Guitar Building STEAM Center SY 2023
Robot Arm Challenge
Six-Weeks Syllabus

Hydraulic Robot Arm

DESIGN CHALLENGE

Time	Cost	Group size (teams)	Activity type
4.25 hours	Medium	3 - 4 students	Design Challenge
Engineering Areas			
• Mechanical Engineering • Hydraulic Engineering		• Engineering Design Process	

Description

An almost incompressible liquid is water. It can therefore transfer force and power very well. Hydraulic systems employ this principle to their advantage to transform small details applied over small regions into massive points spread over broad areas. This is known as Pascal's Law or Pascal's Principle. Such hydraulic systems are widely used in industrial robots, cranes, and earth-moving machinery. Students will create their own hydraulically powered robot arms for this assignment to transport marshmallows from one place to another.

About the Engineering Design Challenge

Students in this design challenge create their own hydraulically powered robot arm that can transport four marshmallows from one place to another while submerging them in water. The robot arm must be capable of grasping and releasing the marshmallows, moving up and down via at least one articulated joint, and swiveling through around 45 degrees.

Students will:

- Learn the about the Engineering Design Process
- Participate in a team-based learning experience
- Learn about hydraulics and hydraulic systems
- Have fun experiencing engineering

Lesson Outcomes

Students will be able to:

- Describe the operation of a fluid power system, including:
  - How pressure and piston area affect force
  - The relationship between piston area, stroke length and force
  - Why pistons are good at pushing but poor at pulling
- Identify live loads and dead loads and their impact on arm performance

- Apply techniques to reduce the impact of dead load on arm performance
- Describe the role of force and distance in calculating moment (torque)
- Use the tools and equipment provided to create a hydraulic robot arm
- Use the robot arm they create to accomplish a predefined task

Assumptions

Students will have basic understanding or background knowledge in the following areas:

- Use of simple hand tools:
  - Wire strippers
  - Hot glue
  - Soldering irons
  - Sharp knives
- Sketching and drawing

Foundational Learning

- Fluid power transmission
  - Pressure/force / area relationship
  - Pushing vs. pulling (you can't "pull")
- How pushing force and distance affect moment (torque)
  - Effect of pushing at an angle when calculating moment

Key Terminology

Area: a measurement of surface.

Cylinder: the outer container of a fluid power actuator.

Degrees of freedom: the number of axes upon which a device moves or rotates. For example, the human arm has seven degrees of freedom: three at the shoulder joint, one at the elbow, and three at the wrist.

End effector: the tool at the end of a robot arm that accomplishes the desired task. Often used to grasp objects, it may be a tool, including a spray gun or welder.

Moment: a twist, or *torque*, created by a force acting at a distance from a pivot point.

Piston: the sliding component inside a cylinder.

Pressure: a force distributed evenly over a surface. Force: a push or pull upon one object exerted by a second object.

Estimated Time

Total time 8–12 hours:

- 2–3 hours of lesson time
- 5–7 hours of build and testing time
- 1–2 hours of activity/competition time

Recommended Number of Students

Two students per arm to a maximum of 20 students, based on *BC Technology Educators' Best Practice Guide*

If time and resources permit, having each student build their robot arm allows them to take the arm home at the end of the activity.

Facilities

A multipurpose tech studies shop or lab with access to:

- Drawing or sketching resources
- Drills (ideally drill presses)
- Fine-toothed saws or sturdy knives for cutting wooden sticks
- Ideally one or more band saws for cutting plywood pieces
- Hot glue area
- Water and “wet workspace” with towels or paper towel for drying parts

Tools

- Drill press (or suitable hand drill arrangement)
- Whitney punch (if available)
- Wire strippers
- Screwdrivers
- Scissors
- Hot glue guns

Materials

- Syringes: available from medical supply stores or online. The “Luer-Lok” tip on the right in Figure 1 holds tubing much better. 10 cc syringes are about the right size for this project.
- Tubing: ¼" clear vinyl tubing from Home Depot works well. Test the tubing with a syringe first to ensure a good fit.
- Wood strips
- Plywood for robot base platform
- Assorted blocks of wood
- Rods
- Screws, nuts, bolts
- Stiff wire or thin rod (1⁄16" and ⅛" welding rods work nicely)
- Cardboard and thumbtacks for “Cardboard Aided Design”
- ¼"–1" game elements for the robot challenge of moving small objects. You can use a range of sizes, giving more points to the little ones. Nuts and bolts work well. Other possibilities include:
  - Marbles and ball bearings
  - Empty aluminum cans
  - M&M candies (The team can share as many M&Ms as they can place into a cup in 60 seconds.)
- You may want to use a plastic cup, about 10 cm high, as the “goal” where the robot will place the game pieces.

Figure 1—Syringes

Resources

This is an everyday STEM activity performed differently in many different schools worldwide. Many excellent resources are available by searching for “syringe robot arm,” “hydraulic robot arm” and similar combinations. Some current resources (as of 2016) include:

Tufts University “Teach Engineering” Educational Outreach is an excellent, alternative activity guide including a short video:
https://www.teachengineering.org/activities/view/wpi_hydraulic_arm_challenge

The “Syringe Hydraulic Arm” at Ideas-Inspire.com is another excellent write-up with photos, videos and instructions for building arms:
http://ideas-inspire.com/syringe-hydraulic-arm/

A well-documented build of an articulated 3 DOF syringe arm with gripper, including plans, is available at:
http://jefenry.com/main/MechanicalArm.php

This site presents instructions for assembling a commercially prepared kit. The fine detail of these instructions may serve as a guide in the design of your students’ arms:
http://www.copernicustoys.com/doc/COP-Arm-Instructions1.2.pdf

The Instructables site has a nice arm built from cardboard and duct tape:
http://www.instructables.com/id/Hydraulic-robot-made-of-cardboard-and-scotch-duct-/

Commercially produced educational robot arm kits are available for purchase. However, they can be manufactured in-house for a fraction of the cost:
http://www.pitsco.com/T-bot_II_Hydraulic_Arm

There are also 3D printable robot arms on Thingiverse:
http://www.thingiverse.com/thing:1328020 and http://www.thingiverse.com/thing:39803

Demonstration

If a sample syringe arm is available, use it to demonstrate the challenge. Otherwise, you may wish to use one of the many online videos. Links are provided above.

Procedure

Following is an outline of the procedures for this lesson. Detailed procedure guidelines are provided below in the *Detailed Procedure Guidelines* section on page 9. Items marked with an asterisk have supporting materials in this activity guide's Lesson Support Materials section.

Week 1: Lesson: Introduce Activity

Discuss types of robot arms.

Discuss types of end effectors.

Activities: Put students into teams.

Begin drawing/modelling exercise to determine arm type anddimensions

Week 2: Lesson: Fluid power

Activities: Fill and bleed syringes.

Compare the force on different size syringes.

Compare the difference between pushing on a syringe and pulling on it.

Where do the bubbles come from when pulling?

Finish design of robot arm if time allows.

Week 3: Lesson: Moments and counterbalances

Activities: Finish design of robot arm.

Begin construction of robot arm.

Week 4: Lesson: Review fluid power and moment concepts

Activities: Continue arm construction.

Week 5: Lesson: Quiz on fluid power and moment concepts

Activity: Continue arm construction.

Week 6: Lesson: Cable and tubing management

Activity: Continue arm construction and test.

Activity: Arm practice and refinement

Robot Arm Challenge Day!

Lesson Support Materials

The following lesson support materials are provided in this activity:

- Robot Arm Challenge page 7
- Fluid Power Worksheet page 18
- Moments and Counterbalances Worksheet page 25
- Robot Arm Quiz page 28