

5.10 A man pushes a 6,675-Newton rock with a force of 95 Newtons. If the rock is already moving, what will its acceleration be? ($\mu_s = 0.15$, $\mu_k = 0.011$)



5.11 A child pushes a 2.3-kg toy along the floor at a constant velocity. What force is the child exerting? ($\mu_s = 0.25$, $\mu_k = 0.13$)



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Newton's Third Law

You never thought we'd get to the last law, did you? Well, you'll be very happy to know that Newton's Third Law does not require nearly as much discussion! Stated simply, Newton's Third Law is easy to remember:

Newton's Third Law - For every action, there is an equal and opposite reaction.

This law is most easily understood by illustration. Suppose you are pushing against a wall:



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When you push the wall, it actually pushes back at you! In fact, it pushes back with equal strength. This is the equal and opposite reaction that Newton's Third Law talks about.

This may seem pretty simple to you, but there are some pretty profound consequences to Newton's Third Law. Suppose, for example, you drop a ball. What happens? Well, it falls to the earth. According to Newton's Third Law, every action must have an equal and opposite reaction. If the action is that the ball falls to the earth, what is the equal and opposite reaction? Believe it or not, the *earth climbs up towards the ball!* That's right! The ball does not just fall; the earth actually moves

up to reach the ball. Now if this sounds a little bizarre, remember one thing. The equal and opposite part of Newton's Third Law applies to the *forces* involved. Thus, the earth exerts a force (gravity) that accelerates the ball to it. The ball exerts an equal and opposite force causing the earth to rise and meet the ball. Think about it, though. The forces are equal, but the masses are not. The earth is millions of times more massive than the ball, which means that the acceleration of the ball towards the earth is millions of times faster than the acceleration of the earth to the ball. Thus, the ball will move a lot, and the earth will only move a little. Nevertheless, it is important to understand that the earth does move a little in this situation.

It is very important to realize that the equal and opposite forces talked about in Newton's Third Law do not act on the *same* object. If that were the case, then there would never be any motion. After all, if equal and opposite forces act on the same object, they cancel each other out and the resulting force would be zero. Instead, the equal and opposite forces discussed in Newton's Third Law affect *different* objects. In our first example, you exerted a force on the wall. The equal and opposite force was exerted not on the wall, but on you. Thus, the two forces acted on two completely different objects. In the second example, the earth exerted a force on the ball, causing it to accelerate. The ball then caused an equal and opposite force on the earth, causing it to accelerate. Once again, the two forces worked on two *separate* objects. One force worked on the earth, the other on the ball. Both were able to accelerate, since the forces did not cancel, because they acted on different objects.

One more example should help. Suppose you jump onto a trampoline. When you hit the trampoline, you exert a force on the trampoline. What does Newton's Third Law say will happen? The trampoline will exert an equal but opposite force on you. How can you tell that this is happening? Well, the trampoline's surface bends. This tells you that you are exerting a force on the trampoline. How do you know that the trampoline is exerting a force back? You start to slow down, stop, and then accelerate in a completely different direction. You could have never done that if a force had not acted on you. That force was the equal and opposite force required in Newton's Third Law. Thus, you exerted a force on the trampoline (causing the surface to bow), and the trampoline exerted a force right back on you (causing you to accelerate in a different direction). See if you can use Newton's Third Law to answer the following "On Your Own" problem:

ON YOUR OWN

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5.12 A tennis ball hits a tennis racquet. What two forces (besides gravity) exist in this situation? What are the visible ramifications of these two forces?



As you review this module, pay close attention to all of our discussions of Newton's Second Law. The next module is devoted exclusively to more applications of this very important law, so you need to have a firm grasp of everything related to it in this module!