Part One The Birth of a New Physics

Classical physics has its origins in the 17th century, with Galileo's[1] experiments on falling bodies, Kepler's[2] calculations of the planetary orbits and Newton's[3] postulates and mathematical laws of motion. During the following two centuries, the Newtonian system of mechanics, together with its theory of gravitation, dominated scientific thinking; its achievements were unprecedented. Perhaps its most impressive feat was predicting the existence of the planet Neptune. Calculations based on Newtonian mechanics indicated that the slight perturbations that had been observed in the orbit of the planet Uranus could be accounted for by the presence of an additional planet in the solar system, one previously unknown. In 1846, this new planet, Neptune, was found at the exact position in space indicated by the calculations.[4]

By the middle of the 19th century, the ancient mystery of the nature of heat had been solved by the kinetic theory of matter and the science of thermodynamics. The latter had also provided an understanding for the 'arrow of time' inherent in the workings of Nature.

Classical physics reached its zenith in the second half of the 19th century with the publication of Maxwell's[5] theory of electromagnetism and the discovery of the electromagnetic waves whose existence it had predicted. This theory summarised and unified everything that was known at the time about electrical and magnetic phenomena and provided the first comprehensive conceptual basis for the science of optics.

However, towards the end of the 19th century, it became clear that there were important physical phenomena for which classical physics had no satisfactory explanation. The electron, X-rays and radioactivity, all of which were discovered within a few years of each other in the last decade of the century, were beyond the competence of classical physics to explain. Moreover, there were even instances where the hypotheses and laws of classical physics were found to be totally incompatible with the results of experiments in more conventional fields, such as studies of the speed of light relative to different observers and the emission and absorption of heat radiation. It became apparent that despite its great achievements, some of the most fundamental

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1 Galileo Galilei 1564-1642, the Italian physicist and astronomer who first asserted that "the book of nature is written in the language of mathematics".

2 Johannes Kepler 1571-1630, German astronomer.

3 Sir Isaac Newton 1642-1727, English mathematician, astronomer and physicist.

4 In a similar technique that is currently being used in the search for planetary systems other than the solar system, the 'wobbling' observed in the motion of certain stars is attributed to the presence of large but as yet unseen orbiting bodies (planets).

5 James Clerk Maxwell 1831-1879, Scottish mathematician and physicist.

principles underlying classical physics were incorrect. Clearly, fresh ideas and theories were needed.

At the beginning of the 20th century, three new hypotheses were put forward that changed the face of physics. They were:

1. The theory of relativity;
2. Quantum theory;
3. The nuclear model of the atom.

This triad laid the foundations of modern physics. They and the effects derived from them are the subject of this book.

The new theories of modern physics not only resolved the problems left unanswered by classical physics but extended the reach of the physical sciences into previously unknown fields. In general, the familiar and well established laws of classical physics remain valid for dealing with phenomena that occur on a 'normal' scale, in the human sense of the term. However, when dealing with phenomena occurring on the cosmic scale on the one hand, and on the atomic scale on the other, only the more comprehensive laws of modern physics can be employed.

Our study of 20th century physics opens with the discovery of the electron, the first elementary particle to be identified. This is followed by a short review of the classical theory of electromagnetic waves. These two topics provide the basis for the comprehensive examination of the theory of special relativity that follows. Part One of this book concludes with a brief survey of the theory of general relativity.