# EVALUATING
# ACADEMIC READINESS
# FOR APPRENTICESHIP TRAINING

**Revised for**

# ACCESS TO APPRENTICESHIP

## SCIENCE SKILLS
## FRICTION and OTHER FORCES
## in BUILDING MATERIALS

## AN ACADEMIC SKILLS MANUAL
## for
## The Construction Trades: Structures

This trade group includes the following trades:
Drywall & Acoustical Applicator, General Carpenter,
Mason (Brick & Stone and Restoration), Reinforcing Rod Worker, Roofer,
Terrazzo, Tile & Marble Mechanic

***Workplace Support Services Branch***
***Ontario Ministry of Training, Colleges and Universities***

***Revised 2011***

In preparing these Academic Skills Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual.

**This trade related material is not intended to instruct you in your trade. It is used only to demonstrate how understanding an academic skill will help you find and use the information you need.**

# SCIENCE SKILLS
# FRICTION AND OTHER FORCES IN BUILDING MATERIALS

***An academic skill required for the study of the Construction Trades: Structures***

## *INTRODUCTION*

You are on a roof nailing on shingles when a gust of wind blows a shingle down the roof. After it slides a bit, it stops moving so you can grab it and put it back where it goes. Why didn't the shingle slide all the way off the slanted roof and fall to the ground?

It stopped sliding because there is a force called friction that resists the movement of one object over another. It is the force of friction that keeps a shingle in place while you get your nailing gun to secure it to the roof. Friction has an effect on all the materials you use on the construction site. It is a help when it holds a nail tightly secured in a sheet of drywall so the wall stays in place and doesn't crack the plaster. It keeps a double hung window from sliding down after it is raised. You take advantage of the friction when you use a piece of sandpaper to smooth a rough surface.

Friction can also be a hindrance. If you don't lubricate certain tools to reduce the friction between moving parts, the heat produced by friction can cause them to wear out. Friction causes machinery to produce loud noises that can damage workers' hearing and it makes it more difficult to push a load across the floor. Understanding friction can help you take advantage of its helpful effects and reduce its negative effects on construction materials.

Other forces besides friction affect building materials. When roof trusses are placed on a wall, the weight of the roof puts a stress on the material that makes up the wall. The material must be strong enough to support the weight or the building can collapse when the load is too heavy. You can pound a large beam into place but the same force would shatter a pane of glass. The way different building materials react to force must be considered in deciding how to work with them.

This skills manual looks at the force of friction and its effects. It covers the following topics:

- Why friction occurs
- Static and kinetic friction
- Friction between solid objects
- Limiting the effects of friction
- Making the most of friction
- Other forces in building materials

## *WHY FRICTION OCCURS*

Friction is a basic force that has an effect on everything in our world. ***Friction*** *is the force that opposes motion between two surfaces*.

- Whenever one object moves over the surface of another, or when an object moves through water or air, the object meets a resistance force that tends to slow it down.
- Since all objects have some contact either with another object or with the air, all objects feel some effect of friction.

### Why Friction Happens

There are several reasons why friction happens:

- Objects are made from molecules. No matter how smooth a surface looks to our eyes, at the molecular level irregular projections grip each other resisting movement. The more closely two surfaces press together, the stronger the grip.
- There is also a force of attraction between molecules of different materials that causes them to resist moving apart. The strength of this attraction depends on the structure of the materials in contact.

The exact reasons why friction varies with different surfaces are not fully understood. In general, the rougher the two surfaces are and the more closely they press together, the stronger the force of friction becomes.

- Objects slide more easily on a surface such as ice or Teflon than on a concrete floor.

An object that is moving has a certain amount of kinetic energy. Friction causes some of the kinetic energy to be converted to heat energy. As the amount of kinetic energy becomes smaller, the object slows down. If two objects rub together as they quickly move back and forth, they can get hot because of the transfer of energy from motion to heat.

When you run an engine using gasoline or electricity, you put energy into it. However, you never get the same amount of energy back out of the machine as you put into it. Friction steals some of the energy along the way. That energy is experienced as heat and sound.

- Whenever friction limits the efficiency of an engine in this way, you try to reduce friction as much as possible.
- At the same time, friction is used in the engine to make brakes, clutches and gears work. Here you work with friction, strengthening its effect.
- So friction can be both a help and a hindrance, an ever-present force you have to learn to control.

## *STATIC AND KINETIC FRICTION*

When you push a carton of tiles across the floor to where you want to install them, it is harder to get it moving in the first place than to keep it moving. We describe these different effects as static friction and kinetic friction.

- ***Static friction*** *makes it difficult to start an object moving*.
- ***Kinetic friction*** *opposes the motion of an object that is already moving*.

Because of static friction, a resting object must be given a push to get it moving across another object. Say you have to slide a cement block over to where it is going to be placed on the foundation. There is a resistance created by the bonds of attraction between the block and the floor. Your muscles need to provide the energy to first overcome static friction in order to start the load moving, and then to overcome kinetic friction to keep it in motion. The force you use to start the block moving is greater than the force you need to keep it going.

## *FRICTION BETWEEN SOLID OBJECTS*

The effects of friction on a construction site, whether you have to push a load, use sandpaper to smooth a piece of wood, or rely on friction to hold a screw in place, mostly occur between solid objects. Friction between two solid objects is usually greater than friction between a solid and a liquid. Sometimes liquids are used between two solid surfaces to reduce friction.

The surface of solid objects can be shaped in different ways. They can be flat, spherical, cylindrical or irregular. The surface of an object affects the amount of force needed to overcome friction when it moves over the surface of another object.

### Sliding friction

When a solid object slides over the flat surface of another solid object the movement creates a large amount of friction called ***sliding friction***. Sliding friction creates heat and noise, and causes surfaces to wear out quickly.

The smoother the surfaces in contact, the less force is needed to overcome sliding friction. When the surface areas in contact are narrow, sliding friction is also reduced. It is easier to drag a load on runners than when it is flat on the ground.

### Rolling friction

If a solid object moves over a spherical or cylindrical surface such as a ball bearing or a roller, there is less friction than when two flat surfaces move over each other. Rolling motion creates less friction than sliding motion. This reduced friction of rolling motion is called ***rolling friction***.

If you pick up heavy material at a warehouse to deliver it to the construction site, it is easier to move it along on using rolling bars than to carry or push it to get it to your truck. The beer store uses the same types of rollers to help you move a case of beer. The huge blocks of limestone used to build the pyramids were rolled to the construction site on round logs.

### Friction in a wheel and axle

Using wheels allows you to move much larger loads because friction is greatly reduced. There is some friction that can cause an axle to heat up and there is some friction between the wheel and the road. (This friction is what causes the squeaky wheel.)

Both sliding and rolling friction are present in a wheel and axle. When a wheel rotates around its axle, the two surfaces are in contact and they rub together.

- This creates sliding friction in the area of contact, which causes heat and wear in this area.
- At the same time, the outer surface of the wheel experiences rolling friction. This reduces the amount of friction considerably compared to if you were pulling the load without wheels. There is less resistance to motion and so less effort is required to move a load.

Even with these two frictions at work, using wheels connected to an axle is a much more efficient way to transport a load than sliding it over the ground.

The next step in efficiency is to reduce the sliding friction between the wheel and the axle. There are two primary methods of doing this.

1. The first way is to coat the area of contact with some kind of ***lubrication***.
2. The second way is to change the sliding friction to rolling friction. This is done by using ***bearings*** that roll, instead of sliding, in the contact area between the wheel and axle.

## *LIMITING THE EFFECTS OF FRICTION*

Friction creates heat in moving parts, resulting in the parts wearing out faster. It can also cause excess noise in machinery, creating a potential hearing problem in the people working nearby. It is calculated that friction adds at least 5% to the force needed to move a load up an incline. (On the other hand, it is easier to push a heavy load up a ramp than to lift it straight up.) Working against the force of friction requires energy, which can be expensive. For these reasons it is important to limit the effects of friction.

A solid part wears out less quickly when it is in contact with fluid oil instead of a solid surface. When a layer of oil is placed between two solid surfaces, the oil adheres (sticks) to the solids.

As one solid surface moves over the other, it is actually the oil molecules adhering to the solids that slide over each other. Oil between moving parts in a motor allows them to move back and forth with less heat and noise. This is the way lubrication works to lessen friction.

Liquid molecules create less friction as they flow over each than solid molecules do. Even so, liquids are still affected by friction. As a liquid flows through a tube, the walls of the tube create friction, slowing down the liquid.

This is one reason a pump must be used to push liquid through a system of enclosed tubing. Also, the more bends in the pipes holding the flowing liquid, the more the friction slows it down. A system with many bends in it requires more energy to pump the flowing liquid.

Even gas molecules create friction in moving objects. When an object falls through the air, it makes contact with invisible air molecules. The friction created by this contact slows it down. Hot air molecules moving in ducts from a furnace are slowed by friction when they rub against the walls of the ducts.

To avoid using too much energy in order to overcome friction, engineers look for ways to decrease the amount of friction. There are several ways to reduce friction:

- the use of suitable materials (steel or glass are smooth surfaces and so create less friction than rubber or wood),
- the use of a lubricant which flows between parts to create a fluid surface, thus creating less friction than that between solid surfaces (see Figure 1),
- the use of ball bearings in machines – steel balls that roll on another steel surface create only 1/100 the friction of flat steel that slides on steel,
- the use of wheels or rollers to move objects,
- making sure that moving parts that are in contact are fitted precisely, so nothing is rubbing together unnecessarily, and
- polishing surfaces so they are as smooth as possible.

***Lubrication***

The most common method of reducing friction is lubrication. Friction is reduced to a much lower level when lubrication creates fluid friction where originally there was dry friction. When a layer of oil is placed between two solid surfaces, the oil adheres (sticks) to the solids. As the solid surfaces move over each other, it is actually the oil molecules adhering to the solids that slide across each other. See Figure 1.

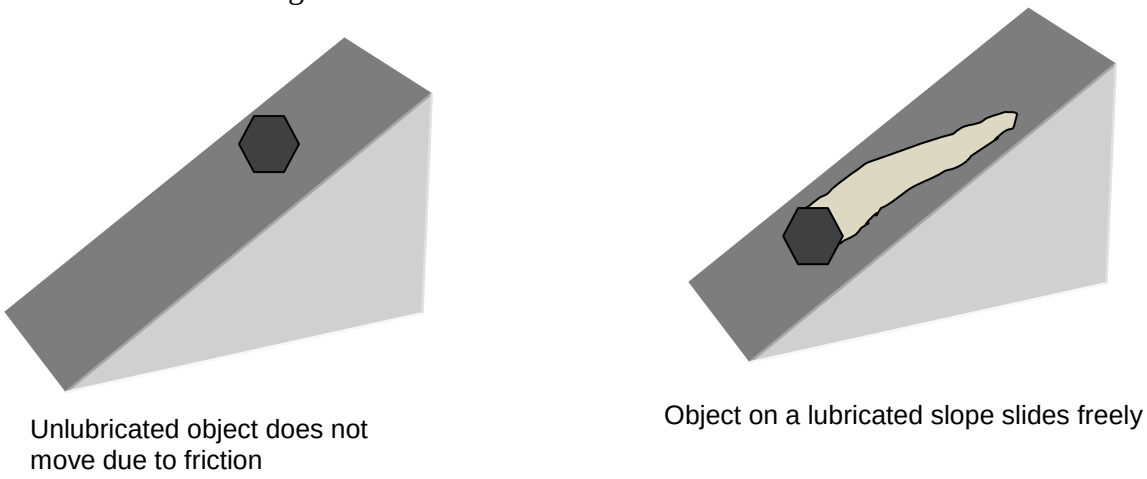


**FIGURE 1: Effect Of Lubrication On Friction**

In small motors, such as those that run drills and table saws, the surfaces of moving parts that are in close contact must be protected from wear and overheating. This is provided by coating the surfaces with a thin film of oil. The molecules of the oil act like miniature ball bearings.

***Oil*** is a liquid substance that has a smooth, flowing feel. It is usually extracted from petroleum. All oils flow, but they do so at different rates depending on their viscosity. ***Viscosity*** *is the resistance of a liquid to flow.*

The viscosity of an oil determines in what situations that oil can be used as a lubricant. In an engine, oil must be thin enough to flow to the areas it is needed while still being thick enough to coat the surfaces. Viscosity increases in cold weather so the oil we use in a car in winter needs to have less viscosity than summer oil.

**Grease** is an oil that is thickened with soap. Grease is used if the lubricant needs to stay in place, if there is a heavy load at low speeds and if a good level of rust protection is required.

**Bearings**

Bearings reduce friction because they have a smooth surface. They roll instead of sliding and, because of their round shape, they have a small surface area of contact. In a wheel, bearings can reduce friction between the housing of the wheel and the shaft of the axle. See Figure 2.

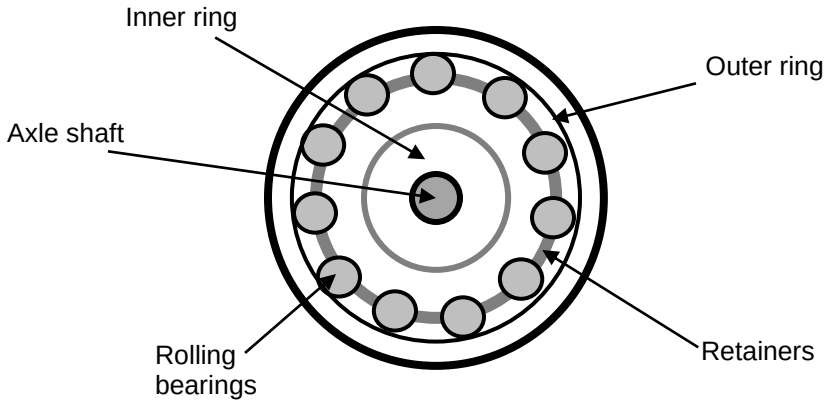


**FIGURE 2: Parts of a Wheel Bearing**

When the shaft rotates, it imparts its rotational motion to the wheel. To increase the efficiency of this transfer of energy, friction between the housing of the wheel and the shaft of the axle must be reduced. This is done by the use of lubrication and the use of bearings.

The bearings in a wheel are designed to work in the circular path between the wheel housing and the shaft. They are evenly spaced by retainers and contained within an inner ring and an outer ring.

## *MAKING THE MOST OF FRICTION*

Excess friction must be limited in machines and when moving heavy objects. However, we also rely on friction to get a grip on things. When you first slide a window into its opening, it is partly friction that holds it there until you nail it firmly in place. And it is friction that helps to hold nails and screws in wood. Even when you nail against gravity, such as when you nail a piece of wallboard to a ceiling, friction holds the nail securely. Fibreglass insulation can be set between the studs of a wall without any fasteners because it is a rough material. It stays in place because of friction between the insulation and the wall.

Friction is used in planes and sanders to create smooth surfaces. The friction between the rough sandpaper and the surface being sanded results in particles being broken off until only a smooth surface remains. Sanding is an important step in the finishing work of a building. No one wants wood floors that are rough and full of slivers. And the smooth plaster surface of a wall is created by the finishing sanding.

Machines depend on the force of friction in order to function. Gears, clutches and brakes would not work without it. The friction of brake linings on the drums enables brakes to slow a vehicle. Even with brakes, we also need the friction between the tires and the road to come to a stop.

## *OTHER FORCES IN BUILDING MATERIALS*

Once the materials you use on a construction site are fastened in place, friction helps hold them in place. However, they are no longer free to move when other forces are applied. They now feel applied force as a ***stress.***

Materials such a wood, steel, glass, drywall and tile react to stress in different ways. Construction materials respond to force by exhibiting elasticity, plasticity or by breaking into two or more pieces. This section looks at some of the ways materials respond to force. It also explains the scientific basis of common terms such as stiffness and hardness used to describe building material.

### Elasticity

Wood can bend a certain amount in response to an applied force and then return to its original shape.

- We say wood has some *elasticity*. Because wood has some elasticity, it can bend and return to its original shape without breaking when a weight or force is applied to it.
- Wood also has *stiffness*. This is a measure of the amount of force required to bend it in the first place. Because wood is stiff, it takes quite a bit of force to bend it.

These characteristics make wood a versatile building material. A thin rod of steel is strong and elastic. It can bend and then return to its original shape, while a thick beam is hard and it takes a very strong force to bend it.

Glass, on the other hand, is a brittle material.

- If a force is applied to a pane of glass, it usually shatters.
- Tile and brick are similar to glass in that they do not bend.
- A sheet of drywall has a small amount of elasticity but if it is bent past a certain point it will also break into pieces.

A roofing shingle is not strong but it is quite bendable.

- It can be bent to curve over the peak of a roof. It also exhibits plasticity. Once it hardens in place, it usually retains its bent shape and can't be bent again. Instead, it will break.
- A plastic material can be bent or pounded into a new shape and will stay in the new configuration.
- Wet mortar is plastic in that it can be pushed between bricks. When it dries it retains its shape and doesn't seep out when more weight is added on top.

**Toughness and Strength**

The toughness of a material is the amount of energy it can absorb before breaking into smaller pieces. Steel and wood are tougher than a sheet of drywall. Tile is tougher than glass because it takes more force to break it.

Toughness and strength are related qualities. Strength refers to the maximum load a material can withstand without breaking. A steel beam is described as being strong because it can support a very large load. It is stronger than a wood beam of the same size.

The forces that a load exerts on the supporting material are called compression and tension forces. When a weight is placed on a board, the top of the board is pushed closer together while the bottom is pulled apart. The force pushing the board together is called compression and the force pulling it apart is called tension. If the tension becomes too great, the board will break.

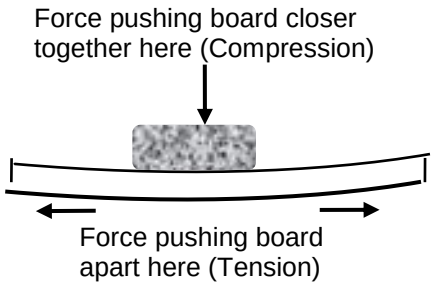


**FIGURE 3: Weight On A Board Produces The Forces Of Compression And Tension**

Materials used in floors, walls, ceilings and roofs must be *strong* enough to withstand the loads placed on them. Code books list the span and load that materials can withstand. For example, the same size of board made from oak is stronger than one of pine. However, pine is easier to work with and cheaper than oak. Luckily, there are ways to increase the strength of a pine beam.

*Strength is proportional to the thickness of the board,* if the other dimensions of length and width are the same. This means the greater the thickness, the greater the strength. It is much harder to break a one inch thick board than a half-inch thick board.

*Strength is inversely proportional to the length* of the board, if the other dimensions are the same. This means the shorter the board, the stronger it is. It is easier to break a four foot board than a one foot board.

*Span* is the distance a beam covers. The longer the distance to be spanned, the more factors such as strength or thickness have to be taken into consideration in choosing what size beam to use. A steel beam is lighter, thinner and stronger than a wooden beam. When larger distances have to be spanned, a steel beam is usually chosen over wood to ensure the beam will be strong enough to withstand the weight put on it.

There is also a *geometric quality* to strength. A board used on its edge is stronger than a board used on its face. The area where the force or load is placed on a beam must also be taken into consideration. An unsupported piece of drywall will break more easily if you push on the center

than if you push near the edge. The different responses of materials to force explain some of the reasons for the size and strength requirements given in the code books.

## *CONCLUSION*

When you run a machine using electricity or gasoline, energy is put into the machine. However, you never get the same amount of work out of the machine as you put into it. Friction steals some of the energy along the way as heat and sound. Whenever friction limits the efficiency of a machine in this way, engineers try to reduce friction as much as possible.

At the same time, friction is needed in these machines to make brakes and clutches work. Friction is used to create smooth surfaces. You also rely on friction in wood to hold fasteners in place.
Friction is a crucial force that has an influence on just about everything you accomplish on the job. Although you must look for ways to control the unwanted effects of friction, you must also work with the useful effects of friction to successfully complete any construction project.

Understanding why friction occurs can help you predict its effects, both positive and negative. This allows you to either limit these efforts or work with them.

In the same way, understanding the different responses of building materials to other forces enables you to choose the correct material for each situation. It also allows you to work in the most effective way with the materials available.

**Underline the correct word to answer these questions. Answers are on the next page.**

1. The force that causes resistance to movement when one object moves over the surface of another is called (energy or friction).

2. It is harder to start an object moving than to keep it moving. This is because static friction is (greater or lesser) than kinetic friction.

3. Kinetic friction acts to (slow down or speed up) a moving object.

4. Overcoming friction in machinery requires the use of (more or less) energy.

5. The use of rollers and bearings are two ways to (increase or decrease) the effects of friction.

6. It is (easier or harder) to slide an object on a flat road than to roll it on wheels.

7. An object moving on a fluid surface meets (more or less) friction compared to a dry surface.

8. Lubricants such as oil create a (fluid or dry) surface for solids to move on.

9. Friction in moving parts can cause (cooling or overheating).

10. The higher the viscosity, (the greater or the less) the resistance to flow.

11. The force of (friction or gravity) helps hold nails and screws in place.

12. Friction between the brake linings and the drums in a vehicle enables it to (speed up or slow down).

**Answer page**

1. friction
2. greater
3. slow down
4. more
5. decrease
6. harder
7. less
8. fluid
9. overheating
10. greater
11. friction
12. slow down