# Preface

Quantum theory is one of the more abstract branches of theoretical physics; yet it makes clear and concrete predictions which are repeatedly verified in the lab. This fact, as well as its deep philosophical implications, has always fascinated the lay public, popular science writers and — of course — the researchers. More recently, there has been a significant amount of interplay and synergy between the concepts of microphysics and those of macrophysics. Currently fashionable ideas in cosmology — related to dark energy, structure formation, physics of the very early universe and even the creation of the universe — are deeply linked to concepts in quantum theory. This connection has given an additional impetus to this subject. Because of this strong background of interest, it is worthwhile to take stock of what quantum theory has achieved and where it is leading to at present, in a manner understandable to an educated layman.

Of course, there have been several such popular accounts written in recent years. I plan to make this book different from many others which are currently available, in the following aspects. To begin with, I have kept this book interesting but *not glamorous or mystifying*. There is an unfortunate tendency in the popular literature to do this while discussing the quantum theory. This appeals more to the sense of awe and wonder in the mind of the general reader; but, in the ultimate analysis, does not make the reader any more informed in the subject matter. The discussion is kept down-to-earth in the sense that the concepts will be described in a strictly scientific manner without trying to make them sound overly philosophical or "hyping" them up.

Second, I have kept the book reasonably up-to-date and focused on a key underlying theme. In order to do that I have decided to concentrate on the specific aspects of quantum theory which interface with gravity and cosmology. Hence, I have not included a variety of other topics (like, for example, the philosophical foundations of quantum mechanics, experimental details, technological applications ....) giving the book a clear focus and — of course — keeping it to reasonable length.

Finally, I have discussed all the aspects of science without diluting or distorting them. This would require careful explanation of the concepts and details (including the technical terminology) in a non-mathematical language. Very often authors tend to either talk down to the audience (saying it is too complicated to be explained in non-mathematical terms) or distorting the concepts in order to give the feeling of understanding to the average reader. I believe both these extremes need to be avoided and that a general reader should be treated with the respect he deserves.

This book is divided into 7 chapters. The first chapter outlines the concepts, successes and some history of classical physics from olden days till the end of the 19th century. The emphasis is on concepts and terminology rather than on the history, and the latter is introduced only to the extent that it illustrates some important ideas. The reader will be able to appreciate why the deterministic model of the universe was well-entrenched by the end of the 19th century and why several leading physicists felt that they only need to calculate more decimal places to understand everything about the universe. This chapter will form the backdrop for everything that follows.

In the second chapter, we start with the two "clouds" which were present in the horizon of classical physics, in the early years of the twentieth century and which led to the storms of quantum theory and relativity. Chapters 2 and 3 deal with them individually. In Chapter 2, I describe both special relativity *and* general relativity in a non-technical language and illustrate how they changed the philosophical foundations of classical physics. The emphasis, in the discussion of special relativity, is on those aspects which are required in the description of quantum field theory and particle physics later on. The emphasis in describing general relativity is twofold. First, it clearly points out how gravity acts as an "odd-man-out" and how several difficulties related to combining gravity with other interactions have their roots in the odd features of gravity. Secondly, it develops the concepts of general relativity to an adequate level for discussing cosmology and the early universe in Chapter 5.

The third chapter discusses the difficulties faced by classical physics which led to the development of quantum theory. I move directly to the fundamental concepts of quantum theory and explain how they are different from the corresponding concepts in classical physics. The discussion will be confined to the so called non-relativistic quantum mechanics at this stage since the ideas can be introduced most easily in that context.

The fourth chapter moves on to the issue of combining the principles of quantum theory and relativity, each of which has been described separately in the last two chapters. This leads one, in a natural fashion, to quantum field theory and particle physics. The concepts from particle physics, the success story of QED — the jewel in the crown — and the further developments in taming weak and strong interactions, all find their place here. I have also described topics like the Casimir effect which play a key role in the last few chapters.

Chapter five describes the connection between microphysics and macrophysics by exploring the role played by quantum effects in several epochs in the evolution of the universe. The thermal history of the universe — especially the nucleosynthesis and recombination — involves direct application of known quantum physics to understand key features about the universe. The inflationary phase, the choice for the dark matter candidate, the origin of initial fluctuations and the ever mysterious dark energy — all have quantum themes flowing through them and are discussed in this chapter.

One could say that the real conflict zone of today's theoretical physics is in the interface between quantum theory and gravity. This is taken up in Chapter 6, concentrating on several aspects of quantum gravity and quantum field theory in curved spacetime. The topics here include several issues (like the origin of black hole entropy) which are still unresolved but can be discussed in a fairly detailed manner based on the formalism developed in the earlier chapters. In a way, I will consider this chapter as the high peak of the climb through the book.

The short last chapter is distinctly more speculative than the rest of the book. But it addresses a question which has fascinated researchers and lay persons alike: How did it all begin? I do not pretend that we have all the answers but at the same time I do not want to downplay the significant advances we have made in understanding the laws of nature which allows us to ask questions which were once considered in the domain of philosophy and develop a framework in which they could be answered. I think this is very important and should be conveyed to the reader.

I have not included references to other works or to other popular books. This is a conscious decision since the increased access to the World Wide Web for the laypublic through powerful search engines makes such an exercise totally irrelevant. Anyone interested in these topics will be able to obtain the necessary information very quickly from the Web without me providing a list.

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