Chapter 5

$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$
$F_g = mg$
$f_s = \mu_s n$
$f_k = \mu_k n$

3. A toy rocket engine is securely fastened to a large puck that can glide with negligible friction over a horizontal surface, taken as the *xy* plane. The 4.00-kg puck has a velocity of $3.00\hat{\mathbf{i}}$ m/s at one instant. Eight seconds later, its velocity is $(8.00\hat{\mathbf{i}} + 10.0\hat{\mathbf{j}})$ m/s. Assuming the rocket engine exerts a constant horizontal force, ﬁ nd (a) the components of the force and (b) its magnitude.

Solution

$$\vec{\mathbf{a}} = \frac{\Delta\vec{\mathbf{v}}}{\Delta t} = \frac{(8.00\hat{\mathbf{i}} + 10.0\hat{\mathbf{j}})\text{m/s - } 3.00\hat{\mathbf{i}}\text{ m/s}}{8.00\text{ s}} = 0.625\hat{\mathbf{i}}\text{ m/s}^2 + 1.25\hat{\mathbf{j}}\text{ m/s}^2$$

In $\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}}$, the only horizontal force is the thrust $\vec{\mathbf{F}}$ of the rocket:

(a) $\vec{\mathbf{F}} = (4.00\text{ kg})(0.625\hat{\mathbf{i}}\text{ m/s}^2 + 1.25\hat{\mathbf{j}}\text{ m/s}^2) = 2.50\hat{\mathbf{i}}\text{ N} + 5.00\hat{\mathbf{j}}\text{ N}$

(b) Its magnitude is $|\vec{\mathbf{F}}| = \sqrt{(2.50\text{ N})^2 + (5.00\text{ N})^2} = 5.59\text{ N}$

8. A woman weighs 120 lb. Determine (a) her weight in newtons (N) and (b) her mass in kilograms (kg).

(a) $F_g = mg = 120\text{ lb} = (4.448\text{ N/lb})(120\text{ lb}) = \boxed{534\text{ N}}$

(b) $m = \frac{F_g}{g} = \frac{534\text{ N}}{9.80\text{ m/s}^2} = \boxed{54.5\text{ kg}}$

1. A 3.00-kg object undergoes an acceleration given by $\vec{\mathbf{a}} = (2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}})$ m/s². Find (a) the resultant force acting on the object and (b) the magnitude of the resultant force.

Solution

Analyze: (a) The total vector force is

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}} = (3.00 \text{ kg})(2.00\hat{\mathbf{i}} + 5.00\hat{\mathbf{j}}) \text{ m/s}^2 = (6.00\hat{\mathbf{i}} + 15.0\hat{\mathbf{j}})\text{N}$$

(b) Its magnitude is $|\vec{\mathbf{F}}| = \sqrt{(F_x)^2 + (F_y)^2} = \sqrt{(6.00 \text{ N})^2 + (15.0 \text{ N})^2} = 16.2 \text{ N}$

7. An electron of mass 9.11×10^{-31} kg has an initial speed of 3.00×10^5 m/s. It travels in a straight line, and its speed increases to 7.00×10^5 m/s in a distance of 5.00 cm. Assuming its acceleration is constant, (a) determine the magnitude of the force exerted on the electron and (b) compare this force with the weight of the electron, which we ignored.

Solution

(a) From $v_f^2 = v_i^2 + 2ax$ and $\Sigma F = ma$

we can solve for the acceleration and then the force: $a = \dfrac{v_f^2 - v_i^2}{2x}$

Substituting to eliminate a, $\sum F = \dfrac{m\left(v_f^2 - v_i^2\right)}{2x}$

Substituting the given information,

$$\sum F = \frac{\left(9.11 \times 10^{-31} \text{ kg}\right)\left[\left(7.00 \times 10^5 \text{ m/s}\right)^2 - \left(3.00 \times 10^5 \text{ m/s}\right)^2\right]}{2(0.0500 \text{ m})}$$

$$\sum F = 3.64 \times 10^{-18} \text{ N}$$

(b) The Earth exerts on the electron the force called weight,

$$F_g = mg = \left(9.11 \times 10^{-31} \text{ kg}\right)\left(9.80 \text{ m/s}^2\right) = 8.93 \times 10^{-30} \text{ N}$$

The ratio of the electrical force to the weight is $F/F_g = 4.08 \times 10^{11}$

2. The average speed of a nitrogen molecule in air is about 6.70×10^2 m/s, and its mass is 4.68×10^{-26} kg. (a) If it takes 3.00×10^{-13} s for a nitrogen molecule to hit a wall and rebound with the same speed but moving in the opposite direction, what is the average acceleration of the molecule during this time interval? (b) What average force does the molecule exert on the wall?

Solution

(a) Let the x-axis be in the original direction of the molecule's motion.

$$v_f = v_i + at: \quad -670 \text{ m/s} = 670 \text{ m/s} + a\left(3.00 \times 10^{-13} \text{ s}\right)$$

$$a = \boxed{-4.47 \times 10^{15} \text{ m/s}^2}$$

(b) For the molecule, $\sum \mathrm{F} = m\mathrm{a}$. Its weight is negligible.

$$\mathrm{F}_{\text{wall on molecule}} = 4.68 \times 10^{-26} \text{ kg}\left(-4.47 \times 10^{15} \text{ m/s}^2\right) = -2.09 \times 10^{-10} \text{ N}$$

$$\vec{\mathrm{F}}_{\text{molecule on wall}} = \boxed{+2.09 \times 10^{-10} \text{ N}}$$

12. A force $\vec{\mathbf{F}}$ applied to an object of mass m_1 produces an acceleration of 3.00 m/s². The same force applied to a second object of mass m_2 produces an acceleration of 1.00 m/s². (a) What is the value of the ratio m_1/m_2? (b) If m_1 and m_2 are combined into one object, find its acceleration under the action of the force $\vec{\mathbf{F}}$.

Solution

For the same force F, acting on different masses

$$F = m_1 a_1$$

and

$$F = m_2 a_2$$

(a) $$\frac{m_1}{m_2} = \frac{a_2}{a_1} = \boxed{\frac{1}{3}}$$

(b) $$F = (m_1 + m_2)a = 4m_1 a = m_1\left(3.00 \text{ m/s}^2\right)$$

$$a = \boxed{0.750 \text{ m/s}^2}$$

22. A 3.00-kg object is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^3 + 2$, where x and y are in meters and t is in seconds. Find the magnitude of the net force acting on this object at $t = 2.00$ s.

Solution

$$v_x = \frac{dx}{dt} = 10t\,,\; v_y = \frac{dy}{dt} = 9t^2$$

$$a_x = \frac{dv_x}{dt} = 10\,,\; a_y = \frac{dv_y}{dt} = 18t$$

At $t = 2.00$ s, $a_x = 10.0\ \text{m/s}^2$, $a_y = 36.0\ \text{m/s}^2$

$$\sum F_x = ma_x: 3.00\ \text{kg}\left(10.0\ \text{m/s}^2\right) = 30.0\ \text{N}$$

$$\sum F_y = ma_y: 3.00\ \text{kg}\left(36.0\ \text{m/s}^2\right) = 108\ \text{N}$$

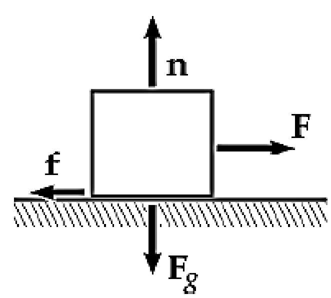
$$\sum F = \sqrt{F_x^2 + F_y^2} = \boxed{112\ \text{N}}$$

39. A 25.0-kg block is initially at rest on a horizontal surface. A horizontal force of 75.0 N is required to set the block in motion, after which a horizontal force of 60.0 N is required to keep the block moving with constant speed. Find (a) the coefficient of static friction and (b) the coefficient of kinetic friction between the block and the surface.

For equilibrium: $f = F$ and $n = F_g$. Also, $f = \mu n$ i.e.,

$$\mu = \frac{f}{n} = \frac{F}{F_g}$$

$$\mu_s = \frac{75.0\ \text{N}}{25.0(9.80)\ \text{N}} = \boxed{0.306}$$



and

$$\mu_k = \frac{60.0\ \text{N}}{25.0(9.80)\ \text{N}} = \boxed{0.245}\,.$$

44. A woman at an airport is towing her 20.0-kg suitcase at constant speed by pulling on a strap at an angle θ above the horizontal (Fig. P5.44). She pulls on the strap with a 35.0-N force, and the friction force on the suitcase is 20.0 N. (a) Draw a free-body diagram of the suitcase. (b) What angle does

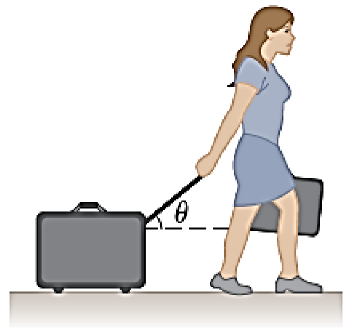


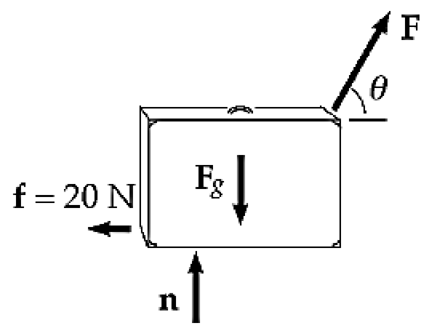
Figure P5.44

$m_{\text{suitcase}} = 20.0 \text{ kg}, \; F = 35.0 \text{ N}$

$$\sum F_x = ma_x: \quad -20.0 \text{ N} + F\cos\theta = 0$$
$$\sum F_y = ma_y: \quad +n + F\sin\theta - F_g = 0$$

(a)

$$F\cos\theta = 20.0 \text{ N}$$
$$\cos\theta = \frac{20.0 \text{ N}}{35.0 \text{ N}} = 0.571$$
$$\boxed{\theta = 55.2°}$$



(b)

$$n = F_g - F\sin\theta = [196 - 35.0(0.821)] \text{ N}$$
$$\boxed{n = 167 \text{ N}}$$

47. Two blocks connected by a rope of negligible mass are being dragged by a horizontal force (Fig. P5.47). Suppose $F = 68.0$ N, $m_1 = 12.0$ kg, $m_2 = 18.0$ kg, and the coefficient of kinetic friction between each block and the surface is 0.100. (a) Draw a free-body diagram for each block. Determine (b) the acceleration of the system and (c) the tension T in the rope.

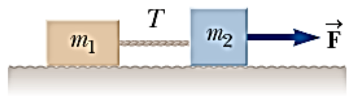
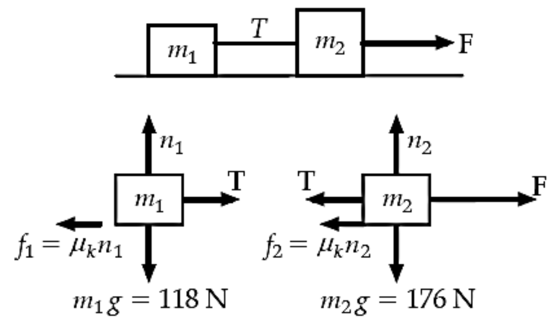


Figure P5.47

(a) See Figure to the right



(b)
$$68.0 - T - \mu m_2 g = m_2 a \quad \text{(Block \#2)}$$
$$T - \mu m_1 g = m_1 a \quad \text{(Block \#1)}$$

Adding,

$$68.0 - \mu(m_1 + m_2)g = (m_1 + m_2)a$$

$$a = \frac{68.0}{(m_1 + m_2)} - \mu g = \boxed{1.29\ \text{m/s}^2}$$

$$T = m_1 a + \mu m_1 g = \boxed{27.2\ \text{N}}$$

9. If a man weighs 900 N on the Earth, what would he weigh on Jupiter, where the acceleration due to gravity is 25.9 m/s^2?

$$F_g = mg = 900\ \text{N},\ m = \frac{900\ \text{N}}{9.80\ \text{m/s}^2} = 91.8\ \text{kg}$$

$$(F_g)_{\text{on Jupiter}} = 91.8\ \text{kg}(25.9\ \text{m/s}^2) = \boxed{2.38\ \text{kN}}$$