15. A 35.0-g bullet strikes a 5.0-kg stationary piece of lumber and embeds itself in the wood. The piece of lumber and bullet fly off together at 8.6 m/s. What was the original speed of the bullet?

$m_b v_{bi} + m_w v_{wi} = (m_b + m_w)v_f$

where v_f is the common final speed of the bullet and piece of lumber.

Because $v_{wi} = 0.0$ m/s,

$$v_{bi} = \frac{(m_b + m_w)v_f}{m_b}$$

$$= \frac{(0.0350\ \text{kg} + 5.0\ \text{kg})(8.6\ \text{m/s})}{0.0350\ \text{kg}}$$

$$= 1.2\times10^3\ \text{m/s}$$

16. A 35.0-g bullet moving at 475 m/s strikes a 2.5-kg bag of flour that is on ice, at rest. The bullet passes through the bag, as shown in **Figure 9-7**, and exits it at 275 m/s. How fast is the bag moving when the bullet exits?

■ **Figure 9-7**

$m_B v_{Bi} + m_F v_{Fi} = m_B v_{Bf} + m_F v_{Ff}$

where $v_{Fi} = 0.0$ m/s

$$v_{Ff} = \frac{(m_B v_{Bi} - m_B v_{Bf})}{m_F}$$

$$v_{Ff} = \frac{m_B(v_{Bi} - v_{Bf})}{m_F}$$

$$= \frac{(0.0350\ \text{kg})(475\ \text{m/s} - 275\ \text{m/s})}{2.5\ \text{kg}}$$

$$= 2.8\ \text{m/s}$$

17. The bullet in the previous problem strikes a 2.5-kg steel ball that is at rest. The bullet bounces backward after its collision at a speed of 5.0 m/s. How fast is the ball moving when the bullet bounces backward?

The system is the bullet and the ball.

$m_{bullet}v_{bullet,\,i} + m_{ball}v_{ball,\,i} = m_{bullet}v_{bullet,\,f} + m_{ball}v_{ball,\,f}$

$v_{ball,\,i} = 0.0$ m/s and $v_{bullet,\,f} = -5.0$ m/s

so $$v_{ball,\,f} = \frac{m_{bullet}(v_{bullet,\,i} - v_{bullet,\,f})}{m_{ball}} = \frac{(0.0350\ \text{kg})(475\ \text{m/s} - (-5.0\ \text{m/s}))}{2.5\ \text{kg}}$$

$$= 6.7\ \text{m/s}$$

18. A 0.50-kg ball that is traveling at 6.0 m/s collides head-on with a 1.00-kg ball moving in the opposite direction at a speed of 12.0 m/s. The 0.50-kg ball bounces backward at 14 m/s after the collision. Find the speed of the second ball after the collision.

Say that the first ball (ball C) is initially moving in the positive (forward) direction.

$m_C v_{Ci} + m_D v_{Di} = m_C v_{Cf} + m_D v_{Df}$

so $$v_{Df} = \frac{m_C v_{Ci} + m_D v_{Di} - m_C v_{Cf}}{m_D}$$

$$= \frac{(0.50\ \text{kg})(6.0\ \text{m/s}) + (1.00\ \text{kg})(-12.0\ \text{m/s}) - (0.50\ \text{kg})(-14\ \text{m/s})}{1.00\ \text{kg}}$$

$$= -2.0\ \text{m/s, or 2.0 m/s in the opposite direction}$$

21. Carmen and Judi dock a canoe. 80.0-kg Carmen moves forward at 4.0 m/s as she leaves the canoe. At what speed and in what direction do the canoe and Judi move if their combined mass is 115 kg?

$p_{Ci} + p_{Ji} = p_{Cf} + p_{Jf}$

where $p_{Ci} = p_{Ji} = 0.0$ kg·m/s

$m_C v_{Cf} = -m_J v_{Jf}$

so $v_{Jf} = \frac{-m_C v_{Cf}}{m_J}$

$= \frac{-(80.0\ \text{kg})(4.0\ \text{m/s})}{115\ \text{kg}}$

= 2.8 m/s in the opposite direction

78. Skateboarding Kofi, with mass 42.00 kg, is riding a skateboard with a mass of 2.00 kg and traveling at 1.20 m/s. Kofi jumps off and the skateboard stops dead in its tracks. In what direction and with what velocity did he jump?

$(m_L v_{Li} + m_s v_{si})v_i = m_L v_{Lf} + m_s v_{sf}$

where $v_{sf} = 0$ and $v_{Li} = v_{si} = v_i$

Thus $v_{Lf} = \frac{(m_L + m_s)v_i}{m_L}$

$= \frac{(42.00\ \text{kg} + 2.00\ \text{kg})(1.20\ \text{m/s})}{42.00\ \text{kg}}$

= 1.26 m/s in the same direction as she was riding

82. A 0.200-kg plastic ball moves with a velocity of 0.30 m/s. It collides with a second plastic ball of mass 0.100 kg, which is moving along the same line at a speed of 0.10 m/s. After the collision, both balls continue moving in the same, original direction. The speed of the 0.100-kg ball is 0.26 m/s. What is the new velocity of the 0.200-kg ball?

$m_C v_{Ci} + m_D v_{Di} = m_C v_{Cf} + m_D v_{Df}$

so, $v_{Cf} = \frac{m_C v_{Ci} + m_D v_{Di} - m_D v_{Df}}{m_C}$

$= \frac{(0.200\ \text{kg})(0.30\ \text{m/s}) + (0.100\ \text{kg})(0.10\ \text{m/s}) - (0.100\ \text{kg})(0.26\ \text{m/s})}{0.200\ \text{kg}}$

= 0.22 m/s in the original direction

90.

b. What is the velocity of the football players after the collision?

$p_{Ai} + p_{Bi} + p_{Ci} = p_{Af} + p_{Bf} + p_{Cf}$

$m_A v_{Ai} + m_B v_{Bi} + m_C v_{Ci} = m_A v_{Af} + m_B v_{Bf} + m_C v_{Cf}$

$= (m_A + m_B + m_C)v_f$

$v_f = \frac{m_A v_{Ai} + m_B v_{Bi} + m_{Ci} v_{Ci}}{m_A + m_B + m_C}$

$= \frac{(92\ \text{kg})(5.0\ \text{m/s}) + (75\ \text{kg})(-2.0\ \text{m/s}) + (75\ \text{kg})(-4.0\ \text{m/s})}{92\ \text{kg} + 75\ \text{kg} + 75\ \text{kg}}$

= 0.041 m/s

c. Does the fullback score a touchdown?

Yes. The velocity is positive, so the football crosses the goal line for a touchdown.