HW 3 Help

31. **ORGANIZE AND PLAN** We can use Newton's second law to find the acceleration of the rocket. The net force on the rocket will be the vector sum of all the forces acting on it, which are the force due to gravity (straight down) and the force from the rocket engine (straight up). We will use a coordinate system where $\hat{j}$ represents the upward vertical direction.

Known: m = 3.5 kg; $\vec{F}_{\text{engine}} = 95.3\ \text{N}\left(\hat{j}\right)$

SOLVE The net force acting on the rocket is [Eq. 1]

$$\vec{F}_{\text{net}} = \vec{F}_{\text{engine}} + m\vec{g} = 95.3\ \text{N}\left(\hat{j}\right) + \left(3.5\ \text{kg}\right)\left(9.8\ \text{m/s}^2\right)(-\hat{j}) = 61\ \text{N}\left(\hat{j}\right).$$

From Newton's second law, the acceleration of the toy rocket is [Eq. 2]

$$\vec{a} = \vec{F}_{\text{net}}/m = 61\ \text{N}\left(\hat{j}\right)/3.5\ \text{kg} = 17.4\ \text{m/s}^2\left(\hat{j}\right).$$

REFLECT The rocket is accelerating upward at almost twice the acceleration due to gravity. This is a significant acceleration, compared to what we experience on a daily basis. To appreciate the acceleration due to gravity, try to catch a stick that falls from a stationary position, with your hand initially positioned above the stick. It can be done, but it's not easy. Imagine now the rocket accelerating at almost twice that rate!

35. **ORGANIZE AND PLAN** This problem involves the application of Newton's second law in vector form, $\vec{F} = m\vec{a}$.

Known: m = 100 *g* = 0.1 kg; $\vec{a} = 0.255\ \text{m/s}^2\left(-\hat{i}\right) + 0.650\ \text{m/s}^2\left(\hat{j}\right)$

SOLVE Inserting the known quantities (with the correct units!) into Newton's second law, we have [Eq. 1]

$$\vec{F} = m\vec{a} = \left(0.1\ \text{kg}\right)\left(0.255\ \text{m/s}^2\left(-\hat{i}\right) + 0.650\ \text{m/s}^2\left(\hat{j}\right)\right) = 0.0255\ \text{N}\left(-\hat{i}\right) + 0.0650\ \text{N}\left(\hat{j}\right)$$

This is the force needed to generate the desired acceleration. The direction of this force is [Eq. 2]

$$\theta = \text{atan}\left(\frac{-0.0255}{0.0650}\right) = -68.6^\circ, 111.4^\circ.$$

From Eq. (1) we know the force vector is in the second quadrant, so we the direction of the force must be 111.4° above the horizontal. The magnitude of the force is [Eq. 3]

$$F = \sqrt{\left(-0.255\ \text{N}\right)^2 + \left(0.0650\ \text{N}\right)^2} = 0.0698\ \text{N}$$

REFLECT Note that we had to convert the mass from grams to kilograms so that the result of our calculation would be in SI units (i.e., Newtons).

44. ORGANIZE AND PLAN The crane supplies an upward force on the beam, and gravity supplies a downward force. The net force will be the vector sum of the two. Once we find the net force, we can use Newton's second law to find the acceleration of the beam. We chose a coordinate system for this problem in which $\hat{j}$ is oriented vertically upward.

Known: m = 185 kg; $\vec{F}_{\text{crane}} = 1960\ \text{N}(\hat{j})$; $\vec{g} = 9.8\ \text{m/s}^2(-\hat{j})$

SOLVE The net force is the vector sum of all the forces on the beam, which in this case is gravity and the force applied by the crane [Eq. 1]:

$$\vec{F}_{\text{net}} = \vec{F}_{\text{crane}} + m\vec{g} = 1960\ \text{N}(\hat{j}) + (185\ \text{kg})(9.8\ \text{m/s}^2)(-\hat{j}) = 147\ \text{N}(\hat{j})$$

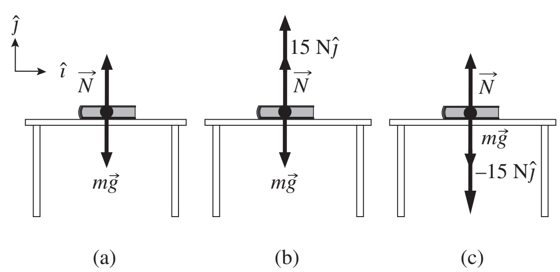
We insert this result into Newton's second law to find the acceleration of the beam [Eq. 2]:

$$\vec{F}_{\text{net}} = m\vec{a},$$

$$\vec{a} = \vec{F}_{\text{net}}/m = \frac{(147\ \text{N})}{(185\ \text{kg})}(\hat{j}) \approx 0.8\ \text{m/s}^2(\hat{j})$$

REFLECT Most of the force applied by the crane is used to overcome gravity. If the net force (i.e., crane + gravity) is applied to the beam for 1 sec, the beam will gain a speed of 0.8 m/s in the upward direction. How much force must the crane now exert to maintain this speed constant? Simply enough to make $\vec{F}_{\text{net}} = 0$. From Eq. 1 this is $\vec{F}_{\text{crane}} = -m\vec{g}$.

46. ORGANIZE AND PLAN Make a drawing of the situation on which all the forces for each case are drawn. Sum up the forces and use Newton's second law to find the normal force in each case.



Known: m = 2.5 kg

SOLVE From Newton's second law it is known that, since the book is stationary, the net force must be zero. From the figure above, the net force for case (a) is [Eq. 1]

$$\vec{F}_{\text{net}} = 0 = \vec{n} - mg(\hat{j})$$

$$\vec{n} = mg(\hat{j}) = (2.5\ \text{kg})(9.8\ \text{m/s}^2)(\hat{j}) \approx 22\ \text{N}(\hat{j})$$

Thus the normal is $22\ \text{N}(\hat{j})$.

Repeating the same calculation for case (b) gives [Eq. 2]

$$\vec{F}_{\text{net}} = 0 = \vec{n} - mg(\hat{j}) + 15\ \text{N}(\hat{j})$$
$$\vec{n} = mg(\hat{j}) - 15\ \text{N}(\hat{j}) = 22\ \text{N}(\hat{j}) - 15\ \text{N}(\hat{j}) = 7\ \text{N}(\hat{j})$$

Thus the normal force applied by the table on the book has been reduced to $7N(\hat{j})$.
For case (c), we have [Eq. 3]

$$\vec{F}_{\text{net}} = 0 = \vec{n} - mg(\hat{j}) - 15\ \text{N}(\hat{j})$$
$$\vec{n} = mg(\hat{j}) + 15\ \text{N}(\hat{j}) = 22\ \text{N}(\hat{j}) + 15\ \text{N}(\hat{j}) = 37\ \text{N}(\hat{j})$$

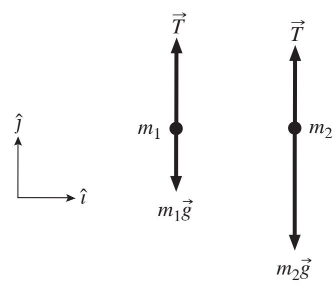
Thus, when you push down on the book with 15 N of force, the table must now supply a force of $37\ \text{N}(\hat{j})$ on the book.

REFLECT What is the normal force supplied by the floor on each of the 4 table legs for each situation, if we assume the book is positioned at the center of the table? You can find this by doing the same calculations, but replacing the mass *m* by the mass of the table plus the book. Also, don't forget that the floor is pushing up on all 4 legs equally, so the force applied on each leg will be ¼ of the total normal force.

62.ORGANIZE AND PLAN This problem involves a frictionless pulley and a presumably massless wire, so the force applied by the wire on each hanging block is the same. In addition, the acceleration of m_1 will be of equal magnitude but antiparallel to the acceleration of m_2 [Eq. 1]: $\vec{a}_1 = -\vec{a}_2$.

Known: $m_2 > m_1$

SOLVE (a) The force diagram is shown in the figure below.



(b) Using Newton's second law, the acceleration on m_1 is [Eq. 2]

$$\vec{F}_1^{\text{net}} = m_1\vec{a}_1 = \vec{T} + m_1\vec{g}$$
$$m_1\vec{a}_1 = (T - m_1 g)(\hat{j})$$

and on m_2 it is [Eq. 3]

$$\vec{F}_2^{\text{net}} = m_2\vec{a}_2 = \vec{T} + m_2\vec{g}$$
$$m_2\vec{a}_2 = (T - m_2 g)(\hat{j})$$

Using Eqs. 1 and 3 to express $\vec{a}_2$ and $\vec{T}$ in terms of the other variables in Eq. 2, we get [Eq. 4]

$$m_1\vec{a}_1 = (m_2a_2 + m_2g - m_1g)(\hat{j})$$

$$\vec{a}_1 = \frac{(m_2a_2 + (m_2 - m_1)g)}{m_1}(\hat{j}) = \frac{(m_2 - m_1)g}{(m_2 + m_1)}(\hat{j})$$

From Eq. 1 [Eq. 5],

$$\vec{a}_2 = \frac{(m_1 - m_2)g}{(m_2 + m_1)}(\hat{j})$$

(c) If $m_1 = 0.150\text{ kg}$ and $m_2 = 0.200\text{ kg}$, then [Eq. 6]

$$\vec{a}_1 = 1.40\text{ m/s}^2(\hat{j})$$

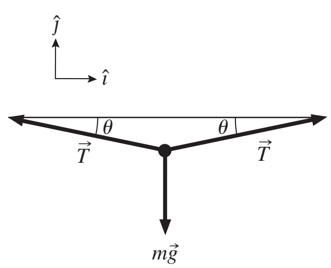
$$\vec{a}_2 = 1.40\text{ m/s}^2(-\hat{j})$$

REFLECT Consider what would happen if $m_1 \to 0$. In this case, m_2 would accelerate down with the acceleration due to gravity, and m_1 would accelerate upward with the same rate. The opposite would be true if $m_2 \to 0$.

68. ORGANIZE AND PLAN Since the tightrope-walker does not accelerate, the net force on her must be zero (Newton's second law).

Known: $m = 63\text{ kg};\ \theta = 9.5°$

SOLVE (a) The force diagram is shown in the figure below.



(b) Summing the forces in the vertical direction, we have [Eq. 1]

$$\vec{F}_{\text{net}} = 0 = m\vec{g} + 2T\sin(\theta)(\hat{j})$$

$$T = \frac{-(63\text{ kg})(9.8\text{ m/s}^2)(-\hat{j})}{2\sin(9.5°)}$$

$$T = 1870\text{ N}$$

REFLECT The horizontal component of the rope tension is $T\cos(\theta) = 1845\text{ N},$ and the vertical component is $T\sin(\theta) = 309\text{ N}.$

72. ORGANIZE AND PLAN Using Eq. 4.6, the magnitude of the kinetic friction force is [Eq. 1] $f_k = \mu_k n$. The friction force will act to oppose the velocity, which we assume is in the $\hat{i}$ direction. Therefore [Eq. 2], $\vec{f}_k = \mu_k mg(-\hat{i})$. From this and Newton's second law we can find the acceleration, and then the distance traveled.

Known: □k = 0.013; $\vec{x} - \vec{x}_0 = 61\ m(\hat{i})$; $\vec{v}_f = 0 m/s$; $\vec{v}_0 \equiv v_0(\hat{i})$

SOLVE Using Newton's second law and Eq. 2, the acceleration of the puck is [Eq. 3]

$$\vec{F}_{\text{net}} = \vec{f}_k = m\vec{a}$$

$$\vec{a} = \frac{\mu_k mg}{m}(-\hat{i}) = 0.013(9.8\text{ m/s}^2)(-\hat{i}) = 0.13\text{ m/s}^2(-\hat{i})$$

(b) To find the distance traveled before stopping, we use [Eq. 4] $\vec{v}_\text{f} = \vec{v}_0 + \vec{a}t$ and [Eq. 5] $\vec{x}_\text{f} = \vec{x}_0 + \vec{v}_0 t + 1/2\vec{a}t^2$ to find [Eq. 6]

$$\vec{x}_\text{f} - \vec{x}_0 = \vec{v}_0\frac{v_0}{a} + 1/2\vec{a}\left(\frac{v_0}{a}\right)^2$$

$$\vec{v}_0 = \sqrt{2(x_\text{f} - x_0)a}\,(\hat{i}) = \sqrt{2(61\text{ m})(0.13\text{ m/s}^2)}\,(\hat{i}) = 4.0\text{ m/s}(\hat{i})$$

Thus, the puck's initial velocity must be $4.0\text{ m/s}(\vec{i})$.

REFLECT Notice that we have to be careful with the direction of the vector quantities in Eq. 6 to ensure the correct result.

76. ORGANIZE AND PLAN We can use the same force diagram as for Problem 75. If the car is moving down the incline at a constant speed, then by Newton's second law there is no net force on the car.

Known: $\theta = 1.4°$; $\vec{a} = 0\text{ m/s}^2$

SOLVE Using Newton's second law and Eq. 4.6, we get [Eq. 1]

$$\vec{F}_{\text{net}} = \vec{f}_k + mg\sin(\theta)(\hat{i}) = m\vec{a}$$

$$\mu_k n(-\hat{i}) + mg\sin(\theta)(\hat{i}) = 0$$

$$\mu_k mg\cos(\theta)(-\hat{i}) + mg\sin(\theta)(\hat{i}) = 0$$

$$\mu_k = \tan(\theta)$$

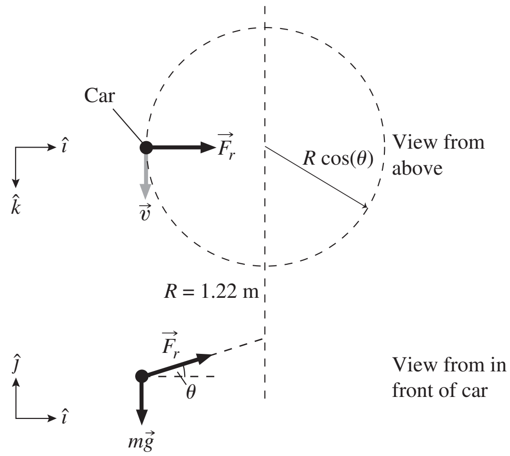
$$\mu_k = 0.024$$

REFLECT This coefficient of kinetic friction is between that of the wooden block (0.87, Problem 75) and that of the stone on ice (0.04, Problem 73).

94. ORGANIZE AND PLAN The horizontal force on the car generates the centripetal acceleration (see Eq. 4.9).

Known: $\vec{F}_r = 790\ \text{N}(\hat{i})$; $R = 210\ \text{m}$; $\vec{v} = 11.5\ \text{m/s}(\hat{k})$

SOLVE (a) See the force diagram below.



There are two diagrams, the upper one is the view from above the car, the lower one is the view from in front of the car.

(b) Using Eq. 4.9, we find the mass of the car is [Eq. 1]

$$F_r = \frac{mv^2}{R}$$

$$m = \frac{F_r R}{v^2} = \frac{(790\ \text{N})(210\ \text{m})}{(11.5\ \text{m/s})^2} = 1254\ \text{kg}$$

REFLECT Notice that the units cancel properly in Eq. 1.

109. ORGANIZE AND PLAN Use the kinematic equations (see, e.g., Problem 42, Eq. 3) to calculate the acceleration. Use Newton's second law to calculate the force due to kinetic friction from the acceleration.

Known: $m = 2.90\ \text{kg};\ x - x_0 = 3.25\ \text{m};\ v_0 = 2.10\ \text{m/s}$

SOLVE From, e.g., Problem 42, Eq. 3, we calculate the magnitude of the acceleration [Eq. 1].

$$a = \frac{v_0^2}{2\left(x - x_0\right)} = \frac{\left(2.10\ \text{m/s}\right)^2}{2\left(3.25\ \text{m}\right)} = 0.678\ \text{m/s}^2$$

Using Newton's second law and Eq. 4.6, we can find the coefficient of kinetic friction [Eq. 2].

$$\begin{aligned} F &= ma \\ \mu_k n &= ma \\ \mu_k mg &= ma \\ \mu_k &= a/g = \frac{0.678\ \text{m/s}^2}{9.8\ \text{m/s}^2} = 0.069 \end{aligned}$$

REFLECT The attentive reader might have noticed a sign difference between Eq. 3, Problem 42, and Eq. 1 of this problem. The difference is that the former is a vector equation, while the later relationship is scalar. Since the acceleration in this problem is due to the kinetic friction force, the direction of the acceleration vector must be antiparallel to the velocity vector.