Chapter 4 Problems

1. When a 58-g tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 44 cm. What is the magnitude of the net force acting on the ball?

Answer: The acceleration of the ball is given by

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

Thus, the magnitude of the net force on the ball is given by

$$\sum F = ma = m\left(\frac{v^2 - v_0^2}{2x}\right) = 130N.$$

2. An arrow, starting from rest, leaves the bow with a speed of 25.0 m/s. If the average force exerted on the arrow by the bow were doubled, all else remaining the same, with what speed would the arrow leave the bow?

Answer: Since both arrows start from rest, $v_0 = 0m/s$. Since x is the same in both cases, from the equation $v^2 = v_0^2 + 2ax$ we have that

$$\frac{v_1^2}{v_2^2} = \frac{2a_1x}{2a_2x} = \frac{a_1}{a_2}.$$

Since $F = ma$, it follows that $a = F/m$. The mass of the arrow is unchanged, and

$$\frac{v_1}{v_2} = \sqrt{\frac{F_1}{F_2}}$$

or

$$v_2 = v_1\sqrt{\frac{F_1}{F_2}} = v_1\sqrt{\frac{2F_1}{F_1}} = 35.4m/s.$$

3. A skater with an initial speed of 7.60 m/s is gliding across the ice. Air resistance is negligible. (a) The coefficient of kinetic friction between the ice and the skate blades is 0.100. Find the deceleration casued by kinetic friction. (b) How far will the skater travel before coming to rest?

Answer: (a) The magnitude of the frictional force on the skater is

$$F_f = \mu_k F_N.$$

Since the skater has no vertical acceleration, $F_N - mg = 0$. Therefore, her acceleration is given by

$$a = \frac{F_f}{m} = \frac{\mu_k F_N}{m} = \frac{\mu_k mg}{m} = \mu_k g = 0.980 m/s^2.$$

Since the skater is slowing down, the acceleration must be opposite to the direction of motion.

(b) The displacement of the skater can be found from $v^2 = v_0^2 + 2ax$ with her final velocity $v = 0m/s$. Then, recalling that $a = -0.980m/s^2$, we obtain

$$x = -\frac{v_0^2}{2a} = 29.5m.$$

4. A stuntman is being pulled along a rough road at aconstant velocity, by a cable attached to a moving truck. The cable is parallel to the ground. The mass of the stuntman is 109 kg, and the coefficient of kinetic friction between the road and him is 0.870. Find the tension in the cable.

Answer: Since there are no forces acting along the y-axis, $\sum F_y = 0$, and so $F_N = mg$. Since the stuntman is being pulled along the x-axis with a *constant* velocity, there is no *net* force acting along the x-axis. From $\sum F_x = 0$, we have $T - F_f = 0$. Then, $T = F_f = \mu_k F_N = \mu_k mg = 929N$.

5. Three forces act on a moving object. One force has a magnitude of 80.0 N and is directed due north. Another has a magnitude of 60.0 N and is directed due west. What must be the magnitude and direction of the third force, such that the object continues to move with a constant velocity?

Answer: In order for the object to move with constant velocity, the net force must be zero. Therefore, the north/south component of the third force must be equal in magnitude and opposite in direction to the 80.0 N force, while the east/west component of the third force must be equal in magnitude and opposite in direction to the 60.0 N force. Therefore, the third force has components: 80.0 N due south and 60.0 N due east. We can use the Pythagorean theorem and trigonometry to find the magnitude and direction of the third force.

The magnitude of the force is $F_3 = \sqrt{(80.0N)^2 + (60.0N)^2} = 1.00 \times 10^2 N$. The direction of F_3 is

$$\theta = \tan^{-1}\left(\frac{80.0}{60.0}\right) = 53.1^\circ$$

south of east.

6. A person is trying to judge whether a picture (mass = 1.10 kg) is properly positioned by temporarily presing it against a wall. The pressing force is perpendicular to the wall. The coefficient of static friction between the picture and the wall is 0.660. What is the minimum amount of pressing force that must be used?

Answer: The forces that act on the picture are the pressing force P, the normal force F_N exerted on the picture by the wall, the weight mg of the picture and the force of static friction F_f^{MAX}. Since the picture is in equilibrium, we have

$$\sum F_x = P - F_N = 0$$

and

$$\sum F_y = F_f^{MAX} - mg = 0.$$

Therefore, $F_f^{MAX} = \mu_s F_N = mg$, and since $\mu_s P = mg$, we have

$$P = \frac{mg}{\mu_s} = 16.3N.$$

7. A box is sliding up an incline that makes an angle of 15.0° with respect to the horizontal. The coefficient of kinetic friction between the box and the surface of the incline is 0.180. The initial speed of the box at the bottom of the incline is 1.50 m/s. How far does the box travel along the incline before coming to rest?

Answer: We work in a coordinate system with the x-axis aligned with the surface of the incline. The box comes to a halt because the kinetic frictional force and the component of its weight parallel to the incline oppose the motion and cause the box to slow down. The distance that the box travles up the incline can be found by solving the equation $v^2 = v_0^2 + 2ax$ for x. We must first find the acceleration of the box up the incline.
In the x-direction we have $\sum F_x = -mg\sin\theta - F_f = ma_x$. In the y-direction we have $\sum F_y = F_N - mg\cos\theta = 0$, since there is no acceleration in the y-direction. With $F_f = \mu_k F_N$, we have

$$-mg\sin\theta - \mu_k mg\cos\theta = ma_x.$$

Solving this equation for a_x and plugging into the equation for x,

$$x = -\frac{v_0^2}{2a} = \frac{v_0^2}{2g(\sin\theta + \mu_k\cos\theta)} = 0.265m.$$

8. In 0.750 s, a 7.00-kg block is pulled through a distance of 4.00 m on a frictionless horizontal surface, starting from rest. The block has a constant acceleration and is pulled by means of a horizontal spring that is attached to the block. The spring constant of the spring is 415 N/m. By how much does the spring stretch?

Answer: The acceleration of the block is given by $a = 2d/t^2$, where d is the distance through which the block is pulled. Therefore, the force applied to the block is $F = ma = 2md/t^2$. The force acting on the block is the restoring force of the spring, $F = -kx$, where k is the spring constant and x is the displacement from equilibrium. Solving for x,

$$x = -\frac{F}{k} = -\frac{2md}{kt^2} = -0.240m.$$

The amount that the spring stretches is $0.240m$.

9. A helicopter is lifting a 2100-kg jeep with a tough spring of spring constant

$k = 2000N/m$. How much does the spring stretch if the helicoptor is moving upward (a) with constant velocity and (b) with an acceleration of $2.5m/s^2$?

Answer: (a) Since the jeep is being lifted upwards at constant velocity, $\sum F_y = 0$. The two forces acting along the y-direction are the jeep's weight, W, and the upward restoring force of of the spring, $F = -kx$. Thus,

$$\sum F_y = 0 = -kx - W = -kx - mg \rightarrow x = -10.3m.$$

(b) When the helicopter accelerates upwards, we no longer have equilibrium in the y-direction, but instead we have a net force, $\sum F_y = ma_y$. Now the sum of the forces takes the following form,

$$\sum F_y = ma_y = -kx - W = -kx - mg \rightarrow x = -12.9m.$$

In both cases, the minus sign indicates that the string is stretching.

10. A train consists of 50 cars, each of which has a mass of $6.8 \times 10^3 kg$. The train has an acceleration of $+8.0 \times 10^{-2} m/s^2$. Ignore friction and determine the tension in the coupling (a) between the 30th and 31st cars and (b) between the 49th and 50th cars.

Answer: (a) The tension between the 30th and 31st cars is responsible for providing the acceleration of the 20 cars from the 31st to the 50th car. Therefore, we have that $T =$(mass of 20 cars)$a = 1.1 \times 10^4 N$.

(b) The tension between the 49th and 50th cars provides the acceleration for just the 50th car, and so $T =$(mass of 1 car)$a = 5.4 \times 10^2 N$.