



FIGURE 4–10 Another example of Newton’s third law: the launch of a rocket. The rocket engine pushes the gases downward, and the gases exert an equal and opposite force upward on the rocket, accelerating it upward. (A rocket does *not* accelerate as a result of its propelling gases pushing against the ground.)

Consider how we walk. A person begins walking by pushing with the foot backward against the ground. The ground then exerts an equal and opposite force forward on the person (Fig. 4–11), and it is this force, *on* the person, that moves the person forward. (If you doubt this, try walking normally where there is no friction, such as on very smooth slippery ice.) In a similar way, a bird flies forward by exerting a backward force on the air, but it is the air pushing forward on the bird’s wings that propels the bird forward.

CONCEPTUAL EXAMPLE 4–4 What exerts the force on a car? What makes a car go forward?

RESPONSE A common answer is that the engine makes the car move forward. But it is not so simple. The engine makes the wheels go around. But if the tires are on slick ice or deep mud, they just spin. Friction is needed. On *solid* ground, the tires push backward against the ground because of friction. By Newton’s third law, the ground pushes on the tires in the opposite direction, accelerating the car forward.

We tend to associate forces with active objects such as humans, animals, engines, or a moving object like a hammer. It is often difficult to see how an inanimate object at rest, such as a wall or a desk, or the wall of an ice rink (Fig. 4–9), can exert a force. The explanation is that every material, no matter how hard, is elastic (springy), at least to some degree. A stretched rubber band can exert a force on a wad of paper and accelerate it to fly across the room. Other materials may not stretch as readily as rubber, but they do stretch or compress when a force is applied to them. And just as a stretched rubber band exerts a force, so does a stretched (or compressed) wall, desk, or car fender.

From the examples discussed above, we can see how important it is to remember *on* what object a given force is exerted and *by* what object that force is exerted. A force influences the motion of an object only when it is applied *on* that object. A force exerted *by* an object does not influence that same object; it only influences the other object *on* which it is exerted. Thus, to avoid confusion, the two prepositions *on* and *by* must always be used—and used with care.

One way to keep clear which force acts on which object is to use double subscripts. For example, the force exerted on the **P**erson by the **G**round as the person walks in Fig. 4–11 can be labeled \vec{F}_{PG} . And the force exerted on the ground by the person is \vec{F}_{GP} . By Newton’s third law

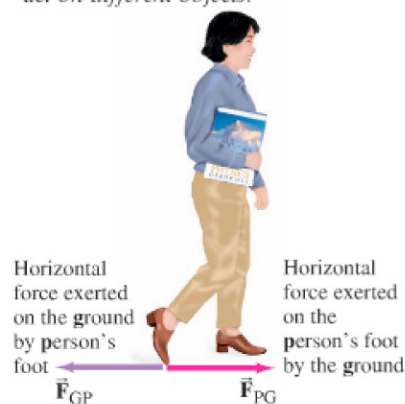
$$\vec{F}_{GP} = -\vec{F}_{PG}. \quad (4-2)$$

\vec{F}_{GP} and \vec{F}_{PG} have the same magnitude (Newton’s third law), and the minus sign reminds us that these two forces are in opposite directions.

Note carefully that the two forces shown in Fig. 4–11 act on different objects—hence we used slightly different colors for the vector arrows representing these forces. These two forces would never appear together in a sum of forces in Newton’s second law, $\Sigma \vec{F} = m\vec{a}$. Why not? Because they act on different objects: \vec{a} is the acceleration of one particular object, and $\Sigma \vec{F}$ must include *only* the forces on that *one* object.

How we can walk

FIGURE 4–11 We can walk forward because, when one foot pushes backward against the ground, the ground pushes forward on that foot. The two forces shown act on different objects.



Inanimate objects can exert a force (due to elasticity)

PROBLEM SOLVING

For each force, be clear **on** which object it acts, and **by** which object it is exerted. $\Sigma \vec{F} = m\vec{a}$ applies only to forces acting **on** an object.

NEWTON'S THIRD LAW OF MOTION