Problems

1. What is the magnitude of the momentum of a 28-g sparrow flying with a speed of 8.4 m/s?

$p = mv = (.028\,kg)(8.4\,\frac{m}{s}) = 0.235\,kg\,m/s$

2. A constant friction force of 25 N acts on a 65-kg skier for 20 s. What is the skier's change in velocity?

$F\Delta t = m\Delta v$

$(25)(20) = 65\,\Delta v$

$\Delta v = 7.69\,m/s$

3. A 0.145-kg baseball pitched at 39.0 m/s is hit on a horizontal line drive straight back toward the pitcher at 52.0 m/s. If the contact time between bat and ball is 3.00x10^{-3}s, calculate the average force between the ball and bat during contact.

$F\Delta t = m\Delta v$ $\Delta v = v' - v = 52 - {}^{-}39 = +91\,m/s$

$F(3\times10^{-3}) = (.145)(91)$

$F = 4398\,N$

4. Calculate the force exerted on a rocket, given that the propelling gases are expelled at a rate of 1500 kg/s with a speed of 4.00x10^{4}m/s (at the moment of takeoff). The force on the gas can be found from its change in momentum.

$F\Delta t = m\Delta v$ $F = (1500\,\frac{kg}{s})(4\times10^{4}\,\frac{m}{s})$

$F = \frac{m\Delta v}{\Delta t}$ kg/s $F = 6.0\times10^{7}\,N$

5. A golf ball of mass 0.045 kg is hit off the tee at a speed of 45 m/s. The golf club was in contact with the ball for 3.5×10^{-3} s. Find (*a*) the impulse imparted to the golf ball, and (*b*) the average force exerted on the ball by the golf club.

$F\Delta t = m\Delta v$

$m\Delta v = (.045)(+45) = 2.025 = $ impulse and momentum

kgm/s

$F\Delta t = 2.025$

$F = 579\,N$

6 You are the design engineer in charge of the crashworthiness of new automobile models. Cars are tested by smashing them into fixed, massive barriers at 50 km/h (30 mph). A new model of mass 1500 kg takes 0.15 s from the time of impact until it is brought to rest. (*a*) Calculate the average force exerted on the car by the barrier. (*b*) Calculate the average deceleration of the car.

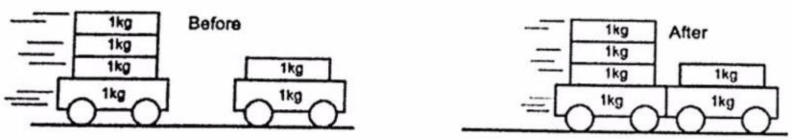
$\Delta v = 0 - 13.9 = -13.9 \frac{m}{s}$

$F\Delta t = m\Delta v$

$F(.15) = (1500)(-13.9)$

$F = 139{,}000\text{N}$

$a = \frac{\Delta v}{\Delta t} = 93 \, m/s^2$

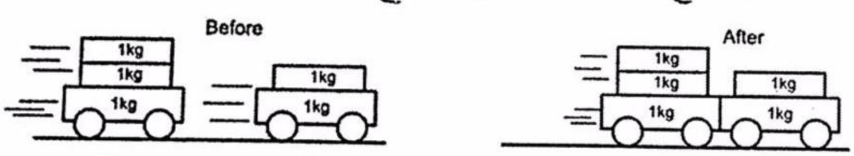


7. v=3m/s v=0m/s v=?

$(4kg)(3m/s) + 2kg(0) = 6kg(v) \Rightarrow v = \frac{12kg\,m/s}{6kg} = 2m/s$

8. v=0m/s v=-2m/s v=?

$(3kg)(0m/s) = (2kg)(-2m/s) + (1kg)(v) \Rightarrow v = 4m/s$



9. v=5m/s v=2m/s v=?

$(3kg)(5m/s) + (2kg)(2m/s) = 5kg(v) \Rightarrow v = 3.8m/s$

10 1. A child in a boat throws a 6.40 kg package out horizontally with a speed of 10.0 m/s. Calculate the velocity of the boat immediately after, assuming that it was initially at rest. The mass of the child is 26.0 kg, and that of the boat is 45.0 kg. Ignore water resistance.

The throwing of the package is a momentum-conserving action, if the water resistance is ignored. Let "A represent the boat and child together, and let "B" represent the package. Choose the direction that the package is thrown as the positive direction. Apply conservation of momentum, with the initial velocity of both objects being 0.

$$p_{\text{initial}} = p_{\text{final}} \rightarrow (m_A + m_B)v = m_A v'_A + m_B v'_B \rightarrow$$
$$v'_A = -\frac{m_B v'_B}{m_A} = -\frac{(6.40\text{ kg})(10.0\text{ m/s})}{(26.0\text{ kg} + 45.0\text{ kg})} = \boxed{-0.901\text{ m/s}}$$

11 2. A 12,600-kg railroad car travels alone on a level frictionless track with a constant speed of 18.0m/s. A 5350-kg load, initially at rest, is dropped onto the car. What will be the car's new speed?

$$p_{\text{initial}} = p_{\text{final}} \rightarrow m_A v_A + m_B v_B = (m_A + m_B)v' \rightarrow$$
$$v' = \frac{m_A v_A + m_B v_B}{m_A + m_B} = \frac{(12{,}600\text{ kg})(18.0\text{ m/s}) + 0}{(12{,}600\text{ kg}) + (5350\text{ kg})} = \boxed{12.6\text{ m/s}}$$

12 3. A 3800 kg open railroad car coasts along level tracks with a constant speed of 8.60 m/s. Snow begins to fall vertically and fills the 3.50 kg/min. Ignoring friction with tracks, what is the speed of the car after 90 min?

$$p_{\text{initial}} = p_{\text{final}} \rightarrow m_A v_A = (m_A + m_B)v'_A$$
$$v'_A = \frac{m_A v_A}{m_A + m_B} = \frac{(3800\text{ kg})(8.60\text{ m/s})}{3800\text{ kg} + \left(\frac{3.50\text{ kg}}{\text{min}}\right)(90.0\text{ min})} = 7.94\text{ m/s} \approx \boxed{7.9\text{ m/s}}$$

13 4. Boat A has a mass of 10kg and a velocity of 3m/s. Boat B has a mass of 15kg and a velocity of -1m/s. The two boats collide and bounce away from one another. After the bounce, boat B has a velocity of 1.4m/s.

a. What is the velocity of boat A after the bounce?

-0.6 m/s

b. What impulse is experienced by boat A during the collision?

$F\Delta t = \Delta p = P_{\text{final}} - P_{\text{initial}} = (-0.6\text{ m/s})(10\text{ kg}) - (10\text{ kg})(3\text{ m/s}) = -36\text{ kg m/s}$

c. What impact force is felt by boat B?

$F(0.1\text{ s}) = -36\text{ kg m/s}$ $F = 360\text{ N}$

d. What impulse is experienced by boat B?

36 kg m/s

e. What impact force is felt by boat A?

$F = -360\text{ N}$

f. What is the coefficient of restitution for this collision?

$$e = \frac{V_B' - V_A'}{V_A - V_B} = \frac{1.4\text{ m/s} - (-0.6\text{ m/s})}{(3\text{ m/s}) - (-1\text{ m/s})} = \frac{2\text{ m/s}}{4\text{ m/s}} = 0.5$$

g. Is the collision elastic or inelastic?

$e < 1$

14 ~~4.~~ A softball of mass 0.220 kg that is moving with a speed of 8.5 m/s collides head-on and elastically with another ball initially at rest. Afterward the incoming softball bounces backward with a speed of 3.7 m/s. Calculate (*a*) the velocity of the target ball after the collision, and (*b*) the mass of the target ball.

~~4.~~ Let A represent the moving softball, and let B represent the ball initially at rest. The initial direction of the softball is the positive direction. We have $v_A = 8.5\,\text{m/s}$, $v_B = 0$, and $v'_A = -3.7\,\text{m/s}$.

(*a*) Use Eq. 7-7 to obtain a relationship between the velocities.

$$v_A - v_B = -(v'_A - v'_B) \rightarrow v'_B = v_A - v_B + v'_A = 8.5\,\text{m/s} - 0 - 3.7\,\text{m/s} = \boxed{4.8\,\text{m/s}}$$

(*b*) Use momentum conservation to solve for the mass of the target ball.

$$m_A v_A + m_B v_B = m_A v'_A + m_B v'_B \rightarrow$$

$$m_B = m_A \frac{(v_A - v'_A)}{(v'_B - v_B)} = (0.220\,\text{kg}) \frac{(8.5\,\text{m/s} - -3.7\,\text{m/s})}{4.8\,\text{m/s}} = \boxed{0.56\,\text{kg}}$$

15 ~~5.~~ Two bumper cars in an amusement park ride collide elastically as one approaches the other directly from the rear (Fig. 7–34). Car A has a mass of 450 kg and car B 550 kg, owing to differences in passenger mass. If car A approaches at 4.50 m/s and car B is moving at 3.70 m/s, calculate (*a*) their velocities after the collision, and ~~(*b*) the change in momentum of each.~~

~~5.~~ Let the original direction of the cars be the positive direction. We have $v_A = 4.50\,\text{m/s}$ and $v_B = 3.70\,\text{m/s}$

(*a*) Use Eq. 7-7 to obtain a relationship between the velocities.

$$v_A - v_B = -(v'_A - v'_B) \rightarrow v'_B = v_A - v_B + v'_A = 0.80\,\text{m/s} + v'_A$$

Substitute this relationship into the momentum conservation equation for the collision.

$$m_A v_A + m_B v_B = m_A v'_A + m_B v'_B \rightarrow m_A v_A + m_B v_B = m_A v'_A + m_B (0.80\,\text{m/s} + v'_A) \rightarrow$$

$$v'_A = \frac{m_A v_A + m_B (v_B - 0.80\,\text{m/s})}{m_A + m_B} = \frac{(450\,\text{kg})(4.50\,\text{m/s}) + (550\,\text{kg})(2.90\,\text{m/s})}{1000\,\text{kg}} = \boxed{3.62\,\text{m/s}} \ (b)$$

$$v'_B = 0.80\,\text{m/s} + v'_A = \boxed{4.42\,\text{m/s}}$$

Conceptual Questions

16 ~~1.~~ Why is momentum conserved for ALL collision, regardless of whether they are elastic or not?

Newton's 3rd Law says that each object feels the same force, but in opposite directions. By extension, they both feel equal and opposite impulses so the change on momentum is equal and opposite. One might say that one's loss is the other's gain.

because impact time is also equal

17 ~~2.~~ A Superball is dropped from a height h onto a hard steel plate (fixed to the Earth), from which it rebounds at very nearly its original speed. (a) Is the momentum of the ball conserved during any part of this process? (b) If we consider the ball and Earth as our system, during what parts of the process is momentum conserved?

(a) The momentum of the ball is not conserved during any part of the process, because there is an external force acting on the ball at all times – the force of gravity. And there is an upward force on the ball during the collision. So considering the ball as the system, there are always external forces on it, and so its momentum is not conserved.

(b) With this definition of the system, all of the forces are internal, and so the momentum of the Earth-ball system is conserved during the entire process.

18. PE of projectile + target at top of swing $= mgh = (1kg + 0.2kg)(9.8 m/s^2)(0.4m)$

* Mechanical Energy is conserved during the swing

equal $\rightarrow mgh = 4.70J$

$KE_{Proj+target}$ at bottom of swing $= 4.70J$

---

* Momentum is conserved during the collision

$KE = \frac{1}{2}mv^2$

$V_{proj+target}$ after collision $= \sqrt{\frac{2KE}{m}}$

$= \sqrt{\frac{2(4.70J)}{1.2kg}} = 2.8 \ m/s$

$P_{projectile+target}$ after collision $= mv$

$= (1.2kg)(2.8 \ m/s)$

$= 3.36 \ kg \, m/s$

$P_{Net\ Before} = P_{Net\ After}$

$0.2kg(V) + 1kg(0) = 3.36 kg\, m/s \Rightarrow 16.8 \ m/s$

Projectile, target, Projectile in target