

Linear momentum.

1. A 4500-kg caboose rolling into a railroad station at a constant +24 km/h collides with a stationary 5700-kg passenger car. If the two cars couple upon impact, how fast do the two of them move together?
2. A 4500-kg caboose rolling into a railroad station at a constant +24 km/h runs into a stationary 5700-kg passenger car. If the two cars are bounce apart upon impact with the caboose moving a +15 km/h, how fast does the passenger car move?
3. A 4500-kg caboose rolling into a railroad station at a constant +24 km/h smacks into a 5700-kg passenger car rolling along at +12 km/h. If the two cars couple upon impact, how fast do the two of them move together?
4. A 4500-kg caboose rolling into a railroad station at a constant +24 km/h smashes into a 5700-kg passenger car rolling along at -12 km/h. If the two cars couple upon impact, how fast do the two of them move together?
5. An 85-lb Alaskan malamute is running northward at 2.5 ft/s while a 55-lb Siberian husky is running eastward at 3.5 ft/s. Their 155-lb owner, who is unfortunately leashed to both of them, has the same momentum as the two dogs taken together. What is the momentum of the center of mass of the dogs and their owner?
6. A 135-kg astronaut and a 1500-kg satellite are at rest relative to the Space Shuttle. The astronaut pushes on the satellite, giving it a speed of 0.25 m/s directly away from the shuttle. $7\frac{1}{4}$ s later, the astronaut comes into contact with the side of the shuttle. What was the initial distance from the Space Shuttle to the astronaut?
7. A 640-kg automobile driving at 15 m/s enters an intersection heading due north; along the y -axis at 90° . An imbecile driving way too fast in an 860-kg SUV runs the red light at the intersection (heading east along $x = 0^\circ$) and smashes into the automobile. The two vehicles stick together and slide away from the point of collision at a combined velocity of $\mathbf{v}_f = (22 \text{ m/s}, 17^\circ)$. What was the original velocity of the SUV?
8. Rene Descartes defined the “quantity” of motion of an object as the product of its mass and speed. Is his quantity of motion conserved as he believed it was? If not, how would you modify his definition so the quantity of motion would be conserved?
10. In the last inning of the final game of the season between the Detroit Tigers and the Cleveland Indians, a relief pitcher throws the 0.15-kg baseball as a speed of 150 km/h. The ball is bunted (softly), with the bat exerting a force of 7.5×10^3 N on the ball for exactly 1.5 ms. The force is directed back toward the pitcher. What is the speed of the baseball as it comes off the bat?
11. A bullet (with a mass of 4.4 oz) is fired into a block of wood weighing $27\frac{1}{2}$ lb. The block of wood and the embedded bullet swing along an arc (hence, the ballistic *pendulum* part of the problem) and rise a distance of exactly $1\frac{3}{4}$ ft. Using conservation of energy and momentum, find the initial velocity of the bullet.
12. A bullet (with a mass of 4.4 oz) is fired into a block of wood weighing $27\frac{1}{2}$ lb. The block of wood and the embedded bullet slide along a frictionless, horizontal surface until it encounters a spring. If the block of wood compresses the spring 6.3 in before coming to rest, (a) what is the spring constant? (b) What initial speed would the block have if it compresses the spring 3.6 in?



13. Firefighters working to put out a four-alarm fire use a high-pressure hose which sprays out water with a speed of 25 m/s at a rate of 120 kg/s. What is the (average) reaction force exerted on the hose and firefighters? Note: In an actual fire, notice how much effort firefighters use to control a large hose.



14. A peregrine falcon is soaring on the thermals above a small mountain range, looking for an afternoon snack. She spots a sparrow flying horizontally along below her at 15 m/s, folds her wings, and dives straight down. When she hits the sparrow, the falcon is moving vertically at -25 m/s. If the falcon's mass is $1\frac{1}{3}$ kg and the sparrow's is 33 g, what will be their combined velocity after the raptor strikes the sparrow?

15. Wile E. Coyote's newest strategy is to attempt to crush the Roadrunner by wedging an Acme Mega-crowbar underneath a large 250-N sandstone boulder and shoving it over a cliff. Unfortunately, Wile E. Coyote falls off the boulder just seconds before it, too, falls. Realizing his peril, he throws a 0.11-kg rubber racquetball at the boulder with a relative velocity of 16.2 m/s as the boulder falls with a terminal speed of 132 km/h, in the hope of slowing down the falling boulder. (a) How fast does the rubber ball bounce back toward Wile E. Coyote? (b) How do you account for the fact that the ball's kinetic energy has increased?



16. Two sleds are located a short distance apart on an ice-covered (and essentially frictionless) pond with one directly behind the other. A $2\frac{1}{4}$ -lb cat, standing on one sled, jumps across to the other and immediately back to the first. Both jumps are made at a speed of 2.7 ft/s relative to the sled the cat is standing on when the jump is made. Find the final speeds of the two sleds if the mass of each sled is 12 lb.
17. During the Korean War in the 1950s, American pilots flying the *F-86 Sabre* jet reported that they lost 30 to 40 mi/h in air speed whenever they fired their guns. Why?
18. While trying to outrun the Burkina Faso National Police – who are attempting to arrest you for the illegal importation of a suitcase containing approximately 2.013 billion CFA Franc BCEAO without proper documentation and without paying customs fees – in a “borrowed Mercedes-Benz S550 sedan, you race through an intersection at a speed of 85 mi/h and collide with a 8700-lb oxcart. If the oxcart is moving at 4 mi/h and the curb weight of the Mercedes-Benz automobile is 4630 lb, (a) what is the net resultant velocity of the two vehicles if they stick together? Assume you “T” the oxcart. (b) How far will the two vehicles travel before stopping if the mass of mangled junk accelerates at -2.35 ft/s²? (c) What will be the length of your prison sentence after you are convicted of drug smuggling?

19. Two cosmonauts are floating at rest with respect to the International Space Station in orbit. They decide to play a round of catch with a 0.55-kg hunk of meteoroid. One astronaut – with a mass of 195 kg, including suit – heaves the meteoroid at a speed of 15 m/s toward the other (who has a mass of 180 kg). The second astronaut catches the rock and hurls it back at 20. m/s (with respect to the ship). After the first cosmonaut catches the meteoroid, how fast is each astronaut moving and in what direction?

