NATIONAL GEOGRAPHIC

RESOURCE LIBRARY
ACTIVITY : 35 MINS

Exploring How Robots Move

Students experiment with pneumatics and hydraulics and apply these systems to produce movement.

GRADES

3 - 8

SUBJECTS

Engineering, Physics

CONTENTS

1 Video

OVERVIEW

Students experiment with pneumatics and hydraulics and apply these systems to produce movement.

For the complete activity with media resources, visit:
http://www.nationalgeographic.org/activity/exploring-how-robots-move/

Program

DIRECTIONS

1. Introduce the concept that air exerts pressure.

Have students place their hands on top of their heads and push down. Ask them if they can feel the pressure of their hands pressing on their heads. Now, have them remove their hands from their heads and ask if they can feel any pressure now (likely not, now that they are not pressing). Explain that even though they cannot feel it, there is constant pressure on their whole body. This pressure is caused by air pressure. Air pressure is the weight of air molecules constantly pressing on you. Tell them that air pressure can be strong enough to move objects and is used in machines, such as robots, to produce movement. Play the provided video clip that shows the Atlas robot walking.

Tell students that the Atlas robot uses a hydraulic system with high-pressure oil to power its joints. Along with other systems, the hydraulic system helps the robot navigate unknown environments, including hazardous ones where humans cannot go. Encourage students to share examples where a robot would be useful in hazardous work.

2. Demonstrate the effects of air pressure on a marshmallow using a syringe.

Explain that you are going to demonstrate the effects of air pressure using a mini marshmallow. Remove the plunger from a 50 mL syringe, drop a mini marshmallow into the syringe, and replace the plunger, but do not push the plunger in at this point. Ask students to predict what will happen to the marshmallow when you press down on the plunger. Use your thumb to cover the end of the syringe so no air can escape. Holding your thumb steady, depress the plunger and let students observe the marshmallow decreasing in size. Ask: *What is happening to the marshmallow? Why?* Explain that air cannot escape from the syringe, so when the plunger is pushed down, the air molecules are squeezed together closer and closer, causing the air pressure inside the syringe to increase. The increase in air pressure squeezes the air inside of the marshmallow, causing the marshmallow (which has a lot of air in it) to shrink.

Now, still keeping a thumb on the opening, ask students to observe the marshmallow as you gently pull the plunger back out as far as possible. The marshmallow will increase in size. Ask: *What is happening to the marshmallow now? Why?* Explain that when the plunger is pulled back, the air molecules have more room to spread out, causing the air pressure to decrease and the marshmallow to expand. Explain that students are witnessing Boyle's Law—the relationship between air pressure and volume.

3. Student groups experiment with air pressure.

Explain that students will experiment with air pressure in small groups. Divide students into small groups and distribute a 30 mL syringe to each group. Give groups enough time to allow each student to play with the syringe. Ask each student to pull the plunger fully back without pulling it all the way out, and then to push the plunger back in all the way to the bottom. Ask groups to describe what is happening. Explain that when the plunger is pulled back, the syringe fills with air. When it is pressed back down to the bottom, the air is pushed out of the syringe.

Next, have a student push the plunger of the syringe all the way to the bottom and then place a finger firmly over the end of the syringe. Then have another student try to pull the plunger up from the bottom. Ask the second student to describe to the group what's happening. Now, with the first student's finger still firmly in place on the end of the syringe, have the second student attempt to push the plunger from the top to the bottom and then describe what happens to his or her group. Explain that it is relatively easy to push the plunger in the beginning, but it becomes harder because as the air molecules are pushed closer together the air has less space, or area, to fit into. This decrease in area increases the air pressure inside the syringe.

Have the second student continue pushing the plunger down, and then release it quickly and observe what happens. Students will see that the plunger pops back up. Ask: *Why does the plunger pop back up?* Explain that when the plunger is pushed down it squeezes the air molecules inside the syringe into a smaller and smaller space. The further the plunger is pushed in, the harder the air molecules push back against the syringe walls and the plunger. When the plunger is released, the pressure created in the syringe causes the plunger to pop up quickly.

4. Students make predictions about and observe a case of pneumatic movement.

Remind the class that air pressure can be powerful enough to make objects, like robot legs, move. Explain that when air is trapped in a closed environment, like the syringe, it can be squeezed into large and small spaces to decrease or increase air pressure, which causes movement. When you push down on the syringe, you are using force to squeeze the air into a smaller space. This causes the pressure inside the syringe to build up because the amount of air molecules stays the same—you're just packing them together closer and closer. This increases the air pressure, and can cause movement if it is released (like how the plunger popped quickly). Using trapped air to create movement is called pneumatics.

Take two 30 mL syringes and 30 cm (~12 in.) of clear, plastic tubing. Remove the plunger from one of the syringes and push the plunger of the other syringe to the bottom. Now, connect one end of the tubing to each of the syringes. Replace the plunger of the first syringe, but do not push it down yet. The setup should have one plunger all the way up, and the other all the way down. Have the students predict what will happen when the first plunger is pushed to the bottom of the syringe. After students make their predictions, demonstrate by pushing the plunger down. The other plunger will move up. Ask: *Why did the plunger move up when the other was pushed down?* Explain that air trapped in the closed space pushed on the second plunger with enough force to move it up.

Next, remove one of the 30 mL syringes from the tubing. Then, push the plunger of the remaining, connected syringe to the bottom. Remove the plunger completely from a 50 mL syringe and place the syringe on the tubing. Replace the plunger of the 50 mL syringe, but do not push it down yet. Ask students to predict what will happen when the plunger on the larger, 50 mL syringe is pressed down. After students make their predictions, demonstrate by pushing the plunger on the larger syringe down. The plunger on the smaller syringe will move up all the way and the plunger on the larger syringe will partially spring back out. Ask: *Why did this happen?* (There was more air than was needed to fill the smaller syringe, so the plunger on the smaller syringe moved completely out. The excess air went back into the larger syringe, moving its plunger partially back out.)

5. Students apply knowledge of pneumatics to hydraulic movement.

Tell the class that a system using trapped water instead of trapped air is called a hydraulic system. It behaves in much the same way as a pneumatic system. In pneumatic systems, trapped air is used to produce movement. In hydraulic systems, trapped water is used to produce movement. This trapped water behaves in a similar manner to the trapped air. When you push down on the syringe, you are using force to squeeze the water into a smaller space. This causes the pressure inside the syringe to build because the amount of water molecules remains the same—they are just being squeezed closer and closer together. This increased water pressure can cause movement if it is released.

Students will be working in their small groups to experiment. Set behavioral expectations by reminding students that any horseplay, such as squirting water with the syringes, will not be tolerated and that any student not following the procedures will be removed from participation in the experiment. Give each table a dish tub filled with water, two 50 mL syringes, and tubing. Have students push the plungers of both syringes all the way to the bottom. They should then submerge one of the syringes and the tubing completely under water and attach the syringe to the tubing. Keeping the tubing and the attached syringe submerged, have them pull the plunger all the way back, filling the syringe and the tubing completely with water. Next, while keeping everything submerged, have them attach the other syringe to the open end of the tubing; once this is complete, they may remove the system from the water.

Lead the students through the same experiments done with the pneumatic system. Have students repeat the same system demonstrations that you demonstrated above, asking them to carefully push in and pull out the plungers of each syringe and observe the movement. Be sure to have students put the entire system back in the water, and reassemble underwater, when it's time to switch to the 50 mL plunger. If time permits, and behavior expectations have been followed, allow for free experimentation.

6. Students discuss the demonstrations and real-world applications of pneumatics and hydraulics.

Ask: *What was surprising about the pneumatic and hydraulic systems? What was alike and different between them?* After students share observations, ask: *How do you think pneumatics and hydraulics are used in everyday life?* Have students recall the video they watched at the beginning of the activity. Ask: *How were pneumatics and hydraulics used to create movement in the robot?* Invite multiple suggestions from students.

Tell the students that pneumatic systems are typically used in robots that are stationary, like robotic arms and their hands, which are used for grasping. Pneumatic systems are desirable because they can allow swift, small, and precise movements, and are cost-effective. Hydraulic systems are more expensive but are preferred in applications where mobility, greater force, and speed are required. Ask students to offer suggestions as to why the Atlas robot uses hydraulics instead of pneumatics.

Modification

All activities can be done as a demonstration using student volunteers if there is not enough equipment to go around.

Tip

Before conducting this activity with students, make sure the tubing fits all of the syringes.

Tip

If you have trouble with the hydraulic system, make sure there are no air bubbles by starting over and keeping it entirely immersed in water during assembly.

Tip

It is recommended that the instructor conduct all of the experiments prior to using the activity in class.

Modification

Students can document the experiment using an iPhone/iPad to produce movie shorts that may be shared on a class blog or website. Caution should be taken that the technology used to document the experiment does not end up in the water.

Informal Assessment

Students apply what they have learned to illustrate how hydraulics or pneumatics could be used to move the arm of a robot that has the task of picking up either small light objects or heavy large objects. Challenge them to think about which system would work best in each of these scenarios. Have students sketch a design of a robotic arm that uses either hydraulics or pneumatics to operate. Then, have students compose an accompanying explanation about how their design works.

Extending the Learning

Provide materials for students to build the robotic arm that they designed in the assessment.

OBJECTIVES

Subjects & Disciplines

- Engineering
- Physics

Learning Objectives

Students will:

- Define pneumatics and hydraulics and explain the differences between the two
- Identify and explore how objects and materials may be moved and manipulated using pneumatics and hydraulics
- Describe how pneumatics and hydraulics could be used to produce movement in a robotic arm

Teaching Approach

- Learning-for-use

Teaching Methods

- Discovery learning
- Experiential learning
- Hands-on learning

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Creativity and Innovation
    - Critical Thinking and Problem Solving
  - Life and Career Skills
    - Flexibility and Adaptability
    - Initiative and Self-Direction
    - Social and Cross-Cultural Skills
- Critical Thinking Skills
  - Analyzing
  - Applying
  - Creating
  - Evaluating
  - Remembering
  - Understanding
- Science and Engineering Practices
  - Asking questions (for science) and defining problems (for engineering)
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Developing and using models
  - Obtaining, evaluating, and communicating information
  - Planning and carrying out investigations

National Standards, Principles, and Practices

NATIONAL SCIENCE EDUCATION STANDARDS

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard A-2:**
Understandings about scientific inquiry
• **(5-8) Standard B-2:**
Motions and forces
• **(5-8) Standard B-3:**
Transfer of energy
• **(5-8) Standard E-1:**
Abilities of technological design
• **(5-8) Standard E-2:**
Understandings about science and technology
• **(K-4) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(K–4) Standard A-2:**
Understanding about scientific inquiry
• **(K-4) Standard B-2:**
Position and motion of objects
• **(K-4) Standard E-1:**
Abilities of technological design
• **(K-4) Standard E-2:**
Understanding about science and technology

NEXT GENERATION SCIENCE STANDARDS

• **Engineering Design:**
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
• **Engineering Design:**
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
• **Engineering Design:**
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new

solution to better meet the criteria for success.

• **Engineering Design**:

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

• **Motion and Stability: Forces and Interactions**:

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Preparation

What You'll Need

MATERIALS YOU PROVIDE

- 1 50 mL syringe per group (Luer Lock type)
- 1 Dish tub per group
- 2 30 mL syringes per group
- 30 cm of 1/8 inch clear, plastic tubing per group
- Pencils
- Mini marshmallow
- Paper
- Paper towels or bath towels
- Water

REQUIRED TECHNOLOGY

- Internet Access: Required

PHYSICAL SPACE

- Classroom

SETUP

Set up so that students can easily work in groups of 2-4 students. Be sure to provide paper towels or other materials to clean up water spills.

GROUPING

- Large-group instruction

BACKGROUND & VOCABULARY

Background Information

Air pressure is the weight of air molecules constantly pressing on all things. Air pressure can be strong enough to move objects and is sometimes used in machines, such as robots, to produce movement. When air is trapped in a closed environment, it can be squeezed into large and small spaces to decrease or increase air pressure. When air is forced into a smaller space, the pressure inside will build because the amount of air molecules remains the same but they must now occupy a smaller space. The air molecules occupy a smaller space by packing closer together. This packing of the molecules increases the air pressure and can cause movement if released. A system that uses trapped air to produce movement is called a pneumatic system.

A system that uses trapped water, or another liquid, is called a hydraulic system. It behaves in much the same way as a pneumatic system, though liquids are far less compressible than gases. Trapped water behaves in the same manner as trapped air. When water, or another liquid, is pushed into a smaller space, it forces the molecules to pack closer together, causing pressure to build. If released it can cause movement.

Pneumatics is typically used in robots that are stationary, like robotic arms and their hands, which are used for grasping. Pneumatic systems are desirable because they can allow swift, small, and precise movements and are cost-effective. Hydraulic systems are more expensive but are preferred in applications where mobility, greater force, and speed are required.

Prior Knowledge

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Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
air pressure	*noun*	force pressed on an object by air or atmosphere.
area	*noun*	a geographic region.
force	*noun*	power or energy that activates movement.
hydraulic	*adjective, noun*	having to do with water or other liquids in motion.
pneumatics	*noun*	study of the uses and properties of air and other gases.

For Further Exploration

Interactives

- Hydraulics Game

FUNDER