EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING

Revised for

ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
WORK

AN ACADEMIC SKILLS MANUAL
for
The Precision Machining And Tooling Trades

This trade group includes the following trades:
General Machinist, Tool & Die Maker,
Mould Maker, Pattern Maker, and
Machine-Tool Builder Integrator

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 Precision Machining and Tooling 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 decide to work really hard 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 wire, you act on the wire 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 used in precision machining and tooling 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

THE RELATIONSHIP BETWEEN FORCE AND WORK

***Work** is done when a force acts on an object and changes its motion.* Every object, no matter how big or small, is considered to be matter.

***Matter** is anything that has mass and occupies space.*

- Matter includes tiny objects at the atomic level, such as a single molecule, and the large, visible objects around us such as a tree or a shovel.

Anything that has mass also has the property of inertia. ***Inertia** is the property of matter which requires that a force be exerted on an object in order to change its 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

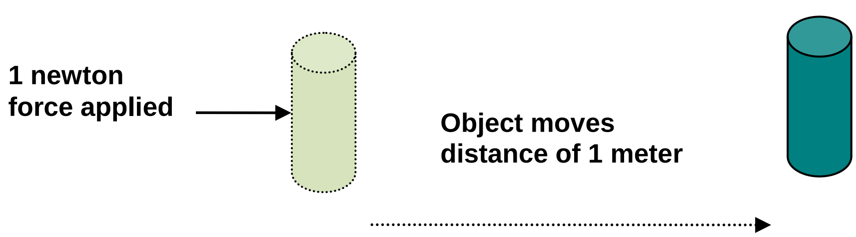

FIGURE 1: Definition Of A Joule

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?

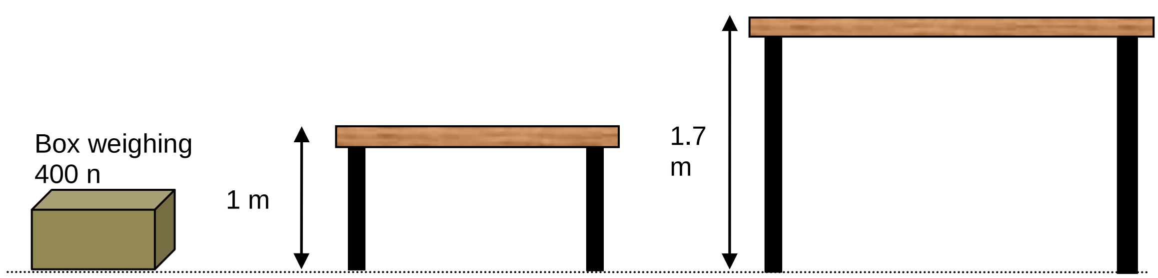

FIGURE 2: Work Equals Force Times Distance

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. You might lift the box in the last example directly onto the worktable. Or, you might first lift it onto the bench and then onto the table.

- Either way, you do the same amount of work, but the power you use to do the work determines how long the task takes.

Power depends on the amount of work done divided by the time required.

- If the work takes longer to do when you lift the box in two steps, there is less power.

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

$$\text{power} = \frac{\text{work}}{\text{time}}$$

$$\mathrm{P} = \frac{\mathrm{W}}{\mathrm{T}}$$

Or:

$$\mathrm{P} = \frac{\text{force } \times \text{distance}}{\text{time}}$$

$$\mathrm{P} = \frac{\mathrm{Fs}}{\mathrm{t}}$$

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?

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

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

$$= 3 \text{ watts}$$

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

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.

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 to 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. The amount of work done if a box is lifted in two steps is the ________________ as when the box is lifted in one step.

10. Power is the rate of doing _____________ .

11. The metric unit of power is the _____________ .

12. To calculate power, work is divided by ____________ .

ANSWER PAGE

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