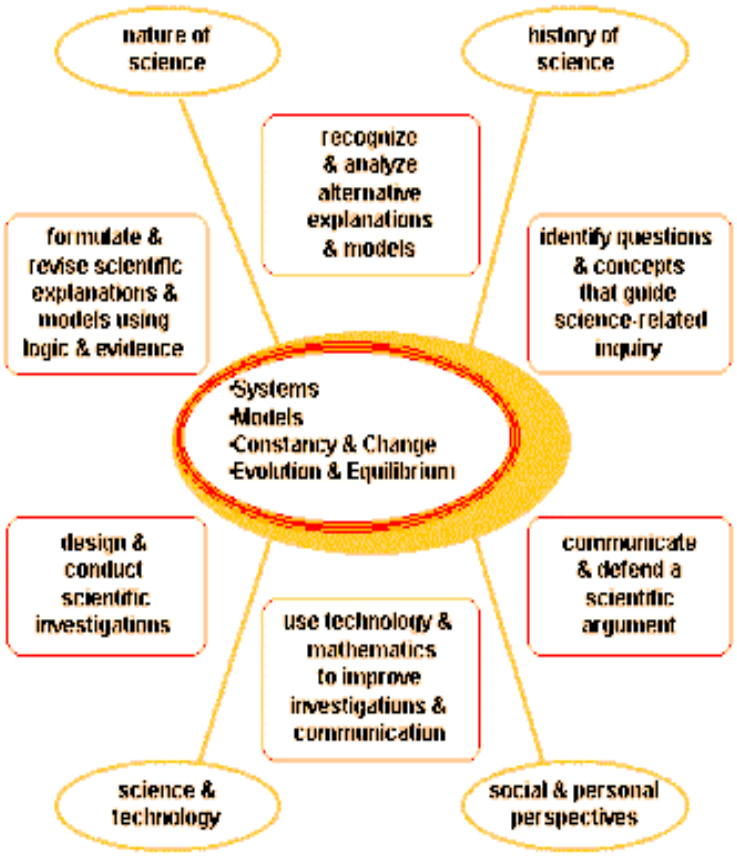
Exploring Hydraulic Systems

Learning Area: Scientific Concepts and Application
Educational Level: Middle School
Content Standards: Physical Systems

1. Students will explore the characteristics and scope of hydraulic systems through an understanding of Pascal's Principle and hands-on activities.
2. Students will explore and apply design concepts and uses for hydraulics.
3. Students will investigate real applications of hydraulics in the transportation industry.
4. They will acquire knowledge of the impact of hydraulic systems in today's society.

LARGE PROCESSES/CONCEPTS:



NEXT STEP: Assessment Task

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ASSESSMENT TASK:

Description:
Over a period of two to three days, students will be introduced to **Pascal's Principle** of hydraulics and will look at some examples of water under pressure; use math formulas to discover the effects of pressure, force, and area on volume in a fluid filled container, and create individual hydraulically operated devices.

Products/Evidence of Learning:

1. Students should be able to complete a math concepts worksheet to determine areas, force, and volume changes in a hypothetical situation.
2. Explain the principle of hydraulics after a compressibility experiment and fill in a response form.
3. In groups, apply this knowledge to create hydraulic systems that are capable of moving an object from one position to another, and fill in a response form.

Overview:

1. **Non-Compressibility Experiment**: Students will experiment with the non-compressibility of fluid. (see http://www.askeric.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Physical_Sciences/PHY0032.html).
    a. Fill an empty 2 liter bottle with water
    b. Fill an eye dropper half way with water
    c. Drop the eyedropper into the bottle and cap the bottle.
    d. Squeeze the bottle. Record your reactions on the attached Non-compressibility Experiment Response Worksheet
2. **Explore Pascal's Principle of Hydraulics** (found at http://www.lerc.nasa.gov/Other_Groups/K-12/WindTunnel/Activities/Pascals_principle.html).
    a. Reassess responses on Non-compressibility Experiment Response Worksheet; answer question #6.
    b. Complete the worksheet at this website on the mathematical principles related to hydraulic systems.

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ASSESSMENT TASK:

3. **Final Activity** – Build a hydraulic system capable of moving an object from one position to another
    a. Review the parts of a hydraulic system: master cylinders, pistons, slave cylinders, controls, etc.
    b. Separate into groups of 3 or 4 students each.
    c. Each group will need two 3"–3½" syringes, three feet of ¼" clear vinyl tubing, duct tape, craft sticks, toilet paper tubes to be used as "slave cylinders", 1" dia. x 4" cylindrical or 1"x1"x4" block of wood (or other objects of similar size) to act as pistons, and any kind of scissors-motion, spring-loaded hand tool or toy that is either normally open or normally closed, upon which the hydraulic system will effect motion.
    d. Have the students connect the syringes to either end of the vinyl tubing and fill the tubing with water. The students then need to figure out how to connect this to their moveable object to change its position when the water pressure is changed.
    e. Fill out the attached Hydraulic System Construction Response Worksheet
    f. Extra Practice: complete the activity listed in the text, *Technology*, by Brad and Terry Thode, Chapter 6, Designing Fluid Systems.

NEXT STEP: Checklist

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CHECKLIST:

STUDENT	TEACHER	
_____	_____	Completed **Pascal's Principle** calculation worksheet
_____	_____	Completed **Non-compressibility** experiment and worksheet
_____	_____	Demonstrated understanding of principles of fluid non-compressibility
_____	_____	Completed construction of a hydraulic system
_____	_____	Hydraulic system was successful in effecting a change of position
_____	_____	Identifies design properties that impact results of the hydraulic system

NEXT PAGES CONTAIN THE WORKSHEETS & EXPERIMENTS:

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NON-COMPRESSIBILITY EXPERIMENT RESPONSE WORKSHEET

1. After completing the set up for the experiment, predict what the reaction will be when the bottle is compressed.
   Bottle:

   Eyedropper:

2. Compress the bottle and describe the reaction:
   Bottle:

   Eyedropper:

3. Release the bottle and describe the reaction:
   Bottle:

   Eyedropper:

4. Was this what you predicted would happen?

5. What do you think caused this reaction?

   (Go on to part 2 of Overview)

6. After discussing **Pascal's Principle**, what do you think caused this

   reaction?

7. How does this answer differ from your answer in 5?

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PASCAL'S PRINCIPLE OF HYDRAULICS EXERCISES

1. A hydraulic press has an input cylinder 1 inch in diameter and an output cylinder 6 inches in diameter.
   a. Assuming 100% efficiency, find the force exerted by the output piston when a force of 10 pounds is applied to the input piston. 360 pounds
   b. If the input piston is moved through 4 inches, how far is the output piston moved? 1/9 inch

2. A hydraulic system is said to have a mechanical advantage of 40. Mechanical advantage (MA) is FR (output) / FE (input). If the input piston, with a 12 inch radius, has a force of 65 pounds pushing downward a distance of 20 inches, find

   a. the volume of fluid that has been displaced 9043 cubic inches
   b. the upward force on the output piston 2600 pounds
   c. the radius of the output piston 75.9 inches
   d. the distance the output piston moves

   MA = D1 / D2
   D2 = D1 / MA
   D2 = 20 in / 40
   D2 = 0.5 in

3. What pressure does a 130 pound woman exert on the floor when she balances on one of her heels? Her heels have an average radius of 0.5 inch. 165.6 psi

4. A car has a weight of 2500 pounds and rests on four tires, each having a surface area of contact with the ground of 14 square inches. What is the pressure the ground experiences beneath the tires that is due to the car? 44.6 psi

Extension: The input and output pistons of a hydraulic jack are respectively 1 cm and 4 cm in diameter. A lever with a mechanical advantage of 6 is used to apply force to the input piston. How much mass can the jack lift if a force of 180 N is applied to the lever and efficiency is 80%? 1105kg

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HYDRAULIC SYSTEM CONSTRUCTION RESPONSE WORKSHEET

1. List all team members' names:

a. Recorder:

b. Manager:

c. Parts assembly:

d. Tester:

2. List the equipment and supplies used in the construction of your hydraulic system:

3. Record the results of your trial runs and any changes or adjustments made: