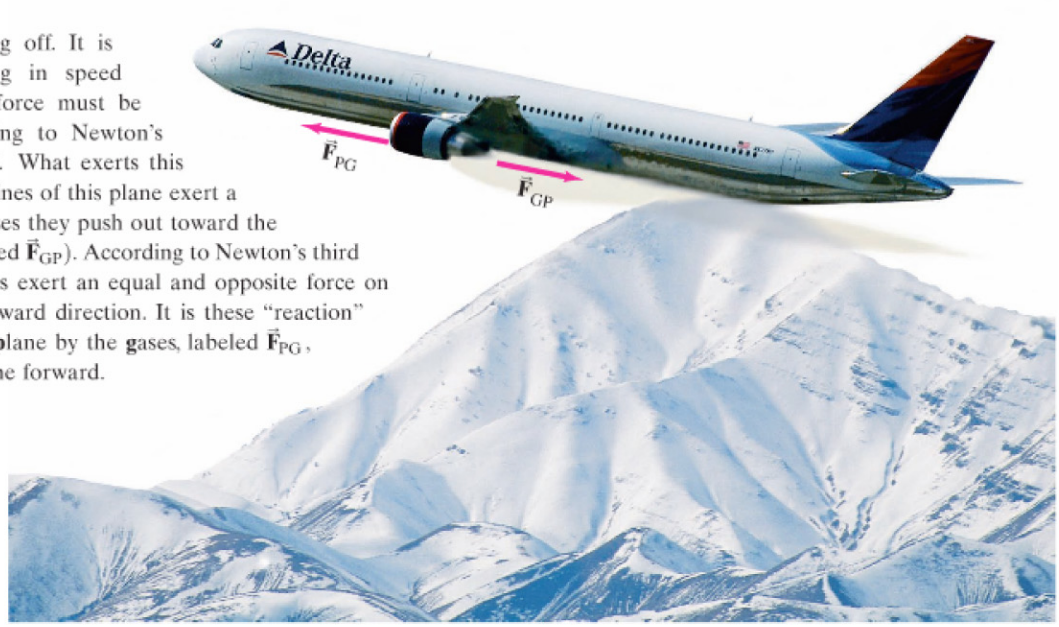

This airplane is taking off. It is accelerating, increasing in speed rapidly. To do so, a force must be exerted on it according to Newton's second law, $\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}$. What exerts this force? The two jet engines of this plane exert a strong force on the gases they push out toward the rear of the plane (labeled $\vec{\mathbf{F}}_{GP}$). According to Newton's third law, these ejected gases exert an equal and opposite force on the airplane in the forward direction. It is these "reaction" forces exerted on the **p**lane by the **g**ases, labeled $\vec{\mathbf{F}}_{PG}$, that accelerate the plane forward.

CHAPTER 4

Dynamics: Newton's Laws of Motion

FIGURE 4–1 A force exerted on a grocery cart—in this case exerted by a child.

We have discussed how motion is described in terms of velocity and acceleration. Now we deal with the question of *why* objects move as they do: What makes an object at rest begin to move? What causes an object to accelerate or decelerate? What is involved when an object moves in a circle? We can answer in each case that a force is required. In this Chapter, we will investigate the connection between force and motion, which is the subject called **dynamics**.

We begin with intuitive ideas of what a force is, and then discuss Newton's three laws of motion. We next look at several types of force, including friction and the force of gravity. We then apply Newton's laws to real problems.

4–1 Force

Intuitively, we experience **force** as any kind of a push or a pull on an object. When you push a stalled car or a grocery cart (Fig. 4–1), you are exerting a force on it. When a motor lifts an elevator, or a hammer hits a nail, or the wind blows the leaves of a tree, a force is being exerted. We say that an object falls because of the *force of gravity*.