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IMPULSE HEATING BY RADIATION*

Reviewed by L. M. Biberman

The technique of impulse heating of bodies by electromagnetic or particle radiation is presently of great significance in various scientific and industrial fields. This state of affairs has been stimulated by the development of powerful pulse radiators, lasers, powerful explosive devices, plasmotrons, electron guns, nuclear reactors, etc. Many scientific studies and industrial applications of brief transient physical phenomena, the development of pulsed measurement methods, and the use of pulse radiation heating in laboratory experiments and industrial tests has produced great interest in the problem of pulse heating of bodies by radiation. Many pressing problems of scientific and engineering significance are related to this phenomenon.

Thus, the appearance of the book reviewed here is most opportune, all the more so since no other Soviet or foreign books of this type are available.

In Grigor'ev's book, in contrast to other works on heat exchange by radiation, a complete analysis of the characteristics of pulse radiation and radiation heating is offered with a study of the transient temperature fields created.

The presentation concerns itself mainly with optical radiation, but is structured so that the material may easily be applied to other forms of electromagnetic and corpuscular (electron and neutron) radiation.

The book generalizes material from the literature (up to 1973-1974) together with results of the author's own studies, some of which are published here for the first time.

The first part of the book consists of two chapters dedicated to the characteristics of pulse irradiation and radiant heat transfer. Of undoubted usefulness, especially to specialists in kindred fields and engineers, are the introductory sections of both chapters, where together with a review of basic radiation and thermophysical concepts and parameters, there are presented brief definitions of equilibrium conditions for the processes considered and limits of applicability of corresponding formulas.

The first chapter briefly considers the types of radiators useful for pulse radiant heating of bodies, and gives their physicotechnical characteristics. Then optical geometric, energy, and time characteristics of various radiators, and formulas and tables for calculation of the irradiation of a plane element at any orientation to the radiator are presented. One must note the originality and depth of the presentation of questions concerning diffuse and volume radiators having the form of a sphere or spherical segment (these include the sun, the radiating bodies in a carbon arc, and explosive radiation sources). A method for calculating the irradiation of moving bodies by such sources is also given. The characteristics of radiation propagation and absorption are considered for planar bodies, and a method is proposed for approximate calculation of irradiation fields within bodies upon nonuniform irradiation, and the conditions for transition to nonlinear absorption are evaluated.

The second chapter presents characteristics of pulse radiant heating of planar bodies with volume and surface absorption of radiation, based on solution of thermal conductivity differential equations of various types. Elementary functions are selected and presented in dimensionless form. These functions permit approximation, either directly or by superposition and combination, of practically arbitrary spatial–temporal heat source distributions produced by radiation absorption. The evaluation of permissible limits for neglect of propagation speed and nonlinearity of absorption, as well as neglect of roughness of the irradiated surface, is interesting and original.

The second part of the book consists of four chapters dedicated to transient temperature fields formed by radiant heat pulses in an infinite plate, and semiinfinite and finite bodies.

*Parts 1 and 2, Nauka, Moscow (1974).

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The third and fourth chapters employ Fourier and Hankel integral transforms to derive general solutions of the three-dimensional linear boundary problem of thermal conductivity with heat sources and boundary conditions of the second type in Cartesian and cylindrical coordinate systems. An original dimensionless treatment of these results is then presented.

Of great practical value is the author's method for engineering calculations and comprehensive summary of dimensionless solutions corresponding to the set of elementary functions presented in the second chapter, complemented by an analysis of ten characteristic problems of radiant impulse heating of bodies.

The fifth chapter proposes simplified methods for temperature field determination, then analyzes errors produced by neglect of the speed of heat propagation, heat transfer to the external medium, heat loss by natural thermal radiation, and the dependence of physical parameter values on temperature. Original maximized error estimate methods are developed for each simplification and assumption.

Especially interesting is the express method of choosing a simplification method with the aid of special diagrams. It is concluded that it is possible to neglect thermal conductivity in determining temperature fields in dielectric bodies for times exceeding the thermal relaxation time by several orders of magnitude.

The sixth chapter presents the thermophysical principles of measuring the most important parameters of impulse radiation and radiant heating using devices and methods in the development of which the author has made a significant contribution. Detailed recommendations are given for determining measurement uncertainties by methods described in Chap. 5.

Grigor'ev's book is of undoubted positive value. The author fully and comprehensively analyzes the very wide range of impulse irradiation and radiant heating conditions actually encountered in solution of engineering problems. He also includes various necessary reference data.

The book is written in a clear concrete style at a contemporary scientific level. It will be of use to both scientists and engineers, specialists in thermophysics, applied optics, light and solar technology, instrumentation and atomic, laser, rocket, and space technology.

The book was published in a small printing (2400 copies) and has rapidly become unavailable. Considering the increasing interest in the subject and the rapid rate at which new data in the field are being accumulated, preparation and publication of a new expanded edition in the near future would be desirable.