Practice

Understanding Concepts

2. A car accelerates southward due to a frictional force between the road and the tires.
(a) In what direction is the frictional force of the road on the tires? Why does that force exist?
(b) Is the frictional force static or kinetic? Explain your answer.

3. The coefficients of friction between a 23-kg exercise mat and the gym floor are $\mu_S = 0.43$ and $\mu_K = 0.36$.
(a) Determine the magnitude of the minimum horizontal force needed to start the mat moving.
(b) Once the mat is moving, what magnitude of horizontal force will keep it moving at a constant velocity?

4. A musician applies a horizontal force of 17 N [W] to an instrument case of mass 5.1 kg. The case slides across a table with an acceleration of 0.39 m/s^2 [W]. What is the coefficient of kinetic friction between the case and the table?

5. A small box is resting on a larger box sitting on a horizontal surface. When a horizontal force is applied to the larger box, both boxes accelerate together. The small box does not slip on the larger box.
(a) Draw an FBD of the small box during its acceleration.
(b) What force causes the small box to accelerate horizontally?
(c) If the acceleration of the pair of boxes has a magnitude of 2.5 m/s^2, determine the smallest coefficient of friction between the boxes that will prevent slippage.

6. Draw an FBD for the larger box in question 5 when it is accelerating.

7. An adult is pulling two small children in a sleigh over level snow. The sleigh and children have a total mass of 47 kg. The sleigh rope makes an angle of 23° with the horizontal. The coefficient of kinetic friction between the sleigh and the snow is 0.11. Calculate the magnitude of the tension in the rope needed to keep the sleigh moving at a constant velocity. (*Hint:* The normal force is not equal in magnitude to the force of gravity.)

Applying Inquiry Skills

8. (a) Describe how you would perform an experiment to determine the coefficient of kinetic friction between your shoes and a wooden board, using only a metre stick to take measurements.
(b) Describe likely sources of random and systematic error in this experiment.

Answers

3. (a) 97 N
   (b) 81 N
4. 0.30
5. (c) 0.26
7. 53 N

DID YOU KNOW?

Low-Friction Materials

Scientists have found ways of producing materials with very low coefficients of friction. Teflon®, a compound of fluorine and carbon developed in 1938, experiences extremely weak electrical forces from molecules such as those in foods, so it makes an excellent coating for frying pans. (To make the coating stick to the pan, the Teflon is blasted into tiny holes in the metal.) Since Teflon does not interact with body fluids, it is also useful in surgical implants.

Making Connections

9. In the kitchen, friction sometimes helps and sometimes hinders.

(a) Describe at least two ways in which you can increase friction when you are trying to open a tight lid on a jar.

(b) What materials and methods can be used to decrease friction between food and a cooking surface?

Section 2.4 Questions

Understanding Concepts

1. When you rub your hands together vigorously, the temperature of the skin rises. Why?

2. A team of horses at a winter carnival is starting to pull a loaded sleigh with wooden runners along a horizontal trail covered in dry snow. The total mass of the sleigh, including its passengers, is 2.1×10^3 kg. The horses apply a force of 5.3×10^3 N [horizontally]. Determine the magnitude of (a) the frictional force and (b) the acceleration of the sled. (*Hint:* Look up the appropriate coefficient of friction in **Table 1**.)

3. Two skiers, A and B, each of mass m, are skiing down a snow-covered hill that makes an angle ϕ above the horizontal. A is moving with constant velocity. B is accelerating.
   (a) Derive an equation for the coefficient of kinetic friction experienced by A, in terms of the angle ϕ.
   (b) Derive an equation for the magnitude of the acceleration experienced by B, in terms of g, ϕ, and μ_K.
   (c) What effect would a change in the mass of skier B have on the magnitude of the acceleration? Explain your answer.

4. A race car is accelerating on a level track. The coefficient of static friction between the tires and the track is 0.88. The tires are not slipping.
(a) Draw an FBD of the car.
(b) Determine the maximum possible magnitude of acceleration if the car is to travel without slipping.

5. A steel ball reaches a terminal speed when falling in glycerine. Will the terminal speed be greater if the glycerine is at 20°C or at 60°C? Explain.

6. Why are pumping stations required at regular intervals along the cross-Canada natural gas pipeline?

7. **Figure 16** shows a *venturi flowmeter*, used to measure the speed of gas flowing through a tube. How does its design illustrate Bernoulli's principle?

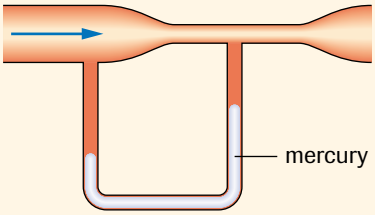

Figure 16
A venturi flowmeter

Applying Inquiry Skills

8. (a) With your hand facing palm downward, slide your fingers across the cover of your textbook. Estimate the coefficient of kinetic friction between your fingers and the cover.
(b) Turn your hand over and repeat the procedure with your fingernails.
(c) Devise and carry out an experiment (using a ruler for measurements) to determine values for the coefficients in (a) and (b). Compare your estimated and calculated values.
(d) Describe what you could do to improve your skill in estimating coefficients of friction.

9. Predict, with an explanation, what will happen when a person blows through the horizontal straw in **Figure 17**. Verify your prediction experimentally with teacher approval. Relate your explanation to the design principle of a paint sprayer.

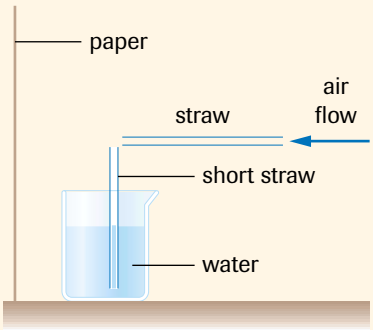

Figure 17

Making Connections

10. In 1896, Carl E. Johansson of Sweden produced the first *gauge blocks* (also called "Jo blocks" in his honour) for quality control in manufacturing. Since the blocks have extremely smooth sides, the coefficient of static friction is high. The blocks thus stick together upon contact. (You have likely noticed a similar strong bonding when microscope slides stick together.) Research the topic of gauge blocks, describing their properties and uses.

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11. What are the meanings of the terms "slice" and "hook" in golf? What causes slices and hooks? What can you do to prevent them?

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12. Running-shoe designs have changed with advances in technology. Research how the soles of running shoes have evolved, writing a few sentences on your findings.

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13. The near-frictionless carbon (NFC) listed in **Table 1** is a new, ultra-hard carbon film with a coefficient of kinetic friction of only about 0.001 in an environment of nitrogen or argon. Although the coefficient is greater in an ordinary environment of air, the friction remains low enough to give this amazing material many applications. Research the advantages and uses of NFC, and write a report on what you discover.

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