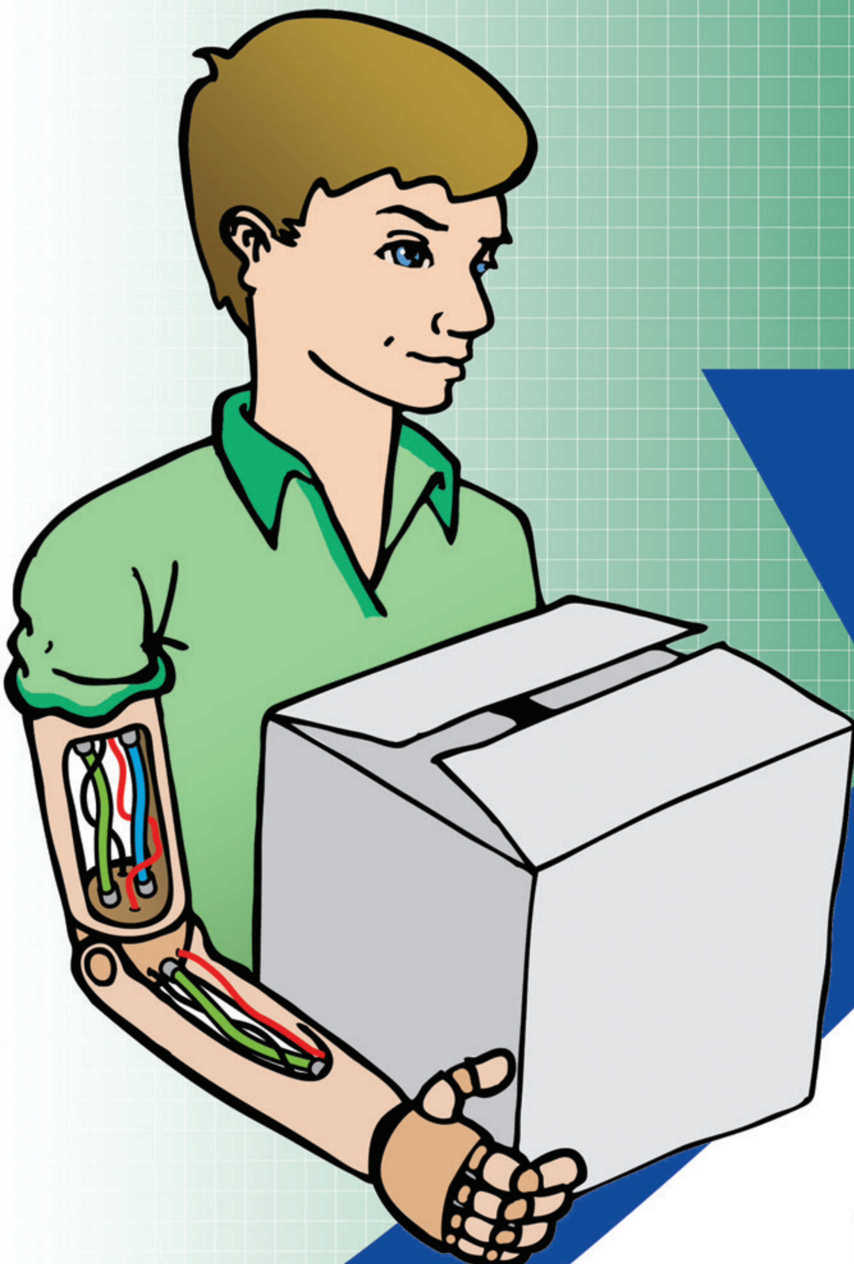

BioMedTech:
Bionic Arm

Pratt School of Engineering, Duke University

techxcite.pratt.duke.edu

TechXcite

Discover Engineering

Instructor's Guide

Table of Contents

Module Overview

This **TechXcite: Discover Engineering** module introduces youth to the ways in which engineers design technology to help people with disabilities. They explore the design considerations for developing a prosthetic arm to improve the quality of life for someone who has lost an arm. The module demonstrates ways in which design of assistive technology is interdisciplinary, combining mechanical, electrical and biomedical engineering concepts.

Activity 1: Youth explore what it is like to perform everyday tasks without the use of one hand. They then learn that assistive technology refers to devices designed by engineers to improve the lives of people with disabilities.

Activity 2: Youth build simple hydraulic and pneumatic systems using oral syringes and plastic tubing.

Activity 3: Youth use what they learned about hydraulic and pneumatic systems and then select one for making their prosthetic arm move.

Activity 4: Youth build a simple circuit with a buzzer.

Activity 5: Youth improve their buzzer circuit and use it as a touch sensor for their prosthetic arms.

At the end of this module, pairs of students will have designed and built a prosthetic arm. They will have learned that engineers design devices to solve problems to help people.

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Engineering

TechXcite Program

TechXcite is a partnership between the Pratt School of Engineering at Duke University, the National 4-H Council/4-H Afterschool and North Carolina 4-H.

The program is directed by Drs. Gary Ybarra (PI) and Paul Klenk (Co-PI). Beginning in 2001, they co-created the successful Techtronics afterschool engineering program at Rogers-Herr Middle School and Lowes Grove Middle School in Durham, N.C. The TechXcite: Discover Engineering curriculum is building on this work by creating engineering learning modules in seven theme areas for use in afterschool programs nationwide. Together they have created an engaging, substantive, experiential and inquiry-based curriculum in engineering, technology and applied science for 4-H-supported middle school youth in afterschool programs across the nation. We hope to encourage youth in both rural and urban settings to pursue careers in engineering and technology.

If your program is interested in adopting any of the TechXcite: Discover Engineering learning modules, please contact us at techxcite@duke.edu.

Online Support

The TechXcite Web site (techxcite.pratt.duke.edu) contains additional material to help you implement this module. There are videos to guide you through facilitating the activities with students. You can download copies of the Instructor's Guide and Youth Handouts. You'll also find a list of sources for any materials you'll need. Finally, there are links to additional resources.

E-Mail and Phone Support

If you have questions about any of the material in this curriculum, please do not hesitate to ask. The Duke team is available to support you if you have questions about implementing the modules. Please contact our staff at **techxcite@duke.edu.** You may also call us anytime at the phone number listed on the Contact Us page on our Web site: **http://techxcite.pratt.duke.edu/contact/index.php**.

Using This Guide

The first portion of this handbook is the Instructor's Guide for all of the activities in the module. It includes this introductory section and also the Instructor's Guide for each activity. This introduction contains general information about the TechXcite curriculum, what to expect in each activity's Instructor's Guide and background on tools you will be using.

The Instructor's Guide for each activity follows the same format. Below is what you can expect to find in each section. At the beginning, you will find basic information about the module. This includes:

- Time Required
- Materials
- Group Size – This is the suggested number of students per group.
- Youth Handouts – These will need to be copied.
- Instructor Preparation – This describes what you need to do before the activity and approximately how much time it will take you.
- Learning Objectives
- Vocabulary

Introduction, Procedure and Activity Closure

Three sections form the body of the activity: Introduction, Procedure and Activity Closure. The Introduction and Activity Closure sections are scripted. You may read these sections verbatim to students. Instructions that are not to be read to students, as well as answers to questions, are in brackets/italics. The Procedure section is not scripted. It contains step-by-step instructions for facilitating the activity with a group of students.

Cleanup

This section appears in activities in which cleaning up in a particular way will help reassemble the kit or prepare for the next activity. Following these instructions will keep the kit in proper order.

Assessment

This section tells you how to assess whether or not students understood the material presented to them in the activity. These assessments are generally based on students' answers to questions asked during the Activity Closure section.

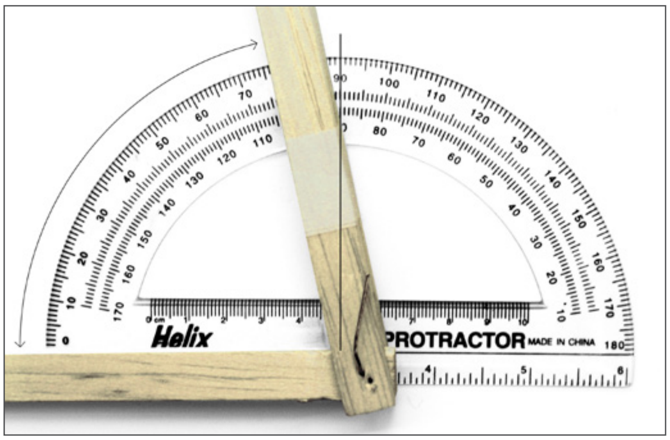
Tools Used in this Module

Protractor

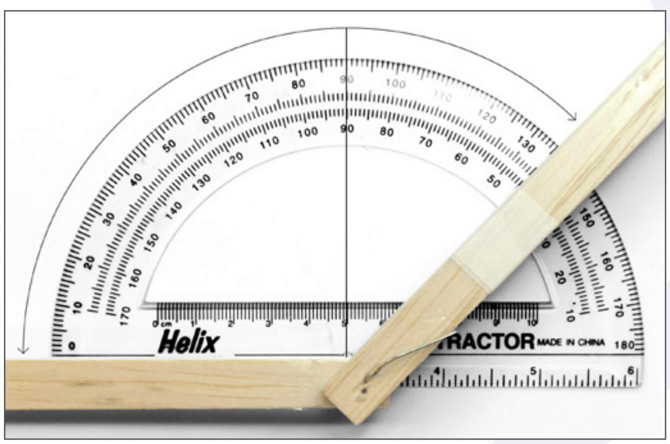
In Activity 3, students will be using a protractor to measure angles. Instructions for using a protractor are included in the Youth Handout for that activity. You might take some extra time between Activities 2 and 3 to introduce the protractor so everyone will be familiar with it.

Show students how to line up one of the sticks along the black line that is near the straight edge of the protractor. Then instruct them to align the inner "elbow" of the sticks with the tiny hole in the protractor. Have them read the number where the inner edge of the second stick crosses the top of the arc. Use these pictures to show some sample measurements.

In this picture, the protractor is measuring an angle of 76 degrees. You read the smaller number because the angle is smaller than a right angle (90 degrees).



The protractor below is measuring an angle of 135 degrees. You read the larger number because the angle is larger than a right angle (90 degrees).



Activity 1: Assistive Technology

Time Required: 45 Minutes **Group Size:** 3

Materials List

Each Group Needs:

- Three rubber bands (large enough to stretch around a closed fist)
- Three socks
- Drawing paper
- "Mystery Container" filled with six objects of various shapes and sizes (not included)

Youth Handouts:

- "Assistive Technology"

Instructor Preparation (20 minutes)

- Assemble a collection of opaque containers (shopping bags, boxes, trash bags, etc.), one per group, large enough to hold six common objects that would be recognizable to students.
- Fill each group's container with an assortment of six items. Feel free to use materials from this kit, including batteries, masking tape, protractors, paper clips, sandpaper or paper cups. Other examples: pens, small books, erasers, rolls of tape, old CDs, drink containers, sponges, etc. It is not necessary for each group to have the same items. Avoid sharp objects because students will be reaching blindly into the bag.

Learning Objectives

After this activity, students should be able to:

- Define assistive technology as a device that helps people with disabilities by either making a task easier or by enabling them to perform a task they could not otherwise do.
- Identify examples of assistive technology.

VOCABULARY	Word	Definition
	Assistive technology	A device that helps people with disabilities by either making a task easier or by enabling them to perform a task they could not otherwise do.
	Engineer	Someone who uses math and science as tools to create technology to solve problems.

Activity 1: Assistive Technology

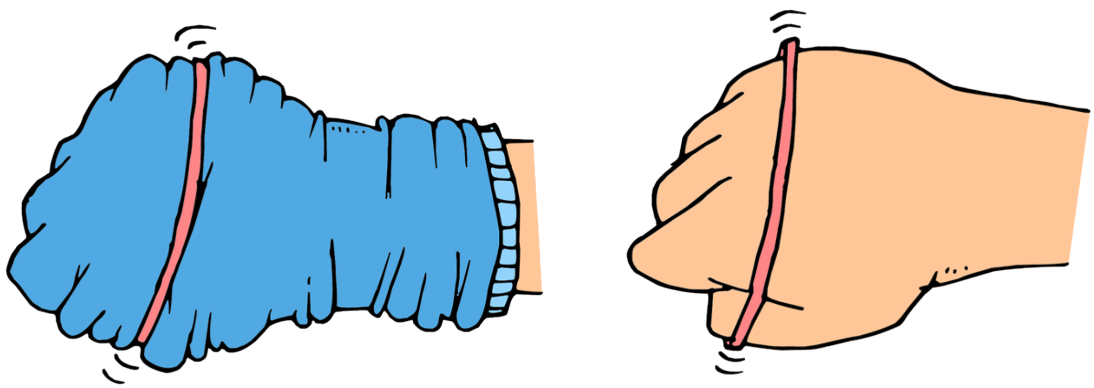
Introduction

Have you ever thought about what you would do if you lost one of your hands? What tasks that are now easy might become difficult? Today you are going to try performing some common tasks without using one of your hands.

[Give one sock and one rubber band to each student.]

1. Place your hand inside the sock and make a fist. Now wrap the rubber band around your fist so that your thumb and fingers cannot move.

[Use this photo for reference and demonstrate for the class.]



2. Now keep the sock on and try tying your shoes. Can you do it? Is it possible to tie your shoes with one hand, but it takes practice.

What are some other activities that would be difficult to do with one hand?

[Lead a brainstorming session and write students' ideas on the board. This information will be revisited during Activity Closure.]

Procedure:

1. Instruct students to keep sock on for the next activity.
2. Place students into groups of three.
3. Provide each group with a mystery container. Tell students not to look inside.
4. Give each group a handout.
5. Instruct students to take turns reaching into the container with the sock-covered hand and trying to identify the objects without opening the fist. They are not to look inside the container or remove any items. After each turn, students should write down the identity of the objects they touched. Have them continue taking turns until they've listed six items on their handouts.

Activity 1: Assistive Technology

Procedure: (continued)

6. After the groups have finished, ask: "What items are you confident your group guessed correctly?"
7. Have students explore the containers using the hand without the sock and make any corrections to their list.
8. Finally, have students open the containers and look at all of the items.

Activity Closure

- How do you think you would feel if you lost the use of one of your hands?
- Which objects were hardest to identify with the sock-covered hand and why?
- If you lost the use of one of your hands due to an accident or illness, what activities might you need to do differently? What activities do you think you would not be able to do? *[Examples: swinging a baseball bat or lifting a heavy box.]*

[List the sample tasks on the board or paper for later use.]

People who lack the use of one hand can often do anything you or I can do. For example, typing on a computer is usually a two-handed activity, but if you had only one hand you might adapt to other methods of typing.

1) You might learn to type using one hand. It is normal for a person who has lost the use of a part of his or her body to compensate in some way.
2) You might use a device to help you type without your hands, such as a computer program that dictates your spoken words. This is an example of assistive technology.

Assistive technology devices help people with disabilities by either making a task easier or by enabling them to perform a task they could not otherwise do. What other assistive technologies can you think of? *[Possible answers: eyeglasses, contact lenses, hearing aids, wheelchairs, etc.]*

[Choose one of the tasks from the brainstorming session for which students will design an assistive technology. Give each student a sheet of drawing paper.]

Engineers use creative problem-solving to design assistive technologies. Now is your opportunity to be engineers. If you could design a device to help a person [insert task here], what might it look like? I want you to sketch your idea. Don't worry about being artistic, but try to be creative with your solution. There are no wrong answers. Before you start drawing, write down the problem for which you're designing a solution.

[Give students about 10 minutes to sketch. If there is time, ask some of the students to share their designs with the group.]

You have just created a design for a new assistive technology device. Over the next few weeks, we will be exploring options for creating assistive technology. Ultimately, you will be building a prosthetic arm—a device designed to help someone who has lost the use of an arm. We will be exploring different functions that a prosthetic arm might perform and learning how to make the arm move.

Assessment

Examine student drawings. These drawings represent an embedded assessment. Students should have identified the need that their device will meet. The device that each student designed should be capable of helping a person with limited ability perform a task and improve his or her quality of life.

Activity 2: Gases and Liquids

Time Required: 45 Minutes **Group Size:** 2

Materials List

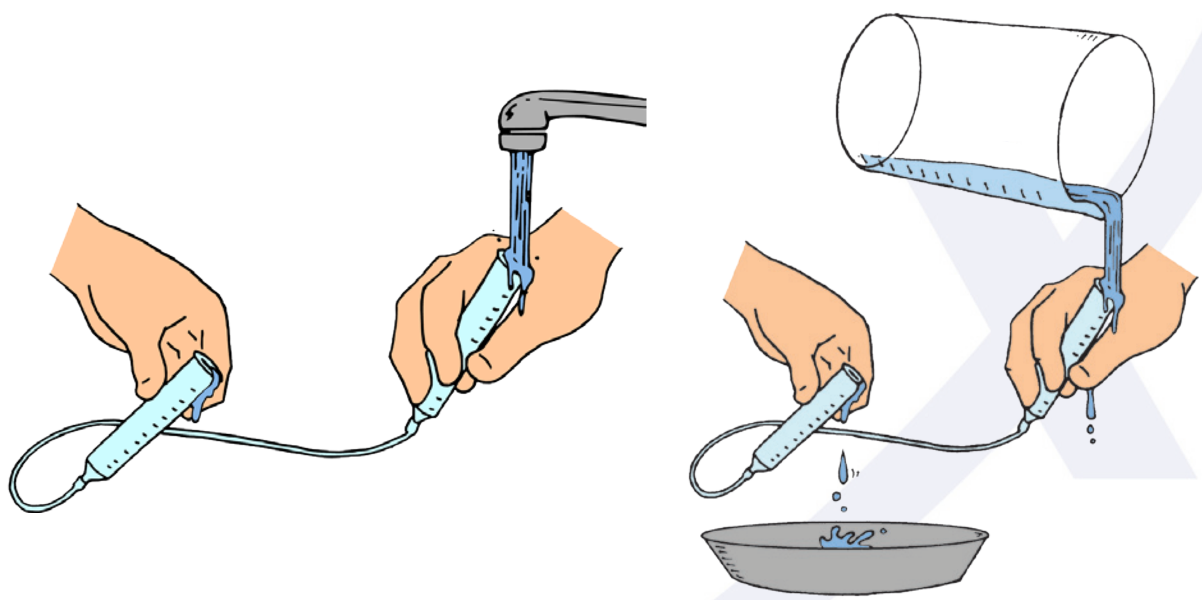
Each Pair Needs:
- Four 10ml oral syringes
- Two 1.5-foot lengths of 1/4" clear plastic tubing
- One "Gases and Liquids" Youth Handout

Entire Class Needs:
- Scissors
- Water source (drinking fountain, sink, pitcher, etc.)
- Towels for spills

Youth Handouts:
- "Gases and Liquids"

Instructor Preparation (25 minutes)

- Cut one 1.5-foot length of tubing for each student. (10 minutes)
- Assemble a sample 1.5-foot system and practice filling it at the water source, following the instructions in the Youth Handout. (10 minutes) If the group is large and workspace is limited, you may need to fill the syringes for students during the exercise to save time.
- Create a pair of demonstration systems using 5-10 feet of tubing for each. One model will use air and the other will use water. During the Activity Closure, you will demonstrate these systems to show that motion can be transferred over longer distances. (5 minutes)



Activity 2: Gases and Liquids

Learning Objectives

After this activity, students should be able to:

- Explain that a hydraulic system uses liquid to transfer motion.
- Explain that a pneumatic system uses a gas to transfer motion.
- Explain that gases are compressible.
- Explain that liquids are incompressible.

VOCABULARY	Word	Definition
	Compressible	Material that takes up less volume as pressure increases.
	Hydraulic	System that transfers motion using liquid pressure.
	Pneumatic	System that transfers motion using air pressure.

Introduction

Today we are going to create two types of systems that engineers use to transfer motion. What do we mean by transferring motion? Motion transfer happens when an object at one location moves an object at another location. For example:

- An airplane pilot might move a rudder outside the plane by using a lever or button in the cockpit. The pilot would be unable to push directly on the rudder while flying.
- A driver stops or slows the wheels of an automobile by pressing a pedal inside. The driver can't push directly on the brake pads while driving. Instead, the driver stops the car by transferring motion from the brake pedal to the tires.

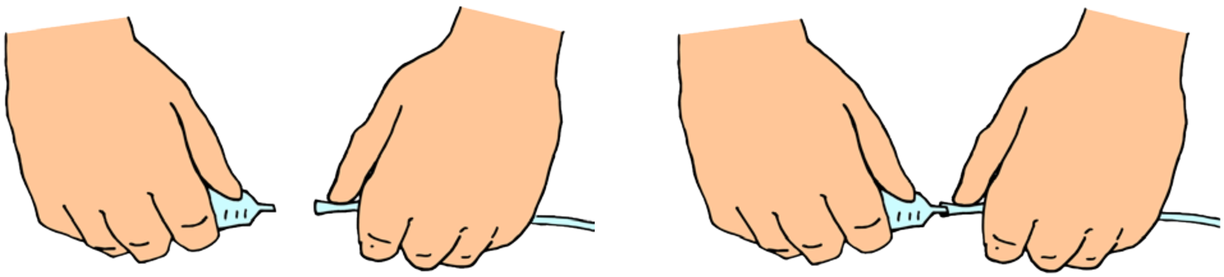
Engineers use many different methods to transfer motion, including electronics, wires, gears, gases and liquids. Today we are going to explore how engineers use gases and liquids to transfer motion.

Procedure

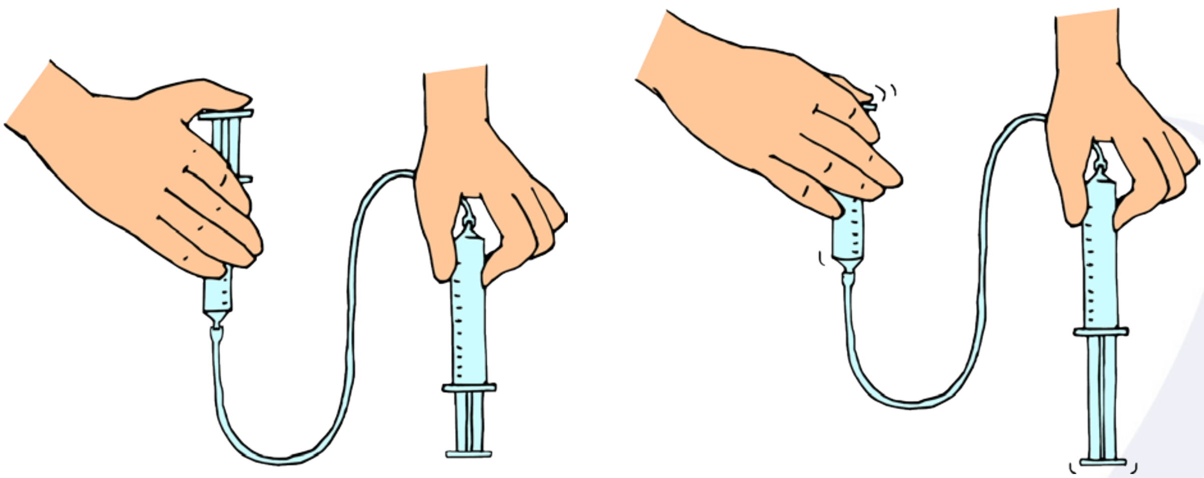
Exercise 1: Transferring Motion Using Air

1. Give each student two syringes and one 1.5-foot section of tubing. (Students will be paired up later.)
2. Instruct students to retract the plunger of one syringe all the way and push the plunger of the other syringe in all the way. Now demonstrate how to attach the tips of the syringes to the ends of the tube.

Activity 2: Gases and Liquids



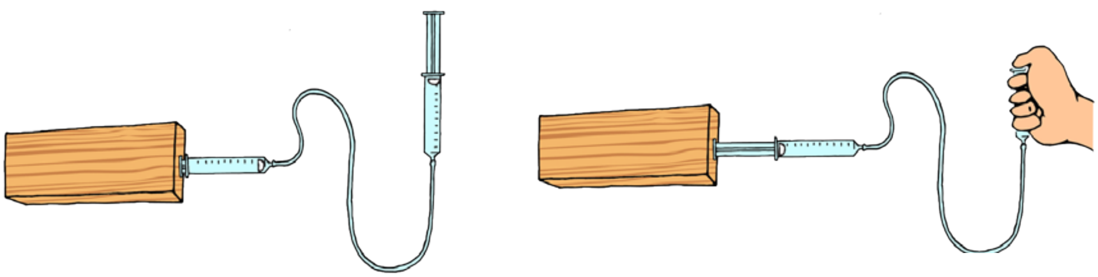
3. Once the systems are assembled, instruct students to push the retracted plunger completely into the syringe. This motion will push air through the tube and cause the plunger in the other syringe to retract.



4. Tell students they've just created a system that uses air pressure to transfer motion. It is called a pneumatic system.

Activity 2: Gases and Liquids

5. Ask students to look at the following two photos. One shows how a person could move a wooden block with a rod. The other shows how to move the block using air pressure. Ask students when an engineer might prefer to move an object using air pressure. If students can't provide a reason, ask them to think about possible answers while doing the next activity. *[At this point, students may recognize that air pressure can transfer motion through curved pathways, which might be more practical and less difficult than using a rod or gears.]*

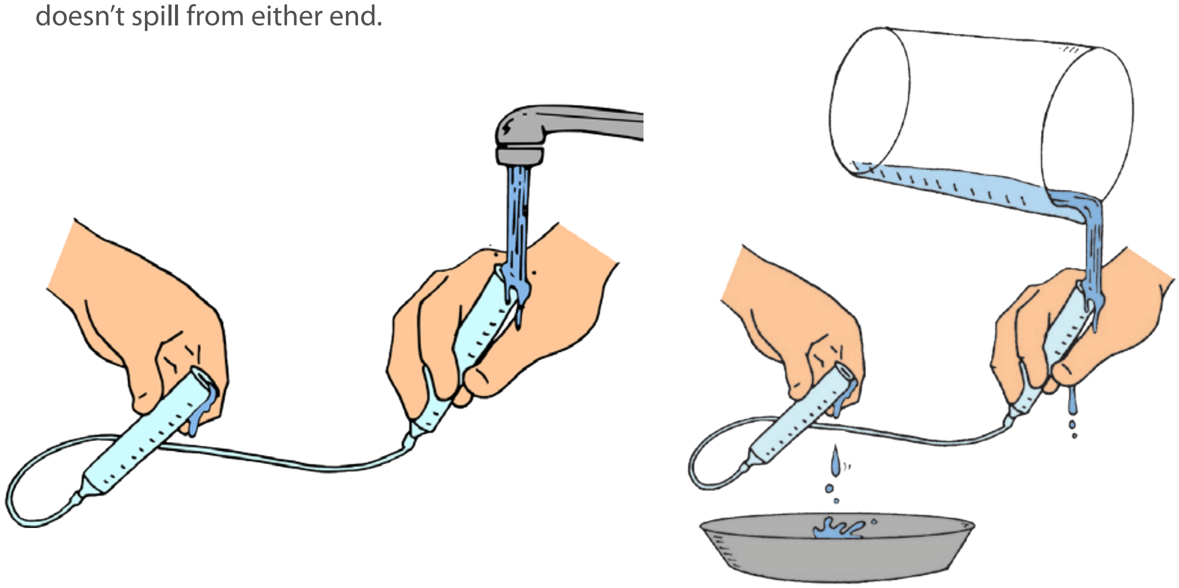


Exercise 2: Transferring Motion Using Water

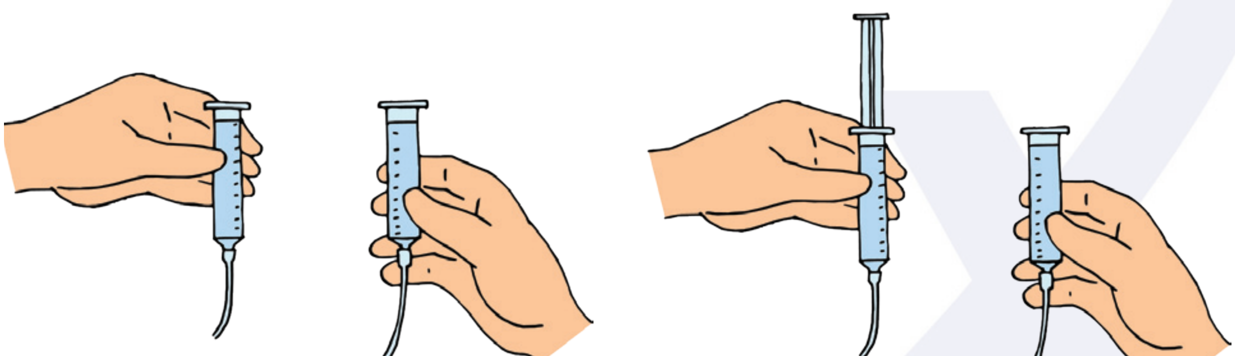
6. Place students in pairs. Each pair of students will be using only one of the systems for this exercise.
7. Prepare to fill students' systems, having them observe so they'll know how to replace any spilled water if necessary. Remove both plungers from each system. Pour water into one of the empty syringes until the entire system, including the other syringe, is filled. Have one student hold the end of the second empty syringe over a catch basin in case water spills out.

Activity 2: Gases and Liquids

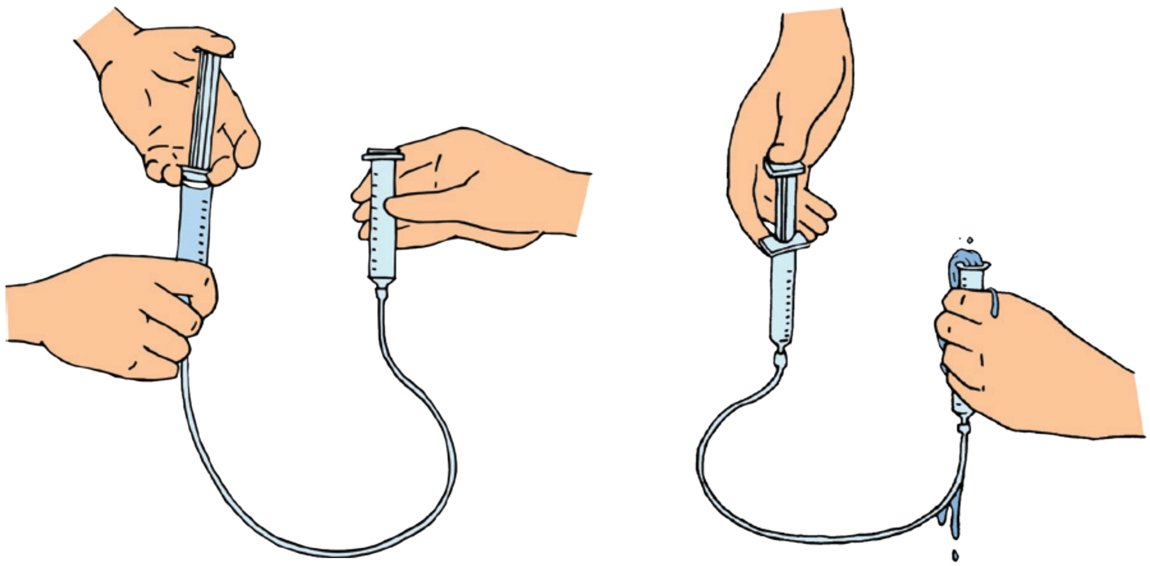
8. Give each pair of students a system and instruct them to hold both syringes level so that water doesn't spill from either end.



9. Instruct students to hold their systems level over a catch basin and push a plunger into one of the syringes. Excess water will flow out of the other syringe. Have them put the plunger back into the other syringe and press it down gently. (Remind students not to apply so much pressure that the other plunger pops out.) If the system was prepared properly, this motion will cause the plunger in the other syringe to retract.



Activity 2: Gases and Liquids



10. Allow students to experiment with pushing the plungers alternately to transfer water back and forth.

11. Tell students they've just created a system that uses water to transfer motion. It is called a hydraulic system.

12. Let students compare their air-filled systems and water-filled systems and note any differences or similarities between them. Give each pair of students enough time to adequately explore and experiment with the two systems.

13. Ask students what differences they observed between the two systems. *[For example, they may have noticed that they were able to push both plungers in the air-filled system simultaneously but not the ones in the water-filled system; that the water-filled system transfers movement faster than the air-filled system; or that it is easier to push air than water.]*

14. Ask students if they can explain why the differences exist. *[Answers may vary, but some students will probably recognize that air is easier to move than water because it is more compressible.]*

Activity 2: Gases and Liquids

Activity Closure

You probably noticed that air is easy to compress. This is because air is a gas. Gases are very compressible, which means that they may be easily squeezed into a smaller volume of space than they normally occupy. When gases are compacted in this way, they will push back. If you push the plungers in the air-filled syringes at the same time, you will feel a pushback force due to increased pressure in the tube.

Liquids are so hard to compress that they are usually considered incompressible for engineering purposes. Incompressible means that a substance cannot be squeezed completely into a smaller space. In the water-filled systems, the plungers moved back and forth more quickly than the ones in the air-filled systems. The motion is transferred almost immediately because the water is nearly incompressible. In the air-filled systems, on the other hand, there was likely more of a delay in the transfer of motion, due to the compression of the air.

[Show the group the pair of demonstration systems you prepared before the activity.]

I've assembled these larger systems to show how motion may be transferred over even longer distances. One is filled with air and the other with water. I'm going to push one plunger in the air-filled system and then I'll push one in the water-filled system. By a show of hands, who thinks that when I press one of the plungers in the air-filled system, the other plunger will move? Who thinks it won't? Who thinks that when I push one of the plungers in the water-filled system, the other plunger will move? Who thinks it won't?

[Ask students to explain their reasoning. Now do the demonstration. The second plunger in the water-filled system will move. The second plunger in the air-filled system may not move. You can then explain why: In this longer system, the air has farther to travel. If the air becomes compressed enough, there may not be enough air flow to move the other plunger.]

You have just learned about hydraulic and pneumatic systems. Hydraulic systems use a liquid, such as water, to transfer motion. Pneumatic systems use a gas, such as air, to transfer motion. Can anyone think of examples of hydraulic systems that people use every day? *[Possible answers: garage lifts, arms and buckets in heavy machinery.]* How about pneumatic systems? *[Possible answers: height-adjustable office chairs, sliding doors in store entrances, etc.]*

Next time, you and your partner will be building a prosthetic arm. You will have to choose between using a pneumatic system or a hydraulic system to make the elbow bend.

Assessment

Use students' answers to the questions you asked during the Activity Closure demonstration to evaluate how well students understand the concept of compressibility.

References

"An Arm and A Leg," www.teachengineering.org, Worcester Polytechnic Institute. 12/14/2007.

HowStuffWorks.com (http://science.howstuffworks.com/hydraulic4.htm)

Activity 3: Making the Arm

Time Required: 45 Minutes **Group Size:** 2

Materials List

Each Pair Needs:

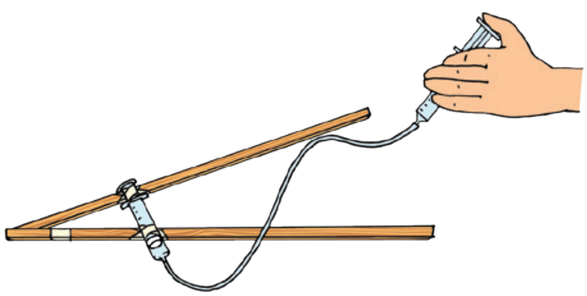
- One hydraulic system and one pneumatic system (from Activity 2)
- Four rubber bands of any size
- Masking tape (one per two pairs)
- Scissors
- String
- Protractor with ruler
- Paper clip
- Four pre-cut balsa wood strips ¼" x ½" x 18"

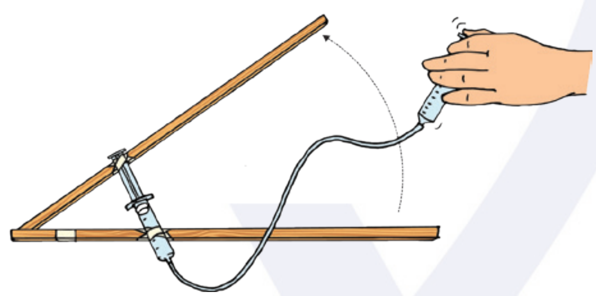
Youth Handouts:

- "Making the Arm"

Instructor Preparation (20 minutes)

- Build two demonstration arms following the instructions in the Youth Handout. Attach a demonstration hydraulic syringe system from Activity 2 to one of the arms (as shown below). This will be the starting point for students to improve their designs. (15 minutes)
- Refill any of the students' hydraulic systems that need water. (5 minutes)





Learning Objectives

After this activity, students should be able to:

- Use a protractor to measure an angle.

VOCABULARY	Word	Definition
	Protractor	A tool used to measure an angle.

Activity 3: Making the Arm

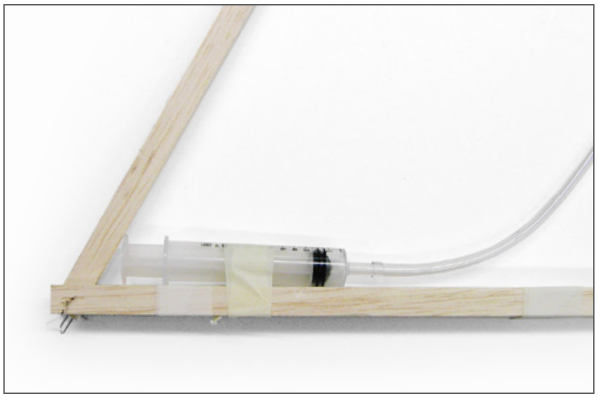
Introduction

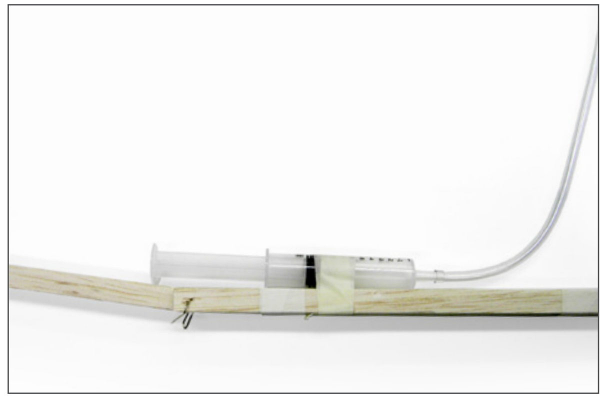
Today we will be building a prosthetic arm. I will show you how to put together the basic skeleton of the arm. Then you will become engineers, devising a way to make the arm move by transferring motion from one location to another. You will be incorporating the hydraulic or pneumatic system you built last time to create your design. Just like real engineers, you will be given design constraints. This means that you will be allowed to use only certain materials, your completed product and its operation must meet specific criteria and you will have a limited amount of time in which to work.

Procedure

1. Distribute handouts and materials for building the arm.
2. Show class what an assembled arm looks like. Allow students to look at it while they are building theirs. Have students follow instructions for Exercise 1 in the handouts. Guide them as necessary.
3. When they have finished building a basic arm, distribute the hydraulic and pneumatic systems from Activity 2.
4. Tell students that they will be using the systems to devise a way to make the arm move back and forth at a specified angle. Their goal is to achieve the largest range of motion possible. Before beginning, they will need to know how to use a protractor.
5. Demonstrate how to use a protractor to measure the angle at the inner elbow. Guide them through the instructions in Exercise 2.
6. Go over the design constraints for the Engineering Design Challenge: a) Only one syringe may be attached to the arm. Movement must be controlled using only the unattached syringe. b) The forearm must move outward (straight position) and back (bent position). c) The elbow must not open wider than 180 degrees. d) You may use one or both pairs of syringes. e) You may use either the hydraulic system or pneumatic system. f) You may use only the materials provided. g) You have only ___ minutes to complete the activity *[10-15 minutes suggested, depending on available time].*
7. Start the design challenge by showing students your demonstration model. Then instruct them to begin building their own, adhering to the design constraints listed in the handout.
8. Circulate among the students to supervise, provide encouragement and answer questions. Pay attention to anyone who may be stumped on a solution.
    - It’s likely that students will be able to straighten the arm to 180 degrees relatively easily but may have difficulty bending it back. An example is depicted on the following page.
    - Encourage them to be ambitious but to strive for only the greatest extension position from which full retraction is possible.
9. Give a five-minute warning and two-minute warning to let students know how much time remains.

Activity 3: Making the Arm





Activity Closure

What angle of rotation was your arm able to attain? *[Let various groups report their angle of rotation. Numbers should range between about 30 degrees and 170 degrees. If any students report something beyond that range or the number doesn't seem right, have them show you after class how they calculated the angle to make sure they used the protractor properly.]*

Now I'm going to give a few of you the opportunity to demonstrate your design. Who wants to show us how your arm works? *[Invite two or three pairs of students that have particularly good examples to demonstrate. In subsequent classes, select different people so as many students as possible have a turn. Students may become bored if everyone presents their work every time.]*

[As students explain their solutions, ask how they decided on their design. Also ask what they would do differently next time.]

In the next activities, we will explore ways of giving the prosthetic arms a sense of touch.

Assessment

Have students report what angle of rotation they were able to achieve. To calculate the angle of rotation, they should record the angle created at maximum extension and then subtract the value created when the arm is bent. Examine each prosthetic to see if students' calculations are correct.

References

"An Arm and A Leg," www.teachengineering.org, Worcester Polytechnic Institute. 12/14/2007.

Activity 4: Prototype Buzzer Circuit

Time Required: 45 Minutes **Group Size:** 2

Materials List

Each Pair Needs:

- Three wires with alligator clips
- One 9-volt battery
- One 9-volt battery snap
- One buzzer (Radio Shack Part #273-055A)
- Push-button/momentary switch (Jameco Part #106112PS)

Youth Handouts:

- "Prototype Buzzer Circuit"

Learning Objectives:

After this activity, students should be able to:

- Explain that for electricity to flow, it must follow a complete loop.
- Build a circuit from a basic circuit diagram.

VOCABULARY	Word	Definition
	Circuit Diagram	A graphic that electrical engineers use to depict their electrical device designs.
	Prototype	An original, full-scale and usually working model of a new product or new version of an existing product.

Introduction

In Activity 1, you tried to identify objects without looking at them and without holding or picking them up. Though you couldn't see the items, you knew you were in contact with something because you have a sense of touch. If you were wearing a typical prosthetic arm, you would have no feeling in that arm.

When you touch something, what sensations do you usually have? *[Help students to recognize that people usually experience the following sensations when they touch something: (1) Contact — Is something there? (2) Pressure — Is the object hard or soft? (3) Temperature — Is the object hot or cold? (4) Texture — Is the object wet, dry, sticky, rough, etc?]* An ideal prosthetic arm would be able to sense contact, pressure, temperature and texture.

When you created your prosthetic arm, you used skills similar to those a mechanical engineer might use. Most modern engineering projects require that different types of engineers work as a team. Designing more sophisticated prosthetics requires the expertise of many types of engineers, including mechanical engineers, electrical engineers and biomedical engineers. Their challenge is to enable the user of the prosthetic device to receive important sensory information when he or she touches something.

Activity 4: Prototype Buzzer Circuit

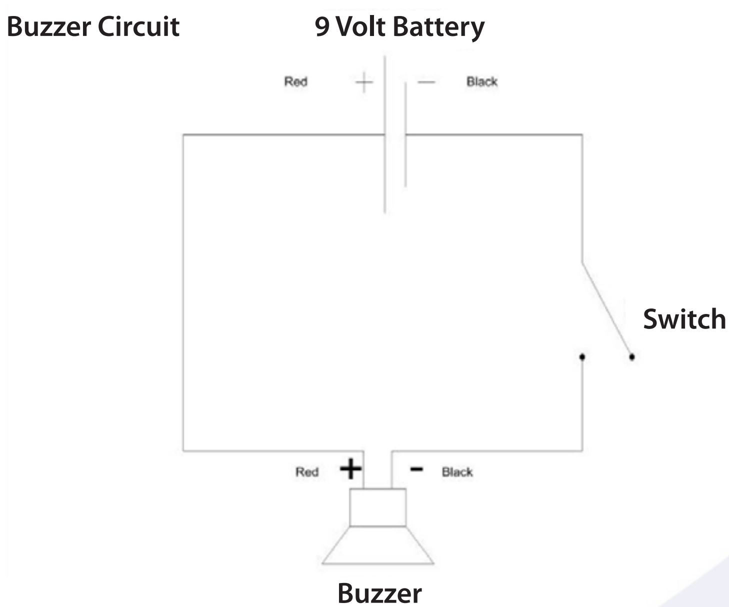
What type of device might you incorporate into a prosthetic arm to let the user know when the arm is touching something? *[Possible answers: buzzer, light, vibrator.]* For a prosthetic sensory device to be effective, the user must have functioning senses in another part of the body, such as sight, hearing or a sense of touch. Some types of sensory devices may have drawbacks. For example, it takes time for the user of the prosthetic to associate a sound or light with contact. If touching something triggers a sound or light, it might also be disruptive. If you were in a meeting, for example, you would not want a buzzer sounding every time you moved your chair.

Doctors and scientists are studying the human body to develop the next generation of prosthetics. In 2006, doctors at the Rehabilitation Institute of Chicago performed a unique type of surgery on a woman who had lost her arm in an accident. The doctors were able to surgically reroute nerves that would have gone to the hand to other muscular tissue. By using the muscles to amplify the electrical nerve signals, she can now control her prosthetic hand in the same way she once controlled her real hand. Now that doctors have identified the nerve pathway to the hand, biomedical engineers may one day be able to design a prosthetic arm that would enable a user to sense pressure and temperature through artificial sensors attached to nerves in healthy parts of the body. The next generation of this technology incorporates sensors on the fingertips that will push on the point where the arm is attached, providing a sense of pressure.
[For reference, see http://ngm.nationalgeographic.com/2010/01/bionics/fischman-text/1]

Next time, you are going to figure out a way to incorporate a sensory device into your prosthetic arm. Before then, we need to learn a little bit about electrical engineering by building a circuit.

Procedure

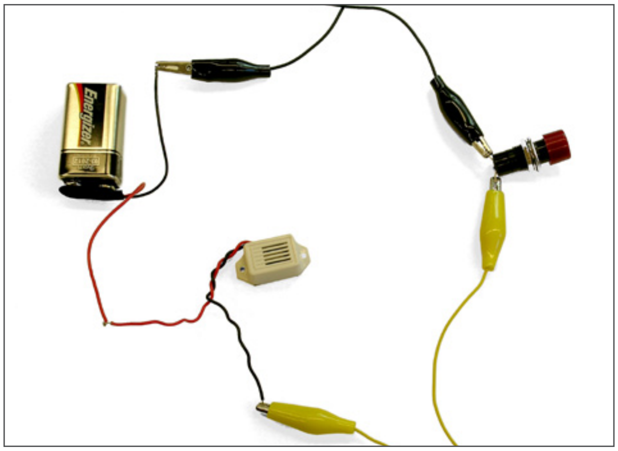
1. Place students into pairs (students should continue with their previous partner).
2. Draw the following circuit diagram on the board.

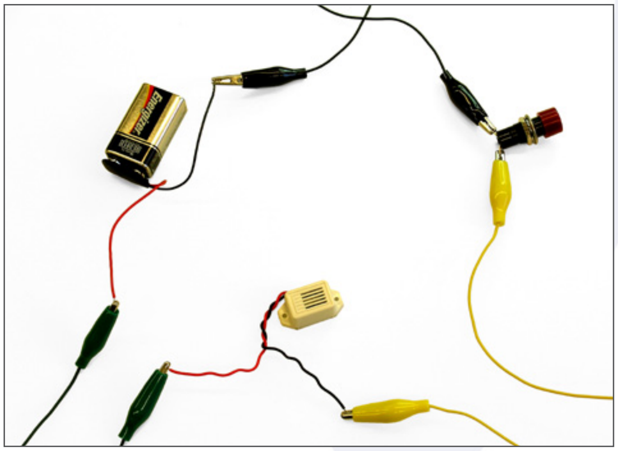


Activity 4: Prototype Buzzer Circuit

Procedure (continued)

3. Tell students that you will be handing out some electrical components and asking them to build the circuit pictured in the diagram. Before distributing any materials, review these rules:
    a. Do not lose any parts. They are expensive and will be used by other classes.
    b. Do not connect the battery terminals to each other. This will cause the battery to discharge ("go dead"). The battery will heat up as it runs out of power and might leak dangerous chemicals.
4. Distribute the parts and handouts.
5. Instruct students to follow the directions on the handout and construct the circuit shown in the diagram. Explain that red wires attached to a component mean positive and that + signs on the diagram correspond to the red wires from the battery and buzzer.
6. Circulate among the students and help them complete their circuits, if necessary. Encourage them to try solving the problem before they ask for any advice, but otherwise answer questions as they ask them. Note that the buzzer has both a red and black wire. The other end of the red wire needs to connect to the battery's positive terminal. For your reference, two correct circuits are pictured here. Remind students that the color of the wires connected to the alligator clips is not important. Only the colors of the wires coming from the buzzer and battery matter.





7. If any of the circuits do not work and students cannot figure out why, help them troubleshoot:
    a. Try connecting the buzzer in the other direction by switching the red and black wires (in case it is connected backward).
    b. Substitute a spare battery in case the battery is dead.
    c. Be sure metal is touching metal at each of the connections.
8. Once students have made functioning circuits, congratulate them on building a circuit from a circuit diagram like a real electrical engineer would.

Activity 4: Prototype Buzzer Circuit

Activity Closure

The most basic function of touch is contact. In other words: Is something there? Am I in contact with something?

How might you use the circuit you built to improve the function of a prosthetic arm? Could you incorporate it in such a way that a user would know when he or she had touched something? How might it work? *[Give students some time to think about the problem and encourage them to share their potential solutions.]* As an example, an engineer might place a sensor, such as a switch, on the hand of the prosthetic arm and place a buzzer at another location to produce a noise or vibration. The buzzer could be anywhere, though putting it near where the prosthetic device is attached would allow the user to feel the vibration of the sensor in addition to hearing it. Using this type of design element could produce a more sophisticated prosthetic device. Next time, you will be deciding how to use a circuit, switch and buzzer in your prosthetic arm to enable it to sense contact.

Does the color of the wires with clips on them matter?

[The color of the covering does not affect the way a circuit works. In some cases, engineers may use them to help keep track of connections.]

Are the wires with clips on them necessary to create this circuit?

[The clips help hold the wires in place, but they are not necessary to complete the circuit.]

[There will likely be time left over at the end of this activity. If so, students could use the opportunity to re-examine the prosthetic arms they've created to be sure they work correctly or to improve them. They might also practice using the protractors to take any new measurements. Remind them to be gentle with the prosthetic arms to avoid damaging or breaking them.]

Assessment

You will assess students during the next class. In the beginning of Activity 5, you will be asking students to recreate the circuit using the diagram you just presented. To make the exercise more challenging, you could add a few extra wires with alligator clips or other components to the kits. Note which students are able to build the circuit using only the diagram and which ones require extra help.

Activity 5: Designing a Touch Sensor

Time Required: 45 Minutes **Group Size:** 2

Materials List

Each pair needs:
- Three wires with alligator clips
- One 9-volt battery
- One 9-volt battery snap
- One buzzer (Radio Shack Part #273-055A)
- Push-button/momentary switch (Jameco Part #106112PS)

Each pair needs these materials for the switch:
- Small paper cup
- 10 paper clips
- Five rubber bands
- Masking tape
- Aluminum foil (2 square feet)
- Four 3x5 index cards
- One 2-inch foam ball

Entire class needs:
- Extra paper clips
- Extra rubber bands
- String
- Optional miscellaneous supplies (Provided by Instructor): small springs, corrugated cardboard, foam, poster board, etc. Additional supplies may encourage even more creative problem-solving.

Youth Handouts:
- "Prototype Buzzer Circuit"
- "Designing a Touch Sensor"

Learning Objectives

After this activity, students should be able to:

- Describe what engineers do.
- Explain that metal conducts electricity.
- Explain how a prosthetic device could provide the user with a sense of touch.

VOCABULARY	Word	Definition
	Engineer	Someone who uses science and math to solve practical problems.
	Circuit Diagram	A graph that electrical engineers use to depict their electrical device designs.

Activity 5: Designing a Touch Sensor

Introduction

For the final part of this project, you will be using electrical engineering concepts to create a touch sensor for your prosthetic arm. As a review, what four sensations do you experience when you touch something?

[Help them to recall, if necessary:

1. Contact: Is something there?
2. Pressure: Is the object hard or soft?
3. Temperature: Is the object hot or cold?
4. Texture: Is the object wet, dry, sticky, rough, etc?]

In Activity 4, we discussed how a buzzer circuit might be incorporated into a prosthetic arm to alert the user when the arm is touching something. Does anyone remember any ideas about how that would work?

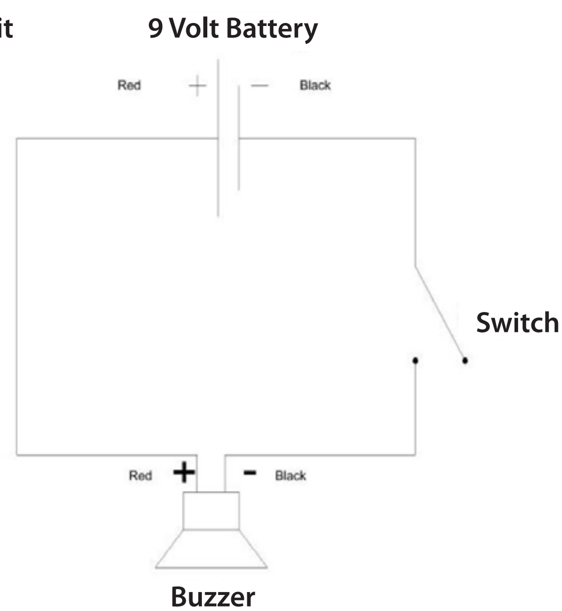
[Help them to recall that they might attach a switch to the hand and put a buzzer at another location. The buzzer could be anywhere, though putting it near where the prosthetic device is attached would allow the user to feel the vibration of the sensor in addition to hearing it.]

Procedure

Recreate Buzzer Circuit from Activity 4.

1. Place students back into the same pairs.
2. Draw the circuit diagram on the board, just like in Activity 4.

Buzzer Circuit



3. Tell students that you will be giving them the electrical components they used in Activity 4 (plus a few extra components if you added some) and that you want them to recreate the buzzer circuit they made before.

Activity 5: Designing a Touch Sensor

Procedure (continued)

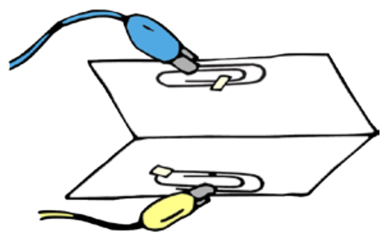
4. Remind them of the rules:
    a. Do not lose any parts. They are expensive and will be used by other classes.
    b. Do not connect the battery terminals to each other. This will cause the battery to discharge ("go dead"). The battery will heat up as it runs out of power and might leak dangerous chemicals.
5. Distribute the parts and "Prototype Buzzer Circuit" handouts.
6. Notice which pairs require help in completing the circuit. This will help you assess what they learned in Activity 4.

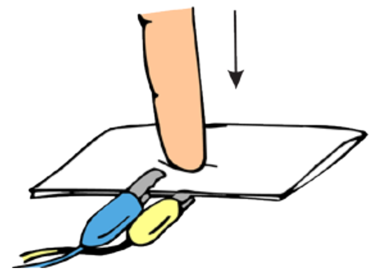
Design the Sensor.

1. Distribute "Designing a Touch Sensor" handouts.
2. Show them one of the push-button switches and ask how they think it works. Explain that the switch they design must do these two things:
    a. It must create a connection when pressed. The alligator clips must connect to the two metal conductors, which must come together to form contacts. The contacts may be made with aluminum foil or paper clips.
    b. It must have some sort of spring release that causes the wires to separate when the switch is disengaged. You may demonstrate options for making a spring, some of which are shown on the handout. Other options might incorporate paper clips folded in various ways, folded index cards or a small piece of foam. Students may be able to devise their own solutions.
3. **Engineering Design Challenge**: Ask students to create a switch. Review with students the four design constraints:
    a. The switch must complete a circuit by causing two wires to connect when the end of the arm touches an object.
    b. The switch must cause the wires to disconnect when the end of the arm no longer touches the object.
    c. The switch must be mounted on the bottom of the paper cup.
    d. The switch must engage whether the arm touches an object directly or at an angle. This will enable the switch to function at as wide a range of angles as possible when the arm touches an object.

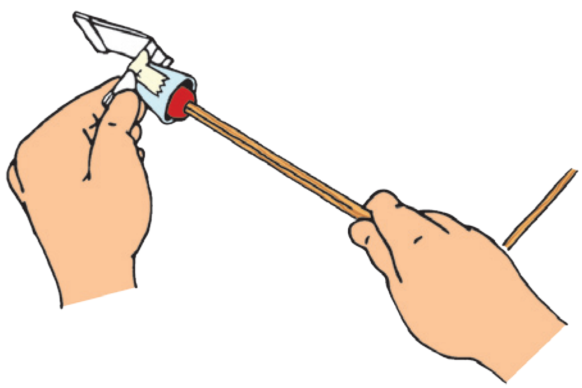
Activity 5: Designing a Touch Sensor

4. For your reference, here is an example of a possible switch design. Do not tell students what the switch should look like. When advising students, be open-minded about ideas that might not look viable to you at first. Their ingenuity might surprise you.





5. Once students have finished their switches, have them stick the foam ball onto the end of the arm and then place the cup securely over the ball.



6. As students finish, encourage them to walk around to see how other students approached the problem.

Activity 5: Designing a Touch Sensor

Activity Closure

Now I'm going to give a few of you the opportunity to present your switches and demonstrate how they work. Who wants to show us how your switch works?

[Ask a few students with particularly good examples to demonstrate their solutions.]

[Ask students some of the following questions and allow them to discuss their responses.]

- What was the hardest part of building the switch?
- Explain how your switch design worked.
- How well did your solution work?
- What would you do differently next time?

Assessment

Assess the prior activity by observing students' ability to recreate the circuit at the beginning of today's activity. Examine responses to the question on the Activity 5 Youth Handout to assess overall understanding of how engineers design assistive technology.