CHAPTER 4: Dynamics: Newton’s Laws of Motion

Answers to Questions

10. The acceleration of both rocks is found by dividing their weight (the force of gravity on them) by
    their mass. The 2-kg rock has a force of gravity on it that is twice as great as the force of gravity on
    the 1-kg rock, but also twice as great a mass as the 1-kg rock, so the acceleration is the same for both.

13. Let us find the acceleration of the Earth, assuming the mass of the freely falling object is \( m = 1 \) kg. If
    the mass of the Earth is \( M \), then the acceleration of the Earth would be found using Newton’s 3rd
    law and Newton’s 2nd law.

\[
F_{\text{Earth}} = F_{\text{object}} \rightarrow Ma_{\text{Earth}} = mg \rightarrow a_{\text{Earth}} = g \frac{m}{M}
\]

Since the Earth has a mass that is on the order of \( 10^{25} \) kg, then the acceleration of the Earth is on the
order of \( 10^{-25} \) g, or about \( 10^{-24} \) m/s\(^2\). This tiny acceleration is undetectable.

14. (a) To lift the object on the Earth requires a force the same size as its weight on Earth,

\[
F_{\text{Earth}} + mg_{\text{Earth}} = 98 \text{ N}.
\]

To lift the object on the Moon requires a force the same size as its
weight on the Moon, \( F_{\text{Moon}} = mg_{\text{Moon}} = mg_{\text{Moon}}/6 = 16 \) N.

(b) The horizontal accelerating force would be the same in each case, because the mass of the
object is the same on both the Earth and the Moon, and both objects would have the same
acceleration to throw them with the same speed. So by Newton’s second law, the forces would
have to be the same.

18. In a whiplash situation, the car is violently pushed forward. Since the victim’s back is against the seat
    of the car, the back moves forward with the car. But the head has no direct horizontal force to push it,
    and so it “lags behind”. The victim’s body is literally pushed forward, out from under their head —
    the head is not thrown backwards. The neck muscles must eventually pull the head forward, and that
    causes the whiplash. To avoid this, use the car’s headrests.
Solutions to Problems

1. Use Newton’s second law to calculate the force.
\[ \sum F = ma = (60.0 \text{ kg})(1.25 \text{ m/s}^2) = 75.0 \text{ N} \]

3. Use Newton’s second law to calculate the tension.
\[ \sum F = F_T = ma = (960 \text{ kg})(1.20 \text{ m/s}^2) = 1.15 \times 10^3 \text{ N} \]

5. (a) The 20.0 kg box resting on the table has the free-body diagram shown. It’s weight is \( mg = (20.0 \text{ kg})(9.80 \text{ m/s}^2) = 196 \text{ N} \). Since the box is at rest, the net force on the box must be 0, and so the normal force must also be 196 N.

(b) Free-body diagrams are shown for both boxes. \( \vec{F}_{12} \) is the force on box 1 (the top box) due to box 2 (the bottom box). That is the normal force on box 1. \( \vec{F}_{21} \) is the force on box 2 due to box 1, and has the same magnitude as \( \vec{F}_{12} \) by Newton’s 3rd law. \( \vec{F}_{N2} \) is the force of the table on box 2. That is the normal force on box 2. Since both boxes are at rest, the net force on each box must be 0. Write Newton’s 2nd law in the vertical direction for each box, taking the upward direction to be positive.

\[ \sum F_1 = F_{N1} - m_1g = 0 \]
\[ F_{N1} = m_1g = (10.0 \text{ kg})(9.80 \text{ m/s}^2) = 98.0 \text{ N} = F_{12} = F_{21} \]

\[ \sum F_2 = F_{N2} - F_{21} = m_2g = 0 \]
\[ F_{N2} = F_{21} + m_2g = 98.0 \text{ N} + (20.0 \text{ kg})(9.80 \text{ m/s}^2) = 294 \text{ N} \]

8. We assume that the fish line is pulling vertically on the fish, and that the fish is not jerking the line. A free-body diagram for the fish is shown. Write Newton’s 2nd law for the fish in the vertical direction, assuming that up is positive. The tension is at its maximum.

\[ \vec{F}_t \]
\[ m \vec{g} \]
\[
\sum F = F_x - mg = ma \quad \rightarrow \quad F_x = m(g + a) \quad \rightarrow \\
m = \frac{F_x}{g + a} = \frac{22 \text{ N}}{9.8 \text{ m/s}^2 + 2.5 \text{ m/s}^2} = 1.8 \text{ kg}
\]

Thus a mass of 1.8 kg is the maximum that the fish line will support with the given acceleration. Since the line broke, the fish’s mass must be greater than 1.8 kg (about 4 lbs).

19. Free body diagrams for the box and the weight are shown below. The tension exerts the same magnitude of force on both objects.

(a) If the weight of the hanging weight is less than the weight of the box, the objects will not move, and the tension will be the same as the weight of the hanging weight. The acceleration of the box will also be zero, and so the sum of the forces on it will be zero. For the box,

\[
F_N + F_T - m_1g = 0 \quad \rightarrow \quad F_N = m_1g - F_T = m_1g - m_2g = 77.0 \text{ N} - 30.0 \text{ N} = 47.0 \text{ N}
\]

(b) The same analysis as for part (a) applies here.

\[
F_N = m_1g - m_2g = 77.0 \text{ N} - 60.0 \text{ N} = 17.0 \text{ N}
\]

(c) Since the hanging weight has more weight than the box on the table, the box on the table will be lifted up off the table, and normal force of the table on the box will be 0 N.