19. (II) A 95-kg fullback is running at 4.0 m/s to the east and is stopped in 0.75 s by a head-on tackle by a tackler running due west. Calculate (*a*) the original momentum of the fullback, (*b*) the impulse exerted on the fullback, (*c*) the impulse exerted on the tackler, and (*d*) the average force exerted on the tackler.

20. (II) Suppose the force acting on a tennis ball (mass 0.060 kg) points in the $+x$ direction and is given by the graph of Fig. 7–33 as a function of time. Use graphical methods to estimate (*a*) the total impulse given the ball, and (*b*) the velocity of the ball after being struck, assuming the ball is being served so it is nearly at rest initially.

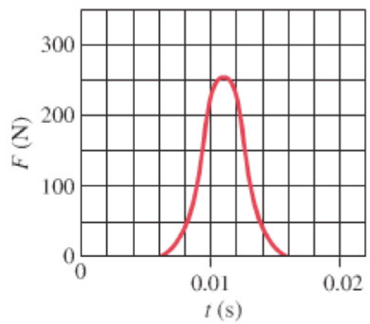

FIGURE 7–33 Problem 20.

21. (III) From what maximum height can a 75-kg person jump without breaking the lower leg bone of either leg? Ignore air resistance and assume the CM of the person moves a distance of 0.60 m from the standing to the seated position (that is, in breaking the fall). Assume the breaking strength (force per unit area) of bone is $170 \times 10^6\ \mathrm{N/m^2}$, and its smallest cross-sectional area is $2.5 \times 10^{-4}\ \mathrm{m^2}$. [*Hint*: Do not try this experimentally.]

7–4 and 7–5 Elastic Collisions

22. (II) A ball of mass 0.440 kg moving east ($+x$ direction) with a speed of 3.30 m/s collides head-on with a 0.220-kg ball at rest. If the collision is perfectly elastic, what will be the speed and direction of each ball after the collision?

23. (II) A 0.450-kg ice puck, moving east with a speed of 3.00 m/s, has a head-on collision with a 0.900-kg puck initially at rest. Assuming a perfectly elastic collision, what will be the speed and direction of each object after the collision?

24. (II) Two billiard balls of equal mass undergo a perfectly elastic head-on collision. If one ball's initial speed was 2.00 m/s, and the other's was 3.00 m/s in the opposite direction, what will be their speeds after the collision?

25. (II) A 0.060-kg tennis ball, moving with a speed of 2.50 m/s, collides head-on with a 0.090-kg ball initially moving away from it at a speed of 1.15 m/s. Assuming a perfectly elastic collision, what are the speed and direction of each ball after the collision?

26. (II) 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.

27. (II) 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.

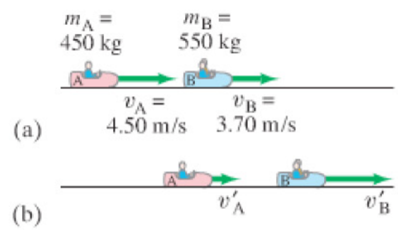

FIGURE 7–34 Problem 27: (a) before collision, (b) after collision.

28. (II) A 0.280-kg croquet ball makes an elastic head-on collision with a second ball initially at rest. The second ball moves off with half the original speed of the first ball. (*a*) What is the mass of the second ball? (*b*) What fraction of the original kinetic energy ($\Delta\text{KE}/\text{KE}$) gets transferred to the second ball?

29. (III) In a physics lab, a cube slides down a frictionless incline as shown in Fig. 7–35, and elastically strikes another cube at the bottom that is only one-half its mass. If the incline is 30 cm high and the table is 90 cm off the floor, where does each cube land? [*Hint*: Both leave the incline moving horizontally.]

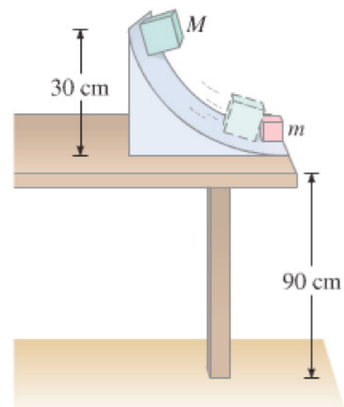

FIGURE 7–35 Problem 29.

30. (III) Take the general case of an object of mass m_A and velocity v_A elastically striking a stationary $(v_B = 0)$ object of mass m_B head-on. (*a*) Show that the final velocities v'_A and v'_B are given by

$$v'_A = \left(\frac{m_A - m_B}{m_A + m_B}\right)v_A,$$

$$v'_B = \left(\frac{2m_A}{m_A + m_B}\right)v_A.$$

(*b*) What happens in the extreme case when m_A is much smaller than m_B? Cite a common example of this. (*c*) What happens in the extreme case when m_A is much larger than m_B? Cite a common example of this. (*d*) What happens in the case when $m_A = m_B$? Cite a common example.

7–6 Inelastic Collisions

31. (I) In a ballistic pendulum experiment, projectile 1 results in a maximum height h of the pendulum equal to 2.6 cm. A second projectile causes the the pendulum to swing twice as high, $h_2 = 5.2$ cm. The second projectile was how many times faster than the first?