Ch. 4 Forces and Newton's Laws of Motion

For Recitation Practice

•**Chapter 4**: FOC 1, 3, 12 & 16.

Problems: 3, 5, 11, 16, 24, 38, 52, 77, 77 & 98.

Note: The answers key of FOC is posted separately

FOC 1 & 5

1. An object is moving at a constant velocity. All but one of the following statements could be true. Which one cannot be true?

(a) No forces act on the object.
(b) A single force acts on the object.
(c) Two forces act simultaneously on the object.
(d) Three forces act simultaneously on the object.

(b)

5. Two forces act on a moving object that has a mass of 27 kg. One force has a magnitude of 12 N and points due south, while the other force has a magnitude of 17 N and points due west. What is the acceleration of the object?

(a) 0.63 m/s^2 directed 55° south of west
(b) 0.44 m/s^2 directed 24° south of west
(c) 0.77 m/s^2 directed 35° south of west
(d) 0.77 m/s^2 directed 55° south of west
(e) 1.1 m/s^2 directed 35° south of west

FOC 12 &16

$W = mg$

Section 4.8 The Normal Force

12. The apparent weight of a passenger in an elevator is greater than his true weight. Which one of the following is true?

- **(a)** The elevator is either moving upward with an increasing speed or moving upward with a decreasing speed.
- **(b)** The elevator is either moving upward with an increasing speed or moving downward with an increasing speed.
- **(c)** The elevator is either moving upward with a decreasing speed or moving downward with a decreasing speed.
- **(d)** The elevator is either moving upward with an increasing speed or moving downward with a decreasing speed.
- **(e)** The elevator is either moving upward with a decreasing speed or moving downward with an increasing speed.

16. Three identical blocks are being pulled or pushed across a horizontal surface by a force $\vec{\mathbf{F}}$ as shown in the drawings. The force $\vec{\mathbf{F}}$ in each case has the same magnitude. Rank the kinetic frictional forces that act on the blocks in ascending order (smallest first).

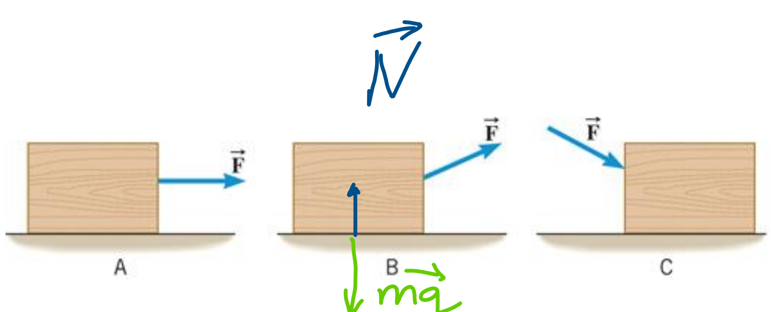
- **(a)** B, C, A
- **(b)** C, A, B
- **(c)** B, A, C
- **(d)** C, B, A
- **(e)** A, C, B

$f = \mu N$

A) $N = mg$

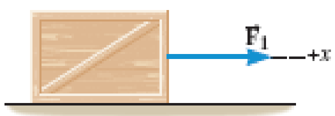
B) $N = mg - F_y$

C) $N = mg + F_y$



Pr. 3

3. Two horizontal forces, $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$, are acting on a box, but only $\vec{\mathbf{F}}_1$ is shown in the drawing. $\vec{\mathbf{F}}_2$ can point either to the right or to the left. The box moves only along the x axis. There is no friction between the box and the surface. Suppose that $\vec{\mathbf{F}}_1 = +9.0$ N and the mass of the box is 3.0 kg. Find the magnitude and direction of $\vec{\mathbf{F}}_2$ when the acceleration of the box is **(a)** +5.0 m/s^2, **(b)** −5.0 m/s^2, and **(c)** 0 m/s^2.



SOLUTION

a. We will use Newton's second law, $\Sigma F_x = ma_x$, to find the force F_2. Taking the positive x direction to be to the right, we have

$$\underbrace{F_1 + F_2}_{\Sigma F_x} = ma_x \qquad \text{so} \qquad F_2 = ma_x - F_1$$

$$F_2 = (3.0\text{ kg})(+5.0\text{ m/s}^2) - (+9.0\text{ N}) = \boxed{+6\text{ N}}$$

b. Applying Newton's second law again gives

$$F_2 = ma_x - F_1 = (3.0\text{ kg})(-5.0\text{ m/s}^2) - (+9.0\text{ N}) = \boxed{-24\text{ N}}$$

c. An application of Newton's second law gives

$$F_2 = ma_x - F_1 = (3.0\text{ kg})(0\text{ m/s}^2) - (+9.0\text{ N}) = \boxed{-9.0\text{ N}}$$

Pr. 5

5. **ssm** A person in a kayak starts paddling, and it accelerates from 0 to 0.60 m/s in a distance of 0.41 m. If the combined mass of the person and the kayak is 73 kg, what is the magnitude of the net force acting on the kayak?

$$\Sigma F = ma \qquad 0$$

SOLUTION Solving Equation 2.9 $\left(v^2 = v_0^{\,2} + 2ax\right)$ from the equations of kinematics for the acceleration, we have

$$a = \frac{v^2 - v_0^{\,2}}{2x}$$

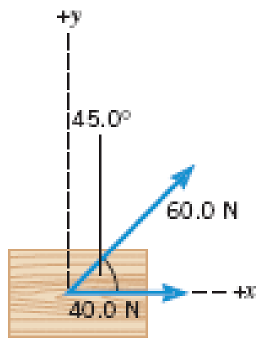
Substituting this result into Newton's second law gives

$$\Sigma F = ma = m\left(\frac{v^2 - v_0^{\,2}}{2x}\right) = (73\text{ kg})\left[\frac{(0.60\text{ m/s})^2 - (0\text{ m/s})^2}{2(0.41\text{ m})}\right] = \boxed{32\text{ N}}$$

Pr. 11

Section 4.5 Newton's Third Law of Motion

11. Only two forces act on an object (mass = 3.00 kg), as in the drawing. Find the magnitude and direction (relative to the *x* axis) of the acceleration of the object.



Problem 11

Pr. 11 Solution

SOLUTION The following table gives the x and y components of the two forces that act on the object. The third row of that table gives the components of the net force.

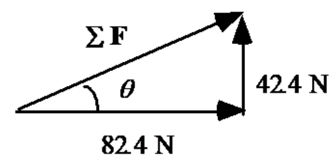
Force	*x-Component*	*y-Component*
$\mathbf{F}_1$	40.0 N	0 N
$\mathbf{F}_2$	(60.0 N) cos 45.0° = 42.4 N	(60.0 N) sin 45.0° = 42.4 N
$\sum \mathbf{F} = \mathbf{F}_1 + \mathbf{F}_2$	82.4 N	42.4 N

The magnitude of $\sum \mathbf{F}$ is given by the Pythagorean theorem as

$$\Sigma F = \sqrt{(82.4\ \text{N})^2 + (42.4)^2} = 92.7\ \text{N}$$

The angle θ that $\sum \mathbf{F}$ makes with the $+x$ axis is

$$\theta = \tan^{-1}\left(\frac{42.4\ \text{N}}{82.4\ \text{N}}\right) = 27.2°$$



According to Newton's second law, the magnitude of the acceleration of the object is

$$a = \frac{\sum F}{m} = \frac{92.7\ \text{N}}{3.00\ \text{kg}} = \boxed{30.9\ \text{m/s}^2}$$

Since Newton's second law is a vector equation, we know that the direction of the right hand side must be equal to the direction of the left hand side. In other words, the direction of the acceleration a is the same as the direction of the net force $\sum \mathbf{F}$. Therefore, the direction of the acceleration of the object is $\boxed{27.2° \text{ above the } +x \text{ axis}}$

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Pr. 16

16. Two skaters, a man and a woman, are standing on ice. Neglect any friction between the skate blades and the ice. The mass of the man is 82 kg, and the mass of the woman is 48 kg. The woman pushes on the man with a force of 45 N due east. Determine the acceleration (magnitude and direction) of **(a)** the man and **(b)** the woman.

SOLUTION

a. The acceleration of the man is, according to Equation 4.1, equal to the net force acting on him divided by his mass.

$$a_{\text{man}} = \frac{\Sigma F}{m} = \frac{45\ \text{N}}{82\ \text{kg}} = \boxed{0.55\ \text{m/s}^2\ \ \text{(due east)}}$$

b. The acceleration of the woman is equal to the net force acting on her divided by her mass.

$$a_{\text{woman}} = \frac{\Sigma F}{m} = \frac{45\ \text{N}}{48\ \text{kg}} = \boxed{0.94\ \text{m/s}^2\ \ \text{(due west)}}$$

Pr. 24

24. The weight of an object is the same on two different planets. The mass of planet A is only sixty percent that of planet B. Find the ratio r_A/r_B of the radii of the planets.

OLUTION According to Newton's law of gravitation, we have

$$\underbrace{\frac{GM_A m}{r_A^2}}_{\text{Weight on planet A}} = \underbrace{\frac{GM_B m}{r_B^2}}_{\text{Weight on planet B}}$$

The mass m of the object, being an intrinsic property, is the same on both planets and can be eliminated algebraically from this equation. The universal gravitational constant can likewise be eliminated algebraically. As a result, we find that

$$\frac{M_A}{r_A^2} = \frac{M_B}{r_B^2} \quad \text{or} \quad \frac{M_A}{M_B} = \frac{r_A^2}{r_B^2}$$

$$\frac{r_A}{r_B} = \sqrt{\frac{M_A}{M_B}} = \sqrt{0.60} = \boxed{0.77}$$

Pr. 38

Section 4.8 The Normal Force,
Section 4.9 Static and Kinetic Frictional Forces

38. A 35-kg crate rests on a horizontal floor, and a 65-kg person is standing on the crate. Determine the magnitude of the normal force that **(a)** the floor exerts on the crate and **(b)** the crate exerts on the person.

SOLUTION

a. There are three vertical forces acting on the crate: an upward normal force $+F_N$ that the floor exerts, the weight $-m_1g$ of the crate, and the weight $-m_2g$ of the person standing on the crate. Since the weights act downward, they are assigned negative numbers. Setting the sum of these forces equal to zero gives

$$\underbrace{F_N + (-m_1g) + (-m_2g)}_{\Sigma F_y} = 0$$

The magnitude of the normal force is

$$F_N = m_1g + m_2g = (35\text{ kg} + 65\text{ kg})(9.80\text{ m/s}^2) = \boxed{980\text{ N}}$$

b. There are only two vertical forces acting on the person: an upward normal force $+F_N$ that the crate exerts and the weight $-m_2g$ of the person. Setting the sum of these forces equal to zero gives

$$\underbrace{F_N + (-m_2g)}_{\Sigma F_y} = 0$$

The magnitude of the normal force is

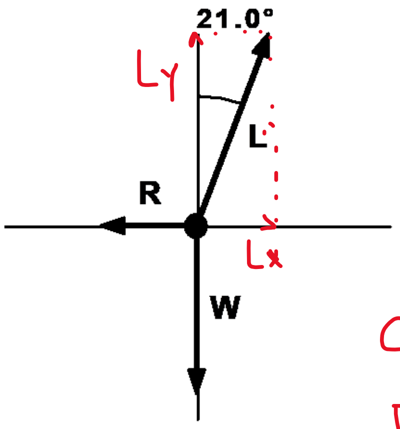
$$F_N = m_2g = (65\text{ kg})(9.80\text{ m/s}^2) = \boxed{640\text{ N}}$$

Pr. 52

Section 4.10 The Tension Force, Section 4.11 Equilibrium Applications of Newton's Laws of Motion

52. mmh The helicopter in the drawing is moving horizontally to the right at a constant velocity $\vec{\mathbf{v}}$ The weight of the helicopter is $W = 53\,800$ N. The lift force $\vec{\mathbf{L}}$ generated by the rotating blade makes an angle of 21.0° with respect to the vertical. **(a)** What is the magnitude of the lift force? **(b)** Determine the magnitude of the air resistance $\vec{\mathbf{R}}$ that opposes the motion.

52. ***REASONING*** The free-body diagram for the helicopter is shown in the drawing. Since the velocity is constant, the acceleration is zero and the helicopter is at equilibrium. Therefore, according to Newton's second law, the net force acting on the helicopter is zero.



SOLUTION Since the net force is zero, the components of the net force in the vertical and horizontal directions are separately zero. Referring to the free-body diagram, we can see, then, that

$a_x = 0$

$R = -L_x$

$L_y = -W$

$$L\cos 21.0° - W = 0 \qquad (1)$$

$$L\sin 21.0° - R = 0 \qquad (2)$$

a. Equation (1) gives

$$L = \frac{W}{\cos 21.0°} = \frac{53\,800\text{ N}}{\cos 21.0°} = \boxed{57\,600\text{ N}}$$

b. Equation (2) gives

$$R = L\sin 21.0° = (57\,600\text{ N})\sin 21.0° = \boxed{20\,600\text{ N}}$$

Pr. 77

Section 4.12 Nonequilibrium Applications of Newton's Laws of Motion

77. A car is towing a boat on a trailer. The driver starts from rest and accelerates to a velocity of +11 m/s in a time of 28 s. The combined mass of the boat and trailer is 410 kg. The frictional force acting on the trailer can be ignored. What is the tension in the hitch that connects the trailer to the car?

SOLUTION Assume that the boat and trailer are moving in the $+x$ direction. Newton's second law is $\Sigma F_x = ma_x$ (see Equation 4.2a), where the net force is just the tension $+T$ in the hitch, so $\Sigma F_x = T$. Thus,

$$T = ma_x \quad (1)$$

Since the initial and final velocities, v_{0x} and v_x, and the time t are known, we may use Equation 3.3a from the equations of kinematics to relate these variables to the acceleration:

$$v_x = v_{0x} + a_x t \quad (3.3a)$$

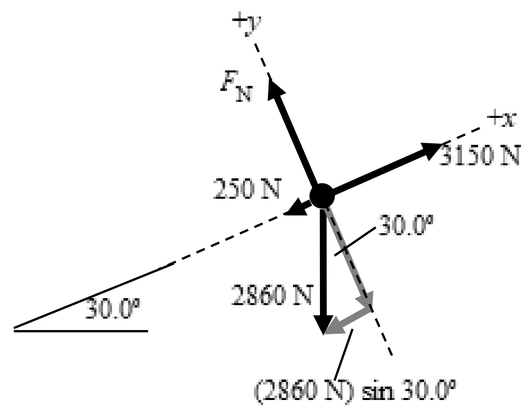
Solving Equation (3.3a) for a_x and substituting the result into Equation (1), we find that

$$T = ma_x = m\left(\frac{v_x - v_{0x}}{t}\right) = (410\text{ kg})\left(\frac{11\text{ m/s} - 0\text{ m/s}}{28\text{ s}}\right) = \boxed{160\text{ N}}$$

Pr. 78

78. A 292-kg motorcycle is accelerating up along a ramp that is inclined 30.0° above the horizontal. The propulsion force pushing the motorcycle up the ramp is 3150 N, and air resistance produces a force of 250 N that opposes the motion. Find the magnitude of the motorcycle's acceleration.

SOLUTION In drawing the free-body diagram for the motorcycle we choose the +*x* axis to be parallel to the ramp surface and upward, the +*y* direction being perpendicular to the ramp surface. The diagram is shown at the right. Since the motorcycle accelerates along the ramp and we seek only that acceleration, we can ignore the forces that point along the *y* axis (the normal force F_N and the *y* component of the weight). The *x* component of Newton's second law is



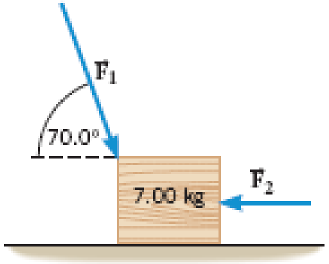
$$\Sigma F_x = 3150\text{ N} - (2860\text{ N})\sin 30.0° - 250\text{ N} = ma_x$$

Solving for the acceleration a_x gives

$$a_x = \frac{3150\text{ N} - (2860\text{ N})\sin 30.0° - 250\text{ N}}{292\text{ kg}} = \boxed{5.03\text{ m/s}^2}$$

Pr. 98

98. **mmh** Two forces, $\vec{\mathbf{F}}_1$ and $\vec{\mathbf{F}}_2$, act on the 7.00-kg block shown in the drawing. The magnitudes of the forces are $F_1 = 59.0$ N and $F_2 = 33.0$ N. What is the horizontal acceleration (magnitude and direction) of the block?



Problem 98

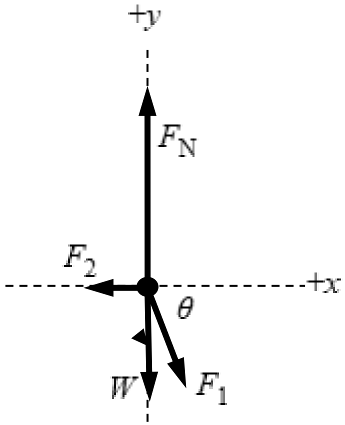
$$\sum F_x = m a_x$$

Pr. 98 Solution

98. ***REASONING*** Newton's second law gives the acceleration as $\mathbf{a} = (\Sigma \mathbf{F})/m$. Since we seek only the horizontal acceleration, it is the x component of this equation that we will use; $a_x = (\Sigma F_x)/m$. For completeness, however, the free-body diagram will include the vertical forces also (the normal force F_N and the weight W).

SOLUTION The free-body diagram is shown at the right, where

$$F_1 = 59.0 \text{ N}$$
$$F_2 = 33.0 \text{ N}$$
$$\theta = 70.0°$$



When F_1 is replaced by its x and y components, we obtain the free body diagram in the following drawing.

Choosing right to be the positive direction, we have

$$a_x = \frac{\Sigma F_x}{m} = \frac{F_1 \cos\theta - F_2}{m}$$

$$a_x = \frac{(59.0 \text{ N})\cos 70.0° - (33.0 \text{ N})}{7.00 \text{ kg}} = -1.83 \text{ m/s}^2$$

Thus, the horizontal acceleration has a magnitude of $\boxed{1.83 \text{ m/s}^2}$, and the minus sign indicates that it points to the $\boxed{\text{left}}$.