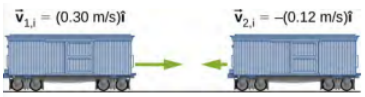
14.E: Collisions (Exercises)

Conceptual Questions

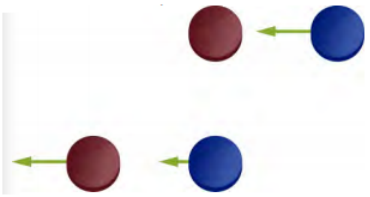
1. Describe examples of a completely elastic collision, a mostly elastic collision, a mostly inelastic collision, and a completely inelastic collision. Which one of these four is most common?
2. Two objects of equal mass are moving with equal and opposite velocities when they collide. Can all the kinetic energy be lost in the collision?
3. Describe a system for which momentum is conserved but mechanical energy is not. Now the reverse: Describe a system for which kinetic energy is conserved but momentum is not.

Problems

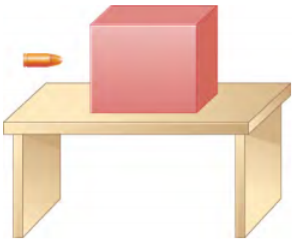
3. Train cars are coupled together by being bumped into one another. Suppose two loaded train cars are moving toward one another, the first having a mass of 1.50 x 10^5 kg and a velocity of (0.30 m/s) $\hat{i}$, and the second having a mass of 1.10 x 10^5 kg and a velocity of −(0.12 m/s) $\hat{i}$. What is their final velocity?



4. Two identical pucks collide elastically on an air hockey table. Puck 1 was originally at rest; puck 2 has an incoming speed of 6.00 m/s to the left. What is the velocity (magnitude and direction) of puck 1 after the collision?



5. The figure below shows a bullet of mass 200 g traveling horizontally towards the east with speed 400 m/s, which strikes a block of mass 1.5 kg that is initially at rest on a frictionless table. After striking the block, the bullet is embedded in the block and the block and the bullet move together as one unit. (a) What is the magnitude and direction of the velocity of the block/bullet combination immediately after the impact? (b) What is the magnitude and direction of the impulse by the block on the bullet? (c) What is the magnitude and direction of the impulse from the bullet on the block? (d) If it took 3 ms for the bullet to change the speed from 400 m/s to the final speed after impact, what is the average force between the block and the bullet during this time?



6. A 5.50-kg bowling ball moving at 9.00 m/s collides with a 0.850-kg bowling pin, which is scattered at an angle of 15.8° to the initial direction of the bowling ball and with a speed of 15.0 m/s. (a) Calculate the final velocity (magnitude and direction) of the bowling ball. (b) Is the collision elastic?
7. Ernest Rutherford (the first New Zealander to be awarded the Nobel Prize in Chemistry) demonstrated that nuclei were very small and dense by scattering helium-4 nuclei from gold-197 nuclei. The energy of the incoming helium nucleus was 8.00 x 10^{-13} J, and the masses of the helium and gold nuclei were 6.68 x 10^{-27} kg and 3.29 x 10^{-25} kg, respectively (note that their mass ratio is 4 to 197). (a) If a helium nucleus scatters to an angle of 120° during an elastic collision with a gold nucleus, calculate the helium nucleus's final speed and the final velocity (magnitude and direction) of the gold nucleus. (b) What is the final kinetic energy of the helium nucleus?

8. A 90.0-kg ice hockey player hits a 0.150-kg puck, giving the puck a velocity of 45.0 m/s. If both are initially at rest and if the ice is frictionless, how far does the player recoil in the time it takes the puck to reach the goal 15.0 m away?
9. In an elastic collision, a 400-kg bumper car collides directly from behind with a second, identical bumper car that is traveling in the same direction. The initial speed of the leading bumper car is 5.60 m/s and that of the trailing car is 6.00 m/s. Assuming that the mass of the drivers is much, much less than that of the bumper cars, what are their final speeds?
10. Repeat the preceding problem if the mass of the leading bumper car is 30.0% greater than that of the trailing bumper car.
11. An alpha particle (^{4}He) undergoes an elastic collision with a stationary uranium nucleus (^{235}U). What percent of the kinetic energy of the alpha particle is transferred to the uranium nucleus? Assume the collision is one-dimensional.
12. A boy sleds down a hill and onto a frictionless ice-covered lake at 10.0 m/s. In the middle of the lake is a 1000-kg boulder. When the sled crashes into the boulder, he is propelled over the boulder and continues sliding over the ice. If the boy's mass is 40.0 kg and the sled's mass is 2.50 kg, what is the speed of the sled and the boulder after the collision?
13. A 0.90-kg falcon is diving at 28.0 m/s at a downward angle of 35°. It catches a 0.325-kg pigeon from behind in midair. What is their combined velocity after impact if the pigeon's initial velocity was 7.00 m/s directed horizontally? Note that $\vec{v}_{1,i}$ is a unit vector pointing in the direction in which the falcon is initially flying.

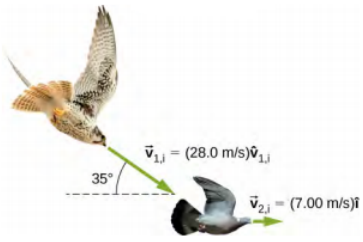
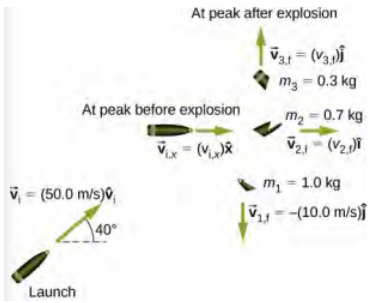


Figure 14.E.1 - (credit "hawk": modification of work by "USFWS Mountain-Prairie"/Flickr; credit "dove": modification of work by Jacob Spinks)

14. A billiard ball, labeled 1, moving horizontally strikes another billiard ball, labeled 2, at rest. Before impact, ball 1 was moving at a speed of 3.00 m/s, and after impact it is moving at 0.50 m/s at 50° from the original direction. If the two balls have equal masses of 300 g, what is the velocity of the ball 2 after the impact?
15. A projectile of mass 2.0 kg is fired in the air at an angle of 40.0 ° to the horizon at a speed of 50.0 m/s. At the highest point in its flight, the projectile breaks into three parts of mass 1.0 kg, 0.7 kg, and 0.3 kg. The 1.0-kg part falls straight down after breakup with an initial speed of 10.0 m/s, the 0.7-kg part moves in the original forward direction, and the 0.3-kg part goes straight up. (a) Find the speeds of the 0.3-kg and 0.7-kg pieces immediately after the break-up. (b) How high from the break-up point does the 0.3-kg piece go before coming to rest? (c) Where does the 0.7-kg piece land relative to where it was fired from?



16. Two asteroids collide and stick together. The first asteroid has mass of 15 x 10^3 kg and is initially moving at 770 m/s. The second asteroid has mass of 20 x 10^3 kg and is moving at 1020 m/s. Their initial velocities made an angle of 20° with respect to each other. What is the final speed and direction with respect to the velocity of the first asteroid?

17. A 200-kg rocket in deep space moves with a velocity of (121 m/s) $\hat{i}$ + (38.0 m/s) $\hat{j}$. Suddenly, it explodes into three pieces, with the first (78 kg) moving at −(321 m/s) $\hat{i}$ + (228 m/s) $\hat{j}$ and the second (56 kg) moving at (16.0 m/s) $\hat{i}$ − (88.0 m/s) $\hat{j}$. Find the velocity of the third piece.
18. A proton traveling at 3.0 x 10^6 m/s scatters elastically from an initially stationary alpha particle and is deflected at an angle of 85° with respect to its initial velocity. Given that the alpha particle has four times the mass of the proton, what percent of its initial kinetic energy does the proton retain after the collision?
19. Three 70-kg deer are standing on a flat 200-kg rock that is on an ice-covered pond. A gunshot goes off and the deer scatter, with deer A running at (15 m/s) $\hat{i}$ + (5.0 m/s) $\hat{j}$, deer B running at (−12 m/s) $\hat{i}$ + (8.0 m/s) $\hat{j}$, and deer C running at (1.2 m/s) $\hat{i}$ − (18.0 m/s) $\hat{j}$. What is the velocity of the rock on which they were standing?
20. A family is skating. The father (75 kg) skates at 8.2 m/s and collides and sticks to the mother (50 kg), who was initially moving at 3.3 m/s and at 45° with respect to the father's velocity. The pair then collides with their daughter (30 kg), who was stationary, and the three slide off together. What is their final velocity?
21. An oxygen atom (mass 16 u) moving at 733 m/s at 15.0° with respect to the $\hat{i}$ direction collides and sticks to an oxygen molecule (mass 32 u) moving at 528 m/s at 128° with respect to the $\hat{i}$ direction. The two stick together to form ozone. What is the final velocity of the ozone molecule?
22. Two cars approach an extremely icy four-way perpendicular intersection. Car A travels northward at 30 m/s and car B is travelling eastward. They collide and stick together, traveling at 28° north of east. What was the initial velocity of car B?
23. Two carts on a straight track collide head on. The first cart was moving at 3.6 m/s in the positive x direction and the second was moving at 2.4 m/s in the opposite direction. After the collision, the second car continues moving in its initial direction of motion at 0.24 m/s. If the mass of the second car is 5.0 times that of the first, what is the final velocity of the first car?
24. Derive the equations giving the final speeds for two objects that collide elastically, with the mass of the objects being m_1 and m_2 and the initial speeds being $v_{1,i}$ and $v_{2,i} = 0$ (i.e., second object is initially stationary).
25. Repeat the preceding problem for the case when the initial speed of the second object is nonzero.
26. Two billiard balls are at rest and touching each other on a pool table. The cue ball travels at 3.8 m/s along the line of symmetry between these balls and strikes them simultaneously. If the collision is elastic, what is the velocity of the three balls after the collision?
27. A billiard ball traveling at (2.2 m/s) $\hat{i}$ − (0.4 m/s) $\hat{j}$ collides with a wall that is aligned in the $\hat{j}$ direction. Assuming the collision is elastic, what is the final velocity of the ball?
28. Two identical billiard balls collide. The first one is initially traveling at (2.2 m/s) $\hat{i}$ − (0.4 m/s) $\hat{j}$ and the second one at −(1.4 m/s) $\hat{i}$ + (2.4 m/s) $\hat{j}$. Suppose they collide when the center of ball 1 is at the origin and the center of ball 2 is at the point (2R, 0) where R is the radius of the balls. What is the final velocity of each ball?
29. Repeat the preceding problem if the balls collide when the center of ball 1 is at the origin and the center of ball 2 is at the point (0, 2R).
30. Repeat the preceding problem if the balls collide when the center of ball 1 is at the origin and the center of ball 2 is at the point $\left(\frac{\sqrt{3}R}{2}, \frac{R}{2}\right)$.

Contributors and Attributions

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