Heart of the Matter

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on the engineering and operation of artificial heart valves, and the interface between man and machine.

Lesson Synopsis

The Heart of the Matter activity explores the concept of valve operation and how engineering adapted valves for use in mechanical heart valve design. Students learn about several different valves used at home and in industry, and three different mechanical heart valve designs. Students examine and operate both a ball valve and a experiment with a gate valve, then they work as a team of "engineers" to develop and sketch enhancements to the mechanical heart valve.

Age Levels

8-18.

Objectives

- Learn about valves.
- Learn about engineering design changes to mechanical heart valves
- Learn about human/machine interface to meet human needs.
- Learn about teamwork and the engineering problem solving/design process.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- valves
- mechanical - human interface
- impact of engineering and technology on society
- engineering problem solving
- teamwork

Lesson Activities

Students learn about how valves operate and the engineering enhancements that have improved mechanical heart valve design over time. Topics examined include problem solving, teamwork, and the engineering design process. Students work in teams to examine and operate two types of valves, then recommend changes to improve the functionality of mechanical heart valves. Student teams sketch their new designs and present to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheets (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- The Franklin Institute Online: The Heart (www.fi.edu/learn/heart)
- American Heart Association - Artificial Heart (www.americanheart.org/presenter.jhtml?identifier=4444)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Robert Jarvik and the First Artificial Heart by John Bankston (ISBN: 1584151161)
- Machines in Our Hearts : The Cardiac Pacemaker, the Implantable Defibrillator, and American Health Care by Kirk Jeffrey (ISBN: 0801865794)
- Advancing the Technology of Bileaflet Mechanical Heart Valves (ISBN: 3798511004)
- Valve Surgery at the Turn of the Millennium (ISBN: 140207834X)

Optional Writing Activities

- Write an essay or a paragraph describing how engineering has replaced or enabled the continued use of a body part. Choose from the following products: knee, teeth, ear, hip, lung.

For Teachers:
Teacher Resources

◆ **Lesson Goal**
Explore how valves operate to control the flow of fluids, and how specifically, the mechanical heart valve operates and has changed over time to improve the health of humans. Students learn about engineering design, and examine and use two different valves. Student teams then discuss and develop a sketch for an improvement to the engineering of mechanical heart valves, which they present to the class.

◆ **Lesson Objectives**
- Students learn about valves.
- Students learn about engineering design changes to mechanical heart valves
- Students learn about human/machine interface to meet human needs.
- Students learn about teamwork and the engineering problem solving/design process.

◆ **Materials**
- Student Resource Sheets
- Student Worksheets
- One set of materials for each group of students:
  - One ball valve (1/4 turn valves show the turning ball and are about $4)
  - Two 12-18" lengths of ¾" galvanized pipe (can be of any material, but this is least expensive)
  - ¾" Gate Valve
  - Two ¾" hose caps
  - One ¾" head plug
  - water source and place to allow water to flow (sink, or outdoors)
  - Funnel for pouring water into pipe

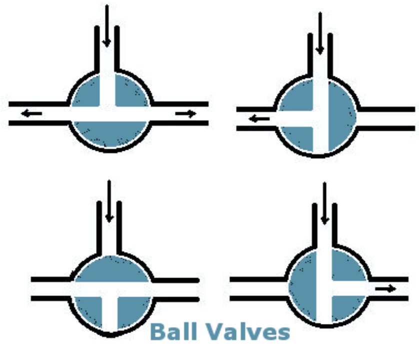
◆ **Procedure**
1. Show students the various Student Reference Sheets. These may be read in class or provided as reading material for the prior night's homework.
2. Divide students into groups of 3-4 students; provide one set of materials per group.
3. Ask students to complete the student worksheets. As part of the process, the students assemble pipes, valves, caps and plugs to explore how valves operate.
4. Students then work in teams as "engineers" to design a new enhancement to the mechanical heart valve. They plan and draw a sketch of their team's proposed enhancement.
5. Each student group presents their proposal to the class.

◆ **Time Needed**
One to two 45 minute sessions.

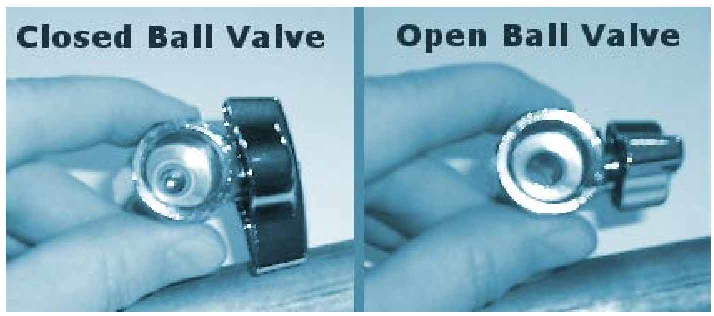
Student Resource: Valves and Hydraulics

◆ What are Valves?

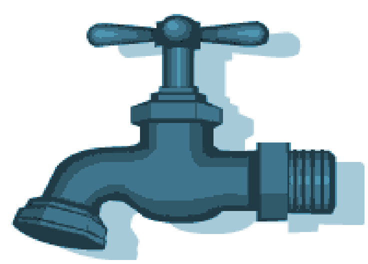
A valve is a device that regulates the flow of many types of fluids by opening, closing, or partially obstructing various passageways. Fluids can include gases, fluidised solids, slurries, or liquids. Examples are blood, gasoline, and water. Valves can be found everywhere, in many applications around your community, from controlling the flow of gasoline in a car, to water in a sink. Some valves are driven by pressure only, they are mainly used for safety purposes in Steam engines and domestic heating or cooking appliances. Here are a few types of valves:



- Ball valves open by turning a handle attached to a ball housed inside the valve. The ball has a hole in it, right through the middle, which allows fluid through when it is aligned with both ends of the valve. If the hole is not aligned, then no fluid can pass. There are also three-way ball valves, with a T-shaped hole through the middle.
- Check valves or "non-return valves" allow fluids to pass in one direction only. Some types of sprinklers and drip irrigation systems use these to make sure the lines don't drain out completely when the sprinkler is not in use.

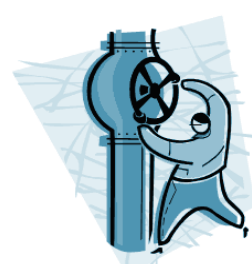


- Rotary valves and piston valves can be found are parts of brass instruments, and are used to change the resulting pitch.
- A tap (British English) or faucet (American English) is the control the flow of water.



- A gate valve is a valve that opens by lifting a round or rectangular gate out of the path of the fluid.
- Reed Valves are the mechanical equivalent of heart valves. They usually consist of thin flexible metal or fiberglass strips fixed on one end that open and close upon changing pressures across opposite sides of the valve -- just like heart valves. They are designed to restrict flow to a single direction and are found in automobile engines to control the intake of gasoline.

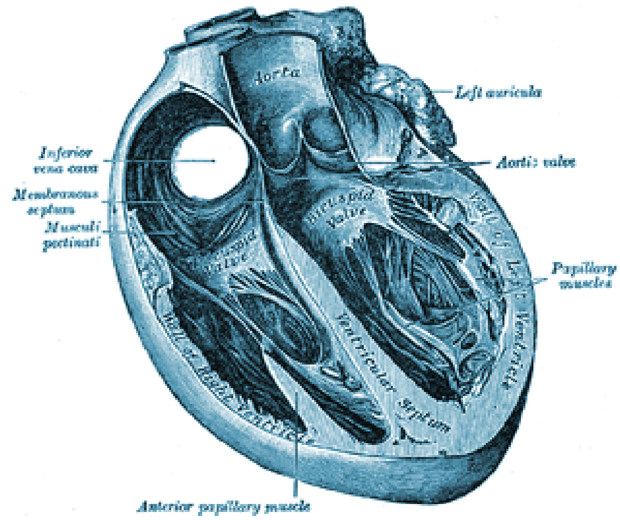
◆ What is Hydraulics?



Hydraulics is a branch of science and engineering concerned with the mechanical properties of liquids. The earliest masters of this art were Hero of Alexandria and Ctesibius. These ancient engineers focused on novelty uses of hydraulics rather than practical applications. Most engineers deal with hydraulic issues, such as pipe flow, dam design, fluid control circuitry, biomaterial, pumps, flow measurement, and erosion.

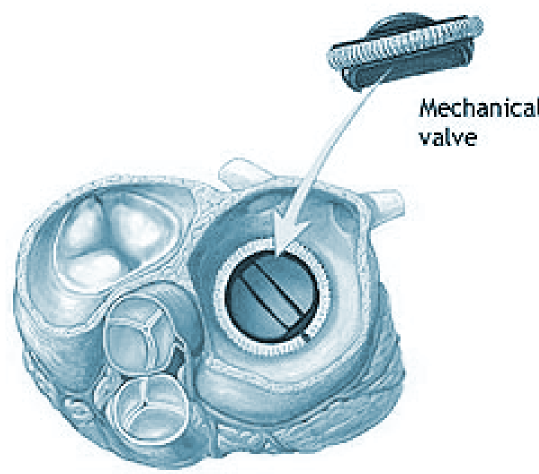
Student Resource: How Heart Valves Work

◆ Human Heart Valves



In the human anatomy, heart valves maintain the unidirectional flow of blood by opening and closing depending on the difference in pressure on each side of the valve. Human valves operate about 40 million times a year or two billion times in a lifetime. There are four valves of the heart. Two are atrioventricular valves that make sure blood flows from the atria to the ventricles, and not the other way around. The other two are semilunar valves which are found in the arteries leaving the heart. Their job is to prevent blood from flowing back from the arteries into the ventricles. The heartbeat sound we are all familiar with is actually caused by the heart valves as they shut. In the United States, about 80,000 adults undergo surgery to repair or replace damaged heart valves every year.

◆ Mechanical Heart Valves



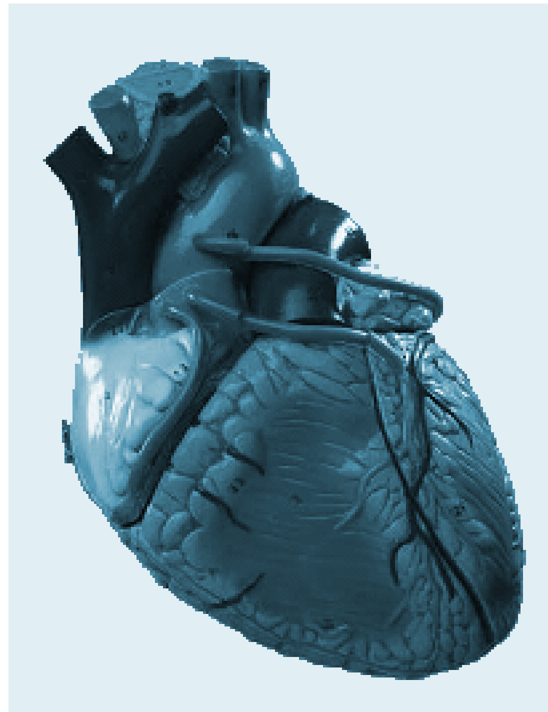
A mechanical heart valve is made of man-made materials. The advantage of mechanical valves is that they can usually last a lifetime. They do not wear out the way natural or biological valves do. They are designed to replicate the natural function of heart valves in humans whose hearts are not functional either due to defect or damage. As with natural heart valves, mechanical heart valves must prevent blood from backing up after it has pumped through chambers in the heart. The drawback of a mechanical heart valve is that it requires the human to take medications to thin their blood. This prevents the working parts of the valve from getting clogged over time, but presents a risk to the human. Thinned blood takes longer to coagulate or thicken in the event of a cut or bruising.

◆ History

The first known operation on a heart valve was in 1913, but replacement of diseased valves did not take place until 1962. Ball valves were the first type of mechanical heart valves and were developed around the same time. In 1952, Dr. Charles Hufnagel implanted caged-ball heart valves in ten patients (six survived the operation), marking the first long-term success in prosthetic heart valves. Currently, the only caged-ball design approved for use in the United States is the Starr-Edwards valve. It consists of a silicon ball enclosed in a cage formed by wires originating from the valve housing. The ball moves with the flow in order to open and close the valve.

Student Resource: How Heart Valves Work (continued)

◆ **Engineered Design**



Caged Ball:
The caged ball design is one of the early mechanical heart valves. It incorporates a small ball held in place by a small metal cage. The ball design was inspired by the ball valves used in home and industry applications that limit the flow of fluids to a single direction. The ball caused damage to blood cells, though, causing the human to use blood thinners to limit blood damage.

Tilting Discs:
A new design for mechanical valves was introduced in the mid-1960s that did a better job of mimicking the natural flow of blood. Tilting discs were used that floated between two bars so that they opened as blood moved forward, and shut when blood began to flow backward. This design had advantages and disadvantages. The tilting discs caused less damage to blood cells so humans no longer needed to take blood thinners. But, the discs wore out occasionally and had to be replaced. The ball design was more reliable.

Bileaflet Valve:
In 1979, another mechanical heart valve was engineered and introduced. The bileaflet valve consists of two semicircular carbon leaflets pivoting on tiny hinges. The design is very reliable, but the valve doesn't close completely, which allows some backflow of blood. They do represent the closest mechanical replacement for the natural heart valve which also occasionally allows blood to flow backward. When a human has this condition in their mitral valve, they are said to have "mitral valve prolapse," which causes some pain but no life threatening impact on the human.

Tissue Valves
An alternate to mechanical heart valves is the use of tissue valves that are made of human or animal tissue. These tissue valves often also include some mechanical parts to offer structural support and to assist with surgical procedures.

Student Worksheet: Valve Functions

Step One: Observe the provided ball valve to observe how the ball rotates to restrict flow of fluids.

Questions:

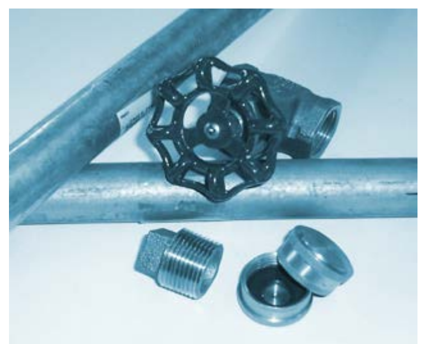
1. What did you notice about the ball inside as the knob or handle was turned? How would this impact the fluid that passed through it?

2. What advantages did you find in this type of valve?

3. What applications can you think of to apply this type of valve?

4. Which valve might be better for controlling the flow of fresh water? Waste water? Why?

Step Two: As a team, assemble a mini valve system for running water, using parts provided to you. This can be done in a sink, or outdoors. Assemble the valve provided to the pipes, and answer the questions below. You should have a gate valve, two lengths of pipe, two hose caps, a head plug, some water and a funnel. First, attach each end of the gate valve to a piece of ¾" pipe. Turn the valve to prevent water flowing through, then add water to one and gradually turn the valve so that only a drop or two of water can pass through the further pipe end. Then try different combinations of parts examining the ability of water to flow.



Questions:

1. Can you completely block the water from flowing? If so, why?

2. What happens if there is a hose cap on one end of one pipe? If you have water completely filling the two tubes, can you shut off the valve?

3. How about if you have two hose caps in place? Does the pressure change? Why or why not?

Student Worksheet:
Valve Functions (continued)

4. How does the functionality of the gate valve differ from the ball valve?

5. Which type of valve do you think would best control the flow of water, if either? Why?

6. Which type of valve do you think would be best to control the flow of blood? Why?

Step Three:
Now that you have tried out valves, and read about the strengths and weaknesses of the three main types of mechanical heart valves, work as a team to engineer an improvement for future mechanical heart valves. Attach a drawing or sketch of your proposed component part, and answer the questions below:

What aspect of current mechanical hearts did you choose to improve? Why?	What materials or parts will you eliminate or add?	How will this new design address the shortcoming you identified?	How do you think your new design will impact society? Why?

4. Present your suggested new design, including sketches, to the class.

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Abilities to distinguish between natural objects and objects made by humans
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Personal health
- ✦ Risks and benefits
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces

CONTENT STANDARD C: Life Science

As a result of their activities, all students should develop understanding of

- ✦ Structure and function in living systems

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Personal health
- ✦ Risks and benefits
- ✦ Science and technology in society

For Teachers: Alignment to Curriculum Frameworks (continued)

◆**National Science Education Standards Grades 5-8 (ages 10-14)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- History of science

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Personal and community health
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆**Standards for Technological Literacy - All Ages**

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 14: Students will develop an understanding of and be able to select and use medical technologies.