The Effect of a Transverse Magnetic Field on the Thermal Conductivity of Metals

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LET us consider a metal, in which there is a heat flow $Q = Q_x$ and a magnetic field $H = H_x$. For the calculation of the coefficient of thermal conductivity we use the model of Sommerfeld,[1] according to which the flow depending on the motion of electrons under the action of the temperature gradient is set equal to zero. Accordingly,[2]

$$I_x = -\frac{3ne}{mv^3}\int \xi f v d\varepsilon, \qquad Q_y = \frac{3n}{2v^3}\int \eta f v^3 d\varepsilon \quad (1)$$

and analogously for I_y and Q_x. Here $(-e)$ is the charge on the electron, m is the mass of the electron, v is the velocity, ξ and η are the components of the velocity along the x and y axes, ϵ is the kinetic energy of the electron. The distribution function is taken to have the form

$$f = f_0 + \xi\chi_x + \eta\chi_y, \quad (2)$$

where f_0 is the Fermi distribution function, and the functions χ_x and χ_y (found with the aid of the kinetic equation, in which the term taking into account collisions, was derived by Lorentz[3]) equal:

$$\chi_x = -l(f_1 - qf_2)/v(1+q^2), \qquad \chi_y = -l(f_1 q + f_2)/v(1+q^2). \quad (3)$$

Here l is the length of the mean free path of the electron, and the rest of the variables are defined as follows:

$$q = \omega l/v = (eH/mc)\,l/v; \quad f_1 = \partial f_0/\partial x - eE_x\partial f_0/\partial\varepsilon; \quad f_2 = \partial f_0/\partial y - eE_y\partial f_0/\partial\varepsilon; \quad (4)$$

E_x and E_y are the components of the electric field resulting from the motion of the electrons under the action of the temperature gradient.

Calculation shows that the dependence of l on v for the present problem is immaterial, because the terms containing the derivative of l with respect to v, are small and do not enter into the expression for the coefficient for thermal conductivity $\varkappa$.

Making the usual calculation for the coefficient of thermal conductivity $\varkappa = -Q_x/\partial T/\partial x$ (in the present problem $I_x = I_y = 0$, $Q_y = 0$) with accuracy to the terms $\sim (kT/\bar{\varepsilon})^3$ ($\bar{\varepsilon}$ is the Fermi level), we obtain

$$\varkappa = \varkappa_0\left[1 - \frac{4\pi^2}{15}\left(\frac{kT}{mv^2}\right)^2 \frac{q^2(4+2q^2+3q^4)}{(1+q^2)^3}\right], \quad (5)$$

where $\varkappa_0 = \pi^2 nlk^2 T/3mv$ is the coefficient of thermal conductivity in the absence of a magnetic field.

Approximate calculation shows that formula (5) gives a decrease in the thermal conductivity of less than 0.01% of $\varkappa_0$ in a field of 10,000 Oersteds.

It can be shown that consideration of the effect is necessary for metals of the type of Bi which have a small number of conduction electrons.

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[1] A. Sommerfeld, Z. Physik 48, 51 (1928).
[2] H. Bethe and A. Sommerfeld, Electron Theory of Metals.
[3] G. Lorents, Theory of the Electron.

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Application of the Theory of Random Processes to Radiation Transfer Phenomena

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IN this note the motion of the photon is treated as a random process under the following very general assumptions: the medium is isotropic; its properties may be functions of time and space; the photon may be scattered, absorbed by an atom and reemitted, or absorbed in a collision of the second kind; the polarization of the radiation and the motion of the atom excited by a photon are not taken into account.

We begin with the function

$$f_{\nu_1}^{\nu_2}(\mathbf{r}_1, \eta_1, \nu_1, t_1;\ \mathbf{r}_2, \eta_2, \nu_2, t_2)\, dV_2\, d\eta_2\, d\nu_2,$$