Solutions to HW18, Chapter 11

NOTE! The problems in masteringphysics.com had their numbers altered slightly for each individual student. The solutions below use the same numbers as those used in the book for that problem!

11.4. Model: The particle is subjected to an impulsive force.

Solve: The impulse is the area under the force-time curve. From 0 to 2 ms the impulse is zero, as with the interval between 8 ms and 12 ms. The only non-zero contribution to the impulse is between 2 ms and 8 ms. From 2 to 8 ms the impulse is

$$\int F(t)dt = \tfrac{1}{2}(2000\text{ N})(8.0\text{ ms} - 2.0\text{ ms}) = 6.0\text{ Ns}$$

This is the entire impulse.

11.8. Model: Model the object as a particle and the interaction with the force as a collision.

Solve: Using the equations

$$p_{\text{fx}} = p_{\text{ix}} + J_x \text{ and } J_x = \int_{t_i}^{t_f} F_x(t)dt = \text{area under force curve}$$

$$(2.0\text{ kg})v_{\text{fx}} = (2.0\text{ kg})(1.0\text{ m/s}) + (\text{area under the force curve})$$

$$v_{\text{fx}} = (1.0\text{ m/s}) + \tfrac{1}{2.0\text{ kg}}(1.0\text{ s})(-2.0\text{ N}) = 0.0\text{ m/s}$$

Assess: For an object with positive velocity, a positive impulse increases the object's speed. The opposite is true for an object with negative velocity.

11.13. Model: Model the ball as a particle, and its interaction with the wall as a collision in the impulse approximation.

Visualize: Please refer to Figure EX11.13.

Solve: Using the equations

$$p_{\text{fx}} = p_{\text{ix}} + J_x \text{ and } J_x = \int_{t_i}^{t_f} F_x(t)dt = \text{area under force curve}$$

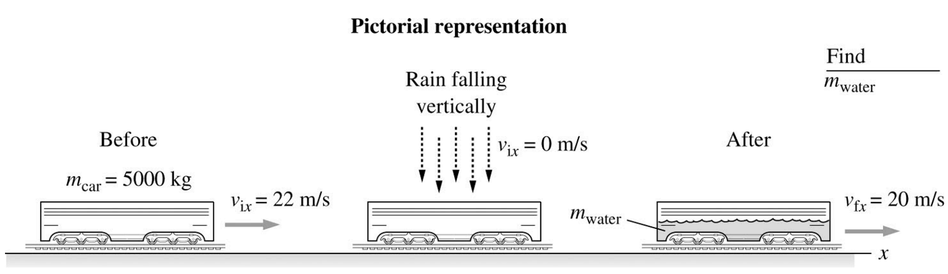
$$(0.250\text{ kg})v_{\text{fx}} = (0.250\text{ kg})(-10\text{ m/s}) + (500\text{ N})(8.0\text{ ms})$$

$$v_{\text{fx}} = (-10\text{ m/s}) + \left(\frac{4.0\text{ N}}{0.250\text{ kg}}\right) = 6.0\text{ m/s}$$

Assess: The ball's final velocity is positive, indicating it has turned around.

11.14. Model: Choose car + rainwater to be the system.

Visualize:



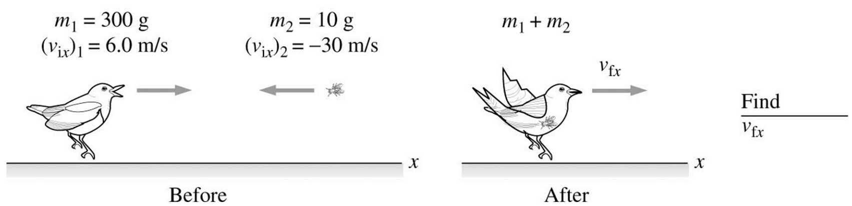
There are no *external* horizontal forces on the car + water system, so the horizontal momentum is conserved.

Solve: Conservation of momentum gives $p_{\text{fx}} = p_{\text{ix}}$. Hence,

$$(m_{\text{car}} + m_{\text{water}})(20\text{ m/s}) = (m_{\text{car}})(22\text{ m/s}) + (m_{\text{water}})(0\text{ m/s})$$

$$(5000\text{ kg} + m_{\text{water}})(20\text{ m/s}) = (5000\text{ kg})(22\text{ m/s}) \quad \Rightarrow \quad m_{\text{water}} = 5.0\times10^2\text{ kg}$$

11.18. Model: We will define our system to be bird + bug. This is the case of an inelastic collision because the bird and bug move together after the collision. Horizontal momentum is conserved because there are no external forces acting on the system during the collision in the impulse approximation.
Visualize:

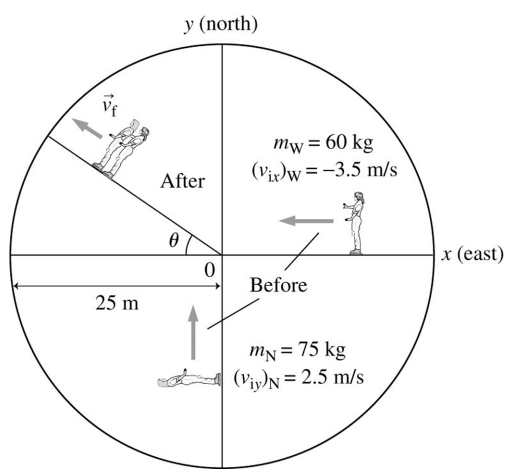


Solve: The conservation of momentum equation $p_{fx} = p_{ix}$ gives

$$(m_1 + m_2)v_{fx} = m_1(v_{ix})_1 + m_2(v_{ix})_2 \quad \Rightarrow \quad (300\text{ g} + 10\text{ g})v_{fx} = (300\text{ g})(6.0\text{ m/s}) + (10\text{ g})(-30\text{ m/s}) \quad \Rightarrow \quad v_{fx} = 4.8\text{ m/s}$$

Assess: We left masses in grams, rather than convert to kilograms, because the mass units cancel out from both sides of the equation. Note that $(v_{ix})_2$ is negative because the bug is flying to the left.

11.34. Model: Model the skaters as particles. The two skaters, one traveling north (N) and the other traveling west (W), are the system. Since the two skaters hold together after the "collision," this is a case of a perfectly inelastic collision in two dimensions. Momentum is conserved since no significant external force in the *x*-*y* plane acts on the system during the "collision."
Visualize:



Solve: **(a)** Applying conservation of momentum in the *x*-direction gives

$$(m_N + m_W)v_{fx} = m_N(v_{ix})_N + m_W(v_{ix})_W \quad \Rightarrow \quad (75\text{ kg} + 60\text{ kg})v_{fx} = 0\text{ kg m/s} + (60\text{ kg})(-3.5\text{ m/s})$$

$$v_{fx} = -1.556\text{ m/s}$$

Applying conservation of momentum in the *y*-direction gives

$$(m_N + m_W)v_{fy} = m_N(v_{iy})_N + m_W(v_{iy})_W \quad \Rightarrow \quad (75\text{ kg} + 60\text{ kg})v_{fy} = (75\text{ kg})(2.5\text{ m/s}) + 0\text{ kg m/s}$$

$$v_{fy} = 1.389\text{ m/s}$$

The final speed is therefore

$$v_f = \sqrt{(v_{fx})^2 + (v_{fy})^2} = 2.085\text{ m/s}$$

The time to glide to the edge of the rink is

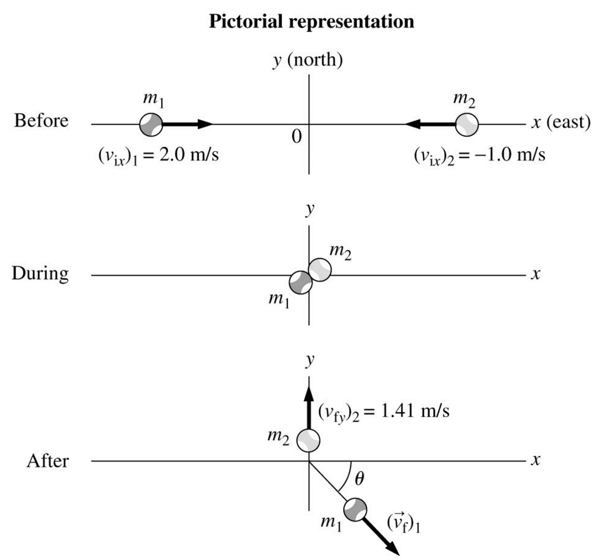
$$\frac{\text{radius of the rink}}{v_f} = \frac{25 \text{ m}}{2.085 \text{ m/s}} = 12 \text{ s}$$

(b) The location is $\theta = \tan^{-1}(v_{fy}/v_{fx}) = 42°$ north of west.

Assess: A time of 12 s in covering a distance of 25 m at a speed of ≈ 2 m/s is reasonable.

11.48. Model: The billiard balls will be modeled as particles. The two balls, m_1 (moving east) and m_2 (moving west), together are our system. This is an isolated system because any frictional force during the brief collision period is going to be insignificant. Within the impulse approximation, the momentum of our system will be conserved in the collision.

Visualize:



Note that $m_1 = m_2 = m$.

Solve: The equation $p_{fx} = p_{ix}$ yields:

$$m_1(v_{fx})_1 + m_2(v_{fx})_2 = m_1(v_{ix})_1 + m_2(v_{ix})_2 \quad \Rightarrow \quad m_1(v_f)_1 \cos\theta + 0 \text{ kg m/s} = m_1(v_{ix})_1 + m_2(v_{ix})_2$$

$$(v_f)_1 \cos\theta = (v_{ix})_1 + (v_{ix})_2 = 2.0 \text{ m/s} - 1.0 \text{ m/s} = 1.0 \text{ m/s}$$

The equation $p_{fy} = p_{iy}$ yields:

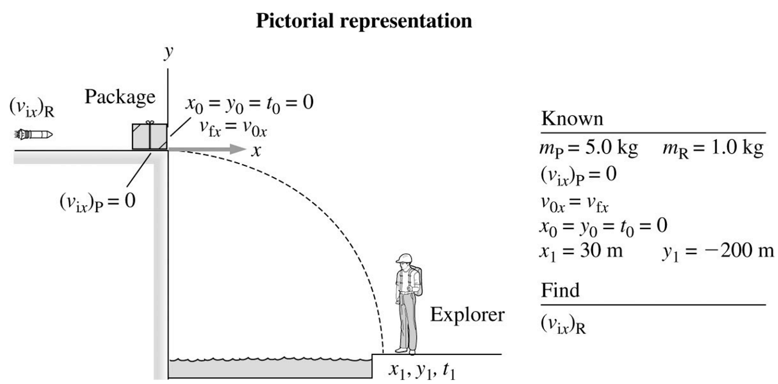
$$+m_1(v_{fy})_1 \sin\theta + m_2(v_{fy})_2 = 0 \text{ kg m/s} \quad \Rightarrow \quad (v_f)_1 \sin\theta = -(v_{fy})_2 = -1.41 \text{ m/s}$$

$$(v_f)_1 = \sqrt{(1.0 \text{ m/s})^2 + (-1.41 \text{ m/s})^2} = 1.7 \text{ m/s}, \; \theta = \tan^{-1}\left(\frac{1.41 \text{ m/s}}{1.0 \text{ m/s}}\right) = 55°$$

The angle is below $+x$ axis, or south of east.

11.50. Model: Model the package and the rocket as particles. This is a two-part problem. First we have an inelastic collision between the rocket (R) and the package (P). During the collision, momentum is conserved since no significant external force acts on the rocket and the package. However, as soon as the package + rocket system leaves the cliff they become a projectile motion problem.

Visualize:



Solve: The minimum velocity after collision that the package + rocket must have to reach the explorer is v_{0x}, which can be found as follows:

$$y_1 = y_0 + v_{0y}(t_1 - t_0) + \tfrac{1}{2}a_y(t_1 - t_0)^2 \quad \Rightarrow \quad -200\text{ m} = 0\text{ m} + 0\text{ m} + \tfrac{1}{2}(-9.8\text{ m/s}^2)t_1^2 \quad \Rightarrow \quad t_1 = 6.389\text{ s}$$

With this time, we can now find v_{0x} using $x_1 = x_0 + v_{0x}(t_1 - t_0) + \tfrac{1}{2}a_x(t_1 - t_0)^2$. We obtain

$$30\text{ m} = 0\text{ m} + v_{0x}(6.389\text{ s}) + 0\text{ m} \quad \Rightarrow \quad v_{0x} = 4.696\text{ m/s} = v_{fx}$$

We now use the momentum conservation equation $p_{fx} = p_{ix}$ which can be written

$$(m_R + m_P)v_{fx} = m_R(v_{ix})_R + m_P(v_{ix})_P$$

$$(1.0\text{ kg} + 5.0\text{ kg})(4.696\text{ m/s}) = (1.0\text{ kg})(v_{ix})_R + (5.0\text{ kg})(0\text{ m/s}) \quad \Rightarrow \quad (v_{ix})_R = 28\text{ m/s}$$