

Lesson Title: Static and Kinetic Friction Forces

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Part I: (2 minutes)

Title: "Friction and Types of Friction. Is It Harmful or Useful?!"

Dear students, peace, mercy and blessings of God. Please, allow me to introduce myself. My name is Osama Abu Al-Shawareb, a physics teacher, in Dhahran National Schools, Kingdom of Saudi Arabia. We have seen images of things we use in our daily life. All of them have something in common; friction, which is always around us, but its impact is usually neglected because we always believe it is not useful to us. Can you give examples of friction in our life? Is there any importance to friction in our daily life? What is the direction of friction? Are there different types of friction force? What is the effect of each type? Which is better to have more friction or less friction between the surfaces? We will try to answer these questions and others as we go through this lesson.

Part II: (2 minutes)

Welcome once again. You must have realized that friction is of a great importance in our daily life. It helps us to move as well as to do a lot of things. In order to identify the impact of friction, let's see its effect on the following objects, which have the same mass but move on two different surfaces. The first one, which is on the right, will move on a piece of carpet while the second will move on a piece of polished wood.

Observe the difference in the movement of objects and try to find the cause of this difference. Now, work with your colleagues to identify what is meant by friction force with the help of your teacher.

Part III: (4 minutes)

Peace be upon you. You may have agreed on a definition of friction force with the help of your teacher. Please, write this definition with a pencil, and you will modify this concept during the lesson. To simplify the concept of friction to your minds, let's do the following activity:

To clarify the idea about the origin and source of friction force between objects, let's see the movement of these two bands with each other, note how the surfaces partially combine with each other, you can draw diagrams through which you can illustrate to your colleagues the mechanism of friction force.

You can see that through the following interactive display:

http://phet.colorado.edu/sims/friction/friction_ar.html

Now, let's learn more about friction force, perhaps you have inferred that friction force is a resistance force created when two surfaces in contact move and usually, the direction of friction force is opposite to the direction of movement, but...Does it always have a constant value or a variable one? Are there different types of friction force? What are these types?

To answer these questions, we will exert a force on this object. I'm trying to push the table, but it has not moved, why? There must be a force that prevents it from movement and works in the opposite direction of the force I exerted and is equal to its amount. This force of friction is called static because it keeps the body motionless. As you have noticed, the greater the force I exert, the stronger the friction force is, so the table remains stationary. Let's try harder. I have made a great effort and exerted a very strong force to be able to move this table, however, I felt like there is a force trying to stop me from moving the table. It is certainly the second type of friction force, which is called kinetic friction force as it affects the body during motion. Surprise! I am pushing the table now with a force, but I feel more comfortable. Do you know what that means? It means that I am exerting less force compared to the force I exerted at the beginning of the movement, and this means the kinetic friction force value has been changed during the object's motion; it's a big surprise and an unexpected result. Now, discuss the factors that affect the force of friction with your colleagues and we will meet shortly.

Part IV: (4 minutes)

Welcome again. We have previously identified two types of friction; the first one is exerted when there is no relative motion between the two surfaces and is called static friction. The second type acts when the surfaces are in relative motion and is called kinetic friction. Now, we will identify the factors that affect friction force.

Friction force depends mainly on the materials that make up the surfaces, for example, the force of friction between the sole of your shoes and a cement surface is larger than that between your shoes and an ice surface. It may seem logical to assume that friction force depends also on the area of the surfaces or their relative speed, but experiments have shown that this is not true; what really affects friction force is the normal force between the objects, the greater the push force of an object to another, the greater the friction force is.

The normal force as you have learned earlier acts vertically on objects, as follows:

For example, if you pull an object on a surface at a constant velocity, the friction force must be equal in magnitude and opposite in direction to the pull force according to Newton's laws. You can drag an object of a known mass on the surface of a table at a constant velocity by a spring balance to measure the force that pulls the object, and then you can put an additional mass on top of the first object to increase the normal force and re-measure again and so on.

Kinetic friction can be experimentally calculated by using the following formula:

$F_k = \mu_k N$, where μ_k is the coefficient of kinetic friction, while static friction can be calculated by using the following formula:

$F_s = \mu_s N$, where μ_s is the coefficient of static friction, and $\mu_s N$ represents the maximum value for static friction force that must be overcome before the object starts to move.

The following table shows the coefficients of friction between different surfaces:

Surfaces	μ_s	μ_k
Rubber on dry concrete	0.8	0.65
Rubber on wet concrete	0.6	0.4
Wood on wood	0.5	0.2
Steel on dry steel	0.78	0.58
Steel on steel (with oil)	0.15	0.06

Note the difference between using dry steel and using steel with oil, and due to the importance of using oil to reduce friction between steel surfaces, you may relate to the use of car engine oil and its impact on extending the life of car engines, you may search the Internet regarding this issue and make a comparison among the types of oils their viscosity and role in reducing friction, you can also interview a specialist mechanical engineer and make a presentation to your colleagues about the findings of this search.

Now, in the following activity, let's try to calculate the values of static and kinetic friction coefficients of an object which in this case is a piece of wood located on the surface of a horizontal wooden surface.

Activity II: (15-30 minutes)

Part I:

Welcome again. As we have mentioned earlier, in this activity, we will try to determine the values of static friction and kinetic friction coefficients of an object which in this case is a piece of wood located on the surface of a horizontal wooden surface in order to compare their values.

As you can see we will need the following apparatus: pulley, pulley clamp, wooden surface, string or rope, a wooden box, and spring balance.

Procedure:

- 1 – Fix the pulley to the table edge and the surface using a pulley clamp.
- 2 - Tie one end of the string to the spring balance and slip the other end through the pulley to the wooden box.

3 - Measure the mass of the wooden piece and convert it to weight as you have learned earlier, and record the reading to represent the vertical force in the data table 1, 2, and 3.

The reading we have is 1030 gram, we convert it to kilogram and then to Newton, to represent the normal force.

Table

4 – Now, move the wooden surface or the wooden box away from the pulley to the extent permitted by the string while maintaining the remaining wooden box on the surface.

5 - Put the spring balance vertically to form a right angle with the wooden surface in this way, then pull the balance up slowly, and observe the force. As you can see, a force is exerted and indicated on the spring balance reading, however the wooden box has not moved yet. Increase the force and record the reading when the wooden box starts to move. This reading represents static frictional force and is recorded in table 1 as follows.

TABLE

6 - Repeat the previous two steps twice to ensure accurate measurements and record the readings each time and calculate the average static friction force.

TABLE

As you can see, we have measured the amount of static friction force, I'll leave you now to make this part and come back again to measure the amount of kinetic friction force.

Part II:

Welcome again. In the first part of the activity we have measured the static friction force. You may have noticed that we must repeat the measurements, and record the readings each time, to ensure the accuracy of the readings as has always been the case with the scientific method approach.

Now, we are going to measure the amount of kinetic friction force by using the same apparatus. We have recorded the static friction force value when the object starts moving, but now we will keep on pulling to record the amount of kinetic friction force .So, what do we do now?

1. Put the spring balance vertically at the pulley to form a right angle with the wooden piece and the balance, then pull the balance up slowly, and observe the force needed for the wooden piece to start sliding. Keep on pulling until the wooden piece moves with constant motion on the horizontal surface.
2. Record the reading in table 2. This reading represents kinetic frictional force. Note that the reading on the spring balance should be converted from gram to kilogram and then to Newton by multiplying it by the acceleration due to gravity.

TABLE

2 - Repeat the previous step twice and make sure to record the readings each time and take the average.

TABLE

3 - Use the data obtained from Tables 1 and 2 to calculate the coefficients of static and kinetic friction by using the formulas we have introduced earlier. Record their values in Table 3.

Now, compare the values of static and kinetic friction coefficients that you have obtained and check whether the results are reasonable or no by checking the units used.

TABLE

Part III:

Peace be upon you, as you have noticed during the activity, the value of static friction force and thus the value of static friction coefficient was greater than that of kinetic friction coefficient as recorded in the table and this proves that the force trying to prevent an object from motion is greater than the force that opposes objects at motion.

We need to take into consideration that static friction force is a response to another force trying to make an object starts moving. If there is no force exerted on the object, the static friction force is equal to zero, but if there is a force trying to cause movement, the static friction force increase to reach the maximum value before it is overcome by the acting force that causes the object to start moving.

You can repeat the experiment, but using other surfaces with different characteristics to check your results.

Closing Remarks:

Now ... Before the end of the lesson ... Try to answer the following question:

If you ski towards the bottom of a hill, and you would like to determine the coefficient of kinetic friction between the ski and the surface of the hill, how can you do that? Try to be accurate when finding the answer.

I hope that you have enjoyed and benefited from this lesson. Please, accept my regards.

Peace, mercy and blessings of God