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Chapter 1 : Radiative Transfer And Interactions With Conduction And Convection by Ozisik

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To overcome these complications, one can make some simplifying assumptions concerning the model, restrict the consideration by 1D or 2D geometry, and apply numerical methods. It can be true at sufficiently low temperatures. In this case the problem becomes uncoupled and a linear one. In fact in this case one can treat temperature field as a prescribed function of spatial coordinate and time and concentrate his effort on solving the radiation transfer problem. Such approximation was used by many authors to study 1D radiation transfer problems see, for examples, monograph [1] and [4 â€" 6]. The principal difficulties in solving the problem in this case are the presence of the scattering integral in RTE and nonlocal boundary conditions, arising when scattering of radiation by the boundary is taken into consideration. There are several effective approaches to overcome this difficulty. Among them is the method of discrete ordinates, in agreement with which RTE is solved for a set of discrete directions, each of which is associated with a solid angle in which the intensity is assumed to be constant [7 , 8]. Another method, known as spherical harmonic method, consists in a Legendre expansion of the radiation intensity and the phase function in the radiation transfer equation [4 â€" 6]. The heat transfer problems in the coupled conductive-radiative formulation are fundamentally nonlinear. Whereupon HCE contains the divergence of the total energy flux including two components, conductive heat flux and radiative energy flux. The conductive flux can be presented, in agreement with Fourier law, as or with the use of generalized form, as. Here is specific heat conductivity, denotes the gradient operator, and stands for relaxation time. These two presentations lead to parabolic and hyperbolic HCE correspondingly. To make these equations well defined the flux should be determined. Hence, to determine one should anyway solve RTE, which, in turn, is depending on the temperature field. Examples of solutions of such coupled problems for a plane layer with the use of numerical methods can be found in [6 â€" 9]. Parabolic HCE was used in [6 , 9], in which temperature field in semitransparent medium subjected to a pulse irradiation was studied numerically. In [9], in particular, implicit central-difference scheme was employed for solving HCE, while a discrete curved ray-tracing method was used to solve RTE. In [7 , 8], the hyperbolic HCE was used in studying of non-Fourier effects on transient coupled radiative-conductive heat transfer in one-dimensional semitransparent medium subjected to a periodic irradiation. We would notice here that the results of numerical study presented, in particular, in [9], were obtained for the layer of optical thickness , that is, for optically thin medium. In [8], where the influence of on temperature field in the layer was studied, the maximum used value of optical thickness was taken to be equal to 1. The reason is the presence of two spatial scales in the problem: As a consequence, the coefficient at the highest spatial derivative in HCE decreases with increasing of as. This becomes apparent in occurrence of so-called boundary layer of thickness of order at sufficiently large. The temperature and radiation intensity are sharply varied in the boundary layer. Whereupon the problem becomes singularly disturbed at large , special approaches should be used to analyze it numerically [10]. In this approximation, radiation flux is also taken to be proportional to temperature gradient , where.

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CRCC occurs between a surface in contact with a moving medium and between various components of dust-loaded flows, the moving medium being considered not only as gas and plasma, but the condensed state as well. Here, self-consistent heat transfer means, in essence, that each of the above-mentioned mechanisms influences to the same extent the energy balance inside and or on the boundary of the domain considered and thereby changes the energy exchange intensity by other mechanisms. The combined action of radiative, convective and conductive heat transfer must be considered when solving a wide class of heat and mass transfer problems in such fields as power, aerospace and process engineering. Heat transfer in hypersonic flows around bodies moving in planetary atmospheres; Heat transfer in arcs, microwaves and optical plasma generators, in combustion chambers and nozzles of rocket engines gaseous, liquid and solid propelled rocket engines; plasma, nuclear and laser rocket engines , in furnaces of steam boilers and other power facilities; Heat transfer in various gas discharges and in intensive shock waves, combustion fronts and laser deflagration waves; Heat transfer in thermal protection materials, in combustion in semi- transparent porous matrices, in laser and plasma engineering, in electronic engineering, etc. CRCC is the most general type of heat transfer; in this general case of heat transfer in a moving medium, all the three mechanisms act. However depending on medium temperature, velocity, density, geometry and optical and physical properties , it is possible for one or two mechanisms to dominate. In these limiting cases, heat transfer may be designated as "convective", "conductive," "radiative," "conductive-convective," "radiative-conductive" and "radiative-convective" heat exchanges. When solving problems of CRCC in whichever mechanisms of the heat transfer are important, a useful first step is to determine the influence of radiation on the moving medium parameters. If this influence is small, one can simplify the problem, treating the medium motion and the radiation heat transfer separately. The problems are then solved successively by the methods for a moving media and for radiation heat transfer â€” the combined action of the mechanisms being taken into account using the additivity principle. In the case of such weak interaction account may be taken of the interdependency of the processes using perturbation methods. This case is the most complicated one in the CRCC problem. To describe the CRCC processes mathematically and estimate how important is each of the heat transfer mechanisms, the following systems of equations are used [Pai]; [Bond et al. In 1 and thereafter, we use tensor designations, the summation is over repeating indices. In most problems of CRCC at temperatures lower than 20, K , one can neglect the radiation stress tensor. Transport equation for selective radiation. When solving problems of CRCC concerned with nonrelativistic motion of a medium, the unsteady term on the left-hand side of Eq. To solve CRCC problems for multiphase, niulticomponent and multitemperature media, one should formulate similar equations for each component and include models, where appropriate, for the turbulent motion of the radiating gas. The necessary steps to solve particular problems arc: Development of relationships for the thermodynamic, thermophysical, transfer and optical properties of the media; Formulation of initial and boundary conditions, including the specification of thermophysical, physicochemical and optical properties of surfaces; Solution of the problem for gas flow with internal heat sources; Solution of selective radiation problems and determination of the radiation flow fields and their divergence. If the radiation stress tensor is negligibly small compared with the viscous stresses, then the radiational energy influences the medium motion described by Eqs. There are problems in estimating the latter value, since it characterizes the photon mean free path averaged over the entire frequency spectrum, while the spectral mean free paths vary a few orders of magnitude. In this last equation, kp is the mean Planck absorption coefficient. If the medium is optically thin for certain wavelengths and thick for others, the above-mentioned approximations for the radiation flux and its divergence cannot apply. Instead, the transport equation 4 must be solved. For a highly-scattering medium, the integro-differential form of Eq. This approximation appears to be even more justified in this case than in the nonscattering case, where it can also be recommended for application. CRCC problems have been intensively studied theoretically and experimentally since the mids and are central to the achievements in aerodynamics and plasma-dynamics, astrophysics, in nuclear reactor theory, shock waves, and high temperature physics. The classical problems of CRCC are problems of viscous, heat conductive radiating gas flow in shock and boundary layers, and of Couette flow in radiation magnetogasdynamics. All CRCC regimes appear in the problems of laser wave deflagration, which are analyzed for optical plasmatron and for laser thruster development. For a small laser beam, laser-supported plasma moves to meet the radiation due to the heat conductivity mechanism, giving rise to motion of the surrounding gas. When laser beam size increases, the heat conductivity mechanism for plasma motion is replaced by a radiational one due to the absorption of radiation in the cold gas surrounding the plasma.

Chapter 3 : Heat transfer - Wikipedia

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Combined radiation and convection occurs between the boundary surfaces and the surrounding medium, between the surfaces separated by the moving medium and inside the moving medium. Depending on conditions in the medium, geometrical factors and surface state, regimes of strong and weak interaction between radiative and convective heat transfer are possible. For weak interaction, problems of heat transfer by radiation and convection can be solved successively and independently, while for strong interaction, these processes are essentially interdependent. Thus, energy transfer by one mechanism can influence heat exchange by the other mechanism and vice versa. Simultaneous radiative and convective heat transfer is taken into account when solving many problems of heat transfer for hypersonic flows around aircraft, for steam boilers, for aircraft and rocket engines for plasma generators, as well as of heat transfer in shocks, deflagration and detonation fronts and laser deflagration waves for various discharges. Mathematical formulation of combined radiation and convection problems includes the continuity equation, the momentum in the Euler or Navier-Stokes forms and energy conservation equations, the state equation and relations for thermodynamic, thermophysical transport and optical properties. The energy conservation equation has no terms corresponding to conductive heat transfer and is of the dimensionless form 1 All the letters and symbols in the above equation are defined in the article on Coupled Radiation, Convection and Conduction. That fact that there are no conductive terms in 1 means that heat conductivity is of no importance in the problem, both for the temperature field formation in the moving medium and for its heat transfer with the surface. Thus, heat conductivity can be ignored for small temperature gradients and when the sharp temperature front is replaced by a contact discontinuity. Obviously, in the latter case, the information on temperature distribution at the front is lost and the medium thermal state on both sides of the contact discontinuity should be determined without heat conductivity. When analyzing combined radiation and convection, the Boltzmann criterion can be represented in the form of the convective to radiative heat flux component ratio 2 The classical problem of combined radiation and convection is the problem of steady-state gas flow across a flat plate at a constant temperature [Sparrow and Cess]. Even such simplified and idealized problem has been addressed by a wide spectrum of methods with a range of results obtained; this is caused by the very complicated radiation problem. For example, in a "grey" gas without scattering and using the exponential approximation of the kernel of the integro-differential equation obtained from 3 by substituting qR, y for the plane layer, the following solution has been obtained by [Sparrow, E. When gas heat conductivity is excluded, any solution of 3 has a temperature discontinuity. Combined radiation and convection in flow across a flat plate. When solving the heat protection problem for flight vehicles entering the dense atmosphere at superorbital velocities the combined radiation and convection approximation appears to be very useful and fruitful. Therefore, the thin boundary layer where the convective flow forms can be neglected. The problem where heat protecting material failure is taken into account is the more realistic one. In this case, in a stagnation streamline the shock layer structure can be represented as two oppositely-directed mass flows separated by a thin transient layer in which the viscosity is essential. Replacing the thin transient layer by a contact surface allows the exclusion of viscosity and thermal conductivity. Considering the flow to be steady-state, the governing equation system can be formulated [Olstad] as: In problems of radiating shock layers, the radiation transfer is considered, as a rule, to be as in a plane-parallel layer, this is justified by a small thickness of the layer. In this situation, radiation transfer strongly influences the shock layer parameters, hence, the problem can be attributed to the class of strong interaction of radiation and convection. Problems on laser wave deflagration applied in laser rocket engines and in the optical plasmatron are also problems involving the strong interaction regime. The plasma exists due to laser energy absorption. The heating rate of the cold gas by heat radiation essentially exceeds that by heat conductivity, even for extremaly high temperature gradients in the laser deflagration wave. The process runs usually at atmospheric or higher pressures, and this makes it possible to use the equilibrium approximation for the thermodynamic medium state and an equation system similar to 5. The main difference is that the integral radiation flux vector is represented as a sum where qR, T and qR, L are the vectors of integral heat flux density and laser radiation flux density, respectively. To obtain the function qR, T the two-dimensional equation for selective radiation transfer must be solved, while for qR, L the geometrical optics approximation may be employed. Combined radiation and convection problems concerned with calculations of heat transfer in devices such as steam boiler furnaces are widely encountered in engineering practice [Siegel and Howell ; Ozisik]. The temperature of the furnace medium multicomponent disperse system of gas and solid phases is maintained by combustion, and the general configuration of the temperature field in the furnaces is determined mainly by convective processes formed when the gas-dust component flows in a working space. The surfaces are heated principally by radiation heat transfer from the furnace medium; therefore, the heat conductivity contribution is neglected when computing real furnace steam boilers. Analyzing the combined radiation and convection processes in furnaces, the transfer equation for this complicated geometry should take into account the radiation scattering and absorptive properties of the furnace medium with various additives the properties of which are hardly known as well as the optical-physical characteristics of the heat-receptive surfaces.

Chapter 4 : Coupled radiation and convection

Radiative transfer and interactions with conduction and convection [by] M. Necati Ã–zÄ±ÅŸÄ±k.

Climate models[edit] Climate models study the radiant heat transfer by using quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice. Heat equation[edit] The heat equation is an important partial differential equation that describes the distribution of heat or variation in temperature in a given region over time. In some cases, exact solutions of the equation are available; [22] in other cases the equation must be solved numerically using computational methods. System analysis by the lumped capacitance model is a common approximation in transient conduction that may be used whenever heat conduction within an object is much faster than heat conduction across the boundary of the object. This is a method of approximation that reduces one aspect of the transient conduction systemâ€”that within the objectâ€”to an equivalent steady state system. That is, the method assumes that the temperature within the object is completely uniform, although its value may be changing in time. For small Biot numbers, the approximation of spatially uniform temperature within the object can be used: Heat-transfer principles may be used to preserve, increase, or decrease temperature in a wide variety of circumstances. Insulation, radiance and resistance[edit] Thermal insulators are materials specifically designed to reduce the flow of heat by limiting conduction, convection, or both. Thermal resistance is a heat property and the measurement by which an object or material resists to heat flow heat per time unit or thermal resistance to temperature difference. Radiance or spectral radiance are measures of the quantity of radiation that passes through or is emitted. Radiant barriers are materials that reflect radiation, and therefore reduce the flow of heat from radiation sources. Good insulators are not necessarily good radiant barriers, and vice versa. Metal, for instance, is an excellent reflector and a poor insulator. The effectiveness of a radiant barrier is indicated by its reflectivity, which is the fraction of radiation reflected. A material with a high reflectivity at a given wavelength has a low emissivity at that same wavelength , and vice versa. An ideal radiant barrier would have a reflectivity of 1, and would therefore reflect percent of incoming radiation. Vacuum flasks , or Dewars, are silvered to approach this ideal. In the vacuum of space, satellites use multi-layer insulation , which consists of many layers of aluminized shiny Mylar to greatly reduce radiation heat transfer and control satellite temperature. A heat engine is a system that performs the conversion of a flow of thermal energy heat to mechanical energy to perform mechanical work. A thermoelectric cooler is a solid state electronic device that pumps transfers heat from one side of the device to the other when electric current is passed through it. It is based on the Peltier effect. A thermal diode or thermal rectifier is a device that causes heat to flow preferentially in one direction. Heat exchangers[edit] A heat exchanger is used for more efficient heat transfer or to dissipate heat. Heat exchangers are widely used in refrigeration , air conditioning , space heating , power generation , and chemical processing. In parallel flow, both fluids move in the same direction while transferring heat; in counter flow, the fluids move in opposite directions; and in cross flow, the fluids move at right angles to each other. Common constructions for heat exchanger include shell and tube, double pipe , extruded finned pipe, spiral fin pipe, u-tube, and stacked plate. Examples of heat sinks are the heat exchangers used in refrigeration and air conditioning systems or the radiator in a car. A heat pipe is another heat-transfer device that combines thermal conductivity and phase transition to efficiently transfer heat between two solid interfaces. Architecture[edit] Efficient energy use is the goal to reduce the amount of energy required in heating or cooling. In architecture, condensation and air currents can cause cosmetic or structural damage. An energy audit can help to assess the implementation of recommended corrective procedures. For instance, insulation improvements, air sealing of structural leaks or the addition of energy-efficient windows and doors. Thermal transmittance is the rate of transfer of heat through a structure divided by the difference in temperature across the structure. Well-insulated parts of a building have a low thermal transmittance, whereas poorly-insulated parts of a building have a high thermal transmittance. Thermostat is a device to monitor and control temperature.

Anthropogenic heat An example application in climate engineering includes the creation of Biochar through the pyrolysis process. Thus, storing greenhouse gases in carbon reduces the radiative forcing capacity in the atmosphere, causing more long-wave infrared radiation out to Space. Climate engineering consists of carbon dioxide removal and solar radiation management. Since the amount of carbon dioxide determines the radiative balance of Earth atmosphere, carbon dioxide removal techniques can be applied to reduce the radiative forcing. Solar radiation management is the attempt to absorb less solar radiation to offset the effects of greenhouse gases. The ability of the atmosphere to capture and recycle energy emitted by the Earth surface is the defining characteristic of the greenhouse effect. The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases. Heat transfer in the human body[edit] See also: Wet-bulb temperature The principles of heat transfer in engineering systems can be applied to the human body in order to determine how the body transfers heat. Heat is produced in the body by the continuous metabolism of nutrients which provides energy for the systems of the body. Therefore, excess heat must be dissipated from the body to keep it from overheating. When a person engages in elevated levels of physical activity, the body requires additional fuel which increases the metabolic rate and the rate of heat production. The body must then use additional methods to remove the additional heat produced in order to keep the internal temperature at a healthy level. Heat transfer by convection is driven by the movement of fluids over the surface of the body. This convective fluid can be either a liquid or a gas. For heat transfer from the outer surface of the body, the convection mechanism is dependent on the surface area of the body, the velocity of the air, and the temperature gradient between the surface of the skin and the ambient air. Heat transfer occurs more readily when the temperature of the surroundings is significantly less than the normal body temperature. Clothing can be considered an insulator which provides thermal resistance to heat flow over the covered portion of the body. This smaller temperature gradient between the surface temperature and the ambient temperature will cause a lower rate of heat transfer than if the skin were not covered. In order to ensure that one portion of the body is not significantly hotter than another portion, heat must be distributed evenly through the bodily tissues. Blood flowing through blood vessels acts as a convective fluid and helps to prevent any buildup of excess heat inside the tissues of the body. This flow of blood through the vessels can be modeled as pipe flow in an engineering system. The heat carried by the blood is determined by the temperature of the surrounding tissue, the diameter of the blood vessel, the thickness of the fluid , velocity of the flow, and the heat transfer coefficient of the blood. The velocity, blood vessel diameter, and the fluid thickness can all be related with the Reynolds Number , a dimensionless number used in fluid mechanics to characterize the flow of fluids. Latent heat loss, also known as evaporative heat loss, accounts for a large fraction of heat loss from the body. When the core temperature of the body increases, the body triggers sweat glands in the skin to bring additional moisture to the surface of the skin. The liquid is then transformed into vapor which removes heat from the surface of the body. The body continuously loses water by evaporation but the most significant amount of heat loss occurs during periods of increased physical activity.

Chapter 5 : Ozisik (Author of Radiative Transfer And Interactions With Conduction And Convection)

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Chapter 6 : Coupled radiation, convection and conduction

The combined radiation/conduction heat transfer in high-temperature multi-layer insulations was modeled using a finite *volume numerical model. The numerical model was validated by comparison with steady-state effective thermal conductivity measurements, and by transient thermal tests simulating re-entry aerodynamic heating conditions.*

Chapter 7 : CiteSeerX â€" Citation Query Radiative Transfer and Interactions With Conduction and Convec

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Chapter 8 : Nanoscale Heat Transport Â« Thermal, Fluids, and Energy Systems

Heat Transfer - Radiation, Conduction, and Convection.

Chapter 9 : - Radiative Transfer & Interactions With Conduction & Convection by Ozisik

It explains the difference between conduction, convection, and radiation. Conduction occurs when heat transfers from one material to another by direct contact. Touching a hot stove is an example.