Introduction

Figure 5.1 A soccer player prepares to kick a soccer ball. (credit: Matteo Brama, CC BY-SA 4.0, via Wikimedia Commons)

A soccer ball is rolling along the ground when a player kicks the ball, changing the ball's speed and direction. What causes the ball's velocity to change? After leaving the player's foot, the ball then travels in projectile-like motion (as you studied in Chapter 4, Motion in Two and Three Dimensions). Again, what causes the ball's velocity to change as it flies through the air?

The answer in both cases is **forces**. While the player's foot is in contact with the ball, it exerts a force on the ball, in addition to the Earth's gravitational force, a contact force with the ground, and a resistive force caused by the air. The vector sum of all these forces can be related to the change in the ball's velocity. When the ball moves through the air, only the gravitational force and air resistance force act on the ball, giving a different total force.

So far in our study of mechanics, we have focused on kinematics, which describes how objects move. This chapter begins our study of **dynamics**, which describes how forces affect the motion of objects. Forces are important because they affect nearly everything in the universe, from the gravitational forces between stars and planets to the atomic forces that hold matter together at the microscopic level.

The foundation of dynamics are the laws of motion stated by Isaac Newton (1642–1727). Newton's laws are the fundamental principles that relate force and motion and are are critical for predicting and explaining a wide range of phenomena, including nearly everything we encounter in everyday life. Not until the advent of modern physics in the early twentieth century was it discovered that there were limits to accuracy of Newton's laws. The motion of objects moving at very high speeds, near the speed of light, are better described by the theory of relativity, developed by Albert Einstein (1879-1955). The theory of quantum mechanics is better at predicting the behavior or objects smaller than the size of most molecules (about 10^{-9} m in diameter).