.*, **16**, 184 (1903).

[4] Rutherford and Cooke, *Ibid.*, **16**, 183 (1903).

[5] Jauncey and Hughes, *Proc. Nat. Acad. Sci.*, **12**, 169 (1926).

[6] Jeans, *Nature*, Dec. 12, 1925.

NEW EVIDENCE IN FAVOR OF A DUAL THEORY OF METALLIC CONDUCTION

BY EDWIN H. HALL

JEFFERSON PHYSICAL LABORATORY, HARVARD UNIVERSITY

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In these PROCEEDINGS for October, 1925, Professor Bridgman, after stating that he has discovered a Peltier development of heat where an electric current changes direction within a metal crystal, remarks, "The mere existence of an internal Peltier heat would seem to have important bearings on our views of the nature of electrical conduction. I cannot see that any of our ordinary pictures of electrical conduction would lead us to expect a reversible absorption of heat on changing the direction of current flow." Shortly after reading this passage I called Professor Bridgman's attention to the fact that a formula which I had published some years ago,[1] as the dual-theory expression for Peltier heat, gives a ready explanation of the newly observed phenomenon. This he at once saw, though he had overlooked it before.

The formula is this,

$$\Pi_{\alpha\beta} = \left(\frac{k_f}{k}\right)_\beta \lambda_\beta - \left(\frac{k_f}{k}\right)_\alpha \lambda_\alpha, \tag{1}$$

where $\Pi_{\alpha\beta}$ is the amount of heat, in ergs, absorbed by the unit quantity of electricity, $(1 \div e)$ electrons, in going from metal α to metal β, $(k_f \div k)$

is the ratio of free-electron conductivity to total conductivity, λ_α is the amount of heat absorbed in freeing $(1 \div e)$ electrons within metal α and λ_β is the corresponding quantity for metal β. Within a single metal crystal α and β refer merely to different directions of current flow, and evidently in this case $\lambda_\alpha = \lambda_\beta$, whereas $(k_f \div k)$ need not be the same for the two directions. Thus the formula reduces to

$$\Pi_{\alpha\beta} = \left[\left(\frac{k_f}{k}\right)_\beta - \left(\frac{k_f}{k}\right)_\alpha\right]\lambda. \qquad (2)$$

In the abstract which heads a recent paper[2] by Doctor Millikan, I find this statement: "The lack of dependence of field currents [drawn from metals by intense electric fields] upon temperature furnishes strong evidence that most of the conduction electrons do not share the energy of thermal agitation. The thermions, however, do share in this energy; they are presumably responsible for the Peltier and thermoelectric effects."

It would require some study to frame within the same compass of words a better statement of my dual theory of conduction than Professor Millikan gives, perhaps unwittingly, in stating the conclusion which he has drawn from the experiments described in his paper. This will be evident to anyone who is familiar with the papers which I have published during the last six or eight years, but, as very few indeed know the contents of these papers, it may be well for me to show here just what I mean.

My λ, in the formula given above, is, when expanded,

$$\lambda = (\lambda'_c + sRT) \div e, \qquad (3)$$

the quantity within brackets indicating the amount of energy required to change one electron from the associated conductive state to the free conductive state. The λ'_c is a constant; the s also is a constant, which, as I have expressly stated,[3] "is always greater than 2.5." The limit 2.5 is fixed because 2.5 RT is the total amount of energy, kinetic and potential, possessed by a monatomic gas molecule, as such, at temperature T. That is, I treat the associated conduction electron as having no energy of thermal agitation, while the free electron has a full quota of such energy. As to the relative importance of free-electron conduction and associated-electron conduction, the greatest value I have found[4] for $(k_f \div k)$ at 0°C., in studying eighteen metals, including two alloys, is about 20 per cent, the smallest value being about 2 per cent. As to thermoelectric action, though both classes of conduction electrons are in my theory taken account of in the discussion of the Peltier effect and of the Thomson effect, the net work of the thermo-electric circuit is attributed entirely to the free-electrons. "In fact, the part which associated electrons play in thermoelectric action is analogous to that played by entrained water in the work done by steam [in a steam engine]. The larger the proportion of water, the smaller is the mechanical effect per unit mass of the mixture."[5]

It will be interesting to see what shape Professor Millikan's conception of conduction takes when it comes to deal expressly and in detail with thermo-electric phenomena.

It is, I think, not inappropriate to mention under the heading of this paper the fact that, on applying the dual theory to the data furnished by Bridgman's experiments on changes of electrical and thermal properties in metals under high pressure, I have found it helpful in showing, or at least suggesting, how all of these changes may be connected in a logical system of interrelations. The methods and results of this study will be published *in extenso* elsewhere.

[1] *Proc. Nat. Acad. Sci.*, **7**, No. 2, p. 63, Feb. 1921.

[2] "Pulling Electrons Out of Metals by Intense Electric Fields: Laws Governing," *Physic. Rev.*, **27**, No. 1, pp. 51–67, January, 1926.

[3] *Proc. Nat. Acad Sci.*, **6**, p. 613 (1920).

[4] *Ibid.*, **7**, pp. 98–107 (1921).

[5] *Ibid.*, **4**, pp. 101–102 (1918).

THE MAGNETIC MOMENT OF THE ELECTRON

By R. DE L. KRONIG

DEPARTMENT OF PHYSICS, COLUMBIA UNIVERSITY

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The large amount of recent work on the analysis and classification of complicated spectra has shown that their formal interpretation can best be accomplished by assigning to every electron two moments of momentum, characterized by quantum numbers K and R, using Landé's notation.[1] While the first undoubtedly is the quantum analogue of the orbital moment of momentum of the electron in the models which have proved themselves so useful a guide in the theory of atomic structure, the significance of R was left open. Led by the fact that R must always be chosen equal to 1, no matter in what orbit or in what atom the electron is bound, Uhlenbeck and Goudsmit[2] have suggested that R might be regarded as the moment of momentum of the electron itself, so that in the model we would have to consider the electron as spinning about an axis of symmetry. Furthermore, these authors[3] as well as Bichowsky and Urey[4] have shown that if the orientation of R with respect to the orbital plane is quantized, then, due to the motion of its magnetic moment in the electric field of the nucleus, the electron would have energies in these orientations whose difference obeys a relativistic doublet formula, going with the fourth power