

## Chapter 4: Linear Kinetics

1. A penny (2.5g) slides into a nickel (5.0g) at a velocity of 1 m/s. If the penny comes to a stop, what will be the velocity of the nickel immediately following the collision?

$$m_{\text{penny}} v_{\text{penny}} = m_{\text{nickel}} v_{\text{nickel}} \quad 0.025 \text{ kg} (1 \text{ m/s}) = 0.050 \text{ kg} (v_{\text{nickel}})$$

$$v_{\text{nickel}} = \frac{0.025 \text{ kg} (1 \text{ m/s})}{0.050 \text{ kg}} = 0.5 \text{ m/s}$$

2. To be a regulation basketball, the ball must be inflated in a way that when dropped from a height of 6 ft, it returns to a height of 49-54 inches on the first bounce. What is the coefficient of elasticity for a ball that bounces to a height of 50 inches?

$$e = \sqrt{\frac{\text{bounce height}}{\text{drop height}}} = \sqrt{\frac{50 \text{ in}}{72 \text{ in}}} = 0.82$$

3. During the impact of a baseball bat with a baseball (0.15kg) that was pitched at 92 mph, the bat exerts an average force of 5 kN for a time of 0.002 s. If the ball leaves the bat in exactly the opposite direction to the pitch, what will be the velocity of the ball immediately following the impact?

Step 1: Convert 92 mph to 41.1 m/s

$$92 \frac{\text{mile}}{\text{hour}} \left( \frac{1609 \text{ m}}{1 \text{ mile}} \right) \left( \frac{1 \text{ hour}}{3600 \text{ s}} \right) = 41.1 \text{ m/s}$$

Step 2:  $F\Delta t = m\Delta v$   $5000 \text{ N} (0.002 \text{ s}) = 0.15 \text{ kg} (\Delta v)$

$$\Delta v = \frac{5000 \text{ N} (0.002 \text{ s})}{0.15 \text{ kg}} = 66.7 \text{ m/s}$$

Step 3: Since 66.7 m/s is the change in velocity, we must combine it with the initial velocity of 41.1 m/s. They are directed oppositely, so the end velocity is 25.6 m/s.

4. During the stance phase of running a 140 lb runner, exerts an average vertical force of 1150 N. What is the average vertical acceleration of the runner? Think about what this means in terms of the vertical velocity of the runner at foot contact and toe-off.

Step 1: Convert 140 lb to 623 N

$$140 \text{ lb} \left( \frac{4.45 \text{ N}}{1 \text{ lb}} \right) = 623 \text{ N}$$

Step 2: Since body weight is working downwards, the resultant vertical force is  $1150 \text{ N} - 623 \text{ N} = 527 \text{ N}$

Step 3: Determine the mass of the runner.

$$W = mg, \text{ thus } m = \frac{W}{g}$$

$$m = \frac{623 \text{ N}}{9.8 \text{ m/s}^2} = 63.6 \text{ kg}$$

Step 4: Use  $F=ma$  to find the acceleration  $a = \frac{527N}{63.6kg} = 8.3 \text{ m/s}^2$

At distance running speeds, a runner's foot is typically on the ground for about 0.2 s. Accelerating at  $8.3 \text{ m/s}^2$  for 0.2 s means the change in velocity would be 1.7 m/s. The velocity of the body at landing is typically quite close to the velocity at takeoff, so the runner might be going about -0.85 m/s at landing and 0.85 m/s at takeoff.

5. The linear momentum of a 90-kg wide receiver is 720 kg·m/s.

a. What is his velocity?

$$L = mv, v = \frac{L}{m} = \frac{720 \text{ kg} \cdot \text{m/s}}{90 \text{ kg}} = 8 \text{ m/s}$$

b. He collides with a linebacker and his velocity is decreased to 5 m/s. What is his new momentum?

$$L = mv, L = 90 \text{ kg} (5 \text{ m/s}) = 450 \text{ kg} \cdot \text{m/s}$$

6. A 0.15 kg baseball collides with a 1.0 kg bat. The ball has a velocity of 44 m/s immediately prior to the collision. The center of mass of the bat also has a velocity of 44 m/s but in the opposite direction just prior to the collision. The coefficient of restitution between the bat and the ball is 0.52. Estimate how fast the ball is moving as it leaves the bat following the collision.

$$m_{ball}u_{ball} + m_{bat}u_{bat} = m_{ball}v_{ball} + m_{bat}v_{bat}$$

$$m_{ball}u_{ball} + m_{bat}u_{bat} = m_{ball}v_{ball} + m_{bat} [e(u_{ball} - u_{bat}) + v_{ball}]$$

$$0.15 \text{ kg}(-44 \text{ m/s}) + 1.0 \text{ kg}(44 \text{ m/s}) = 0.15 \text{ kg}(v_{ball}) + 1.0 \text{ kg}[0.52(-44 \text{ m/s} - 44 \text{ m/s}) + v_{ball}]$$

$$37.4 = 0.15(v_{ball}) + 1.0[0.52(-88) + v_{ball}]$$

$$37.4 = 0.15(v_{ball}) - 45.76 + v_{ball}$$

$$83.16 = 1.15v_{ball}$$

$$v_{ball} = 72.3 \text{ m/s}$$