Reflections

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Newton's Third Law

Uri Haber-Schaim

Years ago, a popular science book made the following statement: The big Earth exerts just a small force on an apple, the apple's weight; you can imagine how much smaller would be the force exerted by the small apple on the Earth. More recently, a physical science textbook for middle schools showed a photograph of two Sumo wrestlers pushing one another strongly without moving. The caption explained that the two wrestlers are not moving because of Newton's Third Law. These two statements are examples of two main misunderstandings of Newton's Third Law: (1) confusing a force with its effect on an object, and (2) forgetting that the two forces related by the Third Law are acting on different objects, and cannot balance one another.

Why are the misunderstandings of Newton's Third law so widely spread and hard to eradicate? I think that at least a partial answer can be found in the sloppy way Newton's Third Law is taught in many textbooks. Here are two experiments that correctly demonstrate Newton's Third Law. Both emphasize that the two forces related by Newton's Third Law are acting on different bodies, and the effects of these forces are measurable.

The first approach is used in Chapter 1 of *Force, Motion and Energy* and in the Ninth Edition of *Introductory Physical Science*. The setup consists of a block of wood with a rough surface resting on a cart. The cart is pulled to the left by a spring scale, and the block is pulled to the right by another spring scale (Figure 1).

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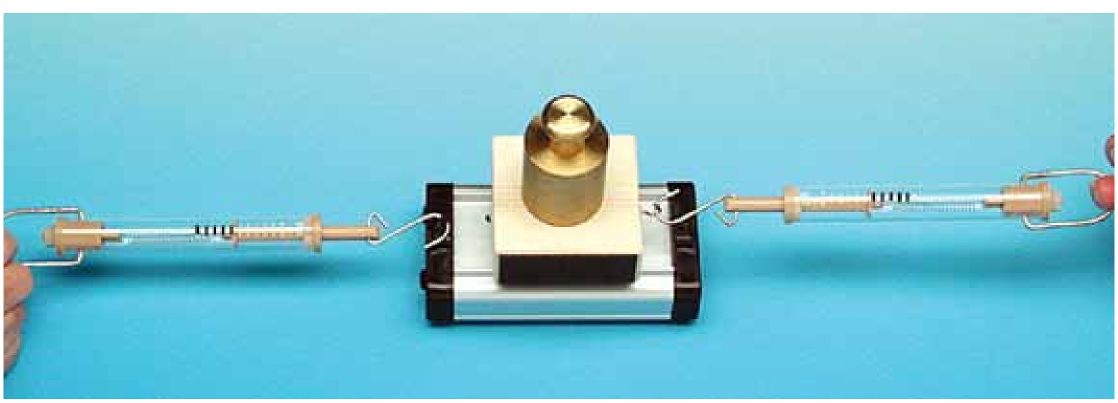

Figure 1
A weight was placed on the block to increase the friction with the cart. The wheels of the cart are not visible in the photograph. (From *Introductory Physical Science* Ninth Edition by Haber-Schaim, Gendel, Kirksey, Pratt and Stair, Science Curriculum Inc., 2010)

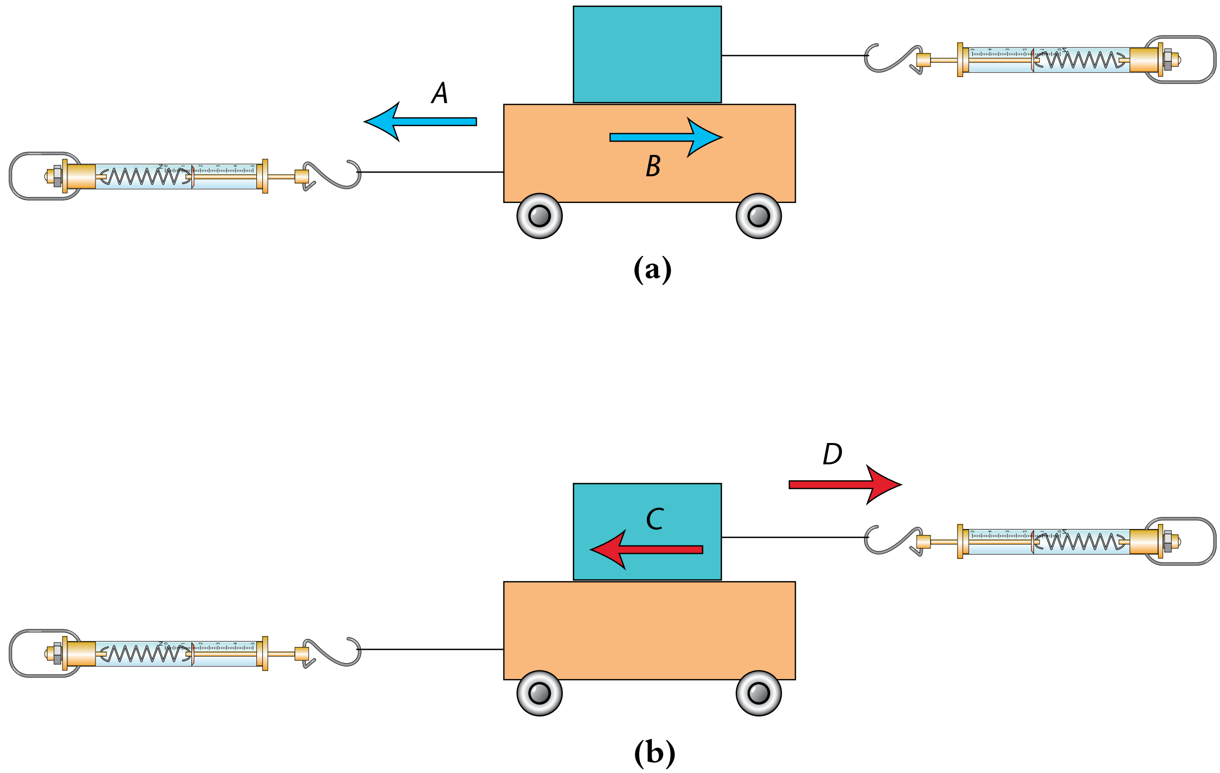

Figure 2
(a) The forces keeping the cart at rest. (b) The forces keeping the block at rest. (From *Introductory Physical Science* Ninth Edition by Haber-Schaim, Gendel, Kirksey, Pratt, and Stair, Science Curriculum Inc., 2010)

The cart is at rest with respect to the table. The wheels of the cart have high-quality bearings. This means that the cart is kept at rest solely by the force of friction exerted on it by the block and the force exerted on it by the spring scale (Figure 2a). Similarly, the block is at rest with respect to the cart. So the force of friction exerted on it by the block is balanced by the force exerted by the second spring scale (Figure 2b). Now look again at Figure 1. The forces exerted by the two spring scales are equal in magnitude. They balance the two frictional forces. Hence, the frictional force exerted by the block on the cart is equal in magnitude to the frictional force exerted by the cart on the block.

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2013 *IPS* National Workshops

In July of 2013, Science Curriculum Inc. will offer three different *IPS* workshops on the Colorado School of Mines campus in Golden, CO. The workshops will cover Chapters 1-6, 7-11, and 12-16, respectively, of the 9th Edition of *IPS*. The dates for the workshops are as follows:

***Introductory Physical Science* – Part 1** (covering Chapters 1–6) July 14–19, 2013
***Introductory Physical Science* – Part 2** (covering Chapters 7–11) July 21–26, 2013
***Introductory Physical Science* – Part 3** (covering Chapters 12–16) July 21–26, 2013

A workshop registration form can be downloaded at **http://www.sci-ips.com/e_workshops.htm**. For questions or additional information, please contact us toll-free (888-501-0957) or by email (workshops@sci-ips.com).

Figure 3
Dry Ice pucks float on a thin layer of carbon dioxide. The gas is produced by the evaporation of solid carbon dioxide inside the containers on top of the metals disks with small holes at their centers. The bent steel strip pushing on the pucks is tied to the left puck. The mass of the left puck was 3.9 kg, the mass of the right puck was 2.0 kg. (From *PSSC Physics*, Seventh Edition by Haber-Schaim, Dodge, Gardner and Shore, Kendall/Hunt Publishing Company, 1991)

In the experiment just described, the cart and the block could move but were prevented from doing so by balancing forces. In the next experiment each of the two bodies will start from rest and actually move under the influence of the forces they exert on each other for a short time. The setup is shown in Figure 3. The two Dry Ice pucks are held together by a thread, which prevents a bent steel strip from pushing the pucks apart. When the thread is cut, the pucks are pushed apart. When the strip is no longer in contact with the puck on the right, both pucks continue to move at a constant velocity (Figure 4). The forces acting on the two pucks were clearly in opposite directions. Were they of equal magnitude? The bent steel strip acts like a spring. Our experience with springs may suggest a positive answer to this question. But suppose the steel strip was hidden from view; all you could see are the two pucks. How could we then find out if the forces were of equal magnitude?

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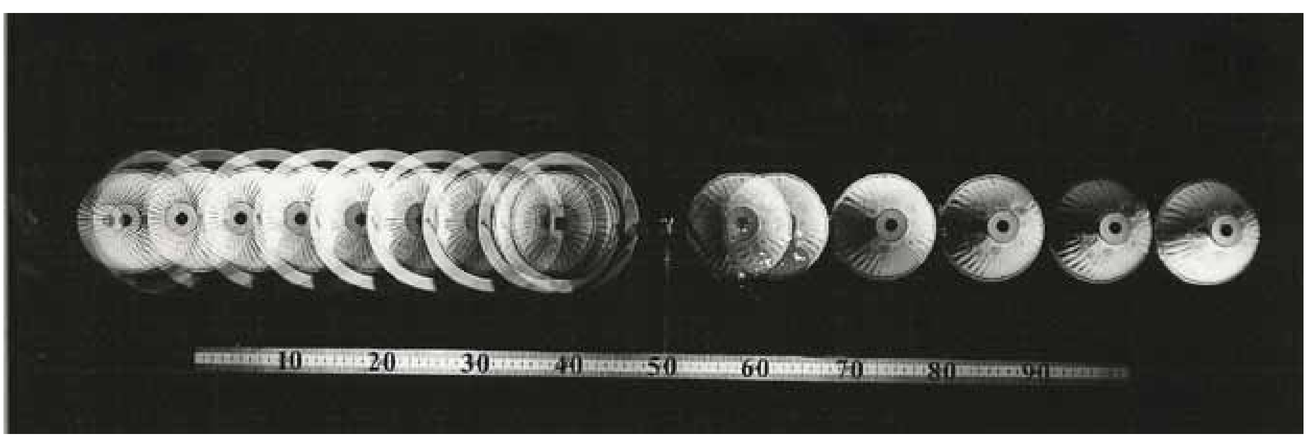

Figure 4
A multiple-flash picture of the motion of the two pucks after being pushed apart by the steel strip. The flash rate was 4 per second, and the scale is in centimeters. The photograph was taken from above. (From *PSSC Physics*, Seventh Edition by Haber-Schaim, Dodge, Gardner and Shore, Kendall/Hunt Publishing Company, 1991)

NEWTON'S THIRD LAW (from page 3)

We can apply Newton's Second Law to the motion of each puck (Section 16.7, *IPS* Ninth Edition):

Force • (time interval) = mass • (change in velocity)

The masses of the pucks were measured just before the experiment was done. With the pucks being at rest at the beginning, their changes in velocities equaled their final velocities. These velocities were measured in Figure 4. It turned out that the product of mass and change in velocity were the same within the experimental uncertainty, except for the sign, one positive and one negative.

On the left side of the equation expressing Newton's Second Law the time intervals must be the same for both forces. Either the spring pushes on both pucks or on neither. Hence, the two forces act in opposite direction with the same magnitude.

Isaac Newton (1642–1727) had neither Dry Ice pucks nor flash photography or motion detectors at his disposal. Yet he did experiments on the motion of two bodies before and after a brief interaction through a force acting along the line connecting them. His equipment was simple but he reached the same conclusion as the one described here.

Finally, suppose that the mass of the left puck in Figure 3 were one thousand times greater than the mass of the right puck. The change in its velocity would be immeasurably small, and we could not conclude anything about the force acting on the massive puck. The confusion between the change in velocity caused by a force and the force itself is at the root of the silly statement that I quoted at the beginning of this article.

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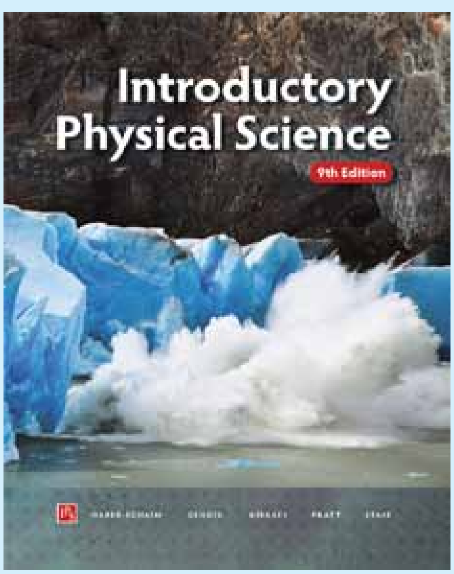

The Ninth Edition of *Introductory Physical Science* is now listed in the iTunes Bookstore! For the low introductory price of $14.99 (in the U.S.), you and your students can purchase the Ninth Edition of *IPS* as an ebook.

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