A bag of sugar weighs 4.50 lb on Earth. What would it weigh in newtons on the Moon, where the free-fall acceleration is one-sixth that on Earth?

3.34 N

Repeat for Venus, where g is 0.904 times that on Earth.

18.1 N

Find the mass of the bag of sugar in kilograms at each of the three locations.

Earth	2.04	kg
Moon	2.04	kg
Venus	2.04	kg

Solution or Explanation

The weight of the bag of sugar on Earth is

$$w_E = mg_E = (4.50 \text{ lbs})\left(\frac{4.448 \text{ N}}{1 \text{ lb}}\right) = 20.0 \text{ N}.$$

If g_M is the free-fall acceleration on the surface of the Moon, the ratio of the weight of an object on the Moon to its weight when on Earth is $w_M/w_E = mg_M/mg_E = g_M/g_E$, so $w_M = w_E(g_M/g_E)$. Hence, the weight of the bag of sugar on the Moon is

$$w_M = (20.0 \text{ N})\left(\frac{1}{6}\right) = 3.34 \text{ N}.$$

On Venus, its weight would be

$$w_V = w_E\left(\frac{g_V}{g_E}\right) = (20.0 \text{ N})(0.904) = 18.1 \text{ N}.$$

The mass is the same at all three locations, and is given by

$$m = \frac{w_E}{g_E} = \frac{(4.50 \text{ lb})(4.448 \text{ N/lb})}{9.80 \text{ m/s}^2} = 2.04 \text{ kg}.$$

A boat moves through the water with two forces acting on it. One is a 1,575-N forward push by the water on the propeller, and the other is a 1,400-N resistive force due to the water around the bow.

(a) What is the acceleration of the 1,200-kg boat?

0.146 m/s^2

(b) If it starts from rest, how far will the boat move in 15.0 s?

16.4 m

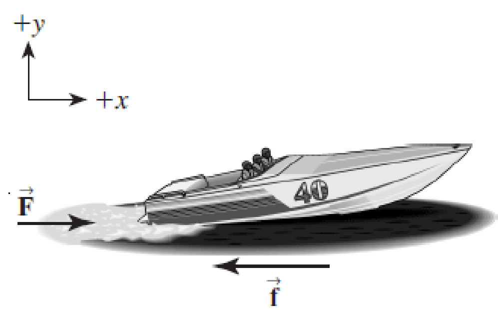
(c) What will its velocity be at the end of that time?

2.19 m/s

Solution or Explanation

(a) From the second law, the acceleration of the boat is

$$a = \frac{\sum F}{m} = \frac{1{,}575\text{ N} - 1{,}400\text{ N}}{1{,}200\text{ kg}} = 0.146\text{ m/s}^2.$$



(b) The distance moved is

$$\Delta x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(0.146\text{ m/s}^2)(15.0\text{ s})^2 = 16.4\text{ m}.$$

(c) The final velocity is

$$v = v_0 + at = 0 + (0.146\text{ m/s}^2)(15.0\text{ s}) = 2.19\text{ m/s}.$$

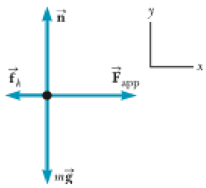
A horizontal force of 85.2 N is applied to a 22.5 kg crate on a rough, level surface. If the crate accelerates at 1.13 m/s^2, what is the magnitude of the force of kinetic friction (in N) acting on the crate?

HINT

59.8 N

Solution or Explanation

Four forces act on the crate. Use the free-body diagram to add all the x-components and apply Newton's second law.

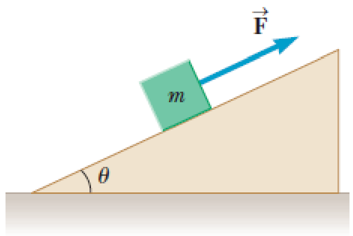


$$\Sigma F_x = ma_x$$
$$F_{app} - f_k = ma$$

Solve for the kinetic friction force, f_k, and substitute values to find the following.

$$f_k = F_{app} - ma$$
$$f_k = (85.2 \text{ N}) - (22.5 \text{ kg})(1.13 \text{ m/s}^2)$$
$$f_k = 59.8 \text{ N}$$

A block of mass m = 5.3 kg is pulled up a θ = 24° incline as in the figure below with a force of magnitude F = 37 N.



(a) Find the acceleration of the block if the incline is frictionless. (Give the magnitude of the acceleration.)

[ ] 3 m/s^2

(b) Find the acceleration of the block if the coefficient of kinetic friction between the block and incline is 0.12. (Give the magnitude of the acceleration.)

[ ] 1.92 m/s^2

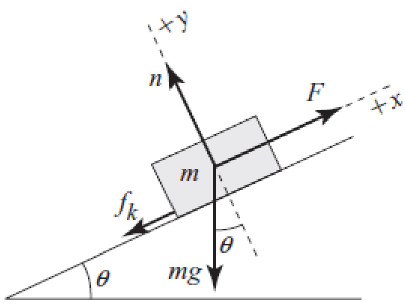
Solution or Explanation

The figure below shows the forces acting on the block. The incline is tilted at θ = 24°, the mass of the block is m = 5.3 kg, while the applied force pulling the block up the incline is F = 37 N. Since $a_y = 0$ for this block,

$$\sum F_y = n - mg \cos\theta = 0$$

and the normal force is

$$n = mg \cos\theta.$$



(a) Since the incline is considered frictionless for this part, we take the friction force to be $f_k = 0$ and find

$$\sum F_x = F - mg \sin\theta = ma_x \quad \text{or} \quad a_x = \frac{F}{m} - g \sin\theta$$

giving

$$a_x = \frac{37\text{ N}}{5.3\text{ kg}} - (9.80\text{ m/s}^2)\sin 24° = 3.00\text{ m/s}^2.$$

-

(b) If the coefficient of kinetic friction between the block and the incline is μ_k, then the friction force is $f_k = \mu_k n = \mu_k mg \cos\theta$, and

$$\sum F_x = F - f_k - mg\sin\theta = F - mg(\mu_k\cos\theta + \sin\theta) = ma_x$$

Thus,

$$a_x = \frac{F}{m} - g(\mu_k\cos\theta + \sin\theta)$$

and

$$a_x = \frac{37\text{ N}}{5.3\text{ kg}} - (9.80\text{ m/s}^2)[(0.12)\cos 24° + \sin 24°] = 1.92\text{ m/s}^2.$$

A dockworker loading crates on a ship finds that a 35-kg crate, initially at rest on a horizontal surface, requires a 72-N horizontal force to set it in motion. However, after the crate is in motion, a horizontal force of 51 N is required to keep it moving with a constant speed. Find the coefficients of static and kinetic friction between crate and floor.

static friction [ ] 0.21

kinetic friction [ ] 0.149

Solution or Explanation

When the block is on the verge of moving, the static friction force has a magnitude $f_s = (f_s)_{max} = \mu_s n$.

Since equilibrium still exists and the applied force is 72 N, we have

$$\sum F_x = 72 \text{ N} - f_s = 0 \quad \text{or} \quad (f_s)_{max} = 72 \text{ N}.$$

In this case, the normal force is just the weight of the crate, or $n = mg$. Thus, the coefficient of static friction is

$$\mu_s = \frac{(f_s)_{max}}{n} = \frac{(f_s)_{max}}{mg} = \frac{72 \text{ N}}{(35 \text{ kg})(9.80 \text{ m/s}^2)} = 0.210.$$

After motion exists, the friction force is that of kinetic friction, $f_k = \mu_k n$.

Since the crate moves with constant velocity when the applied force is 51 N, we find that $\sum F_x = 51 \text{ N} - f_k = 0$ or $f_k = 51$ N. Therefore, the coefficient of kinetic friction is

$$\mu_k = \frac{f_k}{n} = \frac{f_k}{mg} = \frac{51 \text{ N}}{(35 \text{ kg})(9.80 \text{ m/s}^2)} = 0.149.$$

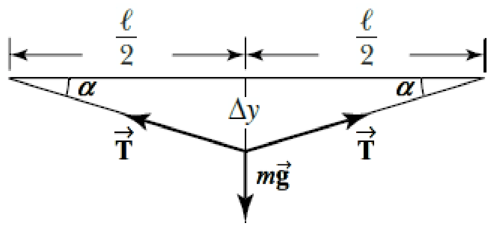
The distance between two telephone poles is 52.0 m. When a 1.00-kg bird lands on the telephone wire midway between the poles, the wire sags 0.170 m. Draw a free-body diagram of the bird. How much tension does the bird produce in the wire? Ignore the weight of the wire.

[ ] 749 N

Solution or Explanation

m = 1.00 kg and mg = 9.80 N.

$$\alpha = \tan^{-1}\left(\frac{0.170\text{ m}}{26.0\text{ m}}\right) = 0.375°$$



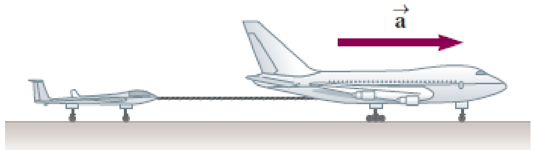
Since $a_y = 0$, this requires that $\sum F_y = T\sin\alpha + T\sin\alpha - mg = 0$, giving

$$2T\sin\alpha = mg$$

or

$$T = \frac{9.80\text{ N}}{2\sin\alpha} = 749\text{ N}.$$

A 285-kg glider is being pulled by a 1,885-kg jet along a horizontal runway with an acceleration of $\vec{\mathbf{a}}$ = 2.20 m/s^2 to the right as in the figure below. Find the following.



(a) the magnitude of the thrust provided by the jet's engines

4770 N

(b) the magnitude of the tension in the cable connecting the jet and glider

627 N

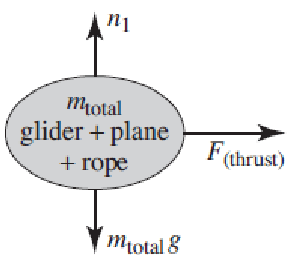
Solution or Explanation

(a) First, we consider the glider, plane, and connecting rope to be a single unit having mass

$$m_{total} = 285 \text{ kg} + 1{,}885 \text{ kg} = 2{,}170 \text{ kg}.$$

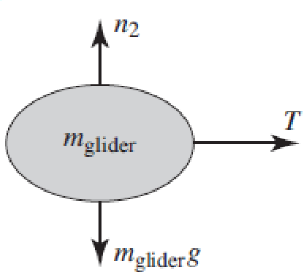
For this system, the tension in the rope is an internal force and is not included in an application of Newton's second law. Applying the second law to the horizontal motion of this combined system gives

$$\sum F_x = m_{total} a_x \quad \Rightarrow \quad F = (2{,}170 \text{ kg})(2.20 \text{ m/s}^2) = 4770 \text{ N} = 4.77 \text{ kN}.$$



(b) To determine the tension in the rope connecting the glider and the plane, we consider a system consisting of the glider alone. For this system, the rope is a external agent and the tension force it exerts on our system (glider) is included in a second law calculation.

$$\sum F_x = m_{glider} a_x \quad \Rightarrow \quad T = (285 \text{ kg})(2.20 \text{ m/s}^2) = 627 \text{ N}.$$



To meet a U.S. Postal Service requirement, employees' footwear must have a coefficient of static friction of 0.5 or more on a specified tile surface. A typical athletic shoe has a coefficient of 0.863. In an emergency, what is the minimum time interval in which a person starting from rest can move 3.40 m on a tile surface if she is wearing the following footwear?

(a) footwear meeting the Postal Service minimum

1.18 s

(b) a typical athletic shoe

0.897 s

Solution or Explanation

When a person walks in a forward direction on a level floor, the force propelling them is a forward reaction force equal in magnitude to the rearward static friction force, f_s, their foot exerts on the floor. The normal force exerted on the person by the level floor is $n = mg$. If the person is to have maximum acceleration (in order to travel distance $d = 3.40$ m in minimum time), the static friction force must have its maximum value, $(f_s)_{max} = \mu_s n = \mu_s mg$, so the maximum acceleration possible is

$$a_{max} = \frac{(f_s)_{max}}{m} = \frac{\mu_s mg}{m} = \mu_s g.$$

The minimum time required to travel distance d (starting from rest) is then given by $\Delta x = v_0 t + \frac{1}{2}at^2$ as

$$3.40 \text{ m} = 0 + \frac{1}{2}(\mu_s g)t^2_{min} \quad \text{or} \quad t_{min} = \sqrt{\frac{6.80 \text{ m}}{\mu_s g}}.$$

(a) If $\mu_s = 0.500$, $\quad t_{min} = \sqrt{\dfrac{6.80 \text{ m}}{0.500(9.80 \text{ m/s}^2)}} = 1.18$ s.

(b) If $\mu_s = 0.863$, $\quad t_{min} = \sqrt{\dfrac{6.80 \text{ m}}{0.863(9.80 \text{ m/s}^2)}} = 0.897$ s.

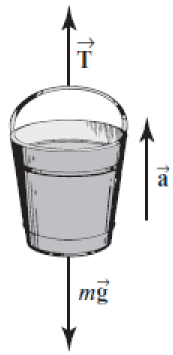
A 5.6-kg bucket of water is raised from a well by a rope. If the upward acceleration of the bucket is 2.2 m/s^2, find the force exerted by the rope on the bucket.

67.2 N

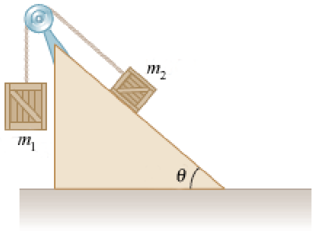
Solution or Explanation

The forces on the bucket are the tension in the rope and the weight of the bucket, mg = (5.6 kg)(9.80 m/s^2) = 54.9 N. Choose the positive direction upward and use Newton's second law:

$$\sum F_y = ma_y$$
$$T - 54.9 \text{ N} = (5.6 \text{ kg})(2.2 \text{ m/s}^2)$$
$$T = 67.2 \text{ N}.$$



Two packing crates of masses m_1 = 10.0 kg and m_2 = 4.40 kg are connected by a light string that passes over a frictionless pulley as in the figure below. The 4.40-kg crate lies on a smooth incline of angle 38.0°. Find the following.



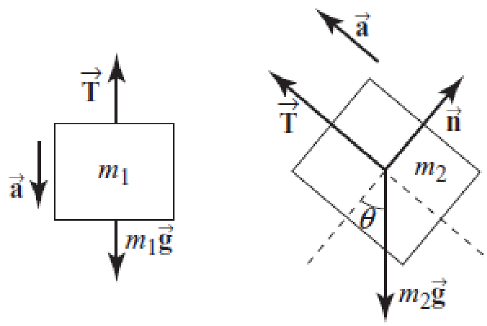
(a) the acceleration of the 4.40-kg crate

4.96 m/s^2 (up the incline)

(b) the tension in the string

48.4 N

Let m_1 = 10.0 kg, m_2 = 4.40 kg, and θ = 38.0°.



(a) Applying the second law to each object gives

$$m_1 a = m_1 g - T \quad \textbf{[1]}$$

and

$$m_2 a = T - m_2 g \sin\theta. \quad \textbf{[2]}$$

Adding these equations yields

$$m_1 a + m_2 a = m_1 g - T + T - m_2 g \sin\theta \quad \text{or} \quad a = \left(\frac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right) g$$

so

$$a = \left(\frac{10.0\text{ kg} - (4.40\text{ kg})\sin 38.0°}{14.4\text{ kg}}\right)(9.80\text{ m/s}^2) = 4.96\text{ m/s}^2.$$

(b) Then, Equation [1] yields

$$T = m_1(g - a) = (10.0\text{ kg})[(9.80 - 4.96)\text{ m/s}^2] = 48.4\text{ N}.$$