Chapter 8

Problems & Exercises

1.

(a) $1.50 \times 10^4 \text{ kg} \cdot \text{m/s}$

(b) 625 to 1

(c) $6.66 \times 10^2 \text{ kg} \cdot \text{m/s}$

3.

(a) $8.00 \times 10^4 \text{ m/s}$

(b) $1.20 \times 10^6 \text{ kg} \cdot \text{m/s}$

(c) Because the momentum of the airplane is 3 orders of magnitude smaller than of the ship, the ship will not recoil very much. The recoil would be -0.0100 m/s, which is probably not noticeable.

5.

54 s

7.

$9.00 \times 10^3 \ N$

9.

a) 2.40×10^3 N toward the leg

b) The force on each hand would have the same magnitude as that found in part (a) (but in opposite directions by Newton's third law) because the change in momentum and the time interval are the same.

11.

a) $800 \text{ kg} \cdot \text{m/s}$ away from the wall

b) 1.20 m/s away from the wall

13.

(a) $1.50 \times 10^6 \ N$ away from the dashboard

(b) $1.00 \times 10^5 \ N$ away from the dashboard

15.

4.69×10^5 N in the boat's original direction of motion

17.

$2.10 \times 10^3 \ N$ away from the wall

19.

$\mathbf{p} = m\mathbf{v} \Rightarrow p^2 = m^2v^2 \Rightarrow \frac{p^2}{m} = mv^2$

$\Rightarrow \frac{p^2}{2m} = \frac{1}{2}mv^2 = \text{KE}$

$KE = \frac{p^2}{2m}$

21.

60.0 g

23.

0.122 m/s

25.

In a collision with an identical car, momentum is conserved. Afterwards $v_\text{f} = 0$ for both cars. The change in momentum will be the same as in the crash with the tree. However, the force on the body is not determined since the time is not known. A padded stop will reduce injurious force on body.

27.

22.4 m/s in the same direction as the original motion

29.

0.250 m/s

31.

(a) 86.4 N perpendicularly away from the bumper

(b) 0.389 J

(c) 64.0%

33.

(a) 8.06 m/s

(b) -56.0 J

(c)(i) 7.88 m/s; (ii) -223 J

35.

(a) 0.163 m/s in the direction of motion of the more massive satellite

(b) 81.6 J

(c) 8.70×10^{-2} m/s in the direction of motion of the less massive satellite, 81.5 J. Because there are no external forces, the velocity of the center of mass of the two-satellite system is unchanged by the collision. The two velocities calculated above are the velocity of the center of mass in each of the two different individual reference frames. The loss in KE is the same in both reference frames because the KE lost to internal forces (heat, friction, etc.) is the same regardless of the coordinate system chosen.

37.

0.704 m/s

–2.25 m/s

38.

(a) 4.58 m/s away from the bullet

(b) 31.5 J

(c) –0.491 m/s

(d) 3.38 J

40.

(a) 1.02×10^{-6} m/s

(b) 5.63×10^{20} J (almost all KE lost)

(c) Recoil speed is 6.79×10^{-17} m/s, energy lost is 6.25×10^{9} J. The plume will not affect the momentum result because the plume is still part of the Moon system. The plume may affect the kinetic energy result because a significant part of the initial kinetic energy may be transferred to the kinetic energy of the plume particles.

42.

24.8 m/s

44.

(a) 4.00 kg

(b) 210 J

(c) The clown does work to throw the barbell, so the kinetic energy comes from the muscles of the clown. The muscles convert the chemical potential energy of ATP into kinetic energy.

45.

(a) 3.00 m/s, 60º below x-axis

(b) Find speed of first puck after collision: $0 = mv_1^{'} \sin 30^{\circ} - mv_2^{'} \sin 60^{\circ} \Rightarrow v_1^{'} = v_2^{'} \frac{\sin 60^{\circ}}{\sin 30^{\circ}} = 5.196$ m/s

Verify that ratio of initial to final KE equals one: $$\left.\begin{aligned} \text{KE} &= \tfrac{1}{2}mv_1{}^2 = 18m \text{ J} \\ \text{KE} &= \tfrac{1}{2}mv\prime_1{}^2 + \tfrac{1}{2}mv\prime_2{}^2 = 18m \text{ J} \end{aligned}\right\} \frac{\text{KE}}{\text{KE}\prime} = 1.00$$

47.

(a) -2.26 m/s

(b) 7.63×10^3 J

(c) The ground will exert a normal force to oppose recoil of the cannon in the vertical direction. The momentum in the vertical direction is transferred to the earth. The energy is transferred into the ground, making a dent where the cannon is. After long barrages, cannon have erratic aim because the ground is full of divots.

49.

(a) 5.36×10^5 m/s at -29.5^{o}

(b) 7.52×10^{-13} J

51.

We are given that $m_1 = m_2 \equiv m$. The given equations then become:

$v_1 = v_1 \cos \theta_1 + v_2 \cos \theta_2$

and

$0 = v_1^{'} \sin \theta_1 + v_2^{'} \sin \theta_2$.

Square each equation to get

$$\begin{aligned} {v_1}^2 &= {v\prime_1}^2 \cos^2 \theta_1 + {v\prime_2}^2 \cos^2 \theta_2 + 2v\prime_1 v\prime_2 \cos \theta_1 \cos \theta_2 \\ 0 &= {v\prime_1}^2 \sin^2 \theta_1 + {v\prime_2}^2 \sin^2 \theta_2 + 2v\prime_1 v\prime_2 \sin \theta_1 \sin \theta_2. \end{aligned}$$

Add these two equations and simplify:

$$\begin{aligned} v_1^2 &= {v\prime_1}^2 + {v\prime_2}^2 + 2v\prime_1 v\prime_2 (\cos \theta_1 \cos \theta_2 + \sin \theta_1 \sin \theta_2) \\ &= {v\prime_1}^2 + {v\prime_2}^2 + 2v\prime_1 v\prime_2 \left[\tfrac{1}{2} \cos (\theta_1 - \theta_2) + \tfrac{1}{2} \cos (\theta_1 + \theta_2) + \tfrac{1}{2} \cos (\theta_1 - \theta_2) - \tfrac{1}{2} \cos (\theta_1 + \theta_2)\right] \\ &= {v\prime_1}^2 + {v\prime_2}^2 + 2v\prime_1 v\prime_2 \cos (\theta_1 - \theta_2). \end{aligned}$$

Multiply the entire equation by $\frac{1}{2}m$ to recover the kinetic energy:

$\frac{1}{2}\mathrm{mv_1}^2 = \frac{1}{2}m{v'_1}^2 + \frac{1}{2}m{v'_2}^2 + mv'_1 v'_2 \cos(\theta_1 - \theta_2)$

53.

$39.2\ \mathrm{m/s^2}$

55.

4.16×10^3 m/s

57.

The force needed to give a small mass Δm an acceleration $a_{\Delta m}$ is $F = \Delta \mathrm{ma}_{\Delta m}$. To accelerate this mass in the small time interval Δt requires $v_\mathrm{e} = a_{\Delta m} \Delta t$, so $F = v_\mathrm{e} \frac{\Delta m}{\Delta t}$. By Newton's third law, this force is equal in magnitude to the thrust force acting on the rocket, so $F_\mathrm{thrust} = v_\mathrm{e} \frac{\Delta m}{\Delta t}$, where all quantities are positive. Applying Newton's second law to the rocket gives $F_\mathrm{thrust} - \mathrm{mg} = \mathrm{ma} \Rightarrow a = \frac{v_\mathrm{e}}{m} \frac{\Delta m}{\Delta t} - g$, where m is the mass of the rocket and unburnt fuel.

60.

2.63×10^3 kg

61.

(a) 0.421 m/s away from the ejected fluid.

(b) 0.237 J.