CHAPTER 1 Introduction

The importance of computers in physics and the nature of computer simulation is discussed. The nature of object-oriented programming and various computer languages is also considered.

1.1 ■ IMPORTANCE OF COMPUTERS IN PHYSICS

Computation is now an integral part of contemporary science and is having a profound effect on the way we do physics, on the nature of the important questions, and on the physical systems we choose to study. Developments in computer technology are leading to new ways of thinking about physical systems. Asking "How can I formulate this problem on a computer?" has led to the understanding that it is practical and natural to formulate physical laws as rules for a computer rather than only in terms of differential equations.

For the purposes of discussion, we will divide the use of computers in physics into the following categories: numerical analysis, symbolic manipulation, visualization, simulation, and the collection and analysis of data. *Numerical analysis* refers to the solution of well-defined mathematical problems to produce numerical (in contrast to symbolic) solutions. For example, we know that the solution of many problems in physics can be reduced to the solution of a set of simultaneous linear equations. Consider the equations

$$2x + 3y = 18$$
$$x - y = 4.$$

It is easy to find the analytical solution $x = 6$, $y = 2$ using the method of substitution. Suppose we wish to solve a set of four simultaneous equations. We again can find an analytical solution, perhaps using a more sophisticated method. However, if the number of simultaneous equations becomes much larger, we would need to use a computer to find a solution. In this mode the computer is a tool of numerical analysis. Because it is often necessary to compute multidimensional integrals, manipulate large matrices, or solve nonlinear differential equations, this use of the computer is important in physics.

One of the strengths of mathematics is its ability to use the power of abstraction, which allows us to solve many similar problems simultaneously by using symbols. Computers can be used to do much of the *symbolic manipulation*. As an example, suppose we want to know the solution of the quadratic equation, $ax^2 + bx + c = 0$. A symbolic manipulation program can give the solution as $x = [-b \pm \sqrt{b^2 - 4ac}]/2a$. In addition, such a program can give the usual numerical solutions for specific values of a, b, and c. Mathematical operations such as differentiation, integration, matrix inversion, and power series expansion can be