### ACTIVITY 1

**Hypothesize**

1. Imagine you put a playing card on top of a cup, then a coin on top of the playing card. Quickly pull the playing card away. What will happen to the coin? Explain your answer.

Watch the video at <http://tinyurl.com/ast2016-1> and check your prediction.

1. Imagine placing a strip of tape on the floor. Then you ask a friend to run towards you from about 30 meters as fast as possible and to stop exactly on the tape. What will happen to your friend when he or she tries to stop? Explain your answer.

**ConcepTest 1!**

What you demonstrated in your two thought experiments, is **Newton’s First Law**. It states that

“an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force.”

In case 1, the coin stayed in place, as the card was pulled away so fast, that friction did not act. In case 2, your friend had some forward motion, that could not be removed immediately.

### ACTIVITY 2

In this activity, you will be asked to draw forces in diagrams. Forces are usually indicated by arrows. The length of the arrow tells us how strong a force is: the longer the arrow, the larger the force.

In the example on the left, we see two vertical forces acting on a falling wooden plank. Its *Weight* is pulling it down and air resistance (*F-air*) is exerting an upward force. The fact that the arrows are equally large, tells us that the two forces have the same magnitude.

**Engage**

1. Tom has just been promoted and pushes his file cabinet down the hall to his new office. He begins pushing on the file cabinet, but at first it *does not move at all* (Fig. 1). So, he pushes it harder until it is just *on the verge of sliding* (Fig. 2). After the cabinet begins moving, Tom pushes just hard enough to slide it across the floor with a constant speed (Fig. 3).
	1. Draw and label all horizontal forces you think are **acting on the file cabinet** in each figure.

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| MM_pushing**Figure 1.** Tom is pushing the file cabinet, but it is not moving. |
| MM_pushing**Figure 2.** Tom is pushing the file cabinet and it is on the verge of sliding. |
| MM_pushing**Figure 3.** Tom is pushing the file cabinet and it is moving to the right with constant speed. |

**Analyse**

* 1. Why do you think the file cabinet moves in Figure 3 but not in Figures 1 or 2?

### ACTIVITY 3

**Investigate**

Go to the PhET website <http://tinyurl.com/ast2016-2>. Install, run and explore the simulation.

* Select “Show” in the upper right-hand box to display a **free-body diagram**; this shows the forces on the crate. You can pull the crate left and right to simulate a person pushing it.
* Now select “Ice (no friction)” in the right-hand panel. You can change the crate to other objects using the pull-down menu in the centre. Apply some forces to the various objects.
1. Apply a momentary force to an object. Make observations and record them below. You can choose the “Force Graphs” tab at the top to get a complete description of the situation.
2. Describe what you have to do to stop the object.
3. If an object is given a push, and then the force is removed, describe the motion of the object. Be sure to discuss the object’s velocity and acceleration. You may want to discuss the two different cases of “Ice (no friction)” and “Wood”.

**ConcepTest 2!**

Now switch to the tab called **Force Graphs**. Turn on the “Sum of Forces” option on the right (under *Vectors*); this will show a green arrow that indicates the total force on the block—denoted as *F*sum or as the net force, *F*net. Make sure the floor is still Ice (no friction).

* Try pushing the cabinet back and forth again. This time, observe the *F*net arrow.
* You can pause and clear the plot using the controls at the bottom of the screen.
1. Check out the different forces to graph: *applied*, *friction*, *wall* and *sum* to see how they are related to each other. Check “Reset All” at the bottom right to clear the graphs.
* Now, change the floor from “Ice (no friction)" to the “Wood” setting. This flooring has friction. Try moving the block back and forth again.
1. When you give an object a push and then remove the force, describe the motion of the object when there is friction. Be sure to discuss the object’s velocity and acceleration.

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| **NOTE: *Friction*** is usually present when any two surfaces slide against each other. There are two types of friction; ***static friction*** exists between objects BEFORE the objects start moving; ***kinetic friction*** exists between objects that ARE MOVING.  |

* Play around to see if you can tell which kind of friction is stronger—static or kinetic. You can plot both the applied force and the frictional force simultaneously.
1. Which type of friction is stronger?
2. How did you know?

**Model**

1. Now that you have learned about forces, try to come up with some rules about how the forces relate to each other and to motion. Think about the friction force, applied force, net force and how the objects moved. Here are two examples:

“frictional force is opposite in direction to applied force”

“kinetic and static friction do not have the same magnitude”

* Check with your classmates and the teacher about some of these rules.

**Apply**

The figure below shows the plot of the applied and friction forces from a trial in the simulation.



1. Did this object ever start moving? If so, indicate at which time the object started moving.
2. Was the object ever accelerating? If so, indicate where the object is accelerating.
3. Explain how the plot supports (or conflicts with) your rules about the differences between static and kinetic friction.

Try to recreate this plot in your own simulation to check your answers to questions 9-11.

**ConcepTest 3!**

### APPENDIX: ConcepTests to be used

1. A crate is moving to the right. If there is no net force acting on it, the crate will
2. speed up.
3. slow down.
4. **remain at the same speed.**
5. remain at the same speed, but change direction.
6. slow down, change direction and then speed up in the direction it came from.
7. A book is moving to the left. If a net force acts on it to the right, the book will
8. speed up.
9. slow down.
10. remain at the same speed.
11. remain at the same speed, but change direction.
12. **slow down, change direction and then speed up in the direction it came from.**
13. A box is sliding on the floor. If there is a net force acting on the box in the same direction as it is sliding, the box will
14. **speed up.**
15. slow down.
16. remain at the same speed, continuing in the same direction.
17. remain at the same speed, but change direction.
18. slow down, change direction and then speed up in the direction it came from.