Friction is Fun

Subject Area(s) Physics

Associated Unit

Associated Lesson

Activity Title Friction is fun

Header

Image 1
ADA Description: Bear didn't heed warning sign
Caption: None
Image file: friction1.jpg
Source/Rights: Copyright © This friction is from web
http://www.school-for-champions.com/science/friction_uses.htm

Grade Level 11 (9-12)

Activity Dependency

Time Required: 40 minutes

Group Size: Make 8 groups out of students

Expendable Cost per Group US$___

Summary

This activity is a hands-on demonstration to help students better understanding the concept of friction, how it affects our life and what the advantages and disadvantages of friction are. Then as an example of engineering friction, a nanoscience research topic that is about mimicking micro-scale hairs on toes of a lizard and creating a super controllable adhesive synthetic material will be introduced to the students.

Engineering Connection

Engineers care about friction! In many cases they are trying to reduce friction in order to help useful work being accomplished. The energy in overcoming friction is dispersed as heat and is considered to be wasted because useful work is not accomplished. This waste heat is a major cause of excessive wear and premature failure of equipments. Also in any type of vehicle—such as a car, boat or airplane—excess friction means that extra fuel must be used to power the vehicle. In other words, fuel or energy is being wasted because of the friction. Aerodynamic engineers are trying to improve the car's body or shape of airplanes to reduce the air friction when they are moving. For many other situations, engineers are trying to create friction to prevent slipping or sliding. They are always trying to have a good compromise in their designs to get just enough friction or a proper combination of frictions.

Engineering Category = #1

Choose the category that best describes this activity's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

Keywords

Friction, Incline Plane, Coefficient of friction, Nanoscience, Nanotechnology, Biomimetics

Educational Standards

Texas, Science: (A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

Texas, Science: (B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials

Pre-Requisite Knowledge

Learning Objectives

After this activity, students should be able to:

- List what some important uses of friction are
- Explain how friction can be a nuisance
- Define what static and kinetic friction are in sliding friction
- Write down the standard friction equation and explain each term
- Describe coefficient of friction
- Describe how coefficient of friction could be determined via an inclined plane
- Explain a summary of the article about super friction micro-hair of gecko toes
-

Materials List

Each group needs:

- copper object (e.g. penny)
- wood surface (e.g. letter size clipboard)

- metal surface (e.g. base of a ring stand)
- ruler, protractor, and scientific calculator
- data table (attached)

To share with the entire class:

- video projector and a big screen

Introduction / Motivation

Whether it's driving on icy roads, rock climbing, or getting a better grip on a bat, the science of friction and adhesion plays a role—large and small—in many human activities.
Have you ever thought why geckos can run rapidly up walls or even upside down on polished glass? What helps gecko to move on vertical surfaces like we walk on the floor? Imagine that we could climb up a wall like a gecko. Scientists have been asking these questions for over a hundred of years. In a new research paper published in the Royal Society journal Interface, biology professor Kellar Autumn shows how the micro-hairs on gecko toes can reveal new insights into the fundamental nature of friction and adhesion.

Image 2
ADA Description: Gecko on a glass window
Caption: None
Image file: gecko.jpg
Source/Rights: Copyright ©

So here let's figure out first what friction means in physical science.
Friction is a force that resists the motion of an object that is in contact with another object or material. The cause of friction is a combination of molecular adhesion, surface roughness, and deformation effects. If the objects are not moving relative to each other, the friction force is called static. If they are moving, the friction is kinetic. When two solid objects are in contact and a pushing force is applied to slide one object against the other, sliding friction force resists the motion. If F is the force pushing on an object and Fr is the force of friction, the relationship between F and Fr will determine whether the object will slide or not move at all. If the pushing force F is less than the resistive force of friction Fr (written as $F < Fr$), there is no motion and the

objects remain static with respect to each other. In this case, the friction is considered static friction, which means it is not moving.

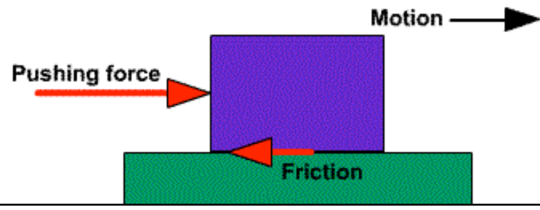


Image 3
ADA Description: this picture shows sliding friction
Caption: None
Image file: friction-slide_kinetic.jpg
Source/Rights: Copyright © This friction is from web http://www.school-for-champions.com

Static > Kinetic

What is interesting is that the static friction that holds an object in place is greater than the kinetic friction that slows down a moving object. In other words, once you start an object moving, the friction decreases from the static friction holding the object in place. You have seen this in trying to slide a heavy box across the floor. It may be very difficult to move, but once it starts sliding, it is easier to push.

Since friction is a resistance force that slows down or prevents motion, it is necessary in many applications to prevent slipping or sliding e.g. walking, writing, moving car on the road, etc. In those cases, there is an advantage of having friction. However, too much friction can be a nuisance, because it can hinder motion and cause the need for expending extra energy or cause heating up or wearing of contact surfaces. A good compromise is necessary to get just enough friction.

Standard friction equation (Friction is f**UN)**

When a force is applied to an object, the resistive force of friction acts in the opposite direction, parallel to the surfaces. The standard equation for determining the resistive force of friction when trying to slide two solid objects together states that the force of friction equals the coefficient friction times the normal force pushing the two objects together. This equation is written as

$$F_r = \mu N$$

where:

- F_r is the resistive force of friction
- μ is the coefficient of friction for the two surfaces (Greek letter "mu")
- **N** is the normal or perpendicular force pushing the two objects together
- μN is μ times **N**

This equation applies to both static and kinetic sliding friction. Static friction is the friction before an object starts to slide. Kinetic friction is the friction when the object is actually moving or sliding.

Weight on incline

If the weight is on an incline, the normal force will be reduced by the cosine of the incline angle.

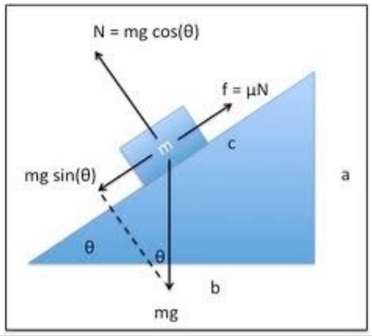


Image 4

ADA Description: this picture shows forces on weight on incline

Caption: None

Image file: incline.jpg

Source/Rights: Copyright ©

The equation is

$$\mathbf{N = w\cos(\theta)}$$

where:

- **N** is the normal force on the incline
- **w** is the weight
- **θ** is the incline angle
- **cos(θ)** is the cosine of the angle **θ**
- **Wcos(θ)** is **W** times **cos(θ)**

The *coefficient of friction*, **μ** (mu), is a number related to the two specific surfaces that are in contact with each other. It is very dependent on the roughness of each surface and how the materials slide against each other. Although there are charts listing average values of the coefficient of friction for various materials, the only true way to establish the number is by experiment and testing or empirical measurements. Also, there are no good formulae or equations to predict **μ**. By dividing both sides of the standard friction equation $\mathbf{F_r = \mu N}$ by **N**, you will get the equation $\mathbf{\mu = F_r/N}$, where $\mathbf{F_r/N}$ is $\mathbf{F_r}$ divided by **N**. This relationship indicates that if you can measure the friction force $\mathbf{F_r}$ and know the normal force **N** pushing the two objects together, you can determine the coefficient of friction **μ**.

A convenient device to measure the coefficients of friction for a pair of materials is an inclined plane device. In order to calculate μ_s (static coefficient), the slope (angle) of the inclined plane is increased gradually until the object first begins to slide down the plane. At that angle, the component of the weight of the object (F_g) parallel to the plane has just succeeded in overcoming the force of static friction. Based on the Newton's second law of motion, this parallel component ($F_g\sin\theta$) is approximately equal to the static frictional force ($\mu_s F_N$): $\mathbf{F_g sin\theta = \mu_s F_N}$. Through "free-body" force analysis, a normal force (F_N) that the object acts on the plane surface is equivalent to the weight of the object perpendicular to the plane ($F_g\cos\theta$): $\mathbf{F_g cos\theta = F_N}$. Mathematically combining the above two equations will generate a useful calculation formula: $\mathbf{\mu_s = tan\theta}$, the coefficient of static friction is determined by the angle of the inclined plane, which is a pure number and has no unit.

Procedure

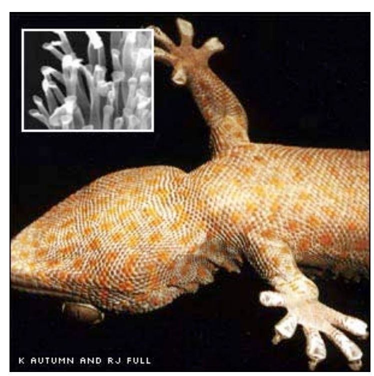
Before the activity just write down the sentence "friction is FUN" on the board and have the students to notice that FUN stands for friction general formula. So F is equal to U that reminds coefficient of friction times N that reminds the normal contact force on the object. Then make 8 groups out of students and number them from 1 to 8. Then ask the students to following steps and record their data in the data table.

1. Place a penny in the center of a clipboard, and slowly lift up one end of the clipboard to generate the effect of an inclined plane.
2. Gradually increase the slope of the plane until the penny first begins to slide down, and record the angle of the inclined plane on the data table.
3. Repeat Step 1 and Step 2 twice, and apply a formula $\mathbf{\mu_s = tan\theta}$ to calculate the coefficient of friction for those three trials. Next, find out the average of the coefficient on the surfaces between copper and wood.
4. Use the base surface of a ring stand (must be smooth without rust) as a metal surface to repeat the above steps for another three trials, and then calculate the average of the coefficient on the surfaces between two kinds of metals.

Then discuss the result with the class.

The next part of the activity is to help students get familiar with one of the nanoscience research topics and that is reviewing article and watching video about mimicking gecko toes to create a super friction synthetic material.

Image 5
ADA Description: this picture shows gecko toes
Caption: None
Image file: geckotoes.jpg
Source/Rights: Copyright ©



Geckos climb vertical and even inverted surfaces with ease using millions of nano-scale adhesive foot-hairs on each toe. Each foot-hair splits into hundreds of tips only 200 nanometers in diameter, permitting intimate contact with rough and smooth surfaces alike. Geckos' adhesive microstructure requires minimal attachment force, leaves no residue, is directional, detaches without measurable forces, is self-cleaning, and works underwater, in a vacuum, and on nearly every surface material and profile. So scientists are getting inspiration from gecko toes and try to make an controllable super adhesive material that they may use it to make climbing robots or spider man in the future.

Image 6
ADA Description: this picture shows spider man with gecko type fingers
Caption: None
Image file: spiderman.jpg
Source/Rights: Copyright ©

Here the related video mentioned in the multimedia support part being shown into the class. It is a very interesting video and the students show a lot of interest on that. Also, it would be very helpful if students have the related scientific article which is again referred in the multimedia support part for reference.

Attachments

1. Data Table

Safety Issues

•

Troubleshooting Tips

Investigating Questions

Assessment

Activity Extensions

Additional Multimedia Support

- Scientific video: "**Gecko Climbing Robot on Weird Connections**"
  http://www.youtube.com/watch?v=anbqiBUmKIA

- Scientific American article **"Sticky Science: Gecko Toes Key to Adhesive That Doesn't Lose Its Tackiness"**
  http://www.scientificamerican.com/article.cfm?id=sticky-situation-gecko-toe-adhesive

References

http://www.school-for-champions.com/science/friction_uses.htm

http://www.scienceteacherprogram.org/physics/wang03.html

Other

Redirect URL

Contributors

Parnia Mohammadi, Roberto Dimaliwat

Copyright

Supporting Program

National Science Foundation GK-12 Program, University of Houston

Version: September 2010

Name:----------------------- Date:--------------------

Find out coefficient of friction from an incline plane and record the data in the following table.

1. Results from each team

	Angle on clipboard (inclined plane of wood surface)	**$\mu_s = \tan\theta$** coefficient of copper on wood	Angle on ring stand (inclined plane of metal surface)	**$\mu_s = \tan\theta$** coefficient of metal on metal
Trial 1				
Trial 2				
Trail 3				
Total				
Average				

2. Results from entire class (eight teams)

	μ_s of copper on wood	μ_s of copper on metal
Team one		
Team two		
Team three		
Team four		
Team five		
Team six		
Team seven		
Team eight		
Class total		
Class average		