Section 4.2: Friction

Tutorial 1 Practice, page 171

1. (a) Given: m = 22 kg; F_a = 62 N

Required: μ_S

Analysis: Before the box starts to move, F_{net} = 0. To keep the box at rest, $F_{S_{max}}$ = 62 N acting in the opposite direction. Use the equation $\mu_S = \frac{F_{S_{max}}}{F_N}$ to calculate the coefficient of static friction. Also $F_N = F_g$.

Solution:

$$\mu_S = \frac{F_{S_{max}}}{F_N}$$
$$= \frac{F_{S_{max}}}{mg}$$
$$= \frac{62\text{ N}}{(22\text{ kg})(9.8\text{ m/s}^2)}$$
$$\mu_S = 0.29$$

Statement: The coefficient of static friction is 0.29.

(b) Given: m = 22 kg; F_a = 58 N

Required: μ_K

Analysis: Since the box is moving at a constant velocity, F_{net} = 0. So the kinetic friction on the box is 58 N. Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the coefficient of kinetic friction.

Solution:

$$\mu_K = \frac{F_K}{F_N}$$
$$= \frac{F_K}{mg}$$
$$= \frac{58\text{ N}}{(22\text{ kg})(9.8\text{ m/s}^2)}$$
$$\mu_K = 0.27$$

Statement: The coefficient of kinetic friction is 0.27.

2. Given: m = 75 kg; μ_K = 0.01

Required: F_K

Analysis: Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the magnitude of the force of kinetic friction.

Solution:

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.01)(75\text{ kg})(9.8\text{ m/s}^2)$$
$$F_K = 7.4\text{ N}$$

Statement: The magnitude of the force of kinetic friction acting on the hockey player is 7.4 N.

3. (a) Given: m = 1300 kg; μ_K = 0.5 to 0.80

Required: F_K

Analysis: Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the magnitude of the force of kinetic friction.

Solution: When μ_K = 0.5,

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.5)(1300\text{ kg})(9.8\text{ m/s}^2)$$
$$F_K = 6400\text{ N}$$

When μ_K = 0.80,

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.80)(1300\text{ kg})(9.8\text{ m/s}^2)$$
$$= 10\,192\text{ N}$$
$$F_K = 1.0 \times 10^4\text{ N}$$

Statement: The magnitude of the force of kinetic friction acting on the car on dry road is 6400 N to 1.0×10^4 N.

(b) Given: m = 1300 kg; μ_K = 0.25 to 0.75

Required: F_K

Analysis: Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the magnitude of the force of kinetic friction.

Solution: When μ_K = 0.25,

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.25)(1300\text{ kg})(9.8\text{ m/s}^2)$$
$$F_K = 3200\text{ N}$$

When $\mu_K = 0.75$,

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.75)(1300 \text{ kg})(9.8 \text{ m/s}^2)$$
$$F_K = 9600 \text{ N}$$

Statement: The magnitude of the force of kinetic friction acting on the car on wet road is 3200 N to 9600 N.

(c) Given: m = 1300 kg; μ_K = 0.005

Required: F_K

Analysis: Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the magnitude of the force of kinetic friction.

Solution: When μ_K = 0.005,

$$\mu_K = \frac{F_K}{F_N}$$
$$F_K = \mu_K F_N$$
$$= \mu_K (mg)$$
$$= (0.005)(1300 \text{ kg})(9.8 \text{ m/s}^2)$$
$$F_K = 64 \text{ N}$$

Statement: The magnitude of the force of kinetic friction acting on the car on icy road is 64 N.

Section 4.2 Questions, page 172

1. Answers may vary. Sample answers:

(a) Friction makes the action more difficult when turning a door knob. Friction is helpful because it allows your hand to apply a force on the door knob. Static friction prevents the knob from starting to turn and kinetic friction acts opposite to the motion of turning.

(b) Friction is not helpful in pushing a heavy box across a rough surface as static friction prevents the box from starting to move and kinetic friction acts opposite to the motion of moving.

(c) Friction is not helpful in gliding across smooth ice as kinetic friction acts opposite to the motion of gliding. For demonstrating uniform motion, friction is often made zero.

(d) Friction is helpful and necessary in tying a knot. Static friction on the tied knob prevents the rope or string from slipping out of the knot.

2. Answers may vary. Sample answer:
When you pull the lever on the handle bars, the brake pads of the bicycle wheel are squeezed. A normal force is applied to the rim of the bicycle wheel. The brake pad near the rim will in turn provide a force of friction to the rim, slowing down the bicycle.

3. (a) To start the block moving, the applied force equals the force of static friction. So the static friction on the block is 5.5 N. Use the equation $\mu_S = \frac{F_{S_{max}}}{F_N}$ to calculate the coefficient of static friction.

$$\mu_S = \frac{F_{S_{max}}}{F_N}$$
$$= \frac{F_{S_{max}}}{mg}$$
$$= \frac{5.5 \text{ N}}{(1.4 \text{ kg})(9.8 \text{ m/s}^2)}$$
$$\mu_S = 0.40$$

The coefficient of static friction is 0.40.

To keep the block moving at a constant velocity, the applied force equals the kinetic friction. So the kinetic friction on the block is 4.1 N. Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the coefficient of kinetic friction.

$$\mu_K = \frac{F_K}{F_N}$$
$$= \frac{F_K}{mg}$$
$$= \frac{4.1 \text{ N}}{(1.4 \text{ kg})(9.8 \text{ m/s}^2)}$$
$$\mu_K = 0.30$$

The coefficient of kinetic friction is 0.30.

(b) The coefficients of friction depend only on the types of materials in contact. The changes in (i) and (iii) will not affect the coefficients of friction and there is no change in the materials involved. The change in (ii) involves changing the type of material in contact so the coefficients of friction will be affected.

(c) (i) Putting an object on the block increases the normal force on the block. Since $F_S = \mu_S F_N = \mu_S mg$ and $F_K = \mu_K F_N = \mu_K mg$, both the static friction and kinetic friction will increase.

(ii) Applying an upward force decreases the normal force on the block. So both the static friction and kinetic friction will decrease.

(iii) Putting slippery grease on the surface will decrease the coefficients of static and kinetic friction. As a result, both the static friction and kinetic friction will decrease.

4. (a) Answers may vary. Sample answer:
The coefficient of kinetic friction for rubber on dry asphalt roads is slightly lower than that on dry concrete roads (0.5 compared to 0.6). However, the coefficient of kinetic friction for rubber on wet asphalt roads could be much lower than that for wet concrete roads (0.25 compared to 0.45). It seems that it is safer to drive on concrete roads, during rainy days in particular.

(b) The coefficient of kinetic friction on wet roads is generally lower than that on dry roads. This means that the force of friction is generally less on wet roads. So drivers should reduce speeds on wet roads to prevent the car from skidding.

(c) In winter, especially when there is freezing rain, the coefficient of kinetic friction of the road surface could be as low as 0.005. With little friction on the roads, cars will skid. Salting roads increases the coefficient of friction on the road surfaces, making driving safer.

5. (a) Given: $m = 110$ kg; $F_a = 380$ N

Required: μ_K

Analysis: Since the trunk is moving at a constant velocity, $F_{net} = 0$. So the kinetic friction on the trunk is 380 N. Use the equation $\mu_K = \frac{F_K}{F_N}$ to calculate the coefficient of kinetic friction.

Solution:

$$\begin{aligned}\mu_K &= \frac{F_K}{F_N} \\ &= \frac{F_K}{mg} \\ &= \frac{380\text{ N}}{(110\text{ kg})(9.8\text{ m/s}^2)} \\ &= 0.353 \\ \mu_K &= 0.35\end{aligned}$$

Statement: The coefficient of kinetic friction is 0.35.

(b) Calculate the normal force on the trunk. Choose up as positive. So down is negative.

$$\begin{aligned}F_N + F_g + F_a &= 0 \\ F_N + (110\text{ kg})(-9.8\text{ m/s}^2) + 150\text{ N} &= 0 \\ F_N &= +928\text{ N}\end{aligned}$$

Use the equation $F_K = \mu_K F_N$ to calculate the force of kinetic friction on the trunk.

$$\begin{aligned}F_K &= \mu_K F_N \\ &= (0.353)(928\text{ N}) \\ F_K &= 330\text{ N}\end{aligned}$$

The force required to pull the trunk is 330 N. With the help of the friend, the force required to pull the trunk at a constant velocity is less.

(c) The total mass on the trunk is:
110 kg + 55 kg = 165 kg

Use the equation $F_K = \mu_K F_N = \mu_K mg$ to calculate the force of kinetic friction on the trunk.

$$\begin{aligned}F_K &= \mu_K F_N \\ &= \mu_K mg \\ &= (0.353)(165\text{ kg})(9.8\text{ m/s}^2) \\ F_K &= 570\text{ N}\end{aligned}$$

The force required to pull the trunk at a constant velocity is 570 N.

6. First use the equation $F_S = \mu_S F_N = \mu_S mg$ to calculate the maximum magnitude of static friction acting on the desk.

$$\begin{aligned}F_{S_{max}} &= \mu_S F_N \\ &= \mu_S mg \\ &= (0.25)(26\text{ kg})(9.8\text{ m/s}^2) \\ F_{S_{max}} &= 64\text{ N}\end{aligned}$$

Calculate the applied force. Choose east as positive. So west is negative.

$$\begin{aligned}F_a &= +52\text{ N} + (-110\text{ N}) \\ &= -58\text{ N} \\ \vec{F}_a &= 58\text{ N [W]}\end{aligned}$$

The applied force is 58 N [W].

Since the applied force of 58 N is less than the static friction of 64 N, the desk will not move.

7. (a) Given: m = 12 000 kg; μ_S = 0.50

Required: $F_{S_{max}}$

Analysis: To start the bin moving, the minimum force exerted by the truck equals the force of static friction. Use the equation $F_S = \mu_S F_N = \mu_S mg$ to calculate the maximum magnitude of the force of static friction.

Solution:

$$\begin{aligned} F_{S_{max}} &= \mu_S F_N \\ &= \mu_S mg \\ &= (0.50)(12\ 000\ \text{kg})(9.8\ \text{m/s}^2) \\ F_{S_{max}} &= 59\ 000\ \text{N} \end{aligned}$$

Statement: The force exerted by the truck to start the bin moving is 59 000 N.

(b) Given: m = 12 000 kg; μ_K = 0.40

Required: F_K

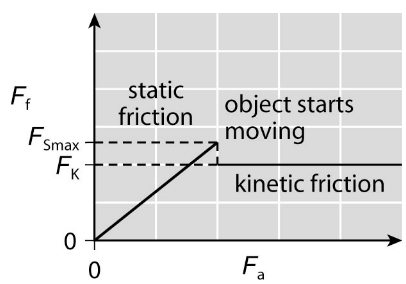
Analysis: To keep the bin moving at a constant velocity, the minimum force exerted by the truck equals the force of kinetic friction. Use the equation $F_K = \mu_K F_N = \mu_K mg$ to calculate the magnitude of the force of kinetic friction.

Solution:

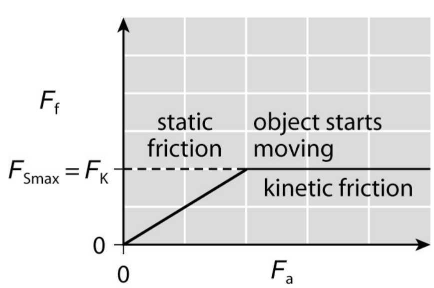
$$\begin{aligned} F_K &= \mu_K F_N \\ &= \mu_K (mg) \\ &= (0.40)(12\ 000\ \text{kg})(9.8\ \text{m/s}^2) \\ F_K &= 47\ 000\ \text{N} \end{aligned}$$

Statement: The force exerted by the truck to keep the bin moving at a constant velocity is 47 000 N.

8. (a)



(b)



9. Answers may vary. Sample answer:
When the wedge is in position, there is friction between the bottom of the wedge and the floor. The force exerted by the door is counteracted by the force of static friction between the bottom of the wedge and the floor.

10. Answers may vary. Sample answers:

(a) First measure the mass of an object using a balance for calculating the force of gravity on the object. Then use a force sensor to pull the stationary object horizontally along a surface. As you increase the applied force of pulling, the reading on the force sensor when the object just starts to move gives the magnitude of the static friction. The coefficient of static friction of the surface is then calculated as the ratio of the magnitude of the force of static friction to the magnitude of the normal force acting on an object. In this case, the magnitude of the normal force equals the force of gravity.

(b) First measure the mass of an object using a balance for calculating the force of gravity on the object. Then use a force sensor to pull the stationary object horizontally along a surface slowly until the object starts to move. Once the object starts to move, decrease the applied force until the object moves at a constant velocity. The reading on the force sensor gives the magnitude of the kinetic friction. The coefficient of kinetic friction of the surface is then calculated as the ratio of the magnitude of the force of kinetic friction to the magnitude of the normal force acting on the object.

11. Answers may vary. Sample answer:
When a runner pushes back on his feet, according to Newton's third law, there is a reaction force, friction in this case, that pushes the runner forwards. Therefore, the manufacturer of a running shoe has to be sure that a running shoe is designed to have a high coefficient of friction that can help the runner accelerate quickly in a race. Dress shoes are not usually used for more than walking, so they do not need a high coefficient of friction.