thorough and logical, analyzing the "security" and the practical political factors with great care. One does not need to have access to classified information to become an expert on arms control. Dr. Stone dug the necessary factual information out of newspapers, magazines, and the *Congressional Record*. One *does* have to apply imagination and analysis and political intuition. This is a timely and stimulating book on a most vital topic.

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AN ILLUMINATING DISCUSSION !

Title Radiative Contributions to Energy and Momentum Transport in a Gas

Author D. H. Sampson

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Reviewer Baxter H. Armstrong

This monograph might more appriately be called "Mathematics of Radiative Contributions to Energy and Momentum Transport in a Gas," or "Formal Theory of . . . ," as it is not the practical treatise the preface might be taken to indicate. Fortunately, there are a number of significant formulas and discussions not to be found (or at least difficult to find) elsewhere. It is disappointing, however, that the reader has to slog through so much poor composition and grammar to find them. Also, the text does not appear to have been proofread with much care; for example, the title to Chapter 7 alone contains two misspelled words. (At least, the typographical errors appear to occur mostly in the text, rather than in the equations.) A particularly annoying peculiarity appears systematically in the format of the equations: the exponential function of an argument x, $\exp(x)$, is often disengaged from its argument with the exp on one line and the argument (sometimes even without parentheses!) on the next line. This seems surprising for an experienced publisher.

The author's prepossession with formality occasionally obscures the more important physical concepts by diverting attention to unnecessary details. There is also a certain inconsistency in his presentation: in the preface he states his purpose, "to . . . provide a tract which . . . will be of use . . . (in) radiative transport problems involving almost any conditions of gas density and temperature." However, he fails to separate important effects into their respective domains of importance. For example, Chapter 8, "Applications of Surface Concepts," begins with time-retardation ($t \rightarrow t - r/c$, where t is time, r is distance, and c is the velocity of light) being included. But at temperatures for which (it seems to me) this could possibly be of importance, there could be no surfaces or walls of any kind—as the author himself indicates on page 3 of the Introduction. In fact, it would have been most interesting if the author had indicated somewhere in the book the practical significance, if any, of the time retardation effect, and of the effects he considers of solving the transport equation in a noninertial frame. This significance is not at all obvious in a field where the calculated and/or measured quantities (emissivities, etc.) rarely are determined to an accuracy of better than 50%—particularly at temperatures above a few thousand degrees. Without such indication, these aspects would appear to remain as superfluous pedantic exercises. A few numbers would go a long way in adding some physical intuition and insight into the presentation. Although somewhat more obvious, the practical significance of Lorentz transformations and availability of final states (both of which the author treats in considerable detail) to problems in radiative transfer, is not satisfactorily indicated. This would have been a valuable service, as these topics are not covered (in this context) in any other book I know of, and yet are certainly important under the proper circumstances.

It doesn't require many of the above-listed shortcomings to make a book appear to be merely an attempt to demonstrate the author's erudition, rather than to educate the ignorant. I am sure this was not this author's motive, but a somewhat better organization of the material and attention to physical reality would prevent the suspicion from arising. In the author's favor, it should be pointed out that he has had the courage to write on a difficult subject about which little has been written. Very few books deal meaningfully with laboratory or terrestrial applications of radiative transfer, and a brief glance at the principal contenders shows Mr. Sampson's tract not to suffer at all by the comparison. In view of this, some more detailed comments are perhaps in order, which will provide the interested prospect with a more definite idea of what the book is about.

In Chapter 1, the author writes down the general Boltzmann transport equation for the distribution function, defines its constituent terms, and the various transport properties (mass, momentum, energy) that can be obtained from this equation or from this distribution function, once it is known. He concludes the chapter with a brief discussion of electron degeneracy. This particular discussion is necessary, but is the same as given in many books. It ends with the usual statement for the condition of nondegeneracy:

$$e^{\eta_e} = (N_e/2)[(h^2/2\pi m_e kT)^{3/2}] \ll 1.$$

This affords an illustration of my earlier remarks. It is often possible to rephrase an old, but essential argument to convey a little more physical insight. This could be done here by noting that $(h^2/2\pi mkT)^{1/2} \equiv \lambda_T$ is the thermal de Broglie wavelength, and that this condition, requiring that $e^{\eta_e} = \frac{1}{2}N_e\,\lambda_T{}^3 \ll 1$ is tantamount to the requirement that there be very few particles in a "thermal de Broglie cube." This condition is usually met in gases, and this type of description would render more perspicuous the author's otherwise excellent discussion, on page 13, of the availability of final states. He also mentions, without explanation, that photons have zero chemical potential $\eta_e kT$. This potential, and the above degeneracy condition, arise through the conservation of the number of particles (N_e). Since the number of photons is not conserved (they are continually being created and destroyed), their chemical potential must be zero, and they are, effectively, always degenerate by the above condition.

In the second chapter, the author specializes the Boltzmann equation (usually written for material particles only) to photons, and reduces it to the radiative transport equation. This is an illuminating discussion which is quite worthwhile. It enables one to consolidate background intuition in kinetic theory with that in radiation theory. As another example of the author's not properly stating or defining regions of applicability, see the footnote on page 10. Here the author makes the categorial statement that Φ_ν, the force on a particle, is completely negligible for photons, as though it is always completely negligible. This is certainly true for practical terrestrial and laboratory conditions. However, the author, with his astrophysical overtones, never explicitly restricts himself to these conditions, but wants to sit on the fence of "almost any conditions." In this vein, I would like to point out that it is just the (effective) gravitational force on a photon that produces the gravitational red shift and deflection of light rays. Also in this chapter, the author discusses bosons and fermions and their statistical definitions without connecting their identifications with the spins of the particles. Since at least part of his intended audience are engineers, these specialized names, along with the "well-known Klein-Nishina formula" (page 18), may not convey sufficient information.

Chapter 3 is devoted to the general features of the macroscopic radiative transport equations, and the combining of the matter and radiative contributions. In Chapter 4, which is very short, he writes down the general formal solution to the radiative transport equation in several alternative forms. Chapter 5, entitled "Specific Applications of the Solution to the Radiative Transport Equation," is really not devoted to applications at all, in the usual sense of the word, but to the limiting optically thin and thick cases wherein relatively simple solutions to the transport equation exist. An error in the footnote on page 54 should be noted: (ν/ν_{0i}) in this footnote should be raised to the fourth power. The discussion of the effects of scattering in Section 5.4 is quite good: the author's personal interests have, to some extent, centered in this area. However, I find the explanation on page 59 of the effect of scattering on the criterion of optical thickness particularly convoluted. It sounds to me as though he contradicts himself several times. A reference would have been in order at the bottom of the page: the name Greenstein stands in splendid isolation.

In Chapter 6, the transport equation is specialized to the case of one-dimensional problems, and cast in forms which prepare for the introduction of the surface concepts that are discussed in the next chapter. Absorptivity, reflectivity, transparency, and emmissivity are introduced, although the treatment is very formal. The frequency-integrated versions of these quantities require a weighting by the spectral flux. He remarks (bottom of page 83) that in spite of this dependence on the flux, these coefficients are often assumed to be functions of the material properties alone. He goes on to say, "Nevertheless, this assumption is fairly good in *many* cases because for *some* materials the spectral coefficients are almost independent of frequency." Aside from the strange language (which I have italicized) that leaves one wondering a bit, this statement would bear further elucidation. If it is true, it must be limited to relatively low temperatures, as a good part of the burden of the next chapter rests on pointing out the inadequacy of such an assumption at high temperatures. The generality or limitations of such important simplifying assumptions constitute much of the lore and experience to be gained from a given field, and are well worth as much space in a book as the formal mathematics.

In Chapter 8, the author does come close to applications in the usual sense of the word. He obtains and discusses expressions for the energy emitted by models (slabs of gas with emitting boundaries) of considerable practical significance, and gives the approximate simple formulas valid when these systems are optically thin (as well as the more complicated formulas of the general case). At the end of this chapter, there is a discussion (Section 8.3) which is somewhat less satisfactory than most of the book. Surprisingly enough, it is a section in which the author is not being formal or mathematical; in fact, he is not being mathematical enough! The author is concerned in this section with an attempt to reduce the general spectral transfer equation to a "grey-gas" equation by use of appropriate frequency averaged quantities. Ultimately, this reduction depends upon a properly defined mean absorption coefficient, or equivalently, mean optical depth. His suggestion, based on one of his own publications, is to replace the optical depth that appears in the transfer equation by a simple rational function of the "Planck optical depth' and "Rosseland Optical depth," which reduce to these quantities in the thin and thick limits, respectively. These quantities are

$$\tau_P \equiv \int_0^y K_P(y')\, dy', \quad \tau_R \equiv \int_0^y K_R(y')\, dy',$$

where K_P and K_R are the Planck and Rosseland mean absorption coefficients, and y, the geometric depth. Although the demonstration of the effectiveness of this procedure which he cites is purely empirical, the procedure is probably a reasonable one. However, in leading up to this suggestion, he has a page of discussion devoted to the effect of the frequency dependence of the absorption coefficient K_ν in producing a difference between K_P and K_R. Specifically, he states that the strong frequency dependence of K_ν, shown by the results of calculations of this quantity above 1.7×10^4°K, produces a K_P that is one or two orders of magnitude larger than K_R. This entire discussion implies heavily, but never states, that K_P is *always* greater than K_R (if the same contributions are included in each). It would have been much simpler and more satisfactory to simply say that it is always true (as I showed in a theorem published in 1962). The specific statement is that

$$K_P \geq 0.950\, K_R,$$

independent of the material or the circumstances of the problem in any way. The author states that for K_P and K_R to be nearly equal, the frequency-dependence must be very slight " . . . as a consequence of the strong frequency-dependence of $dB_\nu(T)/dt$ and $B_\nu(T)$, and the fact that in one case . . . K_ν occurs in the denominator of the (defining) integrand, while in the other case . . . it occurs in the numerator." This is all true except for the remarks concerning the frequency-dependence of $B_\nu(T)$ and $dB_\nu(T)/dT$ which is of almost no importance to the argument (its scale of variation is usually much slower than the scale of variation of the absorption coefficient). This can be demonstrated as follows: The theorem mentioned above is based on the Schwartz inequality; dropping the Planckian weighting functions entirely causes it to become almost trivial. One can state that

$$(\Delta x)^{-2} \left[\int_0^{\Delta x} (k)^{-1/2}(k)^{1/2}\, dx\right]^2$$

$$\leq \left[(\Delta x)^{-1} \int_0^{\Delta x} \frac{dx}{k}\right] \left[(\Delta x)^{-1} \int_0^{\Delta x} k\, dx\right].$$

Since the left-hand side is obviously just unity, one obtains $k_H \leq k_D$, where the harmonic average

$$k_H^{-1} \equiv (\Delta x)^{-1} \int_0^{\Delta x} dx/k$$

corresponds to the Rosseland mean without its weighting function, and the direct average

$$k_D \equiv (\Delta x)^{-1} \int_0^{\Delta x} k dx$$

corresponds to the Planck mean without its weighting function (or in either case, to means defined locally, i.e., for small regions of frequency over which $B_\nu(T)$ and $dB_\nu(T)/dT$ do not change appreciably). From this and the aforementioned difference in the scales of variation of $B_\nu(T)$ and K_ν, one sees that the frequency-dependence of the Planck function and its derivative does not have much effect on the relative values of K_P and K_R. It does, however, prevent them from ever being closer than five percent to equality *even when the absorption coefficient is constant.*

Chapter 9 is a brief and not very useful discussion of nonequilibrium radiation. [See the review of this book by R. Landshoff, *Phys. Today*, **19**, 81 (1966).] The last chapter is a considerably more useful and practical discussion of the conditions required for the existence of local thermodynamic equilibrium. The overly formal tone of some of the previous chapters is not evident here.

The Appendixes appear to be excellent; I have no quarrel with them whatsoever in the light of what one considers an appendix should be. As Dr. Sampson surmised in his preface, some readers will find the Appendixes more useful than the book. They would, for example, provide a sound starting point for the answering of the questions and filling in of the omissions I have noted above.

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REFRESHING REMINDER

Title Beta Decay

Authors C. S. Wu and S. A. Moszkowski

Publisher John Wiley & Sons, Inc., 1966

Pages xiv + 393

Price $16.00

Reviewer Theodore B. Novey

This combination of authors who are well known for the clarity of their experimental and theoretical work has provided a very clear, concise, and valuable contribution to the literature on the weak interactions. As the reviewer has lived through a number of the recent historical stages in beta decay and the weak interactions, it is very fascinating to see the book put together with an emphasis on the historical development simultaneously blending in a large amount of useful reference data.

The book begins with a historical summary giving an insight into the strands of research which branched out and were picked up at various points of time with a series of startling discoveries, and which have brought our knowledge of the weak interactions to its present-day state. A quite comprehensive review of the early theory and development of measurements in beta decay follows, including beta-ray spectra, beta-gamma angular correlation, and all of the various other topics in nuclear spectroscopy which have been active for many years. The exciting experiments of 1957 and subsequent years on parity nonconservation are described, and a very clear summary is given of each of the major experiments of that period. Each experiment is discussed in sufficient detail so that one gets a clear picture of what was done and why.

There follow sections on electron capture, double beta decay, low-energy neutrino and antineutrino physics, leptonic decay of muons, pions, and strange particles. The transition and the interchange of people and ideas and experiments between low energy and high energy physics is made with no difficulty. It is refreshing to be reminded that in this field the barriers between high- and low-energy physics have not been very obvious and that experiments have been done in a way which has brought new developments from both fields. The book ends with some of the recent developments of the treatment of the weak interactions under the conserved vector current hypothesis, the experiments made in the expectation (so far unfulfilled) of discovering the intermediate vector boson, and the high-energy physics experiments leading to the discovery of the existence of two neutrinos, and an indication of the paths which may next be explored.

The main section of the book is followed by a very excellent set of appendixes which will serve as a very useful reference for both novices and specialists in the field. The appendixes summarize relativistic and nonrelativistic transformations involved in beta-decay theory, the Dirac equations, some simple der-