EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING

Revised for

ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
WORK

AN ACADEMIC SKILLS MANUAL
for
The Metal Work Trades

This trade group includes the following trades:
Heat & Frost Insulator, Iron Worker,
Precision Metal Fabricator, Sheet Metal Worker, and
Welder & Fitter

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:
WORK

An academic skill required for the study of the Metal Work Trades

INTRODUCTION

We are all familiar with the concept of work. After a coffee break, you know it's time to get back to work. At school, you work hard to do well at your studies. And you probably can think of lots of work at home that needs to be done. This kind of routine work is any useful activity directed towards some goal.

When we talk about work as a scientific concept, though, it has a more precise meaning. The definition of work gets cut to its bare essentials. In science, ***work** is done when a force acts on matter and changes its motion*. When you carry a roll of metal, you act on the metal and cause it to move. You have done work.

This precise definition enables us to predict what happens when a force is applied to an object. Because we can predict what will happen, we can direct forces to do useful work for us. The machines that cut, punch and bend metal into useful objects were developed as a result of an understanding of the concept of work.

There is a close connection between work, force and motion. Work is simply the measurement of the resulting change of motion when a force acts on an object. This skills manual looks at these concepts in more detail, including:

- The relationship between force and work
- Calculating work done
- Power
- Effect of friction on work done

THE RELATIONSHIP BETWEEN FORCE AND WORK

As we said, work is done when a force acts on an object and changes its motion. Every object, no matter how big or small, is considered a part of matter. ***Matter** is anything that has mass and occupies space.* The mass of an object is determined by the type and arrangement of molecules that make up that object. Anything that has mass also has the property of inertia. ***Inertia** is the property of matter which requires that a force be exerted on a body in order to change its position, whether it is at rest or in motion*.

This means that an object will remain at rest or in motion at a constant velocity, unless a force acts on it. On the surface of the earth, one force that is always acting on all objects is the force of gravity. Gravity holds objects on the ground, keeping them from falling off into space. Another force that is present on the job site is friction. Friction is a force that resists the movement of one object over another. It can be a help or a hindrance when getting work done, depending on the situation.

A ***force*** (F) is defined more by what it does than what it is. Even if we can't say exactly what gravity is, we know it is acting because we stay on the earth instead of floating off into space whenever we jump up.

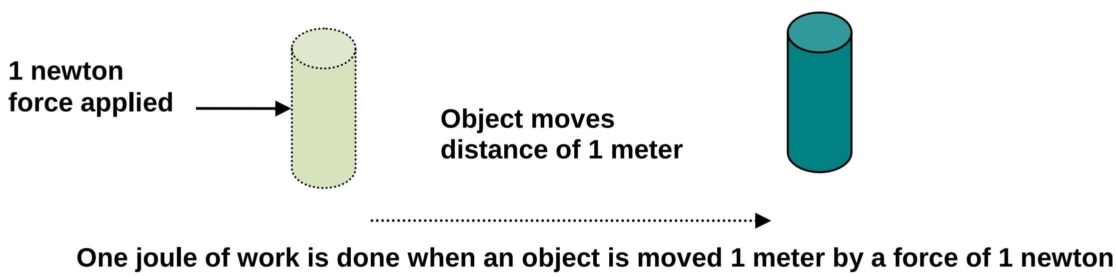
- *A **force** acts upon an object as a push or pull.*
- If the force applied is strong enough and the object is free to move, the force will cause the object to move, resulting in a change in its direction or motion.
- If the force applied is not strong enough to overcome inertia, the object will feel pressure or tension but it won't move.
  - If the object is not free to move and the force increases enough, the object will break.
    - When you use a machine to cut a piece of metal, the machine applies a force that breaks the molecules of the metal apart.
    - Work has been done, because the force exerted by the machine acted on the metal and changed the position of its molecules.

Force is measured in ***newtons (n,)*** in the metric system. The imperial system uses ***pounds (lb)***, or pound-force. These units are derived by measuring and comparing the effect of gravity on the mass of different objects.

CALCULATING WORK DONE

When work is done in a straight line, the unit of work in the metric system is the ***joule (j)***.

***One joule** of work is done when a force of one newton acts through a distance of one meter.*



One joule of work is done when an object is moved 1 meter by a force of 1 newton

FIGURE 1: Definition Of A Joule

The unit of work in the imperial system is the ***foot pound (ft lb)***. ***One foot pound** of work is done when a force of one pound moves an object over a distance of one foot.*

To find the work done in moving an object, the force applied is multiplied by the distance the object is moved.

Work = force x distance

The distance the object is moved is also called the displacement. The short form for displacement is "**s**". So the formula for work is:

W = Fs Where W = work, F = force, and s = displacement (distance)

We use this formula to find how much work is done in moving an object a certain distance. To calculate the amount of work done, multiply the applied force by the distance the object is moved. Let's look at an example.

Example: How much work is done if a load of 15 newtons is lifted to a height of 10 m?

W = Fs
= 15 n x 10 m
= 150 joules

Work is only done when a force actually moves an object. No matter how hard you try to lift a bundle of steel rods, if they don't move, no work has been done. It doesn't matter how many stages it takes to move an object through the total distance when calculating work. Only the total distance needs to be calculated.

- If you are carrying a load up a set of stairs, only the weight of the load and the height of the stairs are considered.

Look at Figure 2, below, as you work out these examples.

Example A: How much work will you do in total if you first lift a box weighing 400 n (newtons) to a bench that is 1 meter high and then onto a worktable 1.7 meters high?

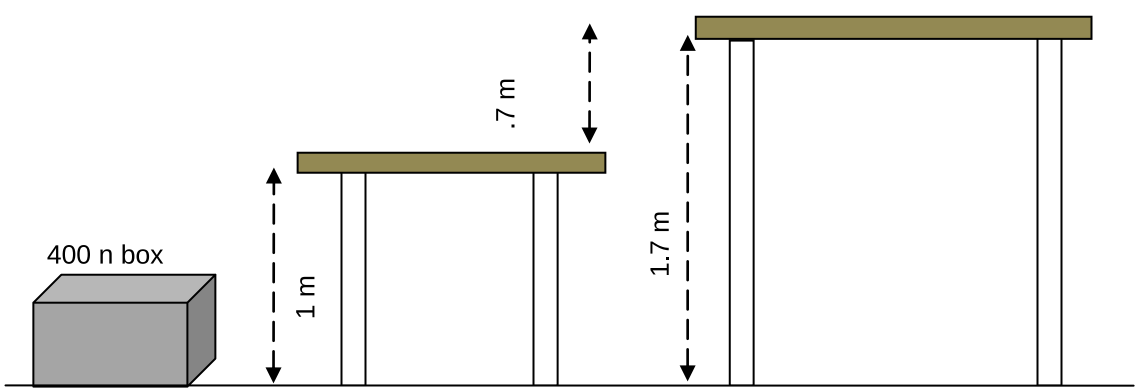


FIGURE 2: Work Equals Force Times Distance

Answer A: It doesn't matter how high the bench is. All we need is the total distance lifted. The total distance lifted is 1.7 m.

W = Fs
= 400 n x 1.7 m
= 680 joules

Example B: If you lift the box directly onto the worktable, will you do more work?

Answer B: If you lift the box directly onto the worktable, the force will still be 400 n and the distance the box is moved will still be 1.7 m. The amount of work is the same:

W = 400 n x 1.7 m
= 680 joules

POWER

Power is the rate of doing work or the work done in a certain amount of time.

- One hoist lifts a bundle of steel rods 10 meters in 60 seconds, while another hoist lifts the same load the same distance in 30 seconds. Both hoists do the same amount of work. However, the second hoist has more power because it lifts the load faster.

Power is calculated by dividing the amount of work done by the time taken to do the work. The formula for power is:

$P = \frac{W}{T}$ where W stands for work done and t stands for time taken.

When work is measured in joules and time in seconds, the metric unit of power is the ***watt (w)***. A watt is 1 joule per second. Because a watt is a small unit, the term kilowatt, meaning 1000 watts, is often used. The unit of power in the imperial system is the ***horsepower (hp)***.

Let's calculate the power required to lift a load a certain distance in a specific time.

Example: How many watts are required to lift a weight of 12 newtons to a height of 5 meters in 20 seconds?

$P = \frac{W}{t}$

$= \frac{12 \text{ n} \times 5 \text{ m}}{20 \text{ sec}}$

= 3 watts

Example: How many kilowatts are required to lift a weight of 294 newtons a height of 15 meters in 10 sec?

$$P = \frac{W}{t}$$

$$= \frac{294 \text{ n} \times 15 \text{ m}}{10 \text{ sec}}$$

$$= 441 \text{ watts}$$

The watts must be changed to kilowatts. Divide by 1000.

441 w ÷ 1000 = .441 kw

EFFECT OF FRICTION ON WORK DONE

On a job site, you need to move some heavy materials. You give them a push. They slide a bit and then stop moving. Another job site, has steel rollers that you can use to push materials on. You easily push the materials on the rollers over to where you need them to finish. Why it is much easier to push a load on metal rollers than on a concrete floor?

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. ***Friction** is the force that opposes motion between two surfaces*. Since all objects have some contact either with another object or with the air, all objects feel the effects of friction.

Friction has an effect on all the materials you use on the work site.

- It is helpful when friction holds a sheet of metal roofing in place while you get your screw gun to secure it to the roof.
- You take advantage of friction when you use sandpaper to smooth a rough surface.
- A type of welding called friction-welding generates heat through mechanical friction. One piece is held still while the other is rotated at high speed. Once friction has generated heat in the moving piece, the two pieces are held together under pressure, causing them to weld together. This friction welding is useful when two different materials such as light-weight aluminum and high-strength steel need to be joined. It is used in a wide variety of applications in the aerospace and automotive industry.

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 materials across the floor.

Understanding friction can enable you to take advantage of its helpful effects and to reduce its negative effects on the amount of work done

Friction in solids and fluids

Most of the time, whether you are pushing a load, using sandpaper to smooth a surface, or relying on friction to hold a screw in place, you are dealing with the effects of friction that 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.

When an object moves over a fluid surface such as oil or water, less friction is created compared to movement over the solid surface.

- When a lathe is cutting through metal, water or oil is sometimes used to make it easier for the saw to move through the material and to reduce the amount of heat created.
- Oil allows moving parts in a motor them to move back and forth with less heat and noise.
- A bearing wears out less quickly when it is in contact with oil instead of a solid housing.

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. The larger the surface area of two flat objects sliding over each other, the larger the amount of friction. On the other hand, the smoother the two flat surfaces are, the less friction is produced and the easier it is to overcome.

If a solid object moves over a spherical or cylindrical surface such as a metal ball bearing or a roller, the area of surface contact will be much smaller and so there will be less friction than when two flat surfaces move over each other. It takes less force to overcome the friction of a rolling surface.

- If you have to move heavy material to where it will be used, it is easier to move it using rolling bars than to carry or push it to get it to your truck.
- The beer store uses the same type 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.

Many devices that we use to lessen the effects of friction are simple machines. The wheel and axle is a simple machine that allows us to move much larger loads because friction is greatly reduced. There is still friction between the wheel and the road, and there is friction between the axle and the bearing that can cause the axle to heat up. (This friction is what causes the squeaky wheel.) But overall, a wheeled vehicle is a much more efficient way of moving a large load.

Limiting the effects of friction

Friction creates heat in moving parts of machines such as drill presses and lathes, and as a result, parts wear out faster. Friction can cause uneven wear in moving parts, resulting in unwanted vibration. It can also cause excess noise in machinery, creating a potential hearing problem in the people working nearby. Friction creates problems that are expensive to overcome, so if possible, it is important to limit the negative effects of friction.

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

- Use suitable materials (steel or glass have smooth surfaces and so create less friction than rubber or wood).
- Use a lubricant which flows between parts to create a fluid surface, thus creating less friction than that between solid surfaces (see Figure 2).
- Use 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.
- Use wheels or rollers to move objects.
- Make sure that moving parts that are in contact are fitted precisely, so nothing is rubbing together unnecessarily.
- Polish surfaces so they are as smooth as possible.

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.

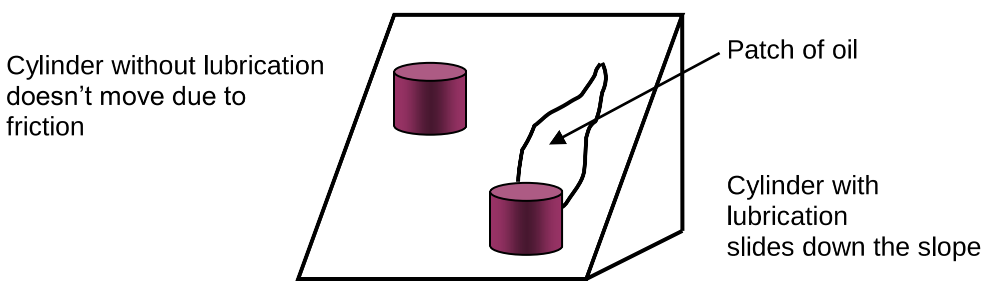


FIGURE 2: Effect Of Lubrication On Friction

In electrical motors, such as those that run drills presses and lathes, 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 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.* Viscosity increases in cold temperatures. The viscosity of an oil determines 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 but thick enough to coat the surfaces. Winter oil must be thin enough to flow at cold starting temperatures.

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.

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.

- It is friction that helps to hold nails and screws in place where they are driven. When you screw a metal heating duct to a ceiling, friction holds the screws securely in place against the pull of gravity.
- Friction is used in grinding and buffing seams, joints and rough surfaces in sheet metal. The friction between the grinder and the surface being smoothed results in particles being broken off until only a flat surface remains.

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.

CONCLUSION

The terms force, work and power are all closely connected. A knowledge of the relationship between these terms led scientists to eventually harness the motion of matter to do work for us. The industrial and technological revolutions were directly dependent on an awareness of this connection between force, matter and motion.

Friction is a force that plays an important role in the amount of work that gets done. It is a force that can be hindrance and a help in the workplace. Knowing how friction affects the motion of objects and how to limits its effect is useful in planning how to complete a job.

Answer the following questions by filling in the blank space. The answers are on the last page.

1. _______________ is anything that has mass and occupies space.

2. The property that requires a force be applied to an object in order to change its motion is called ______________ .

3. The unit of force in the metric system is the _______________ .

4. The unit of force in the imperial system is the ________________ .

5. Work is done when a force moves an object over a _________________ .

6. The metric unit of work is the ______________ .

7. If a load weighing 8 newtons is lifted 20 meters, _____________ joules of work are done.

8. If a crane tries but can't raise a heavy load, _____________ joules of work are done.

9. Power is the rate of doing ______________ .

10. The metric unit of power is the ______________ .

11. To calculate power, work is divided by _____________ .

12. The force that causes resistance to movement when one object moves over the surface of another is called ______________ .

13. It is ______________ to move an object over a fluid surface than a dry surface.

14. Friction in moving parts can cause ______________ to build up.

ANSWER PAGE

1. Matter
2. inertia
3. newton
4. pound
5. distance
6. joule
7. 160 joules
8. 0 joules
9. work
10. watt (or the kilowatt)
11. time
12. friction
13. easier
14. heat