7. Powering an Electric Motor and Gearbox

Build Knowledge

INTRODUCTION

WHAT STUDENTS DO IN THIS ACTIVITY

In this activity, students use the electrical energy from the PEM fuel cell to power an electric motor and gearbox to lift a weight. They investigate the process of turning electrical energy into mechanical energy and determine the amount of work produced by the motor.

RATIONALE

During this activity students observe the transformation of energy from electrical energy to mechanical energy. Students determine the time it takes to lift a weight a given distance as a function of the amount of hydrogen gas used. Students use the data collected to calculate the work done by the motor and the power used to lift the weight.

With the completion of this activity students have experienced all the elements necessary to build a fuel-cell powered toy. Students return to the Looking at Powered Vehicles and complete the Identifying Automobile Components sheet, matching the fuel cell components from the list to each function.

WARNING !

It is important that the voltage and current from electrical sources do not damage the fuel cell. Check the limits on voltage and current for your fuel cell when operating in the electrolyser mode and do not exceed these limits.

Teacher Tip:

Refer to the Looking at Gears section in the Appendix for additional information on gears, speed, and torque.

Remind the students to review the different types of energy transformations:

- electrical energy to chemical energy
- chemical energy to electrical energy
- electrical energy to mechanical energy

Objectives

Upon completion of this activity the student should:

- be able to operate the fuel cell in the fuel cell mode
- be able to describe what takes place during the production of power by the fuel cell
- be able to identify the type of energy transformation taking place
- be able to determine the work done on an object by applying a force through a distance
- be able to determine the power used in moving an object through a distance over time
- be able to collect and graph data resulting from the process
- be able to identify the components of a fuel cell driven automobile and the function each component performs

TIME

1 class session

MATERIALS

For each design team

- the PEM fuel cell from the vehicle materials kit
- two 20 ml syringes
- flexible silicon tubing
- two 8″ leads with alligator clips, black and red
- battery pack
- electric motor and gearbox
- a copy of the PEM Fuel Cell Operating Procedures
- a copy of the Powering An Electric Motor and Gearbox Data sheet
- a copy of the Identifying Automobile Components sheet (with automobile components column completed)

Teacher supplied materials

AA batteries

distilled water

electronic timers

string

load weight (100grams)

Teacher Tip:

Six milliliters of hydrogen gas has the same energy content as half of a Snickers candy bar (7 x 103 joules of energy).

LINKS

http://www.howstuffworks.com/motor2.htm

PREPARATION FOR THE ACTIVITY

Check the web links to see that the sites are still hosting appropriate content. Use a projector to allow the class to view the animations or make computers available for students to view them. Students may want to revisit some of the links that were accessed in earlier activities.

Check the motor/gearbox combinations to determine that they are still operational. Make copies of the Powering An Electric Motor and Gearbox Data sheet and the Identifying Automobile Components sheet (with automobile components completed) for distribution to the class during the activity.

CLASSROOM ACTIVITY

ACTIVITY DESCRIPTION

Students use the fuel cell to supply power to an electric motor and gearbox for the purpose of lifting a weight. In addition, at the completion of this activity students will have experienced all the elements necessary to build a fuel-cell powered toy. Students return to the Looking at Powered Vehicles and complete the Identifying Automobile Components sheet with the fuel cell components.

Powering an Electric Motor and Gearbox. Students use the fuel cell in the electrolyzer mode to produce and store hydrogen and oxygen gas. The stored hydrogen and oxygen gases are then used in the fuel cell mode to produce electrical power to a motor to lift a weight. The mechanical work used to raise the weight through a distance is determined in this activity. The transfer of energy from electrical energy to mechanical energy is observed and defined as production of mechanical power.

Students attach a 100 gm mass (the load weight) to one end of a length of string, and attach the other end of the string to the axle from the gearbox. The axle will be used to wind up the string to lift the weight.

The experiment begins with the making of hydrogen and oxygen gas in the electrolyzer mode.

1. Prepare the fuel cell for electrolysis according to the PEM Fuel Cell Operating Procedures, using the 20ml syringes instead of the 5ml syringes.
2. The battery pack is used to produce electricity as an input to the positive and negative metal terminals on the PEM fuel cell.
3. Make hydrogen and oxygen gas and collect the gas in the syringes. Record the time to produce the hydrogen gas.

Now the PEM fuel cell is used in the fuel cell mode to produce electrical power.

4. The fuel cell is connected electrically to the electric motor.
5. The hydrogen gas is transferred to the fuel cell and the process of creating electricity by the fuel cell begins.
6. Students record the distance the weight is lifted and the time to lift the weight.
7. Students repeat the procedure for several different times of hydrogen production.

Student use the data to calculate the work done and the mechanical power production. They then compare the work and power production against the time of hydrogen production for each of the trials.

Design teams compute the work done on the weight by lifting the weight through a distance from

Weight (newtons) = Mass (gm) x g (9.8 meters/sec)

Work produced by the motor (joules) = Weight (newtons) x distance traveled (meters)

Students determine the power produced by the motor by calculating the rate at which work is done in lifting the weight.

Power (watts) = Work (joules) / Time (sec.)

Teacher Tip:

Refer to the Energy, Work, and Power section of the Appendix for additional information.

A typical data sheet may look like the following.

Fuel Cell Type __H2O2____ Fuel Cell Number __007124_____

Time of Hydrogen Production, sec	Weight, gms	Distance, meters	Time, sec	Work, joules	Power, watts
20	100	0.76	30.1	.745	.0248
30	100	0.97	40.2	.951	.0236
60	100	0.94	37.1	.921	.0248
90	100	0.94	30.4	.921	.0303

From the data collected on the Powering an Electric Motor and Gearbox data sheet, a plot of work versus time can be created.

Students should diagram in their Design Logs the experimental apparatus of the PEM cell, the electric motor and gearbox, and the lifting system doing the work.

1. Diagram the process of lifting a weight vertically a measured distance.
2. Include in the diagram indications of the transfer of energy during the process.
3. Label all equipment involved in the process.
4. Summarize the investigation, structure, goals and outcomes of the experiment.

Teacher Tip:

This would be a good time for students to assess the knowledge they have obtained and revisit the Looking at Powered Vehicles activity to complete the last column under Fuel Cell Components on the Identifying Automobile Components sheet.

Teacher Tip:

The little packs of green fittings are quick connect fittings; when connected gas can flow through them; when disconnected no gas flows. The vendor that produces the kit was trying to sell us gas stations where you would use one fuel cell to produce hydrogen; you would bring your syringe with one end of the quick connect to the 'gas station fuel cell' and attach it to the other side of the quick connect, fill it up with hydrogen then disconnect it and take it to your fuel cell and attach the syringe to the other quick connect. The ac adapters in the teacher kit supply the same voltage as the battery pack so you don't need to keep replacing batteries all of the time and they can be used to do the electrolysis on a fuel cell.

Teacher Tip:

The hose clips are for clamping of tubing. You have four feet of tubing in the kit yet use only about 6-7" on the pressure relief valves and syringes, so what is the rest for? You could actually store the gases in the tubing; the syringes were an idea so students could visualize the H2O concept... twice as much H as O. Saying that, once you have used the syringes for a couple of the activities in lessons, you have determined the rate of hydrogen production and can simply use the tubing to store hydrogen, and it is lighter than the syringe and can be coiled to keep it out of the way. Additionally, when using the syringes there is a slight contamination of the hydrogen with ambient air in the tubing. You can use the tubing to get pure hydrogen stock by purging the ambient air out of the tubing and then clamping it. *(continued on the next page)*

Teacher Tip:

Cut the remaining tubing so that one piece is twice as long as the other; put an open clamp on the end of each piece and submerge them in a container of water. Attach the other end of the tubing to the nozzles on the fuel cell, attach the battery pack and begin the electrolysis. Notice the bubbles in the water...that is from the ambient air in the tubing being forced out by the oxygen and hydrogen being produced by the electrolysis of the water. After a short time close the clamps and a few seconds later turn off the battery pack; you should now have pure hydrogen and oxygen stock in the tubing. Attach the fuel cell to the motor on the gearbox and note the performance versus using the gases stored in syringes.

Identifying Vehicle Forces. Students should complete the Identifying Automobile Components sheet from the earlier activity on Looking at Powered Vehicles by adding the fuel cell components. The completed sheet should look as follows.

Component	Automobile Component	Fuel Cell Component
1. source of fuel	crude oil	water
2. fuel for engine	gasoline	hydrogen/ oxygen
3. converts fuel to power	internal combustion engine	fuel cell
4. changes force and speed	gears	gears
5. transmits power from engine to wheels	transmission/ power train	gearbox
6. transfers force to ground	wheels	wheels
7. permits wheels and gears to rotate	axles	axles
8. supports components	chassis	chassis

SHARING AND INTERPRETING

Pose the following questions to the design teams for discussion:

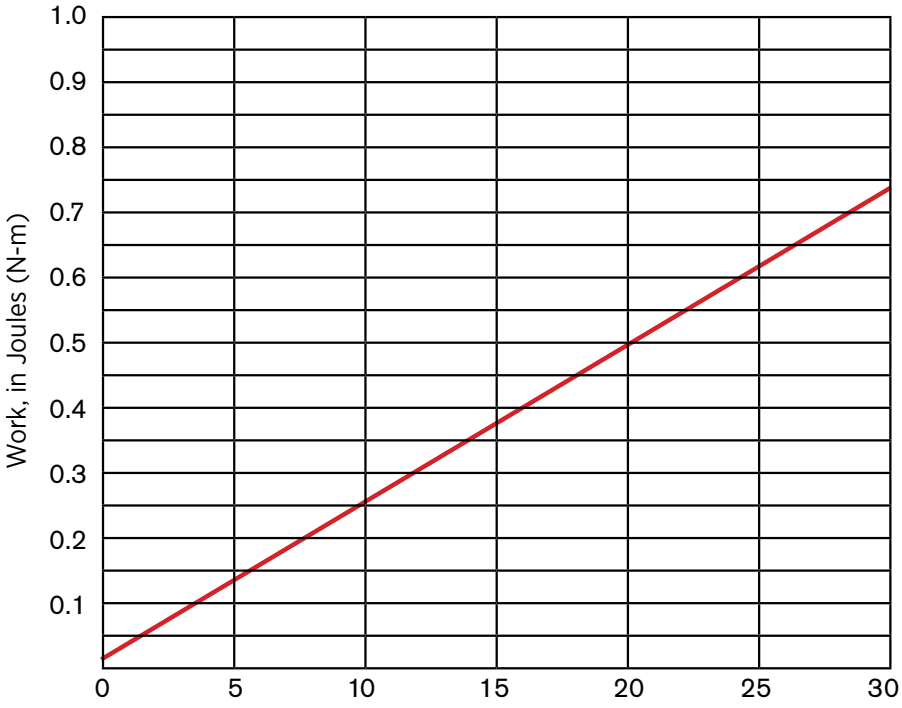
1. What energy transformation was observed during this activity?
   - electrical energy to chemical energy
   - chemical energy to electrical energy
   - electrical energy to mechanical energy
2. What are the factors that determine the output of power produced by the motor and gearbox?

TROUBLESHOOTING HINTS

- After each trial, reconnect the battery to the fuel cell to make additional hydrogen.
- If water collects in the tubing to the syringe, tilt syringe so water flows to the back of the syringe and hydrogen is at the front of the tubing near the fuel cell.

GRAPHS

Using the Design Log graphing paper, student use the data collected on the Powering an Electric Motor and Gearbox data sheet to construct a line graph plotting the work produced as a function of the time it takes to lift the weight. Help the students select an appropriate scale and labels for each axis on these graphs. A typical graph of data for the second trial (30 seconds of hydrogen production) may look as follows:



The slope of the line on the graph will be the power.

Power (watts) = Slope of the line = (Total Work) / (Total Time)

Power Calculations

Power (watts) = 0.747 Joules / 30.1 sec

Power (watts) = 0.0248 Joules / sec = 0.0248 watts = 24.8 mW

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Name _____ Design Team_____Date_____

POWERING AN ELECTRIC MOTOR AND GEARBOX DATA SHEET

Fuel Cell Type _____ **Fuel Cell Number** _____

Time of Hydrogen Production, sec	Weight, gms	Distance, meters	Time, sec	Work, joules	Power, watts

Page_____

Name _____ Design Team_____Date_____

IDENTIFYING AUTOMOBILE COMPONENTS SHEET II

Select one of the automobile components(parts) from the list below and place the component next to the function the component performs.

Gears	Hydrogen/oxygen
Axles	Chassis
Gearbox	Fuel cell
Water	Wheels

Function	**Automobile Component**	**Fuel Cell Component**
1. source of fuel	crude oil	
2. fuel for engine	gasoline	
3. converts fuel to power	internal combustion engine	
4. changes force and speed	gears	
5. transmits power from engine to wheels	transmission/power train	
6. transfers force to ground	wheels	
7. permits wheels and gears to rotate	axles	
8. supports components	chassis	