Section 7 Friction: Sliding on the Moon

What Do You See?

Learning Outcomes

In this section, you will

- **Measure** forces of sliding friction using a spring scale.
- **Compare** frictional forces on Earth and the Moon by applying the definition of the coefficient of sliding friction.

Click Here

What Do You Think?

The Lunar Rover proved that there is enough frictional force on the Moon to operate a passenger-carrying wheeled vehicle.

- **How and why are frictional forces on Earth and the Moon different?**

Record your ideas about this question in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will determine the coefficient of sliding friction between two surfaces. You will find the force required to overcome friction for various weights as you pull a box across a level surface. By graphing the data, you will calculate the coefficient of sliding friction. You will then calculate the force of friction on the Moon and how it affects sports played there.

1. Walk forward for a few steps and then come to an abrupt stop. Make the observations needed to write answers to the following questions in your *Active Physics* log:

a) In what direction do you push your feet to make your body go forward?

b) What force pushes your body forward with each step?

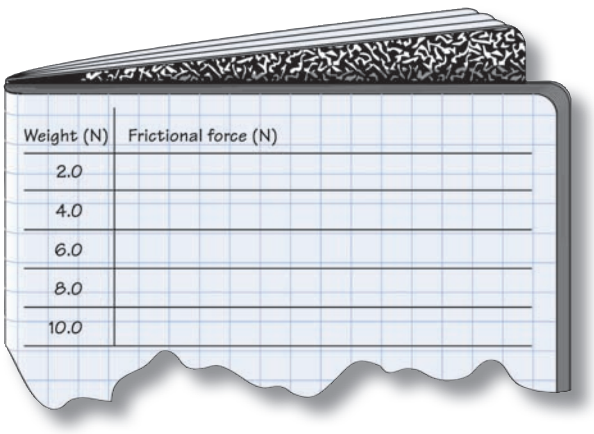
c) In what direction do you push your feet to stop your body?

d) What force makes your body stop?

e) Explain in terms of forces why it is difficult to walk forward or to come to a quick stop on a slippery surface like ice.

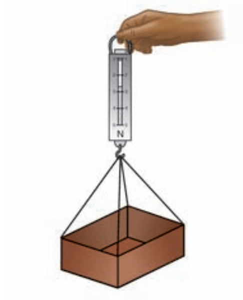
2. The next few steps will help you explore how the frictional force between an object and a surface depends on the weight of the object. Use a box as the object, a surface for it to slide on, sand (or something else) to adjust the weight of the box, and a spring scale for measuring both the weight of the box and the frictional force.

a) Prepare a table in your *Active Physics* log like the one shown for recording data.



Weight (N)	Frictional force (N)
2.0	
4.0	
6.0	
8.0	
10.0	

3. Measure the weight of the box in newtons by suspending it from a newton spring scale. You might have to attach strings to the box to hold it horizontal when it gets heavy with sand. Add sand to adjust the weight of the box to 2 N.

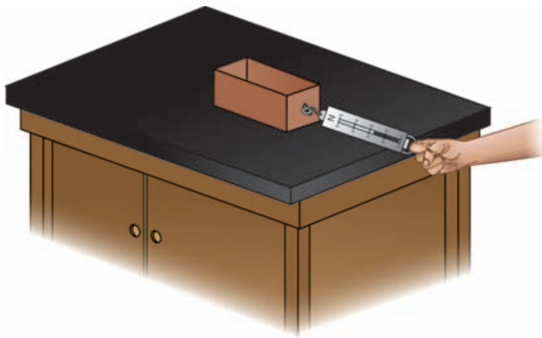


4. Use the spring scale to pull horizontally on the box. Make sure that the spring scale is held parallel to the table surface and that you do not pull up at an angle. Measure the amount of force needed to cause the box to slide on the surface with a slow, constant speed. How will you know that the box is sliding with a constant speed?

a) Record the force measured by the newton spring scale in your table.

b) If the box is traveling at a constant speed in a straight line, what must be the net force acting on it?

c) In view of your answer to *4.b)*, how must the value of the frictional force pulling backward on the box be related to the value of the force with which you are pulling the box forward?



5. Continue adding sand to increase the weight of the box to 4.0, 6.0, 8.0, and 10.0 N, recording the newton force reading of the pull of the spring scale for each weight of the box.

a) Record the frictional force for each weight to complete your data table.

6. Plot a graph of frictional force versus weight. Frictional force is the vertical axis and weight is the horizontal axis.

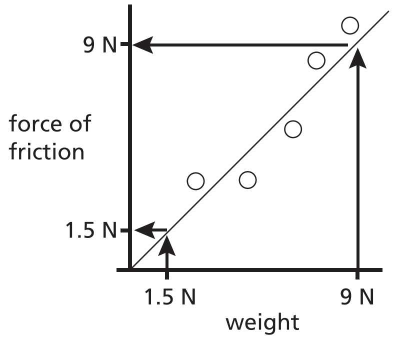
a) Plot the points from the data table. Carefully consider whether the "best-fit" line should be straight or curved. Sketch a "best-fit" line representing the points. (This is a smooth line that has equal distribution of point differences above and below it.)

b) Based on the graph of the data, write a statement in your log that summarizes the relationship between frictional force and weight.

7. These steps will show you how to use the "best-fit" line on the graph of frictional force versus weight to determine what the force of *friction* would be if the same box is pulled on the same surface on the Moon when the box weighs 9 N on Earth.

a) From your graph, determine and record the frictional force on Earth for a box of weight 9 N on Earth.

b) From your graph, determine and record the frictional force on Earth for a box of weight 1.5 N on Earth.



c) You learned in *Section 3* that the weight of an object on the Moon is $\frac{1}{6}$ of the object's weight on Earth. When the box used in this investigation weighs 9 N on Earth, what would the same box weigh on the Moon? Show your calculation in your log.

d) What would be the frictional force on the Moon for a box that weighs 9 N on Earth?

e) If all people and objects weigh $\frac{1}{6}$ on the Moon, what will happen to the friction on the Moon? How will this affect sports on the Moon?

8. Use what you have just learned about friction to ask yourself what walking and running on the Moon is like compared to doing so on Earth.

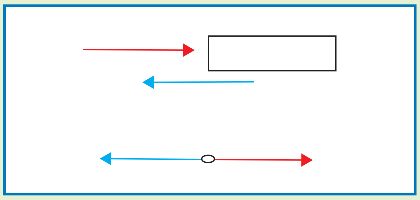
a) Write a statement in your log that explains how friction may affect a person's ability to walk and run on the Moon and thereby, how it will affect sports that involve walking and running.

Physics Talk

FRICTIONAL FORCE

When you observed your walk during the first part of the *Investigate*, you noticed how you push your feet back in order to move forward. The static friction between your shoe and ground is the force that pushes you forward. If there was no friction, you could not get the traction to push your feet back and you would slip in place.

A force called **friction** also arises when an attempt is made to slide an object on a surface. The amount of the force of friction between the object and the surface is equal in magnitude to the amount of horizontal force required to make the object move at constant speed. When the object moves at constant speed, the frictional force resisting the motion is equal in amount but opposite in direction to the applied force causing the motion. This is often shown in a force vector diagram.



The red vector represents the applied force. The blue vector represents the frictional force. Since the two force vectors are equal, the object would have a net force of 0. Newton's second law $(F = ma)$ informs you that if there is no net force, there is no acceleration. Therefore, the object moves at a constant speed.

If the amount of the applied force is less than the maximum frictional force for that weight, the object does not slide at all on the surface; if the amount of the applied force is greater than the force of friction, the object accelerates as it slides across the surface. This occurs on ice where the friction is very small.

In the *Investigate*, you found that the force of friction increases if the weight of the pulled object increases. Since weight on the Moon is $\frac{1}{6}$ the weight on Earth, you can therefore assume that friction on the Moon will be $\frac{1}{6}$ the friction on Earth. That means everybody will be slipping and sliding on the Moon. In basketball, where you have to make a quick shift so you can go left instead of right, the decreased friction may cause you to slip and fall. When you slide into second base in baseball, you may slide right into the outfield.

Frictional forces also depend on surfaces. The lunar (Moon) surface is different than some Earth surfaces. You may be able to vary the surface of the playing field or the traction of the shoes to help players get more friction when they are engaged in a sport on the Moon.

Physics Words

friction: a force that acts to resist the relative motion or attempted motion of objects whose surfaces are in contact with each other.

Checking Up

1. When an object is moving at constant speed, how do the applied force and the frictional force compare in both magnitude and direction?
2. If you try to pull an object with a force less than the frictional force, what will happen?
3. What could be done to increase the friction of playing surfaces of a sport on the Moon?

Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
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The Coefficient of Sliding Friction

1. Astronauts on the Moon found that the soil at the surface is powdery but firm. Describe ways in which you could find out how the nature of the surface beneath an object affects the frictional force. Tell how this would affect the ability to walk or run on the Moon. Some characteristics of surfaces that you also should consider are smooth, rough, clean, dusty, wet, dry, slick, and sticky.

2. The force of sliding friction is proportional to the component of the force perpendicular to the surfaces between the sliding objects. The proportionality constant is called the coefficient of sliding friction and depends on the nature of the surfaces sliding by each other. When two variables are proportional to each other, the graph of one on the vertical axis with respect to the other on the horizontal axis is a straight line passing through the origin. Draw such a line on the graph you constructed in the *Investigate*, making sure it comes as close to your data points as possible. The slope of the line (how much it "rises upward" divided by how much it "runs sideways") is equal to the proportionality constant. Measure the slope of the line you drew.

   a) What is the coefficient of sliding friction for the two surfaces you used?

   b) What are the proper units for the coefficient of sliding friction?

   c) What might you do to change the coefficient of sliding friction between the box and the surface? Design and conduct an experiment.

What Do You Think Now?

At the beginning of this section, you were asked the following question:

- **How and why are frictional forces on Earth and the Moon different?**

Based on what you have learned about frictional forces, how would you answer this question now?

Physics

Essential Questions

What does it mean?

How is the frictional force on Earth related to the frictional force on the Moon for two identical objects moving along the same surfaces?

How do you know?

What observations did you make that support the conclusion that the frictional force on the Moon is $\frac{1}{6}$ the frictional force on Earth when all other conditions are the same?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Forces and motion	Symmetry–laws of physics are the same everywhere	* Experimental evidence is consistent with models and theories

* Physicists assume that the physics on Earth and the Moon are identical. If you could travel to the Moon, how could you measure the frictional forces there?

Why should you care?

Is friction important to the sport you are proposing to NASA? If so, how is the sport going to be different due to the fact that the frictional force on the Moon is less? Does understanding what happens in sports when friction is reduced help you appreciate situations in your own life when friction is suddenly reduced? Some of these situations are potentially very dangerous. (For example, driving a vehicle.) Can you think of what you might do in advance to help with reduced friction situations?

Reflecting on the Section and the Challenge

Friction has some involvement in all sports. Any sport involving walking or running involves friction. Sliding friction is the basis for some sports, such as shuffleboard and curling. Most winter sports are based on sliding; since there is no water, snow, or ice on the Moon, are all winter sports “out,” or could some winter sports equipment be adapted to slide on Moon soil? One thing is certain: your proposal to NASA will not “slide through” if you do not demonstrate that you understand frictional forces on the Moon.

Physics to Go

1. Based on what you have learned about friction, what difficulties do you envision for walking and running on the Moon? Explain your answer.
   a) What problems do you see for quick starts and quick stops for pedestrians, runners, or athletes on the Moon? Explain your answer.

2. How many 10-lb bags of potatoes (that is, a weight of 10 lb on Earth, or 4.5 kg of mass) would a 70-kg person need to carry on the Moon to have the person's combined weight on the Moon (body + potatoes) equal the person's weight on Earth (body only)? Show how you arrived at your answer.
3. Explain how carrying extra weight could create a frictional force that would allow for conventional walking or running on the Moon? Can you think of any problems associated with this?
4. Explain the problems that race cars or bikes would encounter going around curves on the Moon. How might they be solved?
5. Explain how sliding into second base would be different on the Moon and what modifications you might suggest to make the game work better.
6. Identify one sport upon which friction would have no effect as it exists on Earth and on the Moon. Explain why this is the case.
7. Imagine people on the Moon playing a game such as shuffleboard, in which disks are pushed along a surface, stopping at target locations that earn points for the person who pushed the disk. If you want the playing area to be the same size as it is on Earth, and if you want the players to push the disks with the same velocity as on Earth, what might you change about the disks to make playing shuffleboard work on the Moon? Explain what players would notice about your changed disks as they played shuffleboard on the Moon.
8. Will friction between your hand and a football or your hand and a bat be different on the Moon? Explain your answer.
9. If you were to give a shuffleboard disk a push on a shuffleboard court on the Moon, would it slow down just as it does on Earth, or would it take a longer or shorter distance to slow down? Assume that on Earth and on the Moon, the shuffleboard disk starts off with the same speed. Give reasons for your answer.
10. Basketball requires quick starts and stops and quick changes in direction.
    a) Describe how a basketball game will be affected by the decreased friction on the Moon.
    b) Describe a change you can make to basketball to allow the game to be played on the Moon.
11. ***Preparing for the Chapter Challenge***

    Some sports can be improved by having lowered friction. Describe a sport that can be performed better on the Moon than on Earth due to lower friction. How could this sport be adapted to the Moon, either with less or more equipment than needed on Earth?

Inquiring Further

Friction vs. traction

The decreased gravity on the Moon leads to changes in friction. Athletes are more interested in their traction than the frictional force. Look up the difference between friction and traction and think of some ways to improve an athlete's traction on a surface, even in a low-friction environment.