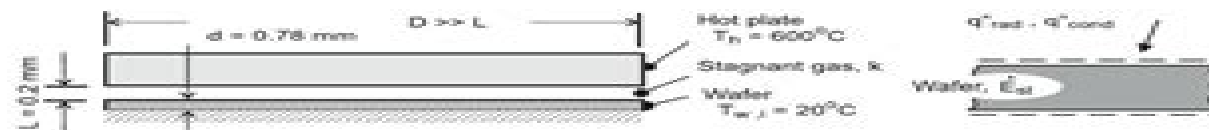


**PROBLEM 1.41**

**KNOWN:** Hot plate-type wafer thermal processing tool based upon heat transfer modes by conduction through gas within the gap and by radiation exchange across gap.

**FIND:** (a) Radiative and conduction heat fluxes across gap for specified hot plate and wafer temperatures and gap separation; initial time rate of change in wafer temperature for each mode, and (b) heat fluxes and initial temperature-time change for gap separations of 0.2, 0.5 and 1.0 mm for hot plate temperatures  $300 < T_h < 1300$  C. Comment on the relative importance of the modes and the influence of the gap distance. Under what conditions could a wafer be heated to 900 C in less than 10 seconds?

**SCHEMATIC:**



**ASSUMPTIONS:** (1) Steady-state conditions for flux calculations, (2) Diameter of hot plate and wafer much larger than gap spacing, approximating plane, infinite planes, (3) One-dimensional conduction through gas, (4) Hot plate and wafer are blackbodies, (5) Negligible heat losses from wafer backside, and (6) Wafer temperature is uniform at the onset of heating.

**PROPERTIES:** Wafer:  $\rho = 2700 \text{ kg/m}^3$ ,  $c = 875 \text{ J/kg} \cdot \text{K}$ ; Gas in gap:  $k = 0.0436 \text{ W/m} \cdot \text{K}$ .

**ANALYSIS:** (a) The radiative heat flux between the hot plate and wafer for  $T_h = 600$  C and  $T_w = 20$  C follows from the rate equation,

$$q_{\text{rad}} = \frac{\sigma}{4} (T_h^4 - T_w^4) = \frac{5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4}{4} (600 + 273)^4 - (20 + 273)^4 = 32.5 \text{ kW/m}^2 \quad \leftarrow$$

The conduction heat flux through the gas in the gap with  $L = 0.2$  mm follows from Fourier's law,

$$q_{\text{cond}} = k \frac{T_h - T_w}{L} = 0.0436 \text{ W/m} \cdot \text{K} \frac{600 - 20 \text{ K}}{0.0002 \text{ m}} = 126 \text{ kW/m}^2 \quad \leftarrow$$

The initial time rate of change of the wafer can be determined from an energy balance on the wafer at the instant of time the heating process begins,

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} - \dot{E}_{\text{st}} = \dot{E}_{\text{st}} = \rho c d \frac{dT_w}{dt} \quad \leftarrow$$

where  $\dot{E}_{\text{out}} = 0$  and  $\dot{E}_{\text{in}} = q_{\text{rad}}$  or  $q_{\text{cond}}$ . Substituting numerical values, find

$$\frac{dT_w}{dt} \bigg|_{\text{rad}} = \frac{q_{\text{rad}}}{\rho c d} = \frac{32.5 \times 10^3 \text{ W/m}^2}{2700 \text{ kg/m}^3 \cdot 875 \text{ J/kg} \cdot \text{K} \cdot 0.00078 \text{ m}} = 17.6 \text{ K/s} \quad \leftarrow$$

$$\frac{dT_w}{dt} \bigg|_{\text{cond}} = \frac{q_{\text{cond}}}{\rho c d} = 68.4 \text{ K/s} \quad \leftarrow$$

Continued

**PROBLEM 1.41 (Cont.)**

(b) Using the foregoing equations, the heat fluxes and initial rate of temperature change for each mode can be calculated for selected gap separations  $L$  and range of hot plate temperatures  $T_h$  with  $T_w = 20$  C.



# Heat Transfer Incropera 5th Edition Solution

**Yogesh Jaluria**



## Heat Transfer Incropera 5th Edition Solution :

**Computational Heat Transfer** Yogesh Jaluria, 2017-10-19 This new edition updated the material by expanding coverage of certain topics adding new examples and problems removing outdated material and adding a computer disk which will be included with each book Professor Jaluria and Torrance have structured a text addressing both finite difference and finite element methods comparing a number of applicable methods *Thermal Radiation Heat Transfer, 5th Edition* John R. Howell, M. Pinar Menguc, Robert Siegel, 2010-09-28 Providing a comprehensive overview of the radiative behavior and properties of materials the fifth edition of this classic textbook describes the physics of radiative heat transfer development of relevant analysis methods and associated mathematical and numerical techniques Retaining the salient features and fundamental coverage that have made it popular Thermal Radiation Heat Transfer Fifth Edition has been carefully streamlined to omit superfluous material yet enhanced to update information with extensive references Includes four new chapters on Inverse Methods Electromagnetic Theory Scattering and Absorption by Particles and Near Field Radiative Transfer Keeping pace with significant developments this book begins by addressing the radiative properties of blackbody and opaque materials and how they are predicted using electromagnetic theory and obtained through measurements It discusses radiative exchange in enclosures without any radiating medium between the surfaces and where heat conduction is included within the boundaries The book also covers the radiative properties of gases and addresses energy exchange when gases and other materials interact with radiative energy as occurs in furnaces To make this challenging subject matter easily understandable for students the authors have revised and reorganized this textbook to produce a streamlined practical learning tool that Applies the common nomenclature adopted by the major heat transfer journals Consolidates past material reincorporating much of the previous text into appendices Provides an updated expanded and alphabetized collection of references assembling them in one appendix Offers a helpful list of symbols With worked out examples chapter end homework problems and other useful learning features such as concluding remarks and historical notes this new edition continues its tradition of serving both as a comprehensive textbook for those studying and applying radiative transfer and as a repository of vital literary references for the serious researcher *Heat and Mass Transfer* Hans Dieter Baehr, Karl Stephan, 2006-08-02 This book provides a solid foundation in the principles of heat and mass transfer and shows how to solve problems by applying modern methods The basic theory is developed systematically exploring in detail the solution methods to all important problems The revised second edition incorporates state of the art findings on heat and mass transfer correlations The book will be useful not only to upper and graduate level students but also to practicing scientists and engineers Many worked out examples and numerous exercises with their solutions will facilitate learning and understanding and an appendix includes data on key properties of important substances *Solar Thermal Energy Systems* Werner Platzer, Robert Stieglitz, 2024 Zusammenfassung This textbook is intended for master s level engineering students in the field

of their studies It begins with an analysis of the growing world population s energy demand heat and electricity and its connection to the undeniable climate change necessitating the expansion of climate friendly technologies The book is divided into two sections The first section Chapters 2 to 7 presents the physical fundamentals of solar thermal energy usage along with the necessary processes methods and models The second section Chapters 8 12 covers the synthesis of the developed fundamentals applied to various functional solar thermal systems It not only provides the logic and methods for transferring the physical fundamentals into an operative technical system but also includes aspects of concept development selection economic evaluation and performance Additionally measurement and control technology are presented underpinned by real projects that have already been successfully implemented

**Heat Transfer** L.C. Wrobel,C.A. Brebbia,2016-11-21 No detailed description available for Heat Transfer

*Proceedings of the 1st International Congress on Engineering Technologies* Suhil Kiwan,Mohammad Banat,2021-09-30 This first volume in the Mosharaka for Research and Studies International Conference Proceedings series P MIC contains peer reviewed papers presented at the 1st International Congress on Engineering Technologies EngiTek 2020 This event was held remotely on 16 18 June 2020 and hosted by the Faculty of Engineering Jordan University of Science Technology Irbid Jordan The conference represented a major forum for professors students and professionals from all over the world to present their latest research results and to exchange new ideas and practical experiences in the most cutting edge areas of the field of engineering technologies Topics covered include electrical engineering computer science and electronics

Smoothed Point Interpolation Methods: G Space Theory And Weakened Weak Forms Gui-rong Liu,Gui-yong Zhang,2013-08-16 Based on the widely used finite element method FEM and the latest Meshfree methods a next generation of numerical method called Smoothed Point Interpolation Method S PIM has been recently developed The S PIM is an innovative and effective combination of the FEM and the meshfree methods and enables automation in computation modeling and simulations one of the most important features of the next generation methods This important book describes the various S PIM models in a systematic concise and easy to understand manner The underlying principles for the next generation of computational methods G space theory novel weakened weak W2 formulations techniques for shape functions formulation procedures and implementation strategies are presented in detail Numerous examples are provided to demonstrate the efficiency and accuracy of the S PIM solutions in comparison with the FEM and other existing methods Effective techniques to compute solution bounds employing both S PIM and FEM are highlighted to obtain certified solutions with both upper and lower bounds The book also presents a systematically way to conduct adaptive analysis for solutions of desired accuracy using these bound properties which is another key feature of the next generation of computational methods This will benefit researchers engineers and students who are venturing into new areas of research and computer code development

*Kern's Process Heat Transfer* Ann Marie Flynn,Toshihiro Akashige,Louis Theodore,2019-05-29 This edition ensures the legacy of the original 1950 classic Process Heat Transfer by

Donald Q Kern that by many is held to be the gold standard This second edition book is divided into three parts Fundamental Principles Heat Exchangers and Other Heat Transfer Equipment Considerations Part I provides a series of chapters concerned with introductory topics that are required when solving heat transfer problems This part of the book deals with topics such as steady state heat conduction unsteady state conduction forced convection free convection and radiation Part II is considered by the authors to be the meat of the book and the primary reason for undertaking this project Other than minor updates Part II remains relatively unchanged from the first edition Notably it includes Kern s original design methodology for double pipe shell and tube and extended surface heat exchangers Part II also includes boiling and condensation boilers cooling towers and quenchers as well as newly designed open ended problems Part III of the book examines other related topics of interest including refrigeration and cryogenics batch and unsteady state processes health safety and the accompanying topic of risk In addition this part also examines the impact of entropy calculations on exchanger design A 36 page Appendix includes 12 tables of properties layouts and design factors WHAT IS NEW IN THE 2ND EDITION Changes that are addressed in the 2nd edition so that Kern s original work continues to remain relevant in 21st century process engineering include Updated Heat Exchanger Design Increased Number of Illustrative Examples Energy Conservation Entropy Considerations Environmental Considerations Health Safety Risk Assessment Refrigeration and Cryogenics

**Partial Differential Equations** Kartikeya Dutta,2025-02-20 Partial Differential Equations A Detailed Exploration is a comprehensive textbook designed for undergraduate students offering an in depth study of Partial Differential Equations PDEs We blend accessibility with academic rigor making it suitable for students in mathematics physics and engineering disciplines Our book starts with a strong foundation in mathematical modeling and analysis tailored to meet the needs of undergraduate learners We provide a balanced approach combining theoretical underpinnings with practical applications Each chapter includes clear explanations illustrative examples and thought provoking exercises to foster active engagement and skill development This journey equips students with essential tools to solve real world problems and instills a deep appreciation for the elegance of PDE theory Whether exploring heat conduction wave propagation or fluid dynamics readers will immerse themselves in the rich tapestry of mathematical methods designed to unravel the secrets of nature Partial Differential Equations A Detailed Exploration invites undergraduates to transform mathematical challenges into triumphs laying the groundwork for a deeper understanding of PDEs

**Handbook of Heating, Ventilation, and Air Conditioning** Jan F. Kreider,2000-12-26 The building industry accounts for about 25 percent of the US gross national product through the design construction operation and maintenance of commercial institutional and residential buildings The Handbook of Heating Ventilation and Air Conditioning provides a current comprehensive review of the latest procedures and trends in the industry It combines practice and theory systems and control and modern methods and technologies to provide in one volume all of the design and operation information needed by HVAC engineers Through a link on the CRC Web site owners of the

handbook can access new material periodically posted by the author      **Thermal-Fluid Sciences** Stephen Turns,2006-01-30 This text is for introduction to thermal fluid science including engineering thermodynamics fluids and heat transfer      *Introduction to Thermal and Fluid Engineering* Allan D. Kraus,James R. Welty,Abdul Aziz,2011-09-06

Introduction to Thermal and Fluid Engineering combines coverage of basic thermodynamics fluid mechanics and heat transfer for a one or two term course for a variety of engineering majors The book covers fundamental concepts definitions and models in the context of engineering examples and case studies It carefully explains the methods used to evaluate changes in equilibrium mass energy and other measurable properties most notably temperature It then also discusses techniques used to assess the effects of those changes on large multi component systems in areas ranging from mechanical civil and environmental engineering to electrical and computer technologies Includes a motivational student study guide on CD to promote successful evaluation of energy systems This material helps readers optimize problem solving using practices to determine equilibrium limits and entropy as well as track energy forms and rates of progress for processes in both closed and open thermodynamic systems Presenting a variety of system examples tables and charts to reinforce understanding the book includes coverage of How automobile and aircraft engines work Construction of steam power plants and refrigeration systems Gas and vapor power processes and systems Application of fluid statics buoyancy and stability and the flow of fluids in pipes and machinery Heat transfer and thermal control of electronic components Keeping sight of the difference between system synthesis and analysis this book contains numerous design problems It would be useful for an intensive course geared toward readers who know basic physics and mathematics through ordinary differential equations but might not concentrate on thermal fluids science much further Written by experts in diverse fields ranging from mechanical chemical and electrical engineering to applied mathematics this book is based on the assertion that engineers from all walks absolutely must understand energy processes and be able to quantify them      *Qpedia Thermal Management eMagazine, Volume 4* Kaveh Azar,Bahman Tavassoli,Advanced Thermal Solutions,Andrea Koss,2011 The complete editorial contents of Qpedia Thermal 4 Issues 1 12 features 48 in depth articles that discuss critical case studies calculations and analysis for thermal engineering professionals and academia      *Design and Optimization of Thermal Systems, Third Edition* Yogesh Jaluria,2019-09-06

*Design and Optimization of Thermal Systems Third Edition with MATLAB Applications* provides systematic and efficient approaches to the design of thermal systems which are of interest in a wide range of applications It presents basic concepts and procedures for conceptual design problem formulation modeling simulation design evaluation achieving feasible design and optimization Emphasizing modeling and simulation with experimentation for physical insight and model validation the third edition covers the areas of material selection manufacturability economic aspects sensitivity genetic and gradient search methods knowledge based design methodology uncertainty and other aspects that arise in practical situations This edition features many new and revised examples and problems from diverse application areas and more extensive coverage

of analysis and simulation with MATLAB

**Membrane Dehumidification and Cooling** Vivekh Prabakaran, Chua Kian Jon, 2023-04-27 Membrane Dehumidification and Cooling Fundamentals and Applications presents the state of the art on membrane dehumidifiers highlighting their most recent advancements and providing key insights into global R D interests With a strong focus on applications the book offers characterization techniques to evaluate the potential of hygroscopic materials as well as experimental methods to study the dehumidifiers performance The book begins by highlighting the demerits of conventional cooling systems and then reviews electrically driven alternative cooling solutions A comparative study between different dehumidification techniques is also given along with sections on fundamental transport mechanisms and thermodynamic modeling Finally scaling heat transfer and thermodynamic analysis are presented along with a review of hybrid membrane based air conditioners This book is a one stop resource for recent advancements in membrane dehumidification and cooling applications It is an essential read for students researchers and engineers interested in thermal engineering heat and mass transfer alternative cooling energy materials and dehumidification Presents the fundamental aspects and applications of the latest membrane dehumidification technologies Comprehensively emphasizes new energy materials experimental techniques numerical methods and thermal evaluation frameworks Focuses on the feasibility of membrane dehumidifiers in the next generation of hybrid cooling systems

**Handbook of Environmental Degradation of Materials** Myer Kutz, 2012-12-31 Nothing stays the same for ever The environmental degradation and corrosion of materials is inevitable and affects most aspects of life In industrial settings this inescapable fact has very significant financial safety and environmental implications The Handbook of Environmental Degradation of Materials explains how to measure analyse and control environmental degradation for a wide range of industrial materials including metals polymers ceramics concrete wood and textiles exposed to environmental factors such as weather seawater and fire Divided into sections which deal with analysis types of degradation protection and surface engineering respectively the reader is introduced to the wide variety of environmental effects and what can be done to control them The expert contributors to this book provide a wealth of insider knowledge and engineering knowhow complementing their explanations and advice with Case Studies from areas such as pipelines tankers packaging and chemical processing equipment ensures that the reader understands the practical measures that can be put in place to save money lives and the environment The Handbook s broad scope introduces the reader to the effects of environmental degradation on a wide range of materials including metals plastics concrete wood and textiles For each type of material the book describes the kind of degradation that effects it and how best to protect it Case Studies show how organizations from small consulting firms to corporate giants design and manufacture products that are more resistant to environmental effects

**Heat and Mass Transfer in Energy Systems** Alessandro Mauro, Nicola Massarotti, 2020-01-09 In recent years the interest of the scientific community towards efficient energy systems has significantly increased One of the reasons is certainly related to the change in the temperature of the planet which has

increased by 0.76 °C with respect to preindustrial levels according to the Intergovernmental Panel on Climate Change (IPCC) and is still increasing. The European Union considers it vital to prevent global warming from exceeding 2 °C with respect to pre-industrial levels as it has been proven that this will result in irreversible and potentially catastrophic changes. These changes in climate are mainly caused by greenhouse gas emissions related to human activities and can be drastically reduced by employing energy systems for the heating and cooling of buildings as well as for power production characterized by high efficiency levels and/or based on renewable energy sources. This Special Issue published in the *Energies* journal includes 13 contributions from across the world including a wide range of applications such as hybrid residential renewable energy systems, desiccant-based air handling units, heat exchangers for engine WHR, solar chimney systems and other interesting topics.

**Design and Optimization of Thermal Systems** Yogesh Jaluria, 2007-12-13 Thermal systems play an increasingly symbiotic role alongside mechanical systems in varied applications spanning materials processing, energy conversion, pollution, aerospace and automobiles. Responding to the need for a flexible yet systematic approach to designing thermal systems across such diverse fields, *Design and Optimization of Thermal Systems* brings together the latest research on boundary layers where there has been remarkable advancements in recent years. This book highlights relevant concepts and solutions to energy issues and environmental sustainability by combining fundamental theory on boundary layers with real-world industrial applications from among others the thermal, nuclear and chemical industries. The book's editors and their team of expert contributors discuss many core themes including advanced heat transfer, fluids and boundary layer analysis, physics of fluid motion and viscous flow, thermodynamics and transport phenomena alongside key methods of analysis such as the Merk-Chao-Fagbenle method. This book's multidisciplinary coverage will give engineers, scientists, researchers and graduate students in the areas of heat, mass, fluid flow and transfer a thorough understanding of the technicalities, methods and applications of boundary layers with a unified approach to energy, climate change and a sustainable future.

*Applications of Heat, Mass and Fluid Boundary Layers* R. O. Fagbenle, O. M. Amoo, S. Aliu, A. Falana, 2020-01-27 *Applications of Heat, Mass and Fluid Boundary Layers* brings together the latest research on boundary layers where there has been remarkable advancements in recent years. This book highlights relevant concepts and solutions to energy issues and environmental sustainability by combining fundamental theory on boundary layers with real-world industrial applications from among others the thermal, nuclear and chemical industries. The book's editors and their team of expert contributors discuss many core themes including advanced heat transfer, fluids and boundary layer analysis, physics of fluid motion and viscous flow, thermodynamics and transport phenomena alongside key methods of analysis such as the Merk-Chao-Fagbenle method. This book's multidisciplinary coverage will give engineers, scientists, researchers and graduate students in the areas of heat, mass, fluid flow and transfer a thorough understanding of the technicalities, methods and applications of boundary layers with a unified approach to energy, climate change and a sustainable future.

*Electromagnetic, Mechanical, and Transport Properties of Composite Materials* Rajinder Pal, 2014-08-27 In the design, processing and applications of composite materials, a thorough understanding of the physical properties is required. It is important to be able to predict the variations of these properties with the kind, shape and concentration of filler materials. The currently available books on composite materials often emphasize mechanical pro

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