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RESEARCH NOTE

ENERGY LOSSES OF LOW-ENERGY PHOTOELECTRONS TO THERMAL ELECTRONS

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Investigators in ionospheric physics have been using an expression derived by Butler and Buckingham (1962) to calculate the photoelectron energy loss rate to the ambient electron gas. Schunk and Hays (1971) have shown that this expression has been incorrectly applied in photoelectron calculations due to the importance of Cerenkov wave generation and quantum effects for energetic electrons. This note extends the loss rate expression for photoelectrons to thermal energies.

The photoelectron energy loss rate can be expressed in a form given by Itikawa and Aono (1966)

$$-\frac{dE}{dt} = \frac{\omega_p^2 e^2}{v}\left\{J_e\left(\frac{v}{v_e}\right)\ln\frac{2\Lambda}{3\gamma} + \frac{v}{v_e}G_e\left(\frac{v}{v_e}\right)\right\} \quad (1)$$

where

$$J_e(u) = \frac{2}{\sqrt{\pi}}\left\{\int_0^u e^{-x^2}\,dx - 2ue^{-u^2}\right\} \quad (2)$$

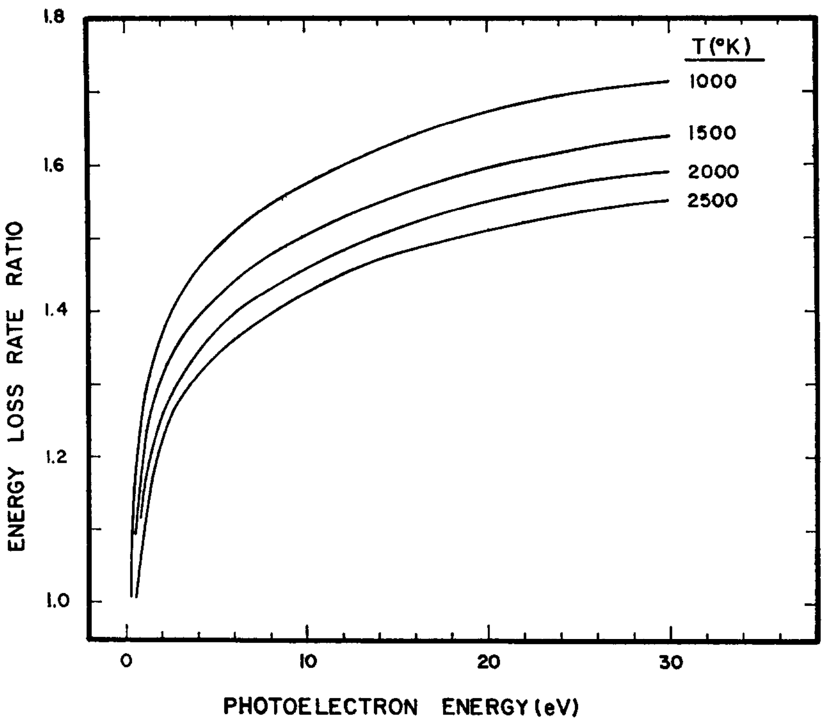

FIG. 1. RATIO OF THE PHOTOELECTRON ENERGY LOSS RATES FOR SEVERAL VALUES OF THE AMBIENT ELECTRON TEMPERATURE.

For these calculations $n = 10^5\ \text{cm}^{-3}$.

TABLE 1. VELOCITY DEPENDENCE OF THE COULOMB LOGARITHM

v/v_e	$(v/v_e)G_e(v/v_e)$
1·0	−0·343
1·2	−0·425
1·4	−0·283
1·6	0·067
1·8	0·551
2·0	1·083
2·2	1·603
2·4	2·069
2·6	2·477
2·8	2·831
3·0	3·135
4·0	4·243
5·0	5·017
6·0	5·618
7·0	6·110
8·0	6·528
9·0	6·890
10·0	7·202

and

$$\Lambda = \frac{3(kT)^{3/2}}{e^3(4\pi n)^{1/2}}, \qquad \omega_p = \left(\frac{4\pi n e^2}{m}\right)^{1/2}. \tag{3}$$

In these expressions ω_p is the electron plasma frequency, m the electron mass, n the electron density, T the electron temperature, k Boltzmann's constant, v the test electron speed, E the energy, $v_e = (2kT/m)^{1/2}$ the electron thermal speed, $-e$ the electron charge and $\ln \gamma$ is Euler's constant. The term $(v/v_e)G_e(v/v_e)$ represents the dependence of the Coulomb logarithm on the photoelectron velocity and contains the energy loss rate due to the Cerenkov emission of plasma waves. The calculation of $G_e(v/v_e)$ was discussed by Itikawa (1963)* and numerical values of $(v/v_e)G_e(v/v_e)$ are presented in Table 1 based on that technique. Figure 1 shows the ratio of the correct energy loss rate to that commonly used in ionospheric physics for several values of the ambient electron temperature. At the higher energies the correct energy loss rate has been calculated from the asymptotic expression given by Schunk and Hays (1971).

In summary, the photoelectron energy loss rate to the ambient electron gas can be obtained for all photoelectron energies from Equation (1) and the asymptotic expression given by Schunk and Hays (1971). For photoelectron energies $E > 49kT$ the asymptotic expression is within one per cent of the complete expression (1).

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* The complete expression for G_e is given in the appendix of a recent review article (Takayanagi and Itikawa, 1970).

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