Hydraulic-Powered Robotic Arm from Cardboard

Introduction

In this project, I demonstrate how to build a **hydraulic-powered robotic arm using cardboard and simple materials**. This robotic arm uses **water-filled syringes and tubes** to create hydraulic pressure, allowing the arm to move without electricity or motors. The project is fun, educational, and environmentally friendly because it uses recycled materials such as cardboard and empty soda cans.

Hydraulic systems are commonly used in real life in **construction machines,**

cranes, excavators, and robotic arms. This project shows how the same scientific principles can be applied on a small scale using everyday materials.

Hypothesis

If more force is applied to the input syringe, then the crane will lift heavier objects because the pressure is evenly transmitted through the hydraulic fluid.

Purpose of the Project

The purpose of this project is to:

- Demonstrate how **hydraulics work**
- Show how **force and motion** can be transferred using liquids

- Build a functional robotic arm using **simple and low-cost materials**
- Learn about **engineering, physics, and problem-solving**
- Create a fun device that can lift and move objects, such as empty soda cans

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What Is a Hydraulic System?

A hydraulic system uses a **liquid (usually water or oil)** to transmit force from one point to another. Liquids cannot be easily compressed, so when pressure is applied to one syringe, the force is transferred through the water to another syringe, causing movement.

This project is based on **Pascal's Principle**, which states that pressure applied to a confined fluid is transmitted equally in all directions.

Materials Needed

To build the hydraulic robotic arm, you will need:

- Cardboard (thick and sturdy)
- 8 syringes with rubber pistons
- 4 plastic tubes (pipes)
- Popsicle sticks
- Glue (hot glue or strong craft glue)
- Water
- An old battery (used as a weight or support, not for power)
- Scissors or a craft knife
- A ruler and pencil

- Patience
- An empty soda can for testing

Safety Precautions

- Be careful when using scissors or craft knives
- Ask for adult supervision if using hot glue
- Do not drink the water used in the syringes
- Handle syringes responsibly

Step 1: Designing the Robotic Arm

Before building, it is important to **plan the design**. The robotic arm includes:

- A base

- A lower arm
- An upper arm
- A claw or gripper

Each joint will be controlled by **a pair of syringes** connected with tubing.

Step 2: Building the Base

The base is made from multiple layers of cardboard glued together to provide stability. A heavy object, such as an old battery, can be added to the base to prevent tipping.

Step 3: Creating the Arm Segments

The arm segments are cut from cardboard and reinforced with popsicle sticks. This makes the arm stronger and prevents bending.

Holes are added at joint points to allow movement.

Step 4: Making the Hydraulic System

1. Fill syringes with water (no air bubbles)
2. Connect two syringes using a plastic tube
3. Push one syringe and observe the other moving
4. Repeat until all syringe pairs are connected

Each syringe pair controls one movement of the arm.

Step 5: Attaching Syringes to the Arm

The syringes are glued to the cardboard structure:

- One syringe stays fixed
- The other syringe moves with the arm joint

When pressure is applied, the arm moves up, down, or closes the claw.

Step 6: Building the Claw

The claw is made from cardboard and popsicle sticks. It opens and closes using hydraulic pressure, allowing it to grip light objects like an empty soda can.

Problem: Claw does not close fully
Solution: Adjust syringe attachment points closer to the hinge

Problem: Fingers bend under pressure
Solution: Add more popsicle stick reinforcement

Problem: Object slips from grip
Solution: Add rubber or foam to the inside of the fingers

Step 7: Testing the Robotic Arm

Once assembled, the arm is tested by:

- Lifting an empty Coca-Cola can
- Moving it from one place to another
- Opening and closing the claw smoothly

Adjustments are made if movement is too stiff or loose.

Problems and Solutions

Section	Problem	Solution
Planning & Design	Design was too complex	Simplified the arm to fewer joints

Planning & Design	Parts not symmetrical	Used templates and careful measuring
Materials	Cardboard bending	Added multiple layers and popsicle sticks
Materials	Glue not strong enough	Used hot glue in high-stress areas
Base	Arm tipping over	Added weight (old battery) to base

Base	Base flexing	Reinforced with extra cardboard layers
Arm Structure	Arm too weak	Shortened arm and added supports
Arm Structure	Uneven movement	Repositioned syringes for balance
Joints & Hinges	Joints too tight	Widened hinge holes slightly

Joints & Hinges	Joints too loose	Used thicker pins and reinforcements
Hydraulics	Air bubbles in syringes	Refilled syringes carefully with water
Hydraulics	Weak pressure	Moved syringe attachment closer to joints
Syringes	Hard to push or pull	Replaced faulty syringes

Syringes	Pistons sticking	Cleaned and re-lubricated with water
Tubing	Tubes kinking	Used longer tubing and smooth curves
Tubing	Tubes popping off	Secured tubes with glue and tape
Claw	Claw not closing evenly	Adjusted finger lengths and linkage

Claw	Fingers bending	Added popsicle stick reinforcement
Claw	Object slipping	Added rubber/foam to finger tips
Controls	Hard to coordinate syringes	Labeled syringes and practiced movements
Controls	Unwanted movement	Applied pressure slowly and evenly

Testing	System failed during full test	Tested each part separately
Testing	Inconsistent results	Repeated tests under same conditions
Safety	Water leaking	Sealed connections and tested over tray
Safety	Sharp edges	Trimmed edges and added tape

Scientific Concepts Demonstrated

- Hydraulics
- Pascal’s Principle
- Force and motion
- Engineering design process
- Simple machines

Real-World Applications

Hydraulic systems are used in:

- Cranes
- Excavators
- Car brakes
- Industrial robotic arms
- Construction equipment

This project shows how these machines work on a smaller scale.

Environmental Benefits

- Uses recycled cardboard
- No electricity required
- Encourages reuse of materials

Structural Design and Stability

The robotic arm is designed to be lightweight but strong. Cardboard is chosen because it is easy to cut, shape, and glue, yet sturdy enough when layered. Multiple layers of cardboard are glued together in areas that experience the most stress, such as the joints and the base. Popsicle sticks are added inside the cardboard to act as internal supports, similar to bones inside a real arm.

The base of the robotic arm is especially important. If the base is too light, the arm will tip over when lifting objects. To solve this problem, an old battery is placed inside or attached to the base to add weight and improve balance. This allows the robotic arm to lift empty cans without falling.

Joint Mechanics

Each joint of the robotic arm acts like a hinge. Holes are carefully cut at the ends of cardboard pieces so that they can rotate smoothly. The joints allow movement in one direction, which makes the arm easier to control.

Hydraulic syringes are positioned so that when one syringe is pushed, it pulls or pushes the joint. This mimics how muscles work in the human body. One syringe acts like a muscle contracting, while the other expands.

Hydraulic System in Detail

The hydraulic system is the most important part of this project. Water is used as the working fluid because it is safe, cheap, and easy to find. Each pair of syringes is connected by a plastic tube filled completely with water. Air bubbles must be removed because air can compress, which makes the system less effective.

When pressure is applied to one syringe, the water transfers that pressure through the tube to the second syringe. This causes the piston in the second syringe to move, which creates motion in the robotic arm. This demonstrates Pascal’s Principle in a clear and visual way.

Control Mechanism

The syringes that control the arm are arranged in a control panel style layout. This allows the user to move the arm by pushing and pulling the syringes with their hands. Each syringe pair controls a specific movement:

- Raising the lower arm
- Moving the upper arm
- Opening the claw
- Closing the claw

With practice, the user can coordinate the movements to pick up and move objects.

Claw Design and Function

The claw is one of the most interesting parts of the robotic arm. It is built from cardboard reinforced with popsicle sticks to prevent bending. The claw opens and closes using hydraulic pressure, allowing it to grab lightweight objects such as empty soda cans.

The shape of the claw is designed to distribute pressure evenly, preventing the object from slipping. This shows how real robotic grippers are designed for efficiency and control.

Testing and Calibration

After assembly, the robotic arm is tested in multiple ways. First, individual joints are tested to make sure they move smoothly. Then, the full arm is tested by lifting and moving an empty soda can.

During testing, adjustments are made:

- Syringes are repositioned if movement is uneven
- Extra cardboard is added if parts bend
- Tubes are checked for leaks

This step highlights the importance of trial and error in engineering.

Troubleshooting Common Issues

One common issue is resistance in the syringes. This can be caused by friction or small air bubbles. Refilling the syringes carefully helps fix this problem.

Another issue is weak joints. Reinforcing joints with additional cardboard layers or popsicle sticks improves durability.

If the arm does not lift properly, reducing the length of the arm or moving the syringe attachment points can increase lifting force.

Engineering Design Process

This project follows the engineering design process:

1. Identify the problem (build a moving robotic arm without electricity)
2. Plan the design
3. Build a prototype

4. Test the prototype
5. Improve the design

Each version of the arm can be improved based on testing results.

Learning Outcomes

By completing this project, we learn:

- How hydraulic systems work
- How force is transferred through liquids
- How to design and build mechanical structures
- How to troubleshoot and improve designs
- How real-world machines are engineered

Possible Improvements

Future improvements could include:

- Using stronger materials such as wood or plastic
- Adding more joints for extra movement
- Using colored water to see fluid motion
- Creating a rotating base
- Improving the claw grip with rubber pads

Real-World Connections

Hydraulic robotic arms are used in factories, hospitals, and construction sites. This model demonstrates the same principles on a smaller scale, making it easier to understand complex machines.

Final Reflection

Building this hydraulic-powered robotic arm shows that science and engineering can be creative and fun. With simple materials like cardboard and syringes, it is possible to build a machine that demonstrates powerful scientific principles

Each problem encountered during the construction of the hydraulic robotic arm led to an improvement in the design. Troubleshooting helped develop problem-solving skills and a better understanding of engineering principles. The final robotic arm functioned smoothly and demonstrated hydraulic movement effectively.

Conclusion

This hydraulic-powered robotic arm proves that **complex machines can be built using simple materials**. The project is educational, fun to play with, and demonstrates real engineering principles. It is a great hands-on way to learn about hydraulics and robotics.
