Preface

Publication of the classic text *Transport Phenomena* by Bird, Stewart and Lightfoot, affectionately known as BSL, started a revolution in chemical engineering. Prior to that, chemical engineering surely was quantitative, but largely empirical. BSL started the strong analytical trend which swept chemical engineering education. I was introduced to it in 1963 and learnt the beautiful foundations on which Unit Operations could be based. Many texts on Transport Phenomena have come since BSL, but it always remained, and remains unique. The natural question that arises in the minds of admirers of BSL like me is about the need for another text. BSL lays out derivations with clarity, selects examples highly illustrative of principles, and poses intellectually teasing problems to be solved. Interpretation of results, possible applications, and potential extensions are left to be dealt with by the teacher, and that is how a book ought to be planned in general. After years of teaching however, I felt that the deliberate gap left by BSL remains unbridged in India. The reason is easy to see. With the rapid expansion of engineering education in India, there has always been a shortage of able teachers, and teaching of Transport Phenomena has suffered especially due to this. My first aim in writing this text has been to help alleviate this difficulty faced by Indian students. However, I always tell my students that while they use my class notes, which formed the starting point for this text, they should read BSL. I have left out fluid mechanics from this text and my reason is the availability of books on this subject in large numbers and in a wide variety. Just as with BSL, I suggest to my students that they should read the classic *Introduction to fluid dynamics* by Batchelor. Radiation is an omission. I feel that as it is so very different from the rest of the transport processes, its inclusion is more for completeness rather than for pedagogical value.

Chemical engineering is going through a phase of expansion and diversification. Chemical engineers are well poised for this phase with their strong connection to mathematics and physics, umbilical binding to chemistry, and natural entry into biology based on these. Several pleas have been made to introduce into texts newer applications which chemical engineers are helping to develop. My second aim has been to do this. However, newer applications have a context and its exposition does eat into the space normally devoted to expounding the basics. A balance is always needed. I introduce applications in processing of materials and fuel cells, normally not found in a text on Transport Phenomena, to fulfil this aim. I must say that many other areas are left out, *e.g.*, biomedical applications on which excellent texts are available, many more separation processes other than the membrane based ones, making of electronic devices, polymer processing, *etc.* This omission is entirely due to limitations imposed by my knowledge base!

My other aims have been dictated by my biases. Computers and computing have made significant impact on not education alone but on life itself. I feel that numerical solutions of transport

phenomena problems, commonly referred to as CFD, has to be known to every chemical engineer. 'There are either beautiful and or useful solutions' summarizes my attitude. With this as the goal, while keeping a few exact solutions, the pretty similarity and scaling arguments, a chapter on CFD was introduced. In the same vein, the chapter on Turbulence mainly emphasizes Kolmogorov's theory, and it also naturally leads to turbulence modeling.

I adopted a style of presentation very much under the influence of the brilliant book *How to solve it?* by Polya. There he presents a systematic approach to solving problems which consists of understanding the problem, hypothesizing an approach to solve it, solution of the problem itself and digesting the results by checking for consistencies. In this text, the first two were combined into *problem identification*, and the last was renamed as *looking at the results*. Hopefully, the last step builds intuition while the first trains in posing well defined problems by suitable physical approximations. I have deliberately laid less emphasis on solution procedures, and the problems at the end of the chapter which do not ask for solutions should make this abundantly clear. This has been prompted by my belief in the great value of teaching to correctly frame problems and relying upon computers to get results.

The three transport processes are similar but not identical, and I tried to simultaneously emphasize the similarities and differences in this text. My teaching experience indicated that chemical engineers understand and visualize heat transfer more easily than mass transfer. I therefore feel that it is best to teach these subjects in series than in parallel. The book is structured in that way. I begin with heat transfer and shell balances. Shell balances give a physical feel while intuition is developed on the basis of heat transfer. Advantage is taken of the experience gained in heat transfer and the problems selected for mass transfer are more complex than the corresponding ones in heat transfer. The same applies for topics selected in the chapters on advanced topics.

I feel that the text is suitable for first year post-graduate students of India. To do justice, two semester long courses will be needed to teach Transport phenomena. It then seems reasonable that only a part of this text can be taught in a semester. I feel that, after laying the basics contained in the first two chapters, third and fourth chapters and a selection of topics from the fifth and sixth chapters will form a good coverage of heat transfer. Seventh and eighth chapters and a selection of topics from the ninth and tenth chapters will give a good view of mass transfer. The chapter on turbulence can be covered, perhaps leaving out the material on spectrum. The last chapter on CFD can be taught in full.

I now have the pleasant task of acknowledging the contributions of my colleagues. Material covered in my classes has formed the basis for this text. I am very grateful to my students who have given valuable feed back. Professor Raj Chhabra of Indian Institute of Technology, Kanpur has patiently read the entire text and his suggestions have helped greatly improve the presentation. Dr Srinivasa Mohan of Fluent, and Ms Akila Harith of Mechanical Engineering, Indian Institute of Science read the chapter on CFD; Professors V Shankar and Raj Pala of Indian Institute of Technology, Kanpur, K. Kesava Rao and S. Venugopal of Indian Institute of Science have read parts of the text and the kind words form all these were encouraging. My understanding and teaching of topics covered in this text was enriched by discussions with many colleagues of Indian Institute of Science, in particular Professor K. Kesava Rao, and I acknowledge these inputs. Finally, I would

like to acknowledge the support lent for writing of this book by the Department of Science & Technology through the USERS scheme. While I tried to make the book error free, I am sure there will be many left. I would be grateful to all readers who find errors in the book if they can kindly communicate those to me.

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