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APPENDIX

APPENDIX

THE SOMMERFELD EXPANSION

The Sommerfeld expansion is applied to integrals of the form[7]

$$\int_{-\infty}^{\infty} dE\, H(E) f(E) \quad , \; f(E) = \frac{1}{\exp\left(\frac{E - E_f}{k_B T}\right) + 1} , \tag{1}$$

where *H*(*E*) vanishes as $E \to -\infty$ and diverges no longer rapidly than some power of E as $E \to \infty$. If one defines

$$K(E) \;=\; \int_{-\infty}^{E} H(E')\, dE' , \tag{2}$$

so that

$$H(E) \;=\; \frac{dK(E)}{dE} , \tag{3}$$

then one can integrate by parts in (1) to get

$$\int_{-\infty}^{\infty} H(E)f(E)dE = \int_{-\infty}^{\infty} K(E)\left(-\frac{\partial f}{\partial E}\right)dE \quad . \tag{4}$$

Since f is indistinguishable from zero when E is more than a few k_BT greater than E_f, and indistinguishable from unity when E is more than a few k_BT less than E_f, its E-derivative will be appreciable only within a few k_BT of E_f. Provided that H is nonsingular and not too rapidly varying in the neighborhood of $E = E_f$, it is very reasonable to evaluate (4) by expanding $K(E)$ in the Taylor series about $E = E_f$, with the expectation that only the first few terms will be of importance :

$$K(E) = K(E_f) + \sum_{n=1}^{\infty}\left[\frac{(E-E_f)^n}{n!}\right]\left[\frac{d^n K(E)}{dE^n}\right]_{E=E_f} . \tag{5}$$

When we substitute (5) in (4) , the leading term gives just $K(E_f)$, since

$$\int_{-\infty}^{\infty}\left(-\frac{\partial f}{\partial E}\right)dE = 1 \; .$$

Furthermore, since $\partial f/\partial E$ is an even function of $E - E_f$, only terms with even n in (5) contribute to (4), and if we reexpress K in terms of the original function H through (2) , we find that :

$$\int_{-\infty}^{\infty} dE\, H(E) f(E) = \int_{-\infty}^{E_f} H(E) dE + \sum_{n=1}^{\infty} \int_{-\infty}^{\infty} \frac{(E-E_f)^{2n}}{(2n)!} \left(-\frac{\partial f}{\partial E}\right) \frac{d^{2n-1}}{dE^{2n-1}} H(E)\Big|_{E=E_f} .(6)$$

Finally, making the substitution $(E-E_f)/k_B T = x$, we find that

$$\int_{-\infty}^{\infty} dE\, H(E) f(E) \;=\; \int_{-\infty}^{E_f} H(E) dE + \sum_{n=1}^{\infty} a_n (k_B T)^{2n} \frac{d^{2n-1}}{dE^{2n-1}} H(E)\Big|_{E=E_f} ,(7)$$

where the a_n are dimensionless numbers given by

$$a_n = \int_{-\infty}^{\infty} \frac{x^{2n}}{(2n)!} \left(-\frac{d}{dx} \frac{1}{e^x+1}\right) dx . \qquad (8)$$

This is usually written in terms of the Riemann zeta function, $\zeta(n)$, as

$$a_n = \left(2 - \frac{1}{2^{2(n-1)}}\right) \zeta(2n) , \qquad (9)$$

where $\zeta(n) = 1 + 1/2^n + 1/3^n + 1/4^n + ...$ (10)

CURRICULUM VITAE

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