CAMBRIDGE
UNIVERSITY PRESS

This review appeared in
CURRENT
ENGINEERING PRACTICE

Dated_____20_____

with compliments

The Edinburgh Building
Shaftesbury Road
Cambridge CB2 2RU, UK
www.cambridge.org

Telephone +44 (0)1223 312393
Fax +44 (0)1223 315052

THE MOTION OF BUBBLES AND DROPS IN REDUCED GRAVITY

by R. Shankar Subramanian and R. Balasubramaniam
2001 (Cambridge, England: Cambridge University Press)
Pp. 471, .Price £ 65.00

Orbiting spacecraft provide a valuable laboratory for experiments on physical and biological systems in a reduced gravity environment. Materials processing experiments have commonly involved the growth of crystals from the melt or solution and the processing of alloys and composites. Biological experiments have been performed on a variety of subjects, including protein crystal growth, bioreactors, and the adaptation of humans to extended periods of weightlessness. In these studies, fluid masses containing bubbles and drops are encountered routinely. This book is the first to provide a clear, thorough review of the motion of bubbles and drops in reduced gravity, particularly motion caused by variations in interfacial tension arising from temperature gradients on their surfaces. The emphasis is on theoretical analysis from first principles; experimental results are discussed and compared with predictions where appropriate. Students and researchers interested in fluid mechanics in reduced gravity will welcome this state-of-the-art reference.

The book is divided into four parts comprising a total of 9 chapters, the first chapter introducing the reader to the role of gravity and interfacial tension in the motion of bubbles and drops.

The monograph is principally about the motion of bubbles and drops caused by variations in interfacial tension arising from temperature gradients on their surfaces. It is the first attempt to provide a reasonably comprehensive picture of the progress and the current status of research on this subject. As the authors opine, in the long run, this driving force for the motion of bubbles and drops will prove to be as ubiquitous in a reduced gravity environment as gravity is on the surface of Earth.

In Part One, the reader is introduced to the role of gravity and interfacial tension in the motion of bubbles and drops in Chapter 1 as mentioned above, and the governing equations in Chapter 2. In this Chapter 2, the governing equations and boundary conditions used in modeling transport problems encountered in the remaining chapters are presented and discussed. Also, discussed are the physical assumptions that will be made, and several dimensionless parameters that will be encountered, in the subsequent chapters. The chapter also provides tables of the governing equations in common coordinate systems.

Part Two is devoted to a discussion of various aspects of the motion of isolated drops. The term *isolated* implies that there are no neighboring objects to interfere with the drop in question, nor are there any neighboring surfaces with which it can interact. Although no physical system is truly isolated, it is a useful exercise to treat this problem. The reason is that, in thermocapillary migration, the velocity and temperature disturbances introduced by such a drop only penetrate a relatively small distance of a few drop radii into the neighboring fluid before becoming too weak to be significant. Although the disturbance decays more slowly in the case of motion driven by a body force, in a sufficiently large container, such motion can be regarded as being isolated. Part Two is divided into two chapters, with Chapter 3 focusing on motion driven by a body force and Chapter 4 dealing with thermocapillary migration. Chapter 4 also includes a discussion of some situations wherein a drop moves under the combined action of gravity and thermocapillarity.

Part Three considers the problem of interactions of moving drops with neighboring drops and surfaces that are sufficiently close and presents results that are currently available. This subject is still one of active investigation at the present time, and much remains to be done. First, a preliminary discussion is provided. Some general solutions are reported in Chapter 5. Then, Part Three is divided into two subsequent chapters in which body force driven motion and thermocapillary migration, respectively, are considered.

Finally, Part Four discusses two related topics. Chapter 8 deals with mass transfer to and from drops and bubbles. There, attention is focused primarily on stationary objects and objects that are propelled by interfacial tension gradients. The chapter does not consider mass transfer

from objects moving because of a body force, since as the authors point out, this topic is discussed in depth in other available books. Chapter 9 considers the related problems of motion driven in a body of liquid by gradients in interfacial tension. Much of Chapter 9 is devoted to problems involving rectangular pools of liquid,

but also covered are elementary cases in cylindrical and spherical geometries. Although this is not strictly the motion of these objects but rather motion in them, the authors have included 'some simple solutions of problems on this subject because some readers might find them useful.'

Although the emphasis in this work is on theoretical analysis, the authors have presented and discussed experimental results wherever appropriate and possible.

Amongst the distinguishing features of a most distinguished book may be mentioned the following:

Scholars who choose to work on bubbles and drops, on fluid mechanics in reduced gravity, and on interfacial phenomena will find this book useful

The authors have employed a level that is suitable for advanced students in engineering and science with the expectation that some of this material may be used in courses dealing with transport phenomena associated with motion driven by the interface.

Also, the topics covered should be of interest to scientists studying the processing of materials in reduced gravity and to many others doing experiments on physical and biological systems in a reduced gravity environment. For example, in n materials processing, it is common to work with fluids in which the temperature varies from one location to the next. The resulting temperature gradients provide a natural way for interfacial tension gradients to arise and cause bubbles and drops to move in a reduced gravity environment. As mentioned earlier, materials processing is an area in which substantial research is being carried out in reduced gravity. The contents of this book will therefore benefit the community of scientists working in various aspects of this endeavor.

The book is well supported by references that are of immediate help to the reader. Citing two instances may convince the reader. Two books that deal with fluid behavior in low gravity conditions. Myshkis et al. (1987) have considered the stability of the equilibrium states of bodies of liquid with free surfaces and their oscillations and also have provided a discussion of thermocapillary motion in liquid bodies. Antar and Nuotio-Antar (1993) have discussed a variety of transport problems in the context of reduced gravity conditions and have included a chapter devoted to drops and bubbles.

Here is a goldmine where, with care and patience, readers concerned with reduced gravity environments should get acquainted with a beautiful subject under the guidance of two of the most original and imaginative minds. The book is of great interest and conviction because it may be the first to provide a clear, thorough review of the motion of bubbles and drops in reduced gravity. This is definitely a book to buy rather than to borrow. The authors have over the last several years made some of the outstanding contributions to research on these topics and kept pace with the work being done. Three outstanding qualities of the book are its readability; its accuracy in regard to analysis, discussion of experimental results and comparisons with predictions; and its pleasing

appearance. The publishers also deserve our grateful thanks for a most magnificent achievement in producing an excellent example of their technique in technical and scientific publishing.

Contents