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Book Review

Nano/Microscale Heat Transfer, Zhoumin Zhang. McGraw-Hill, 2007. 479 pp., 10 Chapters., 253 problems, 56 examples, 404 references

This book is designed to be used to educate both undergraduate and graduate students in the emerging field of energy transport at the micro.nano/molecular scale. The book begins with definitions, the language of nanotechnology, and photos of nano scale objects. The book follows a progression from basic thermodynamics and heat transfer, as taught at the undergraduate level to engineering students, to statistical mechanics, fluid mechanics, solid state physics, and nano/molecular scale energy transport. The book is written so that engineering students learn more about physics and chemistry, and physics and chemistry students learn more about engineering at the nano scale dimension. Nanotechnology requires a multidisciplinary knowledge base, and this book is successfully written towards that end.

Chapter 1 introduces the student to some of the exciting aspects of the "smaller world". The chapter provides discussion of what nanotechnology is and shows some interesting devices and objects that have been created by humans at the scale of the building blocks of Nature. The chapter motivates students to move on and learn more. Chapter 2 is a basic review of core thermodynamics and heat transfer fundamentals. It is a refresher for the students and provides a basic background in engineering and physics that is necessary for more learning more advanced topics. Chapters 3 and 4 begin the journey into statistical mechanics and thermodynamics. Kinetic theory is critical in understanding transport processes at the molecular and sub-molecular scale. The Boltzmann transport process is introduced, and the importance of understanding the importance of the Knudsen number is revealed.

Chapter 5 provides a thorough discussion of the relationship between properties of materials and the size scales that are of interest. It takes the student to the molecular and sub-molecular level of property definition and introduces new concepts such as phonon transport as an energy carrier. The Debye Specific Heat model is discussed, and electron transport versus phonon energy transport is revealed. This is an important issue as it points out the similarities between Electrical and Mechanical Engineering from a sub-molecular point of view. A very important aspect of transport at the nano and molecular scales is the fact that there is a size effect on transport properties. The idea that transport across a boundary is different when the physical dimension between atoms is large compared to the total dimension of interest introduces the concept of ballistic transport as described through the Boltzman Transport Theory. The concept of a "boundary" with infinitely thin dimension, as we think of at the macro or micro scale interface between materials, vanishes. Applications of importance introduced in this chapter include thermoelectric devices.

Chapter 6 helps us think about the sub-molecular transport mechanisms. Electron and Phonon transport are addressed in this chapter. The importance of defects in the crystal structure of matter become of interest. The role of crystal structure and the role and importance of bonds between atoms becomes clear. Phonon dispersion and scattering is nicely explained as is electron transport. The basis of the operation of p–n junctions becomes clear.

In Chapter 7 non-equilibrium energy transport is presented. This discussion leads to a regime mapping for heat conduction.

In Chapter 8 the basics of thermal radiation are extended from the earlier discussion in Chapter 2. A much deeper understanding of thermal radiation results from a nice but brief discussion of the Wave Equation. Blackbody radiation is discussed ad the Photon gas transport concept is compared. In Chapter 9 thermal radiation from nanoscale materials is addressed. The phenomena such as gratings and their interaction with the wave transport are discussed.

Chapter 10 looks at the near field energy transport problem. Here we see how understanding transport across very thin layers of different materials can lead to better understanding of the role of physical dimension of materials on thermal radiation transport, and how the nano scale transport transitions into the micro, meso, and macro scales.

This book is very well designed and written, and it will be the foundation for future courses about nanoscale thermal energy transport. It is a bit advanced for undergraduates except some of the very best students. The progression from macro concepts of thermodynamics and heat transfer into the companion concepts of transport at the nano and molecular scale is especially helpful to the students. For MS and PhD students specializing in nanotechnology, this is one of the best textbooks/reference books published to date. I highly recommend it for anybody who is interested in contemporary aspects of thermal energy transport phenomena.

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