## nT7C-CT15: Two Boxes on a Frictionless Surface—Speed

Two boxes are tied together by a string and are sitting at rest in the middle of a large frictionless surface. Between the two boxes is a massless compressed spring. The string tying the two boxes together is cut suddenly and the spring expands, pushing the boxes apart. The box on the left has four times the mass of the box on the right.



At the instant (after the string is cut) that the boxes lose contact with the spring, will the speed of the box on the left be *greater than, less than,* or *equal to* the speed of the box on the right?

Explain.

Answer: The box on the left will have one-fourth the speed of the box on the right. Before the string is cut, the momentum of the system is zero. Momentum will be conserved, so the boxes will have equal but opposite momenta after they lose contact with the spring. So the box with the larger mass will have a lower speed.

## nT7C-WWT16: Two Skaters Pushing off Each Other—Force

Two skaters, a large girl and a small boy, are initially standing face-to-face but then push off each other. The boy ends up with more kinetic energy than the girl. A physics student who is watching makes the following contention about the forces that the boy and girl exerted on each other:

“Since the boy has more kinetic energy he also has more momentum, so the girl had to have pushed harder on him than he pushed on her.”

What, if anything, is wrong with this contention? If something is wrong, identify all problems and explain how to correct them. If this contention is correct, explain why.

Answer: The boy does not have a larger momentum than the girl after they push off from each other: Their momenta are equal. Newton’s Third Law requires that the forces the two exerted on each other had to have been equal in magnitude and oppositely directed, and since those forces acted for the same time intervals, the change in momentum had to be equal in magnitude but oppositely directed for the two skaters. Consequently, since they both started from rest, their final momenta are equal in magnitude.

## nT7D-RT18: Colliding Carts Sticking Together—Final Speed

In each of the six figures below, two carts traveling in opposite directions are about to collide. The carts are all identical in size and shape, but they carry different loads and are initially traveling at different speeds. The carts stick together after the collision. There is no friction between the carts and the ground.



Rank these situations on the basis of the speed of the two-cart systems after the collision.

Greatest 1 \_\_\_\_\_\_\_ 2 \_\_\_\_\_\_\_ 3 \_\_\_\_\_\_\_ 4 \_\_\_\_\_\_\_ 5 \_\_\_\_\_\_\_ 6 \_\_\_\_\_\_\_ Least

OR, The speed is the same but not zero for these two-cart systems after the collision. \_\_\_

OR, The speed is zero for these two-cart systems after the collision. \_\_\_

OR, We cannot determine the ranking for the speeds of these cart systems after the collision. \_\_\_

**Please explain your reasoning.**

Answer: The speed is zero for all six carts; the total initial momentum is zero so after the collision the carts will be at rest.

## nT7D-CT20: Bullet Strikes a Wooden Block—Block & Bullet Speed After Impact

In Case A, a metal bullet penetrates a wooden block. In Case B, a rubber bullet with the same initial speed and mass bounces off of an identical wooden block.

a) Will the speed of the wooden block after the collision be *greater in Case A, greater in Case B,* or *the same in both cases*?

Explain.

Answer: Greater for B. The initial momentum in both cases is the same and points to the right. The final momentum of the bullet points to the right in Case A and to the left in Case B. Since the final momentum of the system consisting of the bullet and the block is the same as the initial momentum, and this final momentum is the vector sum of the momentum of the bullet and the momentum of the block, the momentum of the block must be greater in Case B.

b) Will the speed of the bullet in Case B after the collision be *greater than*, *less than*, or *the same as* the speed of the bullet just before the collision?

Explain.

Answer: Less than. The energy of the system containing both block and bullet cannot be greater after the collision than before. The initial energy is the kinetic energy of the bullet, and the final energy is the sum of the kinetic energies of the bullet and the block. Since the block has a non-zero final kinetic energy, the final kinetic energy of the bullet must be less than the initial kinetic energy of the bullet.

## nT7D-CCT24: Colliding Carts That Stick Together—Final Kinetic Energy

Two identical carts traveling in opposite directions are shown just before they collide. The carts carry different loads and are initially traveling at different speeds. The carts stick together after the collision.



Three physics students discussing this situation make the following contentions:

Alex: “These carts will both be at rest after the collision since the initial momentum of the system is zero, and the final momentum has to be zero also.”

Belinda: “If that were true it would mean that they would have zero kinetic energy after the collision and that would violate conservation of energy. Since the right-hand cart has more kinetic energy, the combined carts will be moving slowly to the left after the collision.”

Chano: “I think that after the collision the pair of carts will be traveling left at 20 cm/s. That way conservation of momentum and conservation of energy are both satisfied.”

Which, if any, of these three students do you think is correct?

*Alex* \_\_\_\_\_ *Belinda* \_\_\_\_\_ *Chano* \_\_\_\_\_ None of them\_\_\_\_\_\_

Please explain your reasoning.

Answer: Alex is correct. The momenta of the two carts are equal and opposite before the collision, so the total initial momentum is zero and the total final momentum has to be zero also.



