LAB 8

Lab Handout

Lab 8. Friction: Why Are Some Lubricants Better Than Others at Reducing the Coefficient of Friction Between Metal Plates?

Introduction

Friction plays an important role in many of our daily experiences. In many cases, friction between two surfaces is beneficial. Friction between your shoes and the ground allows you to walk; friction between your tires and the road allows your car to move forward; and friction keeps your cell phone from sliding off a table if you accidently bump into it. Frictional forces also produce heat. When you rub your hands together on a cold day, for example, friction produces heat and warms your hands. Sometimes, however, producing heat from friction is an undesirable outcome or unwanted by-product of a specific process. Take the internal combustion engine found in most cars as an example. An internal combustion engine has a set of pistons that are constantly moving when the engine is on. Each of these pistons is found inside a metal cylinder (see Figure L8.1). For the engine to work, each piston must be able to slide up and down inside a metal cylinder. The sliding motion, however, produces heat because of the friction that exists between the piston and the cylinder, which can cause parts of the engine to heat up and eventually reach a temperature where the different parts of the engine expand and deform or break.

The coefficient of friction is the ratio of the frictional force and the normal force that exists between two surfaces when they are in contact. There are two types of friction coefficients. The first type is called the *coefficient of static friction*. This measure is used when there is no relative motion between the two surfaces. For example, when a car is at rest we describe the friction that exists between the tires and the ground using the coefficient of static friction. The second type is called the *coefficient of kinetic friction*. This measure is used when there is relative motion between two surfaces. The coefficient of kinetic friction affects the amount of heat that is generated when objects that are in contact move past each other. In general, as the coefficient of kinetic friction increases, so does the amount of heat that is produced as the result of friction. Finally, it is important to keep in mind that a coefficient of friction, whether it is static or kinetic, only exists between materials that are in contact. For example, the coefficient of kinetic friction between iron and copper is 0.29 when these two materials are in contact, and the coefficient of kinetic friction between iron and zinc is 0.21 when these two materials are in contact. Iron does not have a coefficient of kinetic friction unless it is in contact with another material, such as copper or zinc.

As mentioned earlier, when a piston slides up and down in a cylinder, friction causes the engine to heat up quickly. Engineers therefore use *lubricants* to reduce the coefficient of kinetic friction between the piston and the cylinder. A lubricant is simply a substance that is put in between two materials to reduce the heat generated when the two surfaces move past each other. Oils are often used as lubricants. An oil can be defined as a viscous liquid

that is composed of hydrogen, oxygen, and carbon atoms. Oils do not mix with water, and they feel slippery. *Viscosity* is a measure of how resistant a liquid is to flow. Honey, for example, has a higher viscosity than water, so honey flows slower than water. There are many different types of oils. Each one has a unique set of physical properties. Table L8.1 includes the physical properties and sources of 10 different types of oil. Some of these oils are better than others at reducing the coefficient of kinetic friction between metals because of their unique physical properties.

To be able to make new and better lubricants for engines, it is important to understand what makes oil such a good lubricant. Scientists and engineers, in other words, need to understand how the different physical properties of an oil affect or do not affect its ability to reduce the coefficient of kinetic friction between two materials. This type of research is

FIGURE L8.1

A cross-section of an internal combustion engine, showing three different pistons. Each piston is found inside a cylinder.

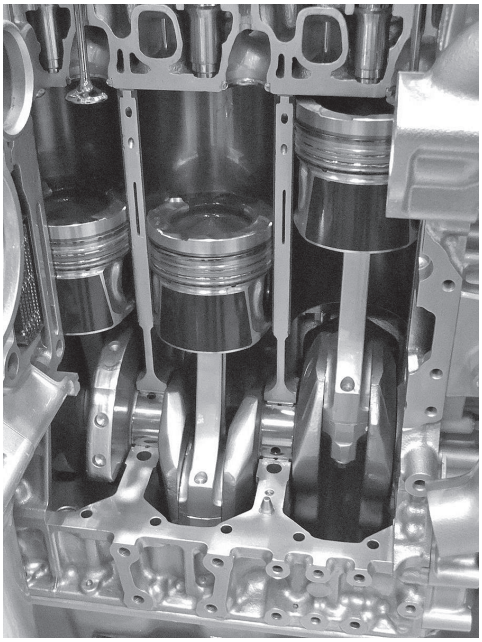


TABLE L8.1

Sources and physical properties of different types of oils

Name	Source	Physical properties			
		Density (g/cm^3)	Viscosity (cP)	Melting point (°C)	Boiling point (°C)
Motor (SAE 40)	Petroleum	0.90	319	–12	315
Motor (SAE 30)	Petroleum	0.89	200	–30	300
Motor (SAE 20)	Petroleum	0.88	125	No data	280
Motor (SAE 10)	Petroleum	0.87	65	No data	260
Canola	Plants	0.91	57	–10	205
Castor	Plants	0.96	985	–18	313
Corn	Plants	0.90	81	–11	230
Mineral	Petroleum	0.87	44	–9	300
Olive	Plants	0.91	84	–6.0	300
Peanut	Plants	0.91	68	3	255

Note: cP = centipoise.

important because it is not enough to determine which type of lubricant works best as a lubricant (like a product reviewer would) if the goal of the scientist or engineer is to create a better product. Instead, scientists or engineers must understand why a lubricant works. It is also important for scientists and engineers to understand how different conditions, such as when there is a high coefficient of kinetic friction or a low coefficient of kinetic friction between two objects, affect how well a lubricant works. Your goal for this investigation is to explain why a lubricant, such as oil, is able to reduce the coefficient of kinetic friction between two surfaces.

Your Task

Use what you know about forces and motion, structure and function, and the role models of systems play in science to design and carry out an investigation to determine how different types of oils change the coefficient of kinetic friction between two metal plates. You will then use what you know about structure and function to develop a model that can be used to explain why some oils reduce the coefficient of friction more than other oils. Your model can be conceptual, mathematical, or graphical. To be valid or acceptable, your model must take into account the different physical properties of the oils. Once you have developed your model, you will need to test it to determine if it allows you to predict how the use of other oils (which you have not tested before) will change the coefficient of kinetic friction between two plates, using only the physical properties of these other oils as a guide.

The guiding question of this investigation is, ***Why are some lubricants better than others at reducing the coefficient of friction between metal plates?***

Materials

You may use any of the following materials during your investigation:

Consumables

- Motor oil (SAE 10)
- Motor oil (SAE 20)
- Motor oil (SAE 30)
- Motor oil (SAE 40)
- Canola oil
- Castor oil
- Corn Oil
- Mineral oil
- Olive oil
- Peanut oil
- Wax paper
- Tape
- String

Equipment

- Safety glasses or goggles (required)
- Chemical-resistant apron (required)
- Gloves (required)
- Electronic or triple beam balance
- Aluminum metal plates
- Brass metal plates
- Steel metal plates
- Spring scale or force probe
- Mass set
- Tray
- Stopwatch
- Meterstick

Safety Precautions

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

1. Follow safety precautions noted on safety data sheets for hazardous chemicals.
2. Wear sanitized indirectly vented chemical-splash goggles and chemical-resistant, nonlatex gloves and aprons during lab setup, hands-on activity, and takedown.
3. Never put consumables in your mouth.
4. Do not eat or drink any food items used in the lab activity.
5. Consult with the teacher about disposal of waste oil. Do not pour any chemicals down the lab sink.
6. Clean up any spilled liquid on the floor immediately to avoid a slip or fall hazard.
7. Wash hands with soap and water after completing the lab.

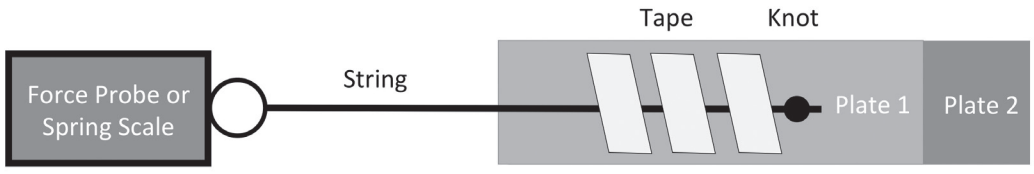
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in developing your model is to determine how the addition of different types of oils changes the coefficient of kinetic friction between two metal plates. One way to gather the information you need to determine the coefficient of kinetic friction between two metal plates is to measure the amount of force it takes to pull a metal plate across another one. Figure L8.2 shows how you can measure this force.

FIGURE L8.2

Equipment used to measure the force required to pull a metal plate across another metal plate



Before you can begin conducting your tests, however, you must decide what other type of data you will need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?

- How do the components of the system interact with each other?
- How could you keep track of changes in this system quantitatively?
- How might the structure of a lubricant impact its function in reducing the coefficient of friction?
- What information do you need to calculate the coefficient of kinetic friction?
- What are all the forces that are acting on each object?
- Are any of the pairs of forces balanced?

To determine *how you will collect the data,* think about the following questions:

- What comparisons will you need to make?
- What other factors will you need to control during your tests?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What types of patterns could you look for in your data?
- What type of calculations will you need to make to determine a coefficient of kinetic friction?
- How could you use mathematics to describe a change in a coefficient of kinetic friction?
- How could you use mathematics to document a difference between types of lubricants?

Once you have determined how the addition of different types of oils changes the coefficient of kinetic friction between two metal plates, your group will need to develop your conceptual model. The model must be able to explain why some of the oils were better than others at reducing the coefficient of friction between metal plates. Your model also must include information about the physical properties of the oils. The physical properties of each oil are provided in Table L8.1. Your model should also include information about what you think is happening between the oils and the plates on the submicroscopic level.

The last step in this investigation is to test your model. To accomplish this goal, you can use different oils (ones that you did not test) to determine if your model enables you to make accurate predictions about how these oils will change the coefficient of kinetic friction between two metal plates. If you are able to use your model to make accurate predictions about how the oils function as a lubricant based on their structure, then you will be able to generate the evidence you need to convince others that your model is valid.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

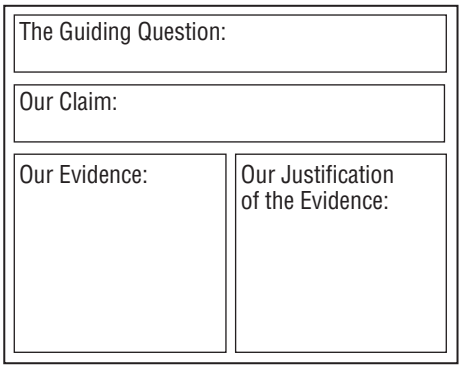
- how the culture of science, societal needs, and current events influence the work of scientists; and
- how scientists use different methods to answer different types of questions.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L8.3.

FIGURE L8.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!