Note to the Student

Overview

These notes will be your guide for this investigation. These notes cover the lessons, key concepts, and reference material.

Glossary

Force A push or pull on an object resulting from an interaction with another object; measured in Newtons (N)

Power Power is the rate of doing work; measured in watts (W)
Below are two ways to calculate power:
(1) The amount of work done divided by the time it takes to do the work
(2) The product of the voltage in a circuit and the current drawn from the circuit

Work Work is the energy transferred by a force to a moving object; measured in Joules (J). Below are two ways to calculate work:
(1) The product of the force on an object and the distance over which this force is applied
(2) The product of the voltage in a circuit, the current drawn, and the amount of time this current is drawn

Current The flow of electric charge; measured in amps

Voltage The pressure behind the flow of electricity; measured in volts

Resistance Opposition to a flow of electrical charge; measured in ohms

Direct Current An electric current that travels in only one direction in a circuit

Alternating Current An electric current that reverses direction in a circuit at regular intervals

Series Batteries are in series when they are laid from positive terminal to negative terminal; their voltages add together

Direct and Alternating Current

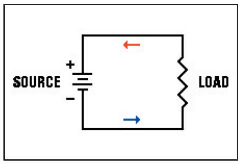

Figure 1

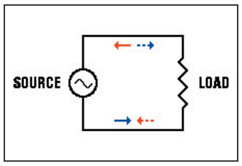

Figure 2

Direct current (DC) is when current always flows in the same direction around an electric circuit, as in Figure 1. For example, batteries, fuel cells, and solar cells all produce direct current. The positive and negative terminals of a battery are always positive and negative. In other words, current always flows in the same direction between those two terminals.

Alternating Current (AC) is when current periodically reverses, or alternates, its direction around a circuit, as in Figure 2. For example, the power that comes from a power plant is alternating current. In the United States, the current alternates 60 times per second. Thus, the power that is available at a wall socket in the United States is 120 volt, 60-cycle AC power.

In this investigation, you will be working with batteries, which produce direct current. You will learn how to use a multimeter to measure the voltage produced by these batteries. For more information about how use a multimeter to read DC Voltage, review "Background / Resources / Multimeter Guide".

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Figure 3

Series Circuits

In this investigation, you will experiment with circuits in series. In the "Background / Resources / Multimeter Guide", you lay 8 batteries in a row touching the positive and negative terminals together and measure the voltage readings. Attaching batteries like this is known as putting the batteries in series. When you put batteries in series, the voltage readings will add together.

For example, if you have two 7.2 V batteries in series (one is shown in Figure 3), the total voltage available will be 14.4 V (2 x 7.2 V = 14.4 V). This property of electronic circuits is useful if you only have batteries with a low voltage, but need more volts to power a circuit. For example, in your Vex radio control transmitter, you need 12 V to power it. However, you might only have access to standard AA batteries, which are 1.5 V each. To get enough voltage to power your radio control transmitter, you must connect 8 of these batteries together in series (8 x 1.5 V = 12 V).

Work and Force

This section explores the relationship between force and work.

A force is a push or pull on an object resulting from an interaction with another object. Force is measured in Newtons (N). When you push or pull on a heavy box, you are exerting a force on that box, even if it does not move. Another example is gravity. Gravity exerts a downward force on any object on the Earth's surface. This is what keeps you from floating off the planet!

You will learn two different methods to calculate "work". The different ways are distinguished by subscripts 1 and 2. In most cases, work refers to an activity involving a force, and a direction of movement. For example, if you push a box in one direction, you are doing work. Work is represented by the capital letter W. Work can be calculated using the formula at left, where F equals force and d is distance. Work is measured in Joules. The following example illustrates the relationship between force and work.

$$Work_1 = F \times d$$

EXAMPLE 1

If your robot has a total force of 35.4 N on it, and it travels 5 m, what is the amount of work done by your robot?

$$1\ J = 1\ N \times m$$

Solution:

From the formula at left, we know that 1 N x m = 1 J.
Work = Force x distance = 35.4 N x 5 m = 177 J

Work and Power

In this lab, we will not be using force or distance to calculate "work." Our way will use current, power and time. First, you will need to know what power is. Power (P) is the rate of doing work. Power is measured in watts (W). You may have seen the term "watt" before; light bulbs are measured by how much power they consume. Similar to work, you will learn two different methods to calculate "power" distinguished by subscripts 1 and 2.

$$Power_1 = \frac{W}{t}$$

The first way is using the formula at left. Power is subscripted with a 1 so that you can easily separate the two ways of calculating power. In this case, power has two parts: the work done, and the time it takes to do the work. The example below illustrates how to use this formula.

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$Power_1 = \frac{W}{t}$

$1\ W = \frac{J}{s}$

EXAMPLE 1

If your robot does 177 J of work in 10 seconds, how much power must your robot produce?

Solution:
From the formula at left, we can plug in the work and time given above.

$$\text{Power} = \frac{177\ \text{J}}{10\ \text{s}} = 17.7\ \text{W}$$

The second way to calculate power is by using the $Power_2$ equation at left. In this case, power consists of voltage and current. This is how power is represented in an electric circuit. The example below illustrates how to use this formula.

$Power_2 = V \times I$

$1\ J = 1\ V \times A$

EXAMPLE 2

If your radio control transmitter is powered by 12 V and draws 0.11 A , how much power is your radio control transmitter producing?

Solution:
Using the formulas at left, we can plug in the voltage and current given above.
Power = 12 V x 0.11 A = 1.32 W

Finally, we are ready to find the second equation for work. The $Power_1$ and $Power_2$ equations are equivalent; they should give you the same amount of power. If we set these two equations equal to each other, we get the second formula for work.

$Power_1 = Power_2$

$$\frac{W}{t} = V \times I$$

$Work_2 = V \times I \times t$

$Work_2 = V \times I \times t$

$1\ Watt = V \times A \times s$

EXAMPLE 3

Your robot draws 0.11 A for 15 seconds. Your robot is also powered by a 7.2 V battery. Find the work done by your robot.

Solution:
Using the formulas at left, it is straightforward to calculate the work your robot does.
Work = 7.2 V x 0.11 A x 15 s = 11.88 W

You will use this relationship in your investigation to experimentally determine the relationship between work and current.

Factors Affecting Current Draw

Figure 4

There are many other factors than work that affect current draw. This section lists a few of these factors. For more information about these factors, refer to “Overview / PowerPoint / Lesson Guide”.

GEAR RATIO

The size of the driving gear as compared to that of the driven gear (Figure 4) will have an effect on speed and the amount of current the motor draws. If the rotations of the driving gear are held constant, larger driving gears and smaller driven gears will cause the motor to draw more current.

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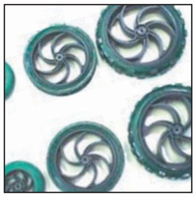
Figure 5

WHEEL SIZE

The larger the wheel, the more current the motor will need (Figure 5).

WEIGHT

The more weight that is added to the robot, the more current the motor will require. A decrease in the weight of the robot will decrease the amount of current the motor will need.

TERRAIN

Irregular surfaces will cause increases in motor current.

BATTERY VOLTAGE

The amount of battery voltage directly affects current draw. If a 6 V battery is used on a 12 V motor, the motor will run slowly and not produce the proper amount of power. If a 12 V battery is used on a 6 V motor, the motor will draw excessive current and be destroyed. Weak or dead batteries will not provide adequate voltages for correct motor operation.

Description of the Lesson

To begin this investigation, you will work in teams of 3 to construct a modified Squarebot with a multimeter attached. You will use this robotic platform to determine the relationship between work and current. There are two parts to this lesson: current draw setup and procedure.

CURRENT DRAW / Setup

In this part, you will connect a battery in series with a multimeter and mount this on your modified Squarebot. Using this system, you will be able to monitor the current draw of your robot while it is running. Once you have constructed your modified Squarebot, you may begin the lesson procedure.

CURRENT DRAW / Lesson Procedure

Your team will use the radio control transmitter to move the robot along planes of increasing incline. You will need to monitor current output and track the time it takes the robot to go up the incline. You will need to graph this data and evaluate it to find the relationship between work and current. Use the “Background / Resources / Current Worksheet” (PDF or xls) as a worksheet for this lesson. The hypothesis is that current draw is directly related to the amount of work the robot does.

References

Use the following resources:

- For a visual presentation of the lesson material, watch “Overview / Video / Video Preview”
- For a slide show summarizing the lesson and discussing factors that affect current draw, watch “Overview / PowerPoint / Lesson Guide”.
- For more information about voltage, refer to the “Background / Helper Link / Voltage”
- For more information about current, refer to the “Background / Helper Link / Current”
- For more information about resistance, refer to the “Background / Helper Link / Resistance”

Note to the Student

- To learn how to use a multimeter for continuity and DC voltage testing, view “Background / Resources / Multimeter Guide” which contains two videos and a PowerPoint presentation.
- To learn how to use a crimping tool to crimp Vex connectors, view “Background / Resources / Crimping Guide” which contains a slide show and a PowerPoint presentation.
- For a copy of the lesson worksheet, refer to the “Background / Resources / Current Worksheet” in either Excel or PDF format
- For the setup guide for the lesson, refer to the “Lesson / Current Draw: Lesson Setup” video and printable PDF
- For the procedural guide for the lesson, refer to the “Lesson / Current Draw: Lesson Procedure” video and printable PDF