Section 4.3 - Solving Friction Problems

Learning Goal: By the end of today, I will be able to solve multi-step problems that include a friction force.

Friction is a force that can be both beneficial and detrimental depending on what we are trying to accomplish.

Friction is the force that allows us to walk across a room or drive down a road, it is the force that keeps our shoes tied and reshapes our planet in for the form of erosion.

However, friction between parts in an automobile is what reduces the efficiency of the machine and creates excessive heat in the engine and it is the same force that makes it really difficult to move heavy objects.

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Sample Problem 1

Two sleds are tied together with a rope (**Figure 3**). The coefficient of static friction between each sled and the snow is 0.22. A small child is sitting on sled 1 (total mass of 27 kg) and a larger child sits on sled 2 (total mass of 38 kg). An adult pulls on the sleds.

Figure 3

(a) What is the greatest horizontal force that the adult can exert on sled 1 without moving either sled?

(b) Calculate the magnitude of the tension in the rope between sleds 1 and 2 when the adult exerts this greatest horizontal force. (but does not get the sleds to move)

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Practice

1. Two trunks sit side by side on the floor. The larger trunk (52 kg) is to the left of the smaller trunk (34 kg). A person pushes on the larger trunk horizontally toward the right. The coefficient of static friction between the trunks and the floor is 0.35. T/I
   (a) Determine the magnitude of the maximum force the person can exert without moving either trunk.
   (b) Calculate the force the larger trunk exerts on the smaller trunk.
   (c) Would either answer change if the person pushed in the opposite direction on the smaller trunk? Explain your reasoning.
2. A 4.0 kg block of wood sits on a table (**Figure 5**). A string is tied to the wood, running over a pulley and down to a hanging object. The greatest mass that can be hung from the string without moving the block of wood is 1.8 kg. Calculate the coefficient of static friction between the block of wood and the table. T/I

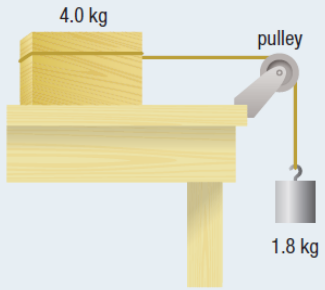

Figure 5

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Static Friction and Motion

It is important to understand that static friction acts on an object when the object is at rest on a surface. This does not mean that static friction cannot be used to make an object move.

Why are the starting blocks to the right an advantage to a runner?

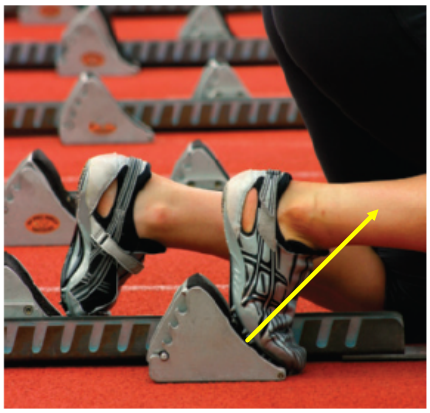

Figure 6 When starting a race, an athlete can achieve a greater forward acceleration by pushing backwards on starting blocks.

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Sample Problem 1

The coefficient of static friction between a person's shoe and the ground is 0.70. Determine the maximum magnitude of acceleration of the 62 kg person, if he starts running on a horizontal surface from rest.

Given: $\mu_S = 0.70$; $m = 62$ kg

Required: a

Analysis: Draw the FBD of the person (**Figure 7**).

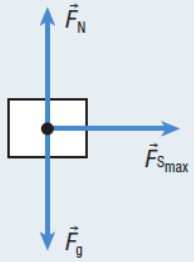

Figure 7

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Practice

1. Two people start running from rest. The first person has a mass of 59 kg and is wearing dress shoes with a coefficient of static friction of 0.52. The other person is wearing running shoes with a coefficient of static friction of 0.66. T/I
   (a) Calculate the maximum possible initial acceleration of the person wearing dress shoes.
   (b) Explain why we do not really need the mass of either person when finding the initial maximum possible acceleration.
   (c) Determine the ratio of the two accelerations and compare it to the ratio of the two coefficients of friction.
2. A skater with mass 58 kg is holding one end of a rope and standing at rest on ice. Assume no friction. Another person with mass 78 kg is standing just off the ice on level ground and is holding the other end of the rope. The person standing on the ground pulls on the rope to accelerate the skater forward. The coefficient of static friction between the ground and the off-ice person is 0.65. Calculate the maximum possible acceleration of the skater. T/I

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Kinetic Friction Problems

When an object is sliding across a surface, kinetic friction acts on the object in a direction opposite to the direction of motion. One common misconception is that kinetic friction always reduces the net force acting on an object.

If you were to push against a moving object in the opposite direction of the motion, your pushing force would work with the kinetic force to slow the object down.

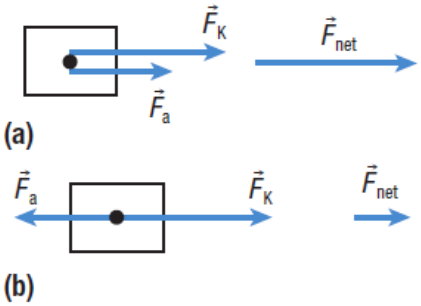

Figure 8 (a) Both the applied force and friction act in the same direction, producing a large net force. (b) The applied force and kinetic friction act in opposite directions, producing a smaller net force.

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Sample Problem 1: Stopping a Sliding Box

A 250 kg box slides down a ramp and then across a level floor. The coefficient of kinetic friction along the floor is 0.20. A person sees the box moving at 1.0 m/s [left] and pushes on it with a horizontal force of 140 N [right].

(a) How far does the box travel before coming to rest?

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Sample Problem 2

Two sleds tied together are pulled across an icy surface with an applied force of 150 N [E] (**Figure 10**). The mass of sled 1 is 18.0 kg and the mass of sled 2 is 12.0 kg. The coefficient of kinetic friction for each sled is 0.20.

(a) Calculate the acceleration of the sleds.

(b) Determine the magnitude of the tension in the rope between the sleds.

Figure 10

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Practice

1. A 0.170 kg hockey puck is initially moving at 21.2 m/s [W] along the ice. The coefficient of kinetic friction for the puck and the ice is 0.005. T/I
   (a) What is the speed of the puck after travelling 58.5 m? [ans: 21.1 m/s]
   (b) After being played on for a while, the ice becomes rougher and the coefficient of kinetic friction increases to 0.047. How far will the puck travel if its initial and final speeds are the same as before? [ans: 6.24 m]

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4. An electric motor is used to pull a 125 kg box across a floor using a long cable. The tension in the cable is 350 N and the box accelerates at 1.2 m/s^2 [forward] for 5.0 s. The cable breaks and the box slows down and stops. T/I C
   (a) Calculate the coefficient of kinetic friction. [ans: 0.16]
   (b) How far does the box travel up to the moment the cable breaks? [ans: 15 m]
   (c) How far does the box travel from the moment the cable breaks until it stops? [ans: 11 m]

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4.3 Questions

1. During fundraising week at school, students decide to hold a competition of strength. Contestants pay $1 to try to move a heavy object. If they can move the object, they win $10. The object is a large box of books of mass 250 kg, with a coefficient of static friction of 0.55. One student has a mass of 64 kg and a coefficient of friction of static friction of 0.72 for his shoes on the floor. K/U
   (a) What is the maximum force of static friction acting on the student?
   (b) What is the maximum force of static friction acting on the box?
   (c) Is the competition fair? Explain your reasoning.
2. In an action movie, an actor is lying on an ice shelf and holding onto a rope. The rope hangs over a cliff to another actor who is hanging on in midair. The actor on the ice shelf has a mass of 55 kg and the actor hanging in midair has a mass of 78 kg. Neither actor can grab onto anything to help stop their motion, yet in the movie neither one is moving. K/U T/I C
   (a) Calculate the minimum coefficient of static friction.
   (b) Is your answer to (a) reasonable considering that the surface is ice? Explain.
   (c) What could the director do to make the scene more realistic? Explain your reasoning.
3. In a physics experiment on static friction, two objects made of identical material are tied together with string. The first object has a mass of 5.0 kg and the second object has a mass of 3.0 kg. Students measure the maximum force of static friction as 31.4 N to move both objects across a horizontal surface. T/I
   (a) What is the coefficient of static friction?
   (b) What is the magnitude of the tension in the string if they pull on the first object?
   (c) A student pushes the 3.0 kg object with a force of 15.0 [down]. What are the magnitudes of the maximum force of static friction and the tension now?
   (d) Will your answers to (c) change if the student pushes down on the 5.0 kg object instead? Explain.
4. A student puts a 0.80 kg book against a vertical wall and pushes on the book toward the wall with a force of 26 N [R]. The book does not move. K/U
   (a) Calculate the minimum coefficient of static friction.
   (b) Describe two ways the student could make the book accelerate down without changing the applied force.
5. A string is tied to a 4.4 kg block and a 120 g hanging bucket (**Figure 13**). Students add 20 g washers one at a time to the bucket. The students are unaware that the coefficient of static friction for the block on the table is 0.42. K/U
   (a) What is the maximum force of static friction for the block?
   (b) How many washers can the students add to the bucket without moving the block?
   (c) Will this investigation yield an accurate result if they use it to find the coefficient of static friction? Explain your reasoning.
   (d) The coefficient of kinetic friction is 0.34. Calculate the acceleration of the block when the final washer is placed in the bucket and the objects start to move.

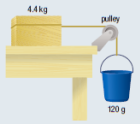

Figure 13

6. In a tug-of-war contest on a firm, horizontal sandy beach, team A has six players with an average mass of 65 kg and team B has five players with an average mass of 64 kg. Team B, pulling with a force of 3.2 kN, dislodges team A and then decreases its force to 2.9 kN to pull team A across the sand at a constant velocity. Determine team A's coefficient of
   (a) static friction (b) kinetic friction K/U
7. Two students push a 260 kg piano across the floor. Kathy pushes with 280 N [forward] while Matt pushes with 340 N [forward]. The piano accelerates at 0.30 m/s^2 [forward]. T/I
   (a) What is the coefficient of kinetic friction?
   (b) How long will it take the piano to stop moving after pushing it for 6.2 s from rest?
8. A 65 kg sprinter accelerates from rest into a strong wind that exerts a frictional force of 62 N. The ground applies a constant forward force of 250 N on the sprinter's feet. K/U
   (a) Calculate
      (i) the sprinter's acceleration
      (ii) the distance travelled in the first 2.0 s
      (iii) the minimum coefficient of friction between the sprinter's shoes and the track
   (b) Is the friction applied on the sprinter from the ground static or kinetic? Explain.
9. A homeowner accelerates a 15.0 kg lawnmower uniformly from rest to 1.2 m/s in 2.0 s. The coefficient of kinetic friction is 0.25. Calculate the horizontal applied force acting on the lawnmower. T/I
10. A 75 kg baseball player is running at 2.8 m/s [forward] when he slides into home plate for a distance of 3.8 m before coming to rest. Calculate the coefficient of kinetic friction. T/I

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