

Chapter 5 – Student Solutions Manual

5. We denote the two forces $\vec{F}_1$ and $\vec{F}_2$. According to Newton's second law, $\vec{F}_1 + \vec{F}_2 = m\vec{a}$, so $\vec{F}_2 = m\vec{a} - \vec{F}_1$.

(a) In unit vector notation $\vec{F}_1 = (20.0 \text{ N})\hat{i}$ and

$$\vec{a} = -(12.0 \sin 30.0^\circ \text{ m/s}^2)\hat{i} - (12.0 \cos 30.0^\circ \text{ m/s}^2)\hat{j} = -(6.00 \text{ m/s}^2)\hat{i} - (10.4 \text{ m/s}^2)\hat{j}.$$

Therefore,

$$\begin{aligned}\vec{F}_2 &= (2.00 \text{ kg}) (-6.00 \text{ m/s}^2)\hat{i} + (2.00 \text{ kg}) (-10.4 \text{ m/s}^2)\hat{j} - (20.0 \text{ N})\hat{i} \\ &= (-32.0 \text{ N})\hat{i} - (20.8 \text{ N})\hat{j}.\end{aligned}$$

(b) The magnitude of $\vec{F}_2$ is

$$|\vec{F}_2| = \sqrt{F_{2x}^2 + F_{2y}^2} = \sqrt{(-32.0)^2 + (-20.8)^2} = 38.2 \text{ N}.$$

(c) The angle that $\vec{F}_2$ makes with the positive x axis is found from

$$\tan \theta = (F_{2y}/F_{2x}) = [(-20.8)/(-32.0)] = 0.656.$$

Consequently, the angle is either 33.0° or $33.0^\circ + 180^\circ = 213^\circ$. Since both the x and y components are negative, the correct result is 213° . An alternative answer is $213^\circ - 360^\circ = -147^\circ$.

13. (a) – (c) In all three cases 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. Its value is $(11.0 \text{ kg})(9.8 \text{ m/s}^2) = 108 \text{ N}$.

19. (a) Since the acceleration of the block is zero, the components of the Newton's second law equation yield

$$\begin{aligned}T - mg \sin \theta &= 0 \\ F_N - mg \cos \theta &= 0.\end{aligned}$$

Solving the first equation for the tension in the string, we find

$$T = mg \sin \theta = (8.5 \text{ kg})(9.8 \text{ m/s}^2) \sin 30^\circ = 42 \text{ N}.$$

(b) We solve the second equation in part (a) for the normal force F_N :

$$F_N = mg \cos \theta = (8.5 \text{ kg})(9.8 \text{ m/s}^2) \cos 30^\circ = 72 \text{ N} .$$

(c) When the string is cut, it no longer exerts a force on the block and the block accelerates. The x component of the second law becomes $-mg \sin \theta = ma$, so the acceleration becomes

$$a = -g \sin \theta = -9.8 \sin 30^\circ = -4.9 \text{ m/s}^2 .$$

The negative sign indicates the acceleration is down the plane. The magnitude of the acceleration is 4.9 m/s^2 .

25. In terms of magnitudes, Newton's second law is $F = ma$, where $F = |\vec{F}_{\text{net}}|$, $a = |\vec{a}|$, 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). The velocity is $v = (1600 \text{ km/h})(1000 \text{ m/km})/(3600 \text{ s/h}) = 444 \text{ m/s}$, so

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

29. The acceleration of the electron is vertical and for all practical purposes the only force acting on it is the electric force. The force of gravity is negligible. We take the $+x$ axis to be in the direction of the initial velocity and the $+y$ axis to be in the direction of the electrical force, and place the origin at the initial position of the electron. Since the force and acceleration are constant, we use the equations from Table 2-1: $x = v_0 t$ and

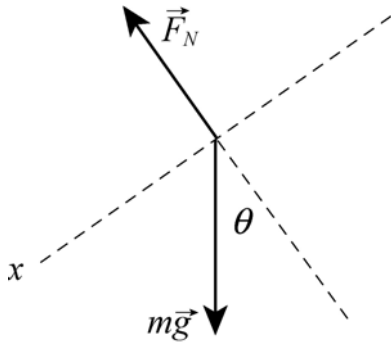
$$y = \frac{1}{2} at^2 = \frac{1}{2} \left(\frac{F}{m} \right) t^2 .$$

The time taken by the electron to travel a distance x ($= 30 \text{ mm}$) horizontally is $t = x/v_0$ and its deflection in the direction of the force is

$$y = \frac{1}{2} \frac{F}{m} \left(\frac{x}{v_0} \right)^2 = \frac{1}{2} \left(\frac{4.5 \times 10^{-16}}{9.11 \times 10^{-31}} \right) \left(\frac{30 \times 10^{-3}}{1.2 \times 10^7} \right)^2 = 1.5 \times 10^{-3} \text{ m} .$$

35. The free-body diagram is shown next. $\vec{F}_N$ is the normal force of the plane on the block and $m\vec{g}$ is the force of gravity on the block. We take the $+x$ direction to be down the incline, in the direction of the acceleration, and the $+y$ direction to be in the direction

of the normal force exerted by the incline on the block. The x component of Newton's second law is then $mg \sin \theta = ma$; thus, the acceleration is $a = g \sin \theta$.



(a) Placing the origin at the bottom of the plane, the kinematic equations (Table 2-1) for motion along the x axis which we will use are $v^2 = v_0^2 + 2ax$ and $v = v_0 + at$. The block momentarily stops at its highest point, where $v = 0$; according to the second equation, this occurs at time $t = -v_0/a$. The position where it stops is

$$x = -\frac{1}{2} \frac{v_0^2}{a} = -\frac{1}{2} \left(\frac{(-3.50 \text{ m/s})^2}{(9.8 \text{ m/s}^2) \sin 32.0^\circ} \right) = -1.18 \text{ m},$$

or $|x| = 1.18 \text{ m}$.

(b) The time is

$$t = \frac{v_0}{a} = -\frac{v_0}{g \sin \theta} = -\frac{-3.50 \text{ m/s}}{(9.8 \text{ m/s}^2) \sin 32.0^\circ} = 0.674 \text{ s}.$$

(c) That the return-speed is identical to the initial speed is to be expected since there are no dissipative forces in this problem. In order to prove this, one approach is to set $x = 0$ and solve $x = v_0 t + \frac{1}{2} at^2$ for the total time (up and back down) t . The result is

$$t = -\frac{2v_0}{a} = -\frac{2v_0}{g \sin \theta} = -\frac{2(-3.50 \text{ m/s})}{(9.8 \text{ m/s}^2) \sin 32.0^\circ} = 1.35 \text{ s}.$$

The velocity when it returns is therefore

$$v = v_0 + at = v_0 + gt \sin \theta = -3.50 + (9.8)(1.35) \sin 32^\circ = 3.50 \text{ m/s}.$$

45. (a) The links are numbered from bottom to top. The forces on the bottom link are the force of gravity $m\vec{g}$, downward, and the force $\vec{F}_{2\text{on}1}$ of link 2, upward. Take the positive direction to be upward. Then Newton's second law for this link is $F_{2\text{on}1} - mg = ma$. Thus,

$$F_{2on1} = m(a + g) = (0.100 \text{ kg}) (2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) = 1.23 \text{ N}.$$

(b) The forces on the second link are the force of gravity $m\vec{g}$, downward, the force $\vec{F}_{1on2}$ of link 1, downward, and the force $\vec{F}_{3on2}$ of link 3, upward. According to Newton's third law $\vec{F}_{1on2}$ has the same magnitude as $\vec{F}_{2on1}$. Newton's second law for the second link is $F_{3on2} - F_{1on2} - mg = ma$, so

$$F_{3on2} = m(a + g) + F_{1on2} = (0.100 \text{ kg}) (2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) + 1.23 \text{ N} = 2.46 \text{ N}.$$

(c) Newton's second for link 3 is $F_{4on3} - F_{2on3} - mg = ma$, so

$$F_{4on3} = m(a + g) + F_{2on3} = (0.100 \text{ N}) (2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) + 2.46 \text{ N} = 3.69 \text{ N},$$

where Newton's third law implies $F_{2on3} = F_{3on2}$ (since these are magnitudes of the force vectors).

(d) Newton's second law for link 4 is $F_{5on4} - F_{3on4} - mg = ma$, so

$$F_{5on4} = m(a + g) + F_{3on4} = (0.100 \text{ kg}) (2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) + 3.69 \text{ N} = 4.92 \text{ N},$$

where Newton's third law implies $F_{3on4} = F_{4on3}$.

(e) Newton's second law for the top link is $F - F_{4on5} - mg = ma$, so

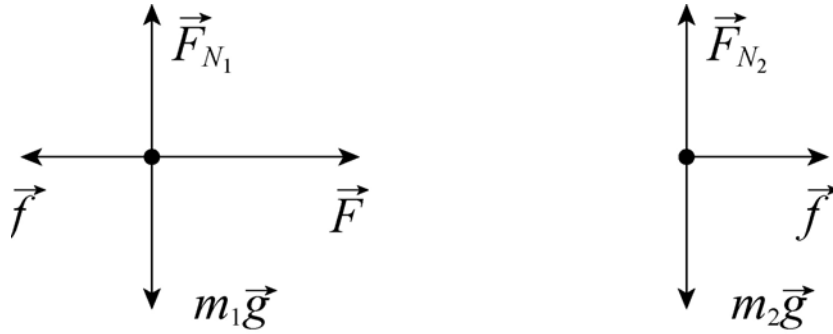
$$F = m(a + g) + F_{4on5} = (0.100 \text{ kg}) (2.50 \text{ m/s}^2 + 9.80 \text{ m/s}^2) + 4.92 \text{ N} = 6.15 \text{ N},$$

where $F_{4on5} = F_{5on4}$ by Newton's third law.

(f) Each link has the same mass and the same acceleration, so the same net force acts on each of them:

$$F_{\text{net}} = ma = (0.100 \text{ kg}) (2.50 \text{ m/s}^2) = 0.250 \text{ N}.$$

53. The free-body diagrams for part (a) are shown below. $\vec{F}$ is the applied force and $\vec{f}$ is the force exerted by block 1 on block 2. We note that $\vec{F}$ is applied directly to block 1 and that block 2 exerts the force $-\vec{f}$ on block 1 (taking Newton's third law into account).



(a) Newton's second law for block 1 is $F - f = m_1 a$, where a is the acceleration. The second law for block 2 is $f = m_2 a$. Since the blocks move together they have the same acceleration and the same symbol is used in both equations. From the second equation we obtain the expression $a = f/m_2$, which we substitute into the first equation to get $F - f = m_1 f/m_2$. Therefore,

$$f = \frac{F m_2}{m_1 + m_2} = \frac{(3.2 \text{ N})(1.2 \text{ kg})}{2.3 \text{ kg} + 1.2 \text{ kg}} = 1.1 \text{ N} .$$

(b) If $\vec{F}$ is applied to block 2 instead of block 1 (and in the opposite direction), the force of contact between the blocks is

$$f = \frac{F m_1}{m_1 + m_2} = \frac{(3.2 \text{ N})(2.3 \text{ kg})}{2.3 \text{ kg} + 1.2 \text{ kg}} = 2.1 \text{ N} .$$

(c) We note that the acceleration of the blocks is the same in the two cases. In part (a), the force f is the only horizontal force on the block of mass m_2 and in part (b) f is the only horizontal force on the block with $m_1 > m_2$. Since $f = m_2 a$ in part (a) and $f = m_1 a$ in part (b), then for the accelerations to be the same, f must be larger in part (b).

57. We take +y to be up for both the monkey and the package.

(a) The force the monkey pulls downward on the rope has magnitude F . According to Newton's third law, the rope pulls upward on the monkey with a force of the same magnitude, so Newton's second law for forces acting on the monkey leads to

$$F - m_m g = m_m a_m,$$

where m_m is the mass of the monkey and a_m is its acceleration. Since the rope is massless $F = T$ is the tension in the rope. The rope pulls upward on the package with a force of magnitude F , so Newton's second law for the package is

$$F + F_N - m_p g = m_p a_p,$$

where m_p is the mass of the package, a_p is its acceleration, and F_N is the normal force exerted by the ground on it. Now, if F is the minimum force required to lift the package, then $F_N = 0$ and $a_p = 0$. According to the second law equation for the package, this means $F = m_p g$. Substituting $m_p g$ for F in the equation for the monkey, we solve for a_m :

$$a_m = \frac{F - m_m g}{m_m} = \frac{(m_p - m_m)g}{m_m} = \frac{(15 \text{ kg} - 10 \text{ kg})(9.8 \text{ m/s}^2)}{10 \text{ kg}} = 4.9 \text{ m/s}^2.$$

(b) As discussed, Newton's second law leads to $F - m_p g = m_p a_p$ for the package and $F - m_m g = m_m a_m$ for the monkey. If the acceleration of the package is downward, then the acceleration of the monkey is upward, so $a_m = -a_p$. Solving the first equation for F

$$F = m_p(g + a_p) = m_p(g - a_m)$$

and substituting this result into the second equation, we solve for a_m :

$$a_m = \frac{(m_p - m_m)g}{m_p + m_m} = \frac{(15 \text{ kg} - 10 \text{ kg})(9.8 \text{ m/s}^2)}{15 \text{ kg} + 10 \text{ kg}} = 2.0 \text{ m/s}^2.$$

(c) The result is positive, indicating that the acceleration of the monkey is upward.

(d) Solving the second law equation for the package, we obtain

$$F = m_p(g - a_m) = (15 \text{ kg})(9.8 \text{ m/s}^2 - 2.0 \text{ m/s}^2) = 120 \text{ N}.$$

61. 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 (which is not its usual use in this chapter). When the mass is M (before the ballast is thrown out) the acceleration is downward and Newton's second law is

$$F_a - Mg = -Ma.$$

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

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

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

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

73. Although the full specification of $\vec{F}_{\text{net}} = m\vec{a}$ in this situation involves both x and y axes, only the x -application is needed to find what this particular problem asks for. We note that $a_y = 0$ so that there is no ambiguity denoting a_x simply as a . We choose $+x$ to the right and $+y$ up. We also note that the x component of the rope's tension (acting on the crate) is

$$F_x = F \cos \theta = 450 \cos 38^\circ = 355 \text{ N},$$

and the resistive force (pointing in the $-x$ direction) has magnitude $f = 125 \text{ N}$.

(a) Newton's second law leads to

$$F_x - f = ma \Rightarrow a = \frac{355 \text{ N} - 125 \text{ N}}{310 \text{ kg}} = 0.74 \text{ m/s}^2.$$

(b) In this case, we use Eq. 5-12 to find the mass: $m = W/g = 31.6 \text{ kg}$. Now, Newton's second law leads to

$$T_x - f = ma \Rightarrow a = \frac{355 \text{ N} - 125 \text{ N}}{31.6 \text{ kg}} = 7.3 \text{ m/s}^2.$$

79. The "certain force" denoted F is assumed to be the net force on the object when it gives m_1 an acceleration $a_1 = 12 \text{ m/s}^2$ and when it gives m_2 an acceleration $a_2 = 3.3 \text{ m/s}^2$. Thus, we substitute $m_1 = F/a_1$ and $m_2 = F/a_2$ in appropriate places during the following manipulations.

(a) Now we seek the acceleration a of an object of mass $m_2 - m_1$ when F is the net force on it. Thus,

$$a = \frac{F}{m_2 - m_1} = \frac{F}{(F/a_2) - (F/a_1)} = \frac{a_1 a_2}{a_1 - a_2}$$

which yields $a = 4.6 \text{ m/s}^2$.

(b) Similarly for an object of mass $m_2 + m_1$:

$$a = \frac{F}{m_2 + m_1} = \frac{F}{(F/a_2) + (F/a_1)} = \frac{a_1 a_2}{a_1 + a_2}$$

which yields $a = 2.6 \text{ m/s}^2$.

91. (a) The bottom cord is only supporting $m_2 = 4.5 \text{ kg}$ against gravity, so its tension is $T_2 = m_2 g = (4.5 \text{ kg})(9.8 \text{ m/s}^2) = 44 \text{ N}$.

(b) The top cord is supporting a total mass of $m_1 + m_2 = (3.5 \text{ kg} + 4.5 \text{ kg}) = 8.0 \text{ kg}$ against gravity, so the tension there is

$$T_1 = (m_1 + m_2)g = (8.0 \text{ kg})(9.8 \text{ m/s}^2) = 78 \text{ N}.$$

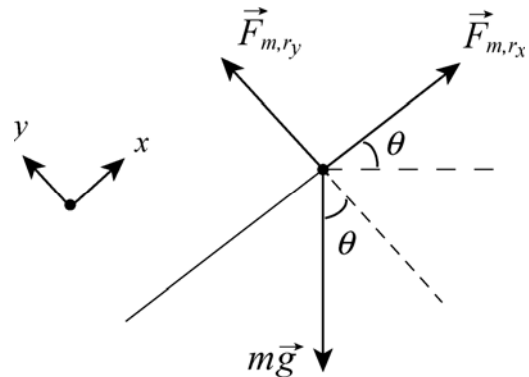
(c) In the second picture, the lowest cord supports a mass of $m_5 = 5.5 \text{ kg}$ against gravity and consequently has a tension of $T_5 = (5.5 \text{ kg})(9.8 \text{ m/s}^2) = 54 \text{ N}$.

(d) The top cord, we are told, has tension $T_3 = 199 \text{ N}$ which supports a total of $(199 \text{ N})/(9.80 \text{ m/s}^2) = 20.3 \text{ kg}$, 10.3 kg of which is already accounted for in the figure. Thus, the unknown mass in the middle must be $m_4 = 20.3 \text{ kg} - 10.3 \text{ kg} = 10.0 \text{ kg}$, and the tension in the cord above it must be enough to support $m_4 + m_5 = (10.0 \text{ kg} + 5.50 \text{ kg}) = 15.5 \text{ kg}$, so $T_4 = (15.5 \text{ kg})(9.80 \text{ m/s}^2) = 152 \text{ N}$. Another way to analyze this is to examine the forces on m_3 ; one of the downward forces on it is T_4 .

95. The free-body diagram is shown on the right.

Note that F_{m,r_y} and F_{m,r_x} , respectively, and thought

of as the y and x components of the force $\vec{F}_{m,r}$ exerted by the motorcycle on the rider.



(a) Since the net force equals ma , then the magnitude of the net force on the rider is $(60.0 \text{ kg})(3.0 \text{ m/s}^2) = 1.8 \times 10^2 \text{ N}$.

(b) We apply Newton's second law to the x axis:

$$F_{m,r_x} - mg \sin \theta = ma$$

where $m = 60.0 \text{ kg}$, $a = 3.0 \text{ m/s}^2$, and $\theta = 10^\circ$. Thus, $F_{m,r_x} = 282 \text{ N}$. Applying it to the y axis (where there is no acceleration), we have

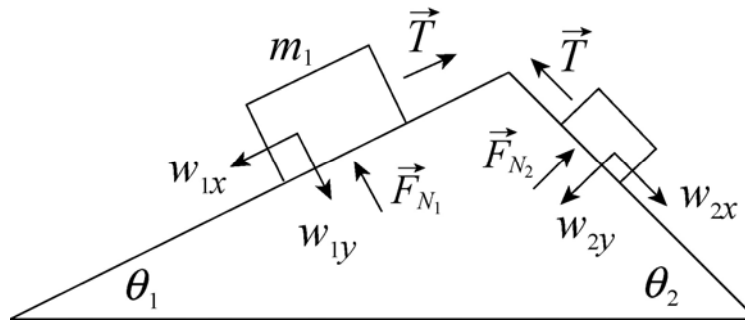
$$F_{m,r_y} - mg \cos \theta = 0$$

which produces $F_{m,r_y} = 579 \text{ N}$. Using the Pythagorean theorem, we find

$$\sqrt{F_{m,r_x}^2 + F_{m,r_y}^2} = 644 \text{ N}.$$

Now, the magnitude of the force exerted on the rider by the motorcycle is the same magnitude of force exerted by the rider on the motorcycle, so the answer is $6.4 \times 10^2 \text{ N}$.

99. The $+x$ axis is "uphill" for $m_1 = 3.0 \text{ kg}$ and "downhill" for $m_2 = 2.0 \text{ kg}$ (so they both accelerate with the same sign). The x components of the two masses along the x axis are given by $w_{1x} = m_1 g \sin \theta_1$ and $w_{2x} = m_2 g \sin \theta_2$, respectively.



Applying Newton's second law, we obtain

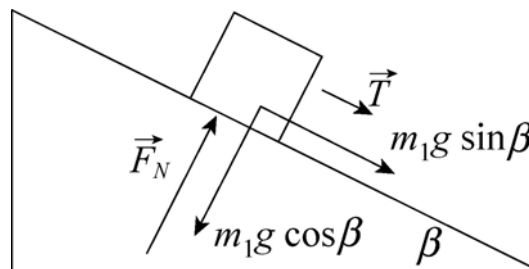
$$\begin{aligned} T - m_1 g \sin \theta_1 &= m_1 a \\ m_2 g \sin \theta_2 - T &= m_2 a \end{aligned}$$

Adding the two equations allows us to solve for the acceleration:

$$a = \left(\frac{m_2 \sin \theta_2 - m_1 \sin \theta_1}{m_2 + m_1} \right) g$$

With $\theta_1 = 30^\circ$ and $\theta_2 = 60^\circ$, we have $a = 0.45 \text{ m/s}^2$. This value is plugged back into either of the two equations to yield the tension $T = 16 \text{ N}$.

101. We first analyze the forces on $m_1 = 1.0 \text{ kg}$.



The $+x$ direction is "downhill" (parallel to $\vec{T}$).

With the acceleration (5.5 m/s^2) in the positive x direction for m_1 , then Newton's second law, applied to the x axis, becomes

$$T + m_1 g \sin \beta = m_1 (5.5 \text{ m/s}^2)$$

But for $m_2 = 2.0 \text{ kg}$, using the more familiar vertical y axis (with *up* as the positive direction), we have the acceleration in the negative direction:

$$F + T - m_2 g = m_2 (-5.5 \text{ m/s}^2)$$

where the tension comes in as an upward force (the cord can pull, not push).

(a) From the equation for m_2 , with $F = 6.0 \text{ N}$, we find the tension $T = 2.6 \text{ N}$.

(b) From the equation for m , using the result from part (a), we obtain the angle $\beta = 17^\circ$.