

Problem 4D

OVERCOMING FRICTION

PROBLEM

In 1988, a very large telephone constructed by a Dutch telecommunications company was demonstrated in the Netherlands. Suppose this telephone is towed a short distance by a horizontal force equal to 8670 N, so that the telephone's net acceleration is 1.30 m/s^2 . Given that the coefficient of kinetic friction between the phone and the ground is 0.120, calculate the mass of the telephone.

SOLUTION

1. DEFINE

Given: $F_{\text{applied}} = 8670 \text{ N}$
 $a_{\text{net}} = 1.30 \text{ m/s}^2$
 $\mu_k = 0.120$
 $g = 9.81 \text{ m/s}^2$

Unknown: $m = ?$

2. PLAN

Choose the equation(s) or situation: Apply Newton's second law to describe the forces acting on the telephone.

$$F_{\text{net}} = ma_{\text{net}} = F_{\text{applied}} - F_k$$

The frictional force, F_k , depends on the normal force, F_n , exerted on the telephone. For a horizontal surface, the normal force equals the telephone's weight.

$$F_k = \mu_k F_n = \mu_k (mg)$$

Substituting the equation for F_k into the equation for F_{net} provides an equation with all known and unknown variables.

$$ma_{\text{net}} = F_{\text{applied}} - \mu_k mg$$

Rearrange the equation(s) to isolate the unknown(s):

$$ma_{\text{net}} + \mu_k mg = F_{\text{applied}}$$

$$m(a_{\text{net}} + \mu_k g) = F_{\text{applied}}$$

$$m = \frac{F_{\text{applied}}}{a_{\text{net}} + \mu_k g}$$

3. CALCULATE

Substitute the values into the equations and solve:

$$m = \frac{8670 \text{ N}}{1.30 \text{ m/s}^2 + (0.120)(9.81 \text{ m/s}^2)}$$

$$m = \frac{8670 \text{ N}}{1.30 \text{ m/s}^2 + 1.18 \text{ m/s}^2}$$

$$m = \frac{8670 \text{ N}}{2.48 \text{ m/s}^2} = \boxed{3.50 \times 10^3 \text{ kg}}$$

4. EVALUATE

Because the mass is constant, the sum of the acceleration terms in the denominator must be constant for a constant applied force. Therefore, the net acceleration decreases as the coefficient of friction increases.

ADDITIONAL PRACTICE

1. Isaac Newton developed the laws of mechanics. Brian Newton put those laws into application when he ran a marathon in about 8.5 h while carrying a bag of coal. Suppose Brian Newton wants to remove the bag from the finish line. He drags the bag with an applied horizontal force of 130 N, so that the bag has a net acceleration of 1.00 m/s^2 . If the coefficient of kinetic friction between the bag and the pavement is 0.158, what is the mass of the bag of coal?
2. The most massive car ever built was the official car of the General Secretary of the Communist Party in the former Soviet Union. Suppose this car is moving down a 10.0° slope when the driver suddenly applies the brakes. The net force acting on the car as it stops is $-2.00 \times 10^4 \text{ N}$. If the coefficient of kinetic friction between the car's tires and the pavement is 0.797, what is the car's mass? What is the magnitude of the normal force that the pavement exerts on the car?
3. Suppose a giant hamburger slides down a ramp that has a 45.0° incline. The coefficient of kinetic friction between the hamburger and the ramp is 0.597, so that the net force acting on the hamburger is $6.99 \times 10^3 \text{ N}$. What is the mass of the hamburger? What is the magnitude of the normal force that the ramp exerts on the hamburger?
4. An extremely light, drivable car with a mass of only 9.50 kg was built in London. Suppose that the wheels of the car are locked, so that the car no longer rolls. If the car is pushed up a 30.0° slope by an applied force of 80.0 N, the net acceleration of the car is 1.64 m/s^2 . What is the coefficient of kinetic friction between the car and the incline?
5. *Cleopatra's Needle*, an obelisk given by the Egyptian government to Great Britain in the nineteenth century, is 20+ m tall and has a mass of about $1.89 \times 10^5 \text{ kg}$. Suppose the monument is lowered onto its side and dragged horizontally to a new location. An applied force of $7.6 \times 10^5 \text{ N}$ is exerted on the monument, so that its net acceleration is 0.11 m/s^2 . What is the magnitude of the frictional force?
6. Snowfall is extremely rare in Dunedin, New Zealand. Nevertheless, suppose that Baldwin Street, which has an incline of 38.0° , is covered with snow and that children are sledding down the street. A sled and rider move downhill with a constant acceleration. What would be the magnitude of the sled's net acceleration if the coefficient of kinetic friction between the snow and the sled's runners is 0.100? Does the acceleration depend on the masses of the sled and rider?
7. The record speed for grass skiing was set in 1985 by Klaus Spinka, of Austria. Suppose it took Spinka 6.60 s to reach his top speed after he started from rest down a slope with a 34.0° incline. If the coefficient of kinetic friction between the skis and the grass was 0.198, what was the magnitude of Spinka's net acceleration? What was his speed after 6.60 s?