Chapter 5

1. We are only concerned with horizontal forces in this problem (gravity plays no direct role). We take East as the $+x$ direction and North as $+y$. This calculation is efficiently implemented on a vector-capable calculator, using magnitude-angle notation (with SI units understood).

$$\vec{a} = \frac{\vec{F}}{m} = \frac{(9.0 \angle 0°) + (8.0 \angle 118°)}{3.0} = (2.9 \angle 53°)$$

Therefore, the acceleration has a magnitude of 2.9 m/s^2.

15. **THINK** We have a piece of salami hung to a spring scale in various ways. The problem is to explore the concept of weight.

EXPRESS We first note that the reading on the spring scale is proportional to the weight of the salami. In all three cases (a) – (c) depicted in Fig. 5-34, the scale is not accelerating, which means that the two cords exert forces of equal magnitude on it. The scale reads the magnitude of either of these forces. In each case the tension force of the cord attached to the salami must be the same in magnitude as the weight of the salami because the salami is not accelerating. Thus the scale reading is mg, where m is the mass of the salami.

ANALYZE In all three cases (a) – (c), the reading on the scale is

$$w = mg = (11.0 \text{ kg}) (9.8 \text{ m/s}^2) = 108 \text{ N}.$$

LEARN The weight of an object is measured when the object is not accelerating vertically relative to the ground. If it is, then the weight measured is called the apparent weight.

19. **THINK** In this problem we're interested in the force applied to a rocket sled to accelerate it from rest to a given speed in a given time interval.

EXPRESS In terms of magnitudes, Newton's second law is $F = ma$, where $F = \left| \vec{F}_{net} \right|$, $a = |\vec{a}|$, and m is the (always positive) mass. The magnitude of the acceleration can be found using constant acceleration kinematics (Table 2-1). Solving $v = v_0 + at$ for the case where it starts from rest, we have $a = v/t$ (which we interpret in terms of magnitudes, making specification of coordinate directions unnecessary). Thus, the required force is $F = ma = mv/t$.

ANALYZE Expressing the velocity in SI units as

$$v = (1600 \text{ km/h}) (1000 \text{ m/km})/(3600 \text{ s/h}) = 444 \text{ m/s},$$

we find the force to be

$$F = m\frac{v}{t} = \left(500\,\text{kg}\right)\frac{444\,\text{m/s}}{1.8\,\text{s}} = 1.2 \times 10^5 \text{ N}.$$

LEARN From the expression $F = mv/t$, we see that the shorter the time to attain a given speed, the greater the force required.

26. Some assumptions (not so much for realism but rather in the interest of using the given information efficiently) are needed in this calculation: we assume the fishing line and the path of the salmon are horizontal. Thus, the weight of the fish contributes only (via Eq. 5-12) to information about its mass ($m = W/g = 8.7$ kg). Our $+x$ axis is in the direction of the salmon's velocity (away from the fisherman), so that its acceleration (''deceleration'') is negative-valued and the force of tension is in the $-x$ direction: $\vec{T} = -T$. We use Eq. 2-16 and SI units (noting that $v = 0$).

$$v^2 = v_0^2 + 2a\Delta x \quad \Rightarrow \quad a = -\frac{v_0^2}{2\Delta x} = -\frac{(2.8 \text{ m/s})^2}{2(0.11 \text{ m})} = -36 \text{ m/s}^2.$$

Assuming there are no significant horizontal forces other than the tension, Eq. 5-1 leads to

$$\vec{T} = m\vec{a} \quad \Rightarrow \quad -T = \left(8.7\,\text{kg}\right)\left(-36\,\text{m/s}^2\right)$$

which results in $T = 3.1 \times 10^2$ N.

29. We choose up as the $+y$ direction, so $\vec{a} = (-3.00 \text{ m/s}^2)\hat{j}$ (which, without the unit-vector, we denote as a since this is a 1-dimensional problem in which Table 2-1 applies). From Eq. 5-12, we obtain the firefighter's mass: $m = W/g = 72.7$ kg.

(a) We denote the force exerted by the pole on the firefighter $\vec{F}_{fp} = F_{fp}\,\hat{j}$ and apply Eq. 5-1. Since $\vec{F}_{net} = m\vec{a}$, we have

$$F_{fp} - F_g = ma \quad \Rightarrow \quad F_{fp} - 712 \text{ N} = (72.7 \text{ kg})(-3.00 \text{ m/s}^2)$$

which yields $F_{fp} = 494$ N.

(b) The fact that the result is positive means $\vec{F}_{fp}$ points up.

(c) Newton's third law indicates $\vec{F}_{fp} = -\vec{F}_{pf}$, which leads to the conclusion that $|\vec{F}_{pf}| = 494$ N.

(d) The direction of $\vec{F}_{pf}$ is down.

37. (a) Since friction is negligible the force of the girl is the only horizontal force on the sled. The vertical forces (the force of gravity and the normal force of the ice) sum to zero. The acceleration of the sled is

$$a_s = \frac{F}{m_s} = \frac{5.2\,\text{N}}{8.4\,\text{kg}} = 0.62\ \text{m/s}^2 \ .$$

(b) According to Newton's third law, the force of the sled on the girl is also 5.2 N. Her acceleration is

$$a_g = \frac{F}{m_g} = \frac{5.2\,\text{N}}{40\,\text{kg}} = 0.13\ \text{m/s}^2 \ .$$

(c) The accelerations of the sled and girl are in opposite directions. Assuming the girl starts at the origin and moves in the $+x$ direction, her coordinate is given by $x_g = \frac{1}{2}a_g t^2$. The sled starts at $x_0 = 15$ m and moves in the $-x$ direction. Its coordinate is given by $x_s = x_0 - \frac{1}{2}a_s t^2$. They meet when $x_g = x_s$, or

$$\frac{1}{2}a_g t^2 = x_0 - \frac{1}{2}a_s t^2 .$$

This occurs at time

$$t = \sqrt{\frac{2x_0}{a_g + a_s}} .$$

By then, the girl has gone the distance

$$x_g = \frac{1}{2}a_g t^2 = \frac{x_0 a_g}{a_g + a_s} = \frac{(15\ \text{m})(0.13\ \text{m/s}^2)}{0.13\ \text{m/s}^2 + 0.62\ \text{m/s}^2} = 2.6\ \text{m}.$$

51. The free-body diagrams for m_1 and m_2 are shown in the figures below. The only forces on the blocks are the upward tension $\vec{T}$ and the downward gravitational forces $\vec{F}_1 = m_1 g$ and $\vec{F}_2 = m_2 g$. Applying Newton's second law, we obtain:
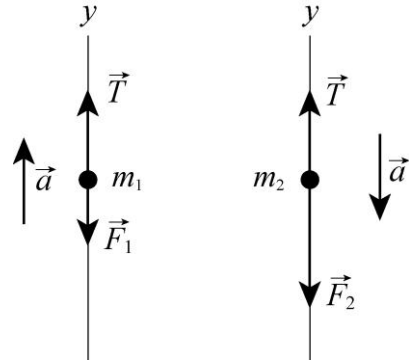
$$T - m_1 g = m_1 a$$

$$m_2 g - T = m_2 a$$

which can be solved to yield

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1} \right) g$$

Substituting the result back, we have

$$T = \left(\frac{2 m_1 m_2}{m_1 + m_2} \right) g$$

(a) With $m_1 = 1.3$ kg and $m_2 = 2.8$ kg, the acceleration becomes

$$a = \left(\frac{2.80 \, \text{kg} - 1.30 \, \text{kg}}{2.80 \, \text{kg} + 1.30 \, \text{kg}} \right) (9.80 \, \text{m/s}^2) = 3.59 \, \text{m/s}^2 \approx 3.6 \, \text{m/s}^2.$$

(b) Similarly, the tension in the cord is

$$T = \frac{2(1.30 \, \text{kg})(2.80 \, \text{kg})}{1.30 \, \text{kg} + 2.80 \, \text{kg}} (9.80 \, \text{m/s}^2) = 17.4 \, \text{N} \approx 17 \, \text{N}.$$

61. **THINK** As more mass is thrown out of the hot-air balloon, its upward acceleration increases.

EXPRESS The forces on the balloon are the force of gravity $m\vec{g}$ (down) and the force of the air $\vec{F}_a$ (up). We take the $+y$ to be up, and use a to mean the *magnitude* of the acceleration. When the mass is M (before the ballast is thrown out) the acceleration is downward and Newton's second law is

$$Mg - F_a = Ma$$

After the ballast is thrown out, the mass is $M - m$ (where m is the mass of the ballast) and the acceleration is now upward. Newton's second law leads to

$$F_a - (M - m)g = (M - m)a.$$

Combing the two equations allows us to solve for m.

ANALYZE The first equation gives $F_a = M(g - a)$, and this plugs into the new equation to give

$$M(g - a) - (M - m)g = (M - m)a \implies m = \frac{2Ma}{g + a}.$$

LEARN More generally, if a ballast mass m' is tossed, the resulting acceleration is a' which is related to m' via:

$$m' = M \frac{a' + a}{g + a} ,$$

showing that the more mass thrown out, the greater is the upward acceleration. For $a' = a$, we get $m' = 2Ma/(g + a)$, which agrees with what was found above.

80. We take down to be the $+y$ direction.

(a) The first diagram (shown below left) is the free-body diagram for the person and parachute, considered as a single object with a mass of 80 kg + 5.0 kg = 85 kg.
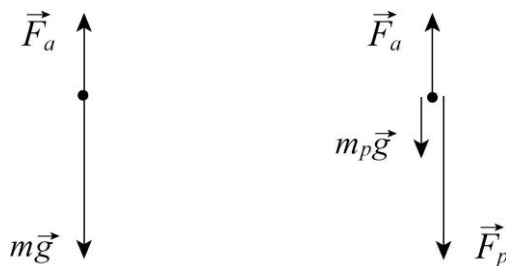
$\vec{F}_a$ is the force of the air on the parachute and $m\vec{g}$ is the force of gravity. Application of Newton's second law produces $mg - F_a = ma$, where a is the acceleration. Solving for F_a we find

$$F_a = m(g - a) = (85 \text{ kg})(9.8 \text{ m/s}^2 - 2.5 \text{ m/s}^2) = 620 \text{ N}.$$

(b) The second diagram (above right) is the free-body diagram for the parachute alone. $\vec{F}_a$ is the force of the air, $m_p\vec{g}$ is the force of gravity, and $\vec{F}_p$ is the force of the person. Now, Newton's second law leads to

$$m_p g + F_p - F_a = m_p a.$$

Solving for F_p, we obtain

$$F_p = m_p(a - g) + F_a = (5.0 \text{ kg})(2.5 \text{ m/s}^2 - 9.8 \text{ m/s}^2) + 620 \text{ N} = 580 \text{ N}.$$

85. (a) Since the performer's weight is $(52 \text{ kg})(9.8 \text{ m/s}^2) = 510 \text{ N}$, the rope breaks.

(b) Setting $T = 425$ N in Newton's second law (with $+y$ upward) leads to

$$T - mg = ma \implies a = \frac{T}{m} - g$$

which yields $|a| = 1.6$ m/s^2.