

## EXERCISES

## Section 4.2 Newton's First and Second Laws

13. **INTERPRET** We interpret this as a problem involving the application of Newton's second law. The object under consideration is the train and the physical quantity of interest is the net force acting on it.

**DEVELOP** The net force can be found by using Equation 4.3,  $F_{\text{net}} = ma$ .

**EVALUATE** Using Equation 4.3, the magnitude of the force acting on the train is found to be

$$F_{\text{net}} = ma = (1.5 \times 10^6 \text{ kg})(2.5 \text{ m/s}^2) = 3.75 \times 10^6 \text{ N}$$

**ASSESS** The result is reasonable, since by definition, one newton is the force required to accelerate a 1-kg mass at the rate of  $1 \text{ m/s}^2$ .

14. Ignoring the probable presence of other forces, we can apply Equation 4.3 to find **(a)**  $a = F/m = (1.2 \times 10^5 \text{ N}) / (6.1 \times 10^4 \text{ kg}) = 1.97 \text{ m/s}^2$ , and **(b)**  $a = (1.2 \times 10^5 \text{ N}) / (1.46 \times 10^6 \text{ kg}) = 8.21 \text{ cm/s}^2$ .

15. **INTERPRET** We interpret this as a problem involving the application of Newton's second law. The object under consideration is the airplane and the physical quantity of interest is the plane's mass.

**DEVELOP** We shall assume that the runway is horizontal (so that the vertical force of gravity and the normal force of the surface cancel) and neglect aerodynamic forces (which are small just after the plane begins to move). Then the net force equals the engine's thrust and is parallel to the acceleration. The plane's mass can be found by using Equation 4.3,  $F_{\text{net}} = ma$ .

**EVALUATE** Using Equation 4.3, the mass of the plane is found to be

$$m = \frac{F_{\text{net}}}{a} = \frac{1.1 \times 10^4 \text{ N}}{7.2 \text{ m/s}^2} = 1.53 \times 10^3 \text{ kg}$$

**ASSESS** First, the units are consistent since  $1 \text{ N} = 1 \text{ kg} \cdot \text{m/s}^2$ . The result is reasonable, since by definition, one newton is the force required to accelerate a 1-kg mass at the rate of  $1 \text{ m/s}^2$ .

16. Assume that the seatbelt holds the passenger firmly to the seat, so that the passenger also stops in 0.14 s without incurring any secondary impact. Then the passenger's average acceleration is  $a_{\text{av}} = (0 - v_0)/t$ , and the average net force on the passenger, while coming to rest, is  $F_{\text{net}} = ma_{\text{av}} = -mv_0/t = -(60 \text{ kg})(110/3.6 \text{ (m/s)}) / (0.14 \text{ s}) = -13.1 \text{ kN}$ , or about 1.5 tons. (Here, we used the one-dimensional form of Newton's second law. The minus sign indicates that the force is opposite to the direction of the initial velocity. It is reasonable to assume that this is a component of the force exerted by the seatbelt.)

17. **INTERPRET** In this problem we want to find the relationship between the initial speed of the car and the force required to stop it.

**DEVELOP** From Equation 4.3, we see that the net force on a car of given mass is proportional to the acceleration,  $F_{\text{net}} \propto a$ . We can then relate the three quantities, displacement, velocity, and acceleration, by Equation 2.11,  $v^2 = v_0^2 + 2a(x - x_0)$ .

**EVALUATE** To stop a car in a given distance,  $(x - x_0)$ , the acceleration is  $a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{-v_0^2}{2(x - x_0)}$ . Therefore, we see that  $F_{\text{net}} \propto v_0^2$ . Doubling  $v_0$  quadruples the magnitude of  $F_{\text{net}}$ .

**ASSESS** The conclusion that  $F_{\text{net}} \propto v_0^2$  is an important fact to remember when driving at high speeds.

# Essential University Physics Solutions Problem 71

**Léo Pomar**



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