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★Radiation in enclosures. (English summary)

Elliptic boundary value problem.
Scientific Computation.
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This graduate textbook deals with both the formulation and the general solution of the radiative heat transfer problem in enclosures of any geometrical shape, and for any temperature distribution and material properties. The book is essentially self-contained and includes a brief historical survey. The foundations are carefully discussed from the point of view of the exact mathematical basis of boundary value problems and their variational solutions as well as of the physical foundations. The computational methods developed by the authors are used in engineering applications. Existence, uniqueness, and reliability of the solutions are shown in the monograph. Convergence and robustness of the numerical approximation are also established. Error estimates and optimal order of convergence of the numerical solution, in the sense of finite elements, are derived and demonstrated.

The book consists of ten chapters. The first chapter presents thermal radiation and a short historical background. Some concepts of boundary value problems are recalled and the basis for their variational solution is underlined. The methodology presented in this chapter is then implemented and detailed in the remaining chapters.

The second chapter describes the physical model considered. In this chapter, the equation of transfer for local intensities and its integral along a single line of sight are derived. The properties pertinent to radiation and the radiative flux are examined. The energy balance relations are then presented and the equation of transfer is formulated for local radiative heat fluxes. The third chapter reviews the developments in the computational methods presently used in radiative heat transfer applications in engineering. These methods are roughly classified into those based on the integrated directional equation of transfer and those based on the net energy balance relations. This review is followed by a description of the equation studied further on. The fourth chapter focuses on establishing a unified theory for the solution of the radiative transfer equation in enclosures. In this chapter, a formulation of a satisfactory mathematical problem and a study of the analytical properties of the solution are developed. Also, a considerable part of this chapter is devoted to the questions of existence, uniqueness, proper posing of the problem and analytical form of the theoretical solution. The fifth chapter is concerned mainly with a representation of the solution in terms of data and related questions, and presents a detailed analysis of the numerical solution. In this chapter, an approximate problem of radiant energy transfer is formulated. Existence and uniqueness of the associated solution are demonstrated on the basis of the variational principle and the finite element method, and the algorithm for numerical calculations is outlined.

The sixth chapter outlines simulations in some specific cases of radiative transfer. Chapter seven describes the theoretical models often used for computing the spectral properties of infrared-

radiating gas species encountered in industrial furnaces. The eighth chapter, concerning an industrial furnace, illustrates the application of the solution procedure for calculating fluxes to the heat sink. To this end, the radiant energy exchanges are computed for four flames: three natural gas flames and a propane flame. The flames were generated in Furnace No. 1 at the International Flame Research Foundation. The chapter provides a comprehensive validation of the mathematical procedure developed against the measured data (fluxes). Chapter nine deals with both radiative heat transfer in systems where the effects of scattering on the overall radiation exchange are not negligible, and the coupling of radiation with conduction and/or convection heat transfer. A general overview of the book is given in the last chapter.

Reviewed by *P. Rochus* (Liège)