Solutions to Assignment 5

Due: 11:59pm on Thursday, October 6, 2011

5

4.2. **IDENTIFY:** We know the magnitudes and directions of three vectors and want to use them to find their components, and then to use the components to find the magnitude and direction of the resultant vector.

SET UP: Let $F_1 = 985$ N, $F_2 = 788$ N, and $F_3 = 411$ N. The angles θ that each force makes with the $+x$ axis are $\theta_1 = 31°$, $\theta_2 = 122°$, and $\theta_3 = 233°$. The components of a force vector are $F_x = F\cos\theta$ and $F_y = F\sin\theta$, and $R = \sqrt{R_x^2 + R_y^2}$ and $\tan\theta = \dfrac{R_y}{R_x}$.

EXECUTE: **(a)** $F_{1x} = F_1\cos\theta_1 = 844$ N, $F_{1y} = F_1\sin\theta_1 = 507$ N, $F_{2x} = F_2\cos\theta_2 = -418$ N, $F_{2y} = F_2\sin\theta_2 = 668$ N, $F_{3x} = F_3\cos\theta_3 = -247$ N, and $F_{3y} = F_3\sin\theta_3 = -328$ N.

(b) $R_x = F_{1x} + F_{2x} + F_{3x} = 179$ N; $R_y = F_{1y} + F_{2y} + F_{3y} = 847$ N. $R = \sqrt{R_x^2 + R_y^2} = 886$ N; $\tan\theta = \dfrac{R_y}{R_x}$ so $\theta = 78.1°$. $\vec{R}$ and its components are shown in Figure 4.2.

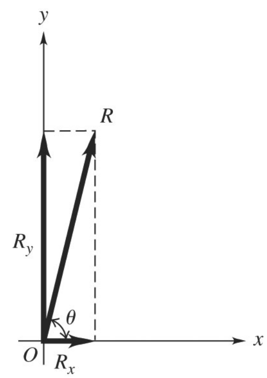

Figure 4.2

EVALUATE: A graphical sketch of the vector sum should agree with the results found in (b). Adding the forces as vectors gives a very different result from adding their magnitudes.

4.3. **IDENTIFY:** We know the resultant of two vectors of equal magnitude and want to find their magnitudes. They make the same angle with the vertical.

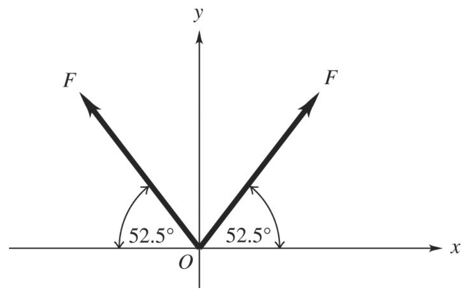

Figure 4.3

SET UP: Take $+y$ to be upward, so $\sum F_y = 5.00\text{ N}$. The strap on each side of the jaw exerts a force F directed at an angle of 52.5° above the horizontal, as shown in Figure 4.3.
EXECUTE: $\sum F_y = 2F\sin 52.5° = 5.00\text{ N}$, so $F = 3.15\text{ N}$.
EVALUATE: The resultant force has magnitude 5.00 N which is *not* the same as the sum of the magnitudes of the two vectors, which would be 6.30 N.

4.10. **IDENTIFY:** Use the information about the motion to find the acceleration and then use $\sum F_x = ma_x$ to calculate m.
SET UP: Let $+x$ be the direction of the force. $\sum F_x = 80.0\text{ N}$.
EXECUTE: **(a)** $x - x_0 = 11.0\text{ m}$, $t = 5.00\text{ s}$, $v_{0x} = 0$. $x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2$ gives

$$a_x = \frac{2(x-x_0)}{t^2} = \frac{2(11.0\text{ m})}{(5.00\text{ s})^2} = 0.880\text{ m/s}^2.\quad m = \frac{\Sigma F_x}{a_x} = \frac{80.0\text{ N}}{0.880\text{ m/s}^2} = 90.9\text{ kg}.$$

(b) $a_x = 0$ and v_x is constant. After the first 5.0 s, $v_x = v_{0x} + a_x t =$ $(0.880\text{ m/s}^2)(5.00\text{ s}) = 4.40\text{ m/s}$.

$x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2 =$ $(4.40\text{ m/s})(5.00\text{ s}) = 22.0\text{ m}$.

EVALUATE: The mass determines the amount of acceleration produced by a given force. The block moves farther in the second 5.00 s than in the first 5.00 s.

4.14. **IDENTIFY:** The force and acceleration are related by Newton's second law. $a_x = \frac{dv_x}{dt}$, so a_x is the slope of the graph of v_x versus t.
SET UP: The graph of v_x versus t consists of straight-line segments. For $t = 0$ to $t = 2.00\text{ s}$, $a_x = 4.00\text{ m/s}^2$. For $t = 2.00\text{ s}$ to 6.00 s, $a_x = 0$. For $t = 6.00\text{ s}$ to 10.0 s, $a_x = 1.00\text{ m/s}^2$.
$\sum F_x = ma_x$, with $m = 2.75\text{ kg}$. $\sum F_x$ is the net force.
EXECUTE: **(a)** The maximum net force occurs when the acceleration has its maximum value.
$\sum F_x = ma_x = (2.75\text{ kg})(4.00\text{ m/s}^2) = 11.0\text{ N}$. This maximum occurs in the interval $t = 0$ to $t = 2.00\text{ s}$.

(b) The net force is zero when the acceleration is zero. This is between 2.00 s and 6.00 s.

(c) Between 6.00 s and 10.0 s, $a_x = 1.00\text{ m/s}^2$, so $\sum F_x = (2.75\text{ kg})(1.00\text{ m/s}^2) = 2.75\text{ N}$.

EVALUATE: The net force is largest when the velocity is changing most rapidly.

4.19. **IDENTIFY** and **SET UP:** $w = mg$. The mass of the watermelon is constant, independent of its location. Its weight differs on earth and Jupiter's moon. Use the information about the watermelon's weight on earth to calculate its mass:

EXECUTE: **(a)** $w = mg$ gives that $m = \dfrac{w}{g} = \dfrac{44.0\text{ N}}{9.80\text{ m/s}^2} = 4.49\text{ kg}$.

(b) On Jupiter's moon, $m = 4.49\text{ kg}$, the same as on earth. Thus the weight on Jupiter's moon is

$w = mg = (4.49\text{ kg})(1.81\text{ m/s}^2) = 8.13\text{ N}$.

EVALUATE: The weight of the watermelon is less on Io, since g is smaller there.

4.23. **IDENTIFY:** The system is accelerating so we use Newton's second law.

SET UP: The acceleration of the entire system is due to the 100-N force, but the acceleration of box B is due to the force that box A exerts on it. $\sum F = ma$ applies to the two-box system and to each box individually.

EXECUTE: For the two-box system: $a_x = \dfrac{100\text{ N}}{25\text{ kg}} = 4.0\text{ m/s}^2$. Then for box *B*, where F_A is the force exerted on *B* by *A*, $F_A = m_B a = (5.0\text{ kg})(4.0\text{ m/s}^2) = 20\text{ N}$.

EVALUATE: The force on B is less than the force on A.

4.24. **IDENTIFY:** The reaction forces in Newton's third law are always between a pair of objects. In Newton's second law all the forces act on a single object.

SET UP: Let $+y$ be downward. $m = w/g$.

EXECUTE: The reaction to the upward normal force on the passenger is the downward normal force, also of magnitude 620 N, that the passenger exerts on the floor. The reaction to the passenger's weight is the gravitational force that the passenger exerts on the earth, upward and also of magnitude 650 N. $\dfrac{\sum F_y}{m} = a_y$ gives

$a_y = \dfrac{650\text{ N} - 620\text{ N}}{(650\text{ N})/(9.80\text{ m/s}^2)} = 0.452\text{ m/s}^2$. The passenger's acceleration is 0.452 m/s^2, downward.

EVALUATE: There is a net downward force on the passenger and the passenger has a downward acceleration.

4.28. **IDENTIFY:** The surface of block B can exert both a friction force and a normal force on block A. The friction force is directed so as to oppose relative motion between blocks B and A. Gravity exerts a downward force w on block A.

SET UP: The pull is a force on B not on A.

EXECUTE: **(a)** If the table is frictionless there is a net horizontal force on the combined object of the two blocks, and block B accelerates in the direction of the pull. The friction force that B exerts on A is to the right, to try to prevent A from slipping relative to B as B accelerates to the right. The free-body diagram is sketched in Figure 4.28a. f is the friction force that B exerts on A and n is the normal force that B exerts on A.

(b) The pull and the friction force exerted on B by the table cancel and the net force on the system of two blocks is zero. The blocks move with the same constant speed and B exerts no friction force on A. The free-body diagram is sketched in Figure 4.28b.

EVALUATE: If in part (b) the pull force is decreased, block B will slow down, with an acceleration directed to the left. In this case the friction force on A would be to the left, to prevent relative motion between the two blocks by giving A an acceleration equal to that of B.

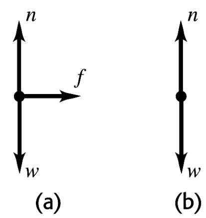

Figure 4.28

4.37. **IDENTIFY:** If the box moves in the $+x$-direction it must have $a_y = 0$, so $\sum F_y = 0$.

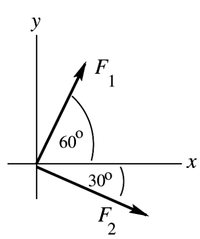

Figure 4.37

The smallest force the child can exert and still produce such motion is a force that makes the y-components of all three forces sum to zero, but that doesn't have any x-component.

SET UP: $\vec{F}_1$ and $\vec{F}_2$ are sketched in Figure 4.37. Let $\vec{F}_3$ be the force exerted by the child.

$\sum F_y = ma_y$ implies $F_{1y} + F_{2y} + F_{3y} = 0$, so $F_{3y} = -(F_{1y} + F_{2y})$.

EXECUTE: $F_{1y} = +F_1 \sin 60° = (100\text{ N})\sin 60° = 86.6\text{ N}$

$F_{2y} = +F_2 \sin(-30°) = -F_2 \sin 30° = -(140\text{ N})\sin 30° = -70.0\text{ N}$

Then $F_{3y} = -(F_{1y} + F_{2y}) = -(86.6\text{ N} - 70.0\text{ N}) = -16.6\text{ N}$; $F_{3x} = 0$

The smallest force the child can exert has magnitude 17 N and is directed at $90°$ clockwise from the $+x$-axis shown in the figure.

(b) IDENTIFY and **SET UP:** Apply $\sum F_x = ma_x$. We know the forces and a_x so can solve for m. The force exerted by the child is in the $-y$-direction and has no x-component.

EXECUTE: $F_{1x} = F_1 \cos 60° = 50 \text{ N}$

$F_{2x} = F_2 \cos 30° = 121.2 \text{ N}$

$\sum F_x = F_{1x} + F_{2x} = 50 \text{ N} + 121.2 \text{ N} = 171.2 \text{ N}$

$$m = \frac{\sum F_x}{a_x} = \frac{171.2 \text{ N}}{2.00 \text{ m/s}^2} = 85.6 \text{ kg}$$

Then $w = mg = 840 \text{ N}$.

EVALUATE: In part (b) we don't need to consider the y-component of Newton's second law. $a_y = 0$ so the mass doesn't appear in the $\sum F_y = ma_y$ equation.

4.39. **IDENTIFY:** We can apply constant acceleration equations to relate the kinematic variables and we can use Newton's second law to relate the forces and acceleration.

(a) SET UP: First use the information given about the height of the jump to calculate the speed he has at the instant his feet leave the ground. Use a coordinate system with the $+y$-axis upward and the origin at the position when his feet leave the ground.

$v_y = 0$ (at the maximum height), $v_{0y} = ?$, $a_y = -9.80 \text{ m/s}^2$, $y - y_0 = +1.2 \text{ m}$

$v_y^2 = v_{0y}^2 + 2a_y(y - y_0)$

EXECUTE: $v_{0y} = \sqrt{-2a_y(y - y_0)} = \sqrt{-2(-9.80 \text{ m/s}^2)(1.2 \text{ m})} = 4.85 \text{ m/s}$

(b) SET UP: Now consider the acceleration phase, from when he starts to jump until when his feet leave the ground. Use a coordinate system where the $+y$-axis is upward and the origin is at his position when he starts his jump.

EXECUTE: Calculate the average acceleration:

$$(a_{av})_y = \frac{v_y - v_{0y}}{t} = \frac{4.85 \text{ m/s} - 0}{0.300 \text{ s}} = 16.2 \text{ m/s}^2$$

(c) SET UP: Finally, find the average upward force that the ground must exert on him to produce this average upward acceleration. (Don't forget about the downward force of gravity.) The forces are sketched in Figure 4.39.

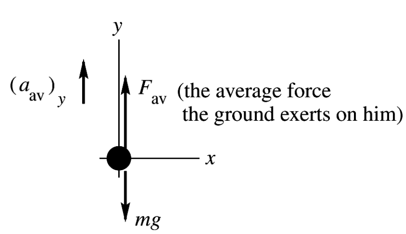

Figure 4.39

EXECUTE:

$$m = w/g = \frac{890 \text{ N}}{9.80 \text{ m/s}^2} = 90.8 \text{ kg}$$

$\sum F_y = ma_y$

$F_{av} - mg = m(a_{av})_y$

$F_{av} = m(g + (a_{av})_y)$

$F_{av} = 90.8 \text{ kg}(9.80 \text{ m/s}^2 + 16.2 \text{ m/s}^2)$

$F_{av} = 2360 \text{ N}$

This is the average force exerted on him by the ground. But by Newton's third law, the average force he exerts on the ground is equal and opposite, so is 2360 N, downward. The net force on him is equal to *ma*, so

$F_{\text{net}} = ma = (90.8\text{ kg})(16.2\text{ m/s}^2) = 1470\text{ N}$ upward.

EVALUATE: In order for him to accelerate upward, the ground must exert an upward force greater than his weight.