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Interiors of the planets

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FOR ISABELL

'The works of the Lord are great, sought out of all them that take pleasure therein.'

From Psalm 111; carved over the entrance to the Cavendish Laboratory

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FOREWORD

The planets, which have always been objects of wonder and curiosity to those with the opportunity or need to lift their eyes to the heavens, now in our times shine with new and strange lights revealed to us by the far seeing instruments carried upon space craft. The Moon, Mars, Venus and Mercury all bear on their surfaces the crater scars of innumerable meteorites that have fallen upon them from the beginning of the solar system. The Earth alone has an active surface that has obliterated those scars. The fluid surface of Jupiter is in constant and vigorous motion, driven by heat flowing out from the interior or, it may be, brought to it by the ultra-violet radiation from the Sun or by the solar wind. The Medicean satellites of Jupiter now present to us strange and individual faces: would Galileo who first saw the mountains on the Moon or the spots on the Sun have been surprised by the eruption of sodium and sulphur from Io and the cloud of gas within which it moves, or by the strange stress patterns upon other of the satellites? Seeing these strange and varied faces of the planets, each apparently different from any other, who can forbear to ask, what bodies are these, how are they made up, that their appearances are so distinctive? Why are some active, and others apparently dead, some dry, and others thickly covered with atmosphere or ocean? We have indeed little to go on to answer those questions, just the sizes of the planets, the grosser features of the fields of gravity around them and the magnetic fields they possess. But within recent years, as we have learnt more by experiment and by theory of the behaviour of solids and liquids at very high pressures, it has become possible to supplement our knowledge of the planets with understanding of how their possible constituents might behave. That, in essence, is the theme of this book. I aim to explain how the mechanical properties of the planets are determined nowadays, to describe the behaviour of planetary materials at planetary pressures, and to combine the Newtonian physics of celestial mechanics with the quantum physics of highly compressed matter to establish the general constitution of the planets. No detailed explanation of the state of each planet can be expected, indeed I shall often emphasize the limitations upon our knowledge and understanding, but some connexions can be made between what we see of the surfaces and what there must be within, and, more speculatively, something may be said about how the system of planets came into being. But for all the great achievements of space research our understanding of the planets is still rudimentary, with many surprises no doubt yet to come, and my emphasis is upon the ways in which we approach the study of the planets, rather than on the results we have so far attained.

I am indebted to Mr. W. B. Harland and to Professor V. Heine for reading certain chapters in typescript and to many other colleagues for discussions on various topics of this book. I am most grateful to the staff of the Cambridge University Press for their outstanding help.

Note on the expression of planetary masses

The masses of all planets are derived from the acceleration of some object in the vicinity at a known distance. The fundamental quantity observed is thus the product, *GM*, of the mass and the gravitational constant. For example, the value of this product for the Earth is

$$GM_E = 3.986\,03 \times 10^{14}\ \mathrm{m^3/s^2}.$$

Values of such products are known to very high accuracy, that of the Earth, for example, to a few parts in a million. The constant of gravitation is, however, poorly known. In this book its value is taken to be

$$6.67 \times 10^{-11}\ \mathrm{m^3/s^2\,kg};$$

it has an uncertainty of a few parts in a thousand.

It follows that ratios of masses are well known, as are the accelerations to which they give rise, but densities expressed in kilogrammes per cubic metre have uncertainties of a few parts in a thousand, and that should be borne in mind in comparing estimates of planetary densities with laboratory data.