PLAXTRACTBOT:

Priming Microplastic Extraction Conditions by Utilizing Ferrofluids and Arduino IR Detection Methods

Lab Notebook

Synopsys Science and Engineering Fair 2020-2021

Impana Chimmalagi

Project # F90, Non-RRI, Physical (Environmental) Science & Engineering

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Development of Ideas

- **7/30:** bug goes through the sample injecting ferrofluid and then goes through with a magnet to attract the microplastics
- **8/1:** bot uses a dust sensor or other infrared sensor to check for pieces of microplastics, then injects and whisks ferrofluid, then attracts microplastics with magnet
- **8/5:** bot uses a waterproof ultrasonic sensor to detect microplastics. If the plastics are within a certain distance, then the bot will scoop up the area where the plastic was detected using a tube. The bot will then add oil and magnetite and shake the tube, and finally, it will bring this tube to a magnet, which will attract all the microplastics.
    - Drawbacks: although there are waterproof ultrasonic sensors, they do not necessarily work underwater. The sonar/ultrasonic sensors that do work underwater are little, and they can be very expensive
- **8/6:** bot measures distance and density of plastics using IR sensor from the surface of water, then closes sensor and continues with other tasks
- **9/11:** IR sensor moves with the help of hand, then sends values back to computer, which sends back to bot that removes the microplastics accordingly
- **11/20:** IR sensor moves using linear actuator to scan the surface area, then peristaltic pump dispenses ferrofluid, and stirrer servo stirs water
- ★ **1/24:** IR sensor stays at one edge of container. Stirrer pushes the water from the back side into the front side of the container, IR sensor checks for plastics, repeat process 4 times. Dispense ferrofluid if needed and stir water.

INITIAL RESEARCH

↓

Microplastics

7/28

https://oceanservice.noaa.gov/facts/microplastics.html

- Small plastic pieces less than five millimeters long (about size of sesame seed)
- Plastic is most prevalent marine debri in oceans and Great Lakes
- Sources:
    - Larger plastic that degrades into smaller pieces
    - Microbeads: tiny manufactured polyethylene plastic pieces added to healthy and beauty products

https://www.washingtonpost.com/health/youre-literally-eating-microplastics-how-you-can-cut-down-exposure-to-them/2019/10/04/22ebdfb6-e17a-11e9-8dc8-498eabc129a0_story.html

- Effect on human health is uncertain, but “there cannot be no effect” (Pete Myers) on human health
- Microplastics can expose us to harmful chemicals from other plastics which cause a variety of health problems, including reproductive harm, obesity, organ problems, and developmental delays in children.
- Only 10% of 8 billion tons of plastic produced since the 1950s has been recycled
- Americans ingest at least 74,000 microplastic particles annually
- Can cross the hardy membrane that protects the brain from many foreign bodies, allowing potentially harmful chemicals to get into the bloodstream
- They can even get to a developing fetus
- Some could potentially leak bisphenol A and phthalates, can result in interference/disruption of hormones, even decrease testosterone in male offspring
- Polychlorinated biphenyls can cause various cancers

https://www.sciencedirect.com/science/article/pii/S0025326X11003055

- Weathering degradation of plastics on the beaches
- First reports of plastic litter in 1970’s
    - https://www.sciencedirect.com/science/article/pii/S0025326X11003055#b0300
    - https://www.sciencedirect.com/science/article/pii/S0025326X11003055#b0205

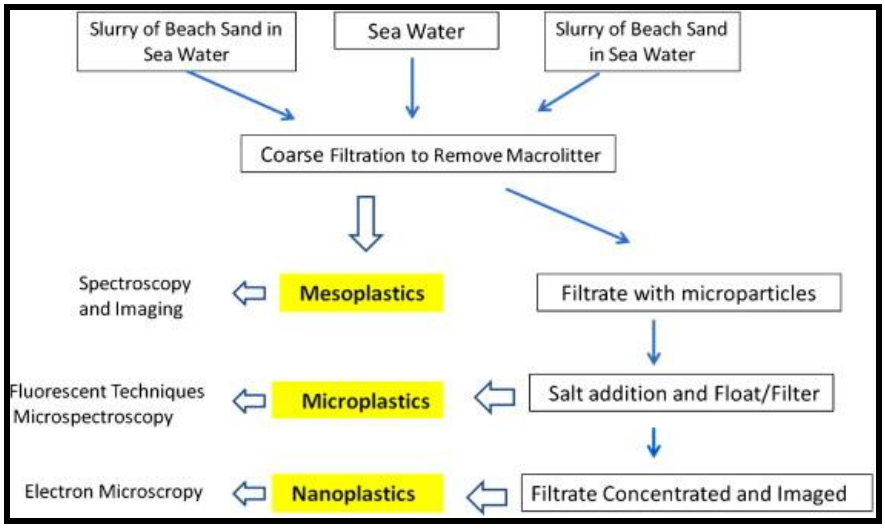
    - https://www.sciencedirect.com/science/article/pii/S0025326X11003055#b0210
    - https://www.sciencedirect.com/science/article/pii/S0025326X11003055#b0225
    - https://www.sciencedirect.com/science/article/pii/S0025326X11003055#b0230
- Different broad classes of plastics in packaging: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyethylene terephthalate (PET); and Polyvinyl chloride (PVC)
- Land-based sources including beach littler = about 80% of plastic debris
- Global fisherman all use plastic fishing gear
- Amount of floating plastic debris is an underestimate of the plastics in water
- Denser plastics submerge deeper and can reach the coastal sediment
- Microplastics in water include: virgin resin pellets, compounded masterbatch pellets
- Not readily visible to naked eye

Existing Methods of Microplastic Detection

7/29

https://www.sciencedirect.com/science/article/pii/S0025326X11003055

- Mesolitter is removed through a coarse filter
- Get the microplastics to float on the surface by adding sediment/sand samples or salt
    - This will increase the density of the water to cause the microplastic particles to float
- Can also concentrate samples of water with microplastics through evaporation
- Use lipophilic dye to stain the microplastics
    - This will stain only the microplastics, not the surrounding microplankton and other microbiota



https://www.draper.com/explore-solutions/microplastics-sensor

- Draper is designing a autonomous portable sensor to measure microplastics

Raman Microscopy

7/31
https://www.earth.com/news/detecting-microplastics-water-bodies/

- Non-destructive spectroscopic method
- Can determine type of plastic in a sample

https://www.thermofisher.com/blog/materials/detecting-microplastics-in-drinking-water-and-freshwater/

- Depend on change in polarizability
- Polymer backbone structures
- Delocalized electrons

https://www.horiba.com/en_en/raman-imaging-and-spectroscopy/#:~:text=Raman%20Spectroscopy%20is%20a%20non,chemical%20bonds%20within%20a%20material.

- Interaction of light with chemical bonds

https://www.stellarnet.us/systems/raman-spectrometers-lasers-and-probes/

- Costs over $3,000

Infrared Spectroscopy

7/31
https://www.thermofisher.com/blog/materials/detecting-microplastics-in-drinking-water-and-freshwater/

- Depends on changes in dipole moments
- Can detect polar functional groups found in plastics ((hydroxyl, amines, amides, carbonyls)

https://www.labmanager.com/product-focus/ftir-spectroscopy-picking-up-steam-in-nontraditional-markets-19666

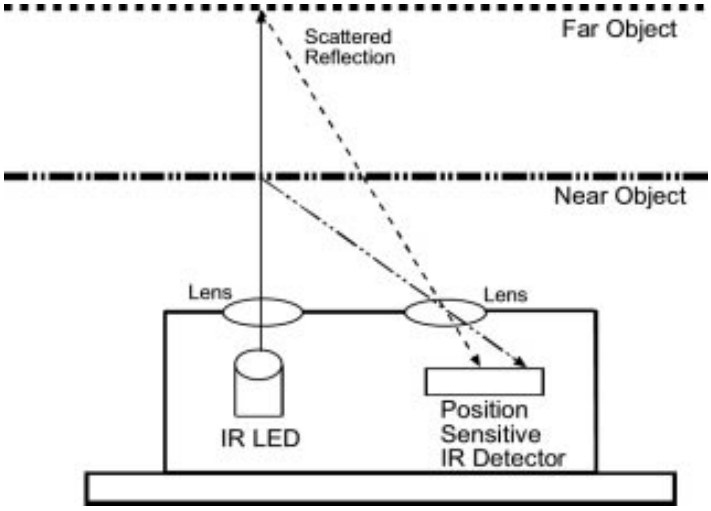
- Can cost over $100,000

Affordable Detection Methods

8/1

Infrared Sensors

Dust Sensors



https://www.researchgate.net/profile/Kimberly_Frey2/publication/3050788/figure/fig5/AS:394651015106575@1471103542537/Operation-of-sharp-IR-distance-detector.png

Infrared LED and phototransistors detect reflected light of dust in air.

- GP2Y1010AU0F Sensor: https://www.sparkfun.com/products/9689
- Mating Connector: https://www.sparkfun.com/products/9690
- Instructions: https://www.instructables.com/id/How-to-Interface-With-Optical-Dust-Sensor/

Particulate Matter Sensor

Measure 2.5 µm PM and 10.0 µm PM concentrations

- HPMA115S0-XXX Particle Sensor: https://www.digikey.com/product-detail/en/honeywell-sensing-and-productivity-solutions/HPMA115S0-XXX/480-7035-ND/7202204
- Teensy LC: https://www.pjrc.com/teensy/teensyLC.html
- Instructions: https://www.allaboutcircuits.com/projects/build-a-particulate-matter-detector-for-air-quality-measurement/

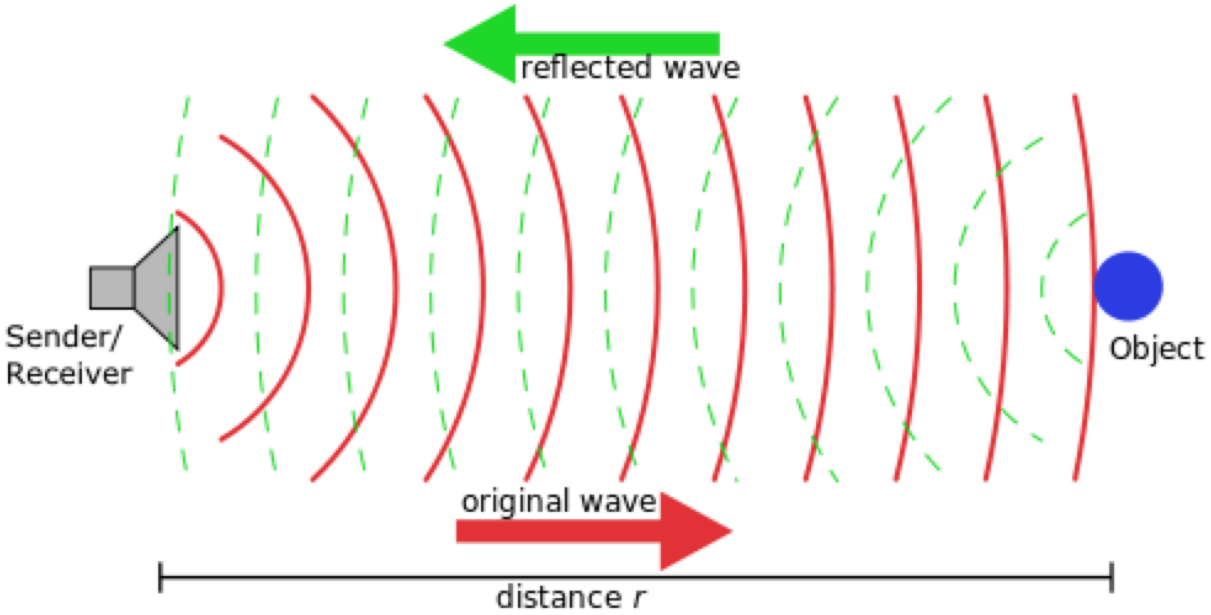
Ultrasonic Sensor

Sends out ultrasound waves, the waves get reflected by an object, an sensor detects the waves, then calculates distance using this formula: *(Distance (cm) = Speed of sound (cm/µs) × Time (µs) / 2)*

- ➢ JSN-SR04T Sensor: https://amzn.to/2C1qb2a
- ➢ Instructions: https://www.makerguides.com/jsn-sr04t-arduino-tutorial/
- ➢ Instructions 2: http://www.beckymarshall.com/depthSensor.html

Sonar Sensor

Sonar detects distance, depending on time that signal takes to come back to sonar, it can detect the range or distance of object and orientation



- ➢ MaxBotix Ultrasonic Range Finder: https://www.adafruit.com/product/982
- ➢ Instructions: https://www.allaboutcircuits.com/projects/measure-distance-with-a-sonar-sensor-on-an-arduino/
- ➢ Waterproofing: http://robogoby.blogspot.com/2014/03/waterproofed-maxbotix-sonar-w-arduino.html?showComment=1499931403136#c7946650262085866105

Extraction & Removal

7/29
https://tappwater.co/us/how-to-filter-and-remove-microplastics-2/

- Removing microplastics from tap water:
    - Granular Activated Carbon (GAC) faucet filters: removes some but not all microplastics
    - Carbon Blocks faucet filters: can remove up to 100% of microplastics
    - Reverse Osmosis filters: Can filter down to to 0.001 micron, but expensive and high-maintenance

https://www.businessinsider.com/microplastics-water-pollution-solution-from-google-2019-8

- 'Magnetic liquid' invented by NASA
- Ferrofluid = suspending magnetite in vegetable oil
- When magnet is placed inside microplastic-ridden water injected with ferrofluid, it will soak up all the microplastics in the water

Common Microplastic Types

8/1
http://www.waterkeeper.ca/blog/2016/11/15/zooming-in-on-the-five-types-of-microplastics

- 5 Types of Microplastics
    1. Fibers
        - 71% of total microplastic pollution in Great Lakes
        - Fleece clothing, diapers, cigarette butts, washing machines
    2. Microbeads
        - Non-degradable plastic particles
        - Less than 1 mm in diameter
        - Facial cleansers, exfoliating soap products, and toothpaste
        - Officially banned din 2019
    3. Fragments
        - Smaller pieces that break off from larger pieces
        - UV Radiation
        - Cutlery, lids, or single-use products
    4. Nurdles
        - Small plastic pellets
    5. Foam
        - Food containers, coffee cups, and packing material
        - Can break down into smaller pieces

https://theconversation.com/ten-stealth-microplastics-to-avoid-if-you-want-to-save-the-oceans-90063

- Styrene butadiene (tires)
- Polyamide, spandex and nylon (synthetic clothing)
- Cellulose acetate (cigarette butts)
- Polyester (baby wipes)
- Thermoplastic (paints)

https://onlinelibrary.wiley.com/doi/full/10.1002/wer.1229

- The most common polymer types in microplastics include:
    1. Polyethylene (PE)
    2. Polypropylene (PP)
    3. Polymethyl methacrylate (PMMA)
    4. Polyvinyl chloride (PVC)
    5. Polyethylene terephthalate (PET)

6. Polystyrene (PS)

Properties of Different Plastics

8/2

Polyethylene (PE)

https://omnexus.specialchem.com/selection-guide/polyethylene-plastic

- Resistance to most solvents, alcohol, dilute acids and alkalis
- Moderate resistance to oils
- Poor resistance to hydrocarbons
- Lightweight, durable thermoplastic

Polypropylene (PP)

https://omnexus.specialchem.com/selection-guide/polypropylene-pp-plastic

- Lightweight
- High resistance to cracking, acids, organic solvents and electrolytes
- High melting point
- Non-toxic

Polyvinyl chloride (PVC)

https://omnexus.specialchem.com/selection-guide/polyvinyl-chloride-pvc-plastic

- Thermoplastic material used in building and construction
- White, brittle, solid
- Lightweight, durable, easily processable

Polyethylene terephthalate (PET)

https://omnexus.specialchem.com/selection-guide/polyethylene-terephthalate-pet-plastic

- Mechanical, thermal, chemical resistance
- Most recycled thermoplastic
- Very flexible, colorless, semi-crystalline resin
- Resistance to impact, moisture, alcohols and solvents

Polystyrene (PS)

https://www.azom.com/article.aspx?ArticleID=798#:~:text=Polystyrene%20homopolymer%2C%20known%20as%20%E2%80%9Ccrystal,poor%20chemical%20and%20UV%20resistance.

- Amorphous, colorless, transparent
- Rigid, brittle, hard
- Resistance to gamma radiation
- Good electrical properties

Polyamide (PA)

https://omnexus.specialchem.com/selection-guide/polyamide-pa-nylon

- Repeating amide linkages
- Formed by condensing identical units
- Can be amorphous or semi-crystalline
- Two most widely used are **PA66** and **PA6**

Where to Find These Plastics

- Polyethylene (HDPE): **containers for milk**, motor oil, shampoos and conditioners, soap bottles, detergents, and bleaches, plastic bags
    - https://www.ryedale.gov.uk/attachments/article/690/Different_plastic_polymer_types.pdf
- Polypropylene: lunch boxes, margarine containers, yogurt pots, syrup bottles, prescription bottles, **plastic bottle caps**
- Polyvinyl chloride: pipes and tiles
- Polyethylene terephthalate: **beverage bottles**, medicine jars, rope, clothing and carpet fibre
- Polystyrene: disposable coffee cups, plastic food boxes, plastic cutlery and **packing foam**
- Polyamide: Toothbrushes, Wear pads, Wheels, Gloves, Guitar strings and pics, Tennis racket strings, Medical implants, Electrical connectors , Fishing line, Tents, Gears
    - https://matmatch.com/learn/material/polyamide-nylon

Plastics in Project

- Milk Carton Box
- Milk Carton Cap
- Water Bottles
- Styrofoam/packing foam

Attracting Plastic

Oil & Plastic

8/1

https://www.quora.com/Why-does-vegetable-oil-cling-to-the-sides-of-a-container-if-it-doesnt-have-dipole-bonds-like-water

- Plastics are polymers of hydrocarbon
- Van der Waals forces in oil and plastic
- Both are nonpolar molecules, so they attract

https://www.reddit.com/r/askscience/comments/meqh0/why_is_oilgrease_more_difficult_to_wash_from/

- Grease can stick and dissolve into plastics
- Coating the plastic with dish soap and leaving it for a while can pull out grease
    - Detergent and soap molecules are half and half polar and nonpolar
    - Charged (polar) end with a long (non-polar) fatty tail, can bind to both polar and nonpolar things simultaneously

Magnetizing Plastics

https://www.quora.com/Is-it-possible-to-magnetize-plastic-waste

- Suspension of iron filings

https://davehakkens.nl/community/forums/topic/magnetizing-plastic-is-it-possible/

- Can use a vacuum with a fine mesh to hoover up the plastic bits
- Create a static electric field
- Cat scupper

https://www.sciencedaily.com/releases/2001/11/011119071918.htm

- Organic polymer = carbon-based, plastic magnet
- Magnetic polymers unstable unless in an oxygen-free environment at temperatures below 10 degrees Kelvin, so not feasible

PROJECT

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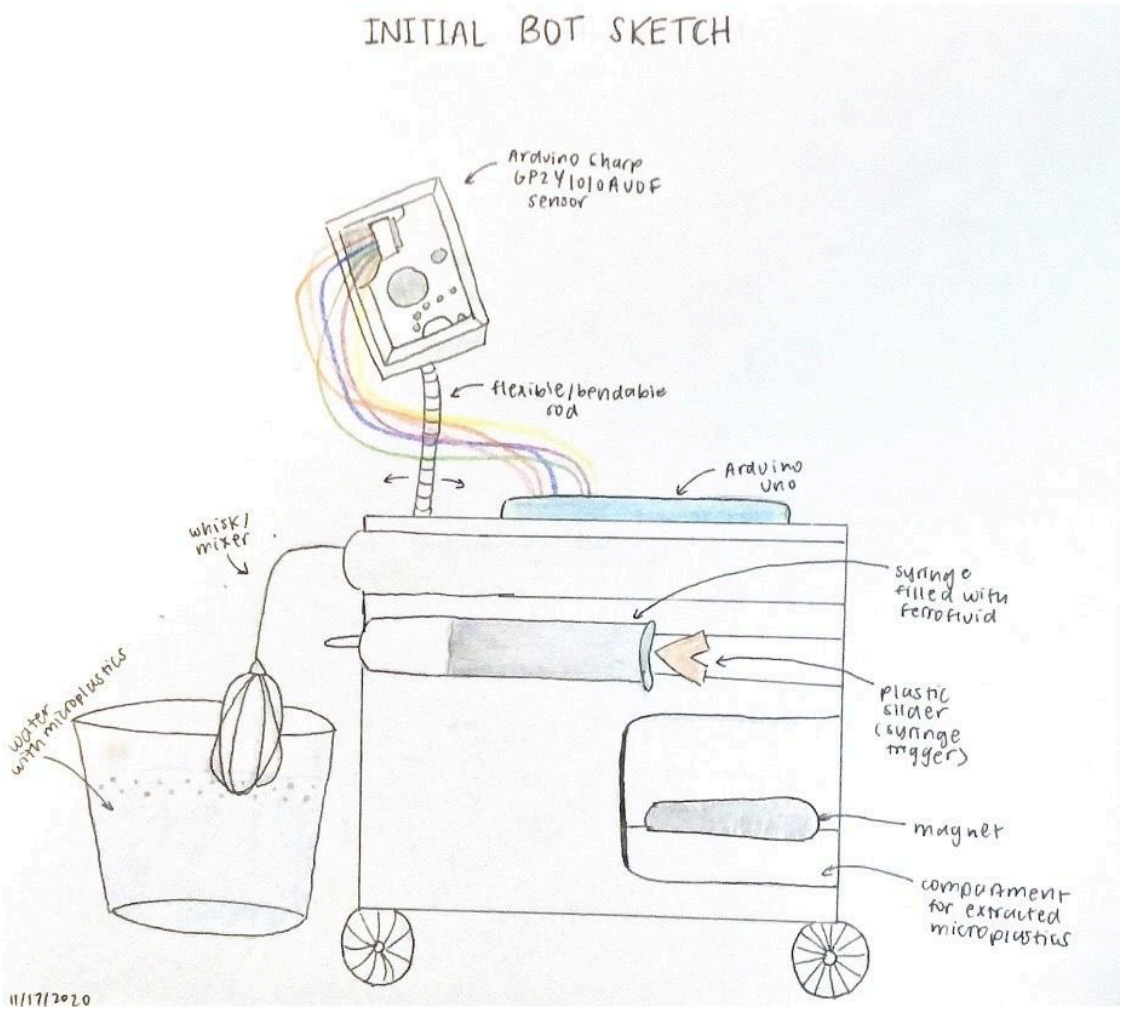
Initial Bot Sketch

11/18



1. Arduino Sharp Dust Sensor detects microplastics, bendable rod allows sensor to rotate and move (angled horizontally above the water for best detection)
2. Each time microplastics are detected, overwrites "PlasticCount" file in Arduino
3. Once entire water surface is scanned, ferrofluid will be pumped into the water based on microplastic concentration (how much the plastic slider is pushed)
4. Mixer stirs ferrofluid in water
5. User can now place magnet in water and stir once, plastics will stick to the magnet

IR Sensor

Movement

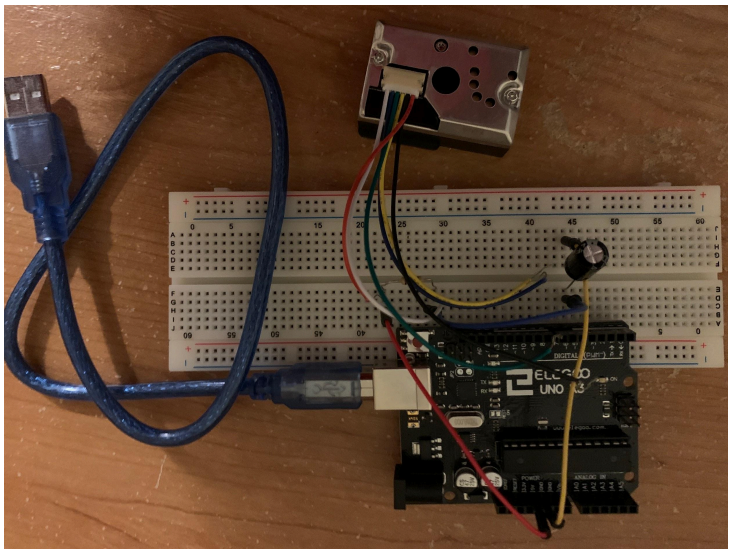
11/19
https://www.youtube.com/watch?v=mp6cbTtiQzU

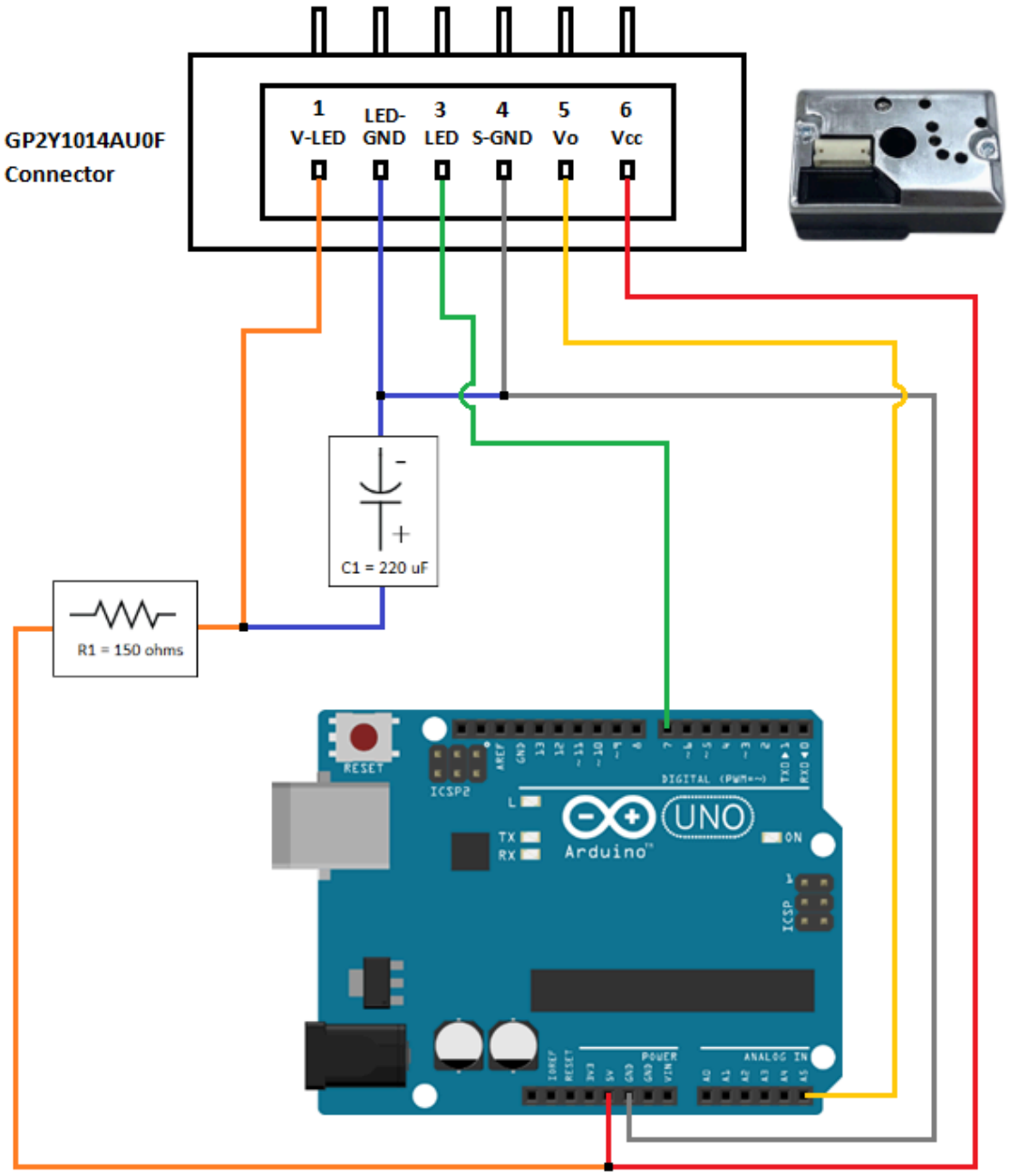
- Using Servo
- Arduino Linear Actuator

Detection

12/25
https://www.instructables.com/How-to-Interface-With-Optical-Dust-Sensor/

- Utilized this tutorial and got the dust sensor output to show up on the Serial Monitor
- The dust density values didn't fluctuate much, even when I put my finger on the dust detection hole
    - This inaccuracy may have been caused by the fact that the mating connector was female-to-female (mating connector was on both sides: I had to cut off the wires which might have made the readings less accurate.





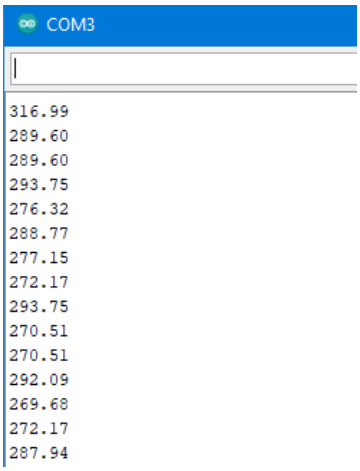
(green wire goes to pin 7)

1/2

https://create.arduino.cc/projecthub/mircemk/diy-air-quality-monitor-with-sharp-gp2y1010au0f-sensor-7b0262

- Utilized the correct mating connector (wire on one side, closed on the other)
- Also changed the code to the code in this link
    - In the previous code, the dust density values were unchanging, even when I blew on the detection hole
    - Used a more accurate measurement

    - More precise: units are ug/m^3
    - Values were fluctuating, but did not change much when I put my finger in the detector hole
- Made wiring more compact in order to make room for remaining parts of project



3

1/15
http://arduinolearning.com/code/arduino-dust-sensor-example.php

- Changed the code to this link
- Noticed that normally, the dust density is ~ 0.75
- When something goes into the detection hole, the dust density decreases
- Can maybe attach a funnel to the detection hole in order to isolate the water+microplastics from rest of environment

```
GP2Y1010AU0F readings
Raw Signal Value = 997.00
Voltage = 4.87
Dust Density = 0.73

GP2Y1010AU0F readings
Raw Signal Value = 386.00
Voltage = 1.88
Dust Density = 0.22

GP2Y1010AU0F readings
Raw Signal Value = 314.00
Voltage = 1.53
Dust Density = 0.16

GP2Y1010AU0F readings
Raw Signal Value = 1007.00
Voltage = 4.92
Dust Density = 0.74

GP2Y1010AU0F readings
Raw Signal Value = 984.00
Voltage = 4.80
Dust Density = 0.72

GP2Y1010AU0F readings
Raw Signal Value = 1019.00
Voltage = 4.98
Dust Density = 0.75
```

Where something was put in the detection area

Materials

1. Sharp GP2Y1010AU0F Sensor
2. 220 µF Capacitor
3. 150 ohm Resistor
4. JST ZH 1.5MM 6 Pin Female Single Connector (with wires)
5. 3 Jumper Wires

Ferrofluid Pump

11/19
http://www.learningaboutelectronics.com/Articles/Peristaltic-pump-circuit-with-an-arduino-microcontroller.php

- Peristaltic pump

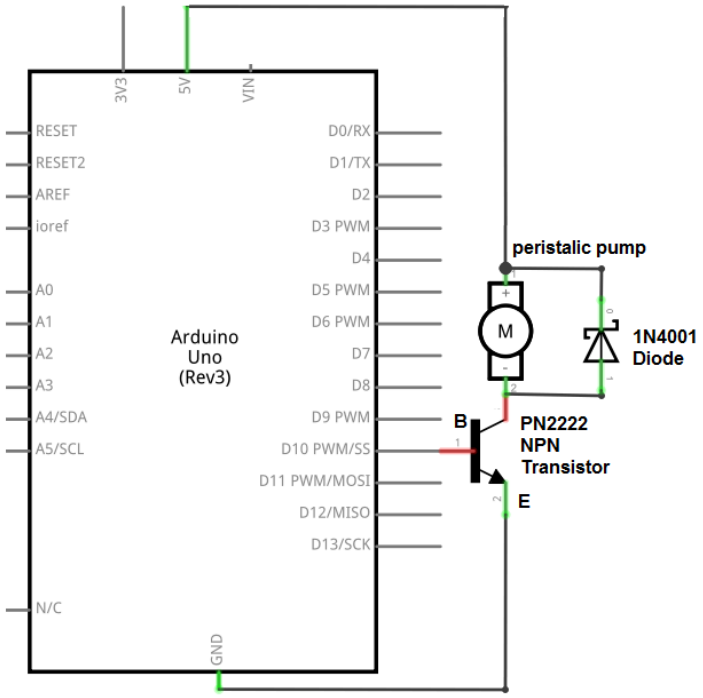
What Is A Peristaltic Pump?

12/16
http://www.learningaboutelectronics.com/Articles/Peristaltic-pump-circuit-with-an-arduino-microcontroller.php

- Allow liquids to flow from one area and out into another area
- Each pump has a flexible hose or tubing (silicone)

Arduino Peristaltic Pump

1/7
http://www.learningaboutelectronics.com/Articles/Peristaltic-pump-circuit-with-an-arduino-microcontroller.php



- Got the pump to start working today

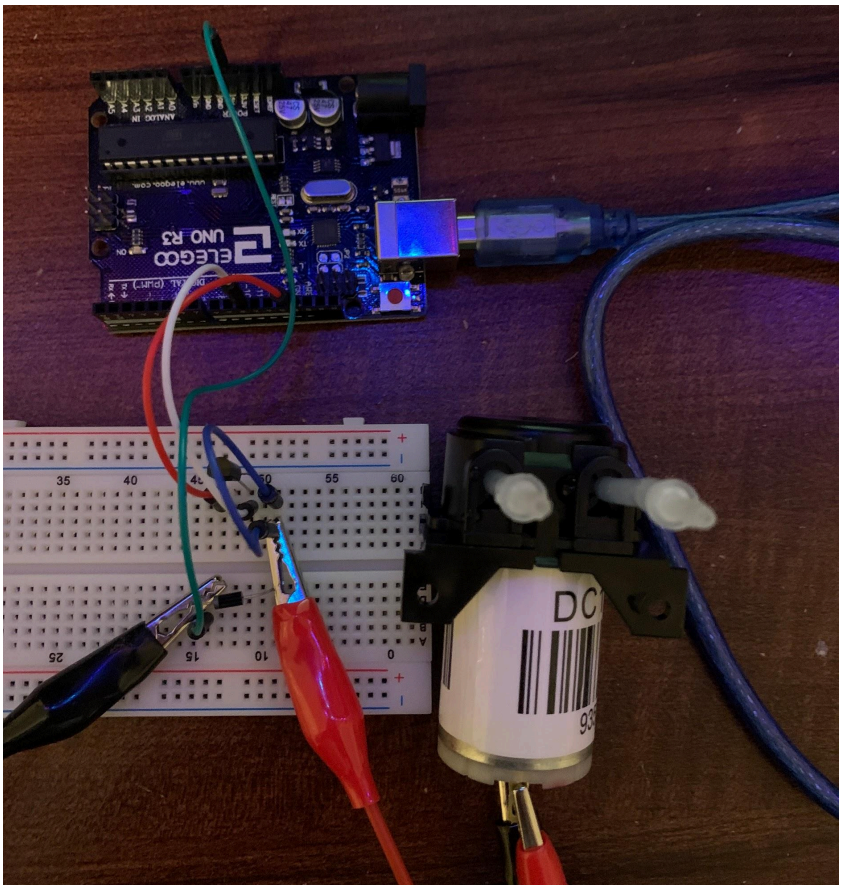
- Water was pumped out very slowly, maybe due to the fact that the only voltage source was 5V, it can take up to 12 V
- Tubing was also too small, was a hassle: need to attached longer silicone tubes

1/18
https://circuitjournal.com/how-to-use-a-p-channel-mosfet-with-an-arduino

- Pump drips water too slowly
- Need to buy a MOSFET and 12V power supply

1/24
https://circuitjournal.com/how-to-use-a-p-channel-mosfet-with-an-arduino

- Couldn't get the MOSFET to work
- Due to time constraints, the peristaltic pump will have to run on 5 volts, it will pump quite slowly



Materials

1. Peristaltic pump 12V
2. PN2222 NPN Transistor

3. 1N4001 Diode
4. 2 Alligator Clip Wires
5. 4 Jumper Wires

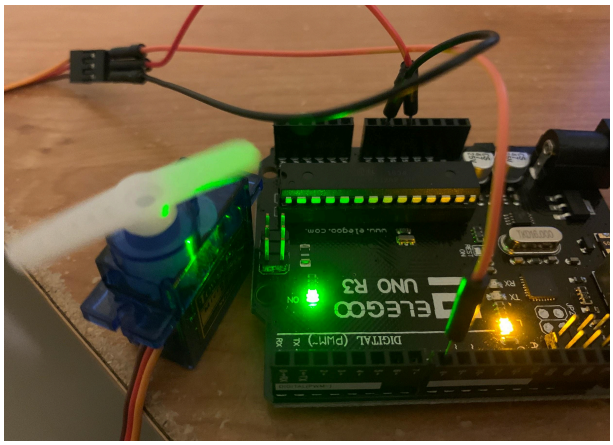
Stirrer

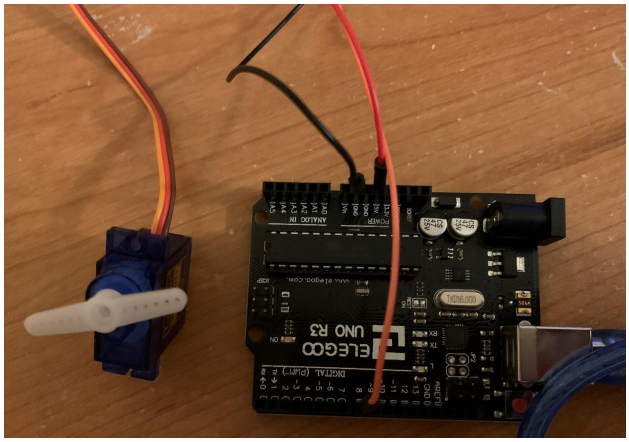
11/20
https://www.youtube.com/watch?v=rQ4Myd6csxo
https://www.youtube.com/watch?v=hfu7-9Gyp3I

- Using Servo

11/25
http://educ8s.tv/arduino-servo-tutorial/

- I finished coding for the rotation of the servo
- Decreasing the "delay" of the rotation increases the rotation speed





Materials

1. Servo Motor (SG90)
    a. Comes with Elegoo Kit
2. Plastic Spoon

Code

PlaxTractBot

```
#include <Servo.h>
Servo servo;
int angle = 10;

int dustPin = 5;
int ledPin = 12;
int count = 0;
int plasCount = 0;
float voltsMeasured = 0;
float calcVoltage = 0;
float dustDensity = 0;
float runningSum = 0;
float runningAvg = 0;
double first = 0;

const int pump = 10;

bool on = true;
unsigned long myTime;

void setup()
{
  Serial.begin(9600);
  pinMode(ledPin,OUTPUT);
  pinMode(pump, OUTPUT);
  servo.attach(8);
  servo.write(angle);
}


void loop(){
  digitalWrite(ledPin,LOW); // power on the LED
  delayMicroseconds(280);

  myTime = millis();
  voltsMeasured = analogRead(dustPin);

  delayMicroseconds(40);
  digitalWrite(ledPin,HIGH);
  delayMicroseconds(9680);
```

```
  if (count < 8){
    Serial.println("Stabilizing...");
    count++;
    }
  else{
    calcVoltage = voltsMeasured * (5.0 / 1024.0);
    dustDensity = 0.17 * calcVoltage - 0.1;
    if (count < 15){
      runningSum += dustDensity;
      runningAvg = runningSum/(count-7);
      Serial.println("Stabilizing...");
      count++;
      first = dustDensity;
    }
    else{
      if (on == true){
        Serial.print("Dust Density = ");
        Serial.println(dustDensity); //mg/m3
        if (((dustDensity <= (runningAvg-0.03)) || (dustDensity >= (runningAvg+0.03))) &&
((dustDensity <= (first-0.01)) || (dustDensity >= (first+0.01)))){
          plasCount++;
          Serial.println("+ plastic!");
          }
        else{
          runningSum += dustDensity;
          runningAvg = runningSum/(count-7);
          count++;
          }
        Serial.print("Running Average = ");
        Serial.println(runningAvg);
        Serial.print("MicroPlastic Count = ");
        Serial.println(plasCount);
        Serial.println("");
        first = dustDensity;
      }
    }
    Serial.print("Time: ");
    Serial.println(myTime);
    if
(((myTime<26200)&&(myTime>24800))||((myTime<51200)&&(myTime>49800))||((myTime<76200)&&(myTime
>74800))||((myTime<101200)&&(myTime>99800))){
      on = false;
      for (int i = 0; i<4; i++){
        for(angle = 40; angle < 110; angle++)
        {
          servo.write(angle);
          delay(10);
        }
        for(angle = 110; angle > 40; angle--)
```

```
      {
        servo.write(angle);
        delay(10);
      }
    }
  }
   else if (myTime>124990){
    on = false;
    if ((plasCount>0)&&(plasCount<=5)){
      Serial.println("1");
      digitalWrite(pump,HIGH);
      delay(30000);
      digitalWrite(pump,LOW);
      for (int i = 0; i<20; i++){
        for(angle = 40; angle < 110; angle++)
        {
          servo.write(angle);
          delay(5);
        }
        for(angle = 110; angle > 40; angle--)
        {
          servo.write(angle);
          delay(5);
        }
      }
      Serial.println("Done!");
      delay(60000);
    }
    else if ((plasCount>5)&&(plasCount<=10)){
      Serial.println("2");
      digitalWrite(pump,HIGH);
      delay(45000);
      digitalWrite(pump,LOW);
      for (int i = 0; i<20; i++){
        for(angle = 40; angle < 110; angle++)
        {
          servo.write(angle);
          delay(5);
        }
        for(angle = 110; angle > 40; angle--)
        {
          servo.write(angle);
          delay(5);
        }
      }
      Serial.println("Done!");
      delay(60000);
    }
    else if ((plasCount>10)){
```

```
        Serial.println("3");
        digitalWrite(pump,HIGH);
        delay(60000);
        digitalWrite(pump,LOW);
        for (int i = 0; i<20; i++){
          for(angle = 40; angle < 110; angle++)
          {
            servo.write(angle);
            delay(5);
          }
          for(angle = 110; angle > 40; angle--)
          {
            servo.write(angle);
            delay(5);
          }
        }
        Serial.println("Done!");
        delay(60000);
      }
      else {
        Serial.println("0");
        Serial.println("Done!");
        delay(60000);
      }
    }
    else {
      on = true;
    }
    delay(1000);
  }
}
```

IR Dust Sensor

```
int dustPin = 5;
int ledPin = 12;
int count = 0;
int plasCount = 0;

float voltsMeasured = 0;
float calcVoltage = 0;
float dustDensity = 0;
float runningSum = 0;
float runningAvg = 0;
double first = 0;

void setup()
{
```

```
  Serial.begin(9600);
  pinMode(ledPin,OUTPUT);
}


void loop()
{
  digitalWrite(ledPin,LOW); // power on the LED
  delayMicroseconds(280);

  voltsMeasured = analogRead(dustPin);

  delayMicroseconds(40);
  digitalWrite(ledPin,HIGH);
  delayMicroseconds(9680);

  if (count < 8){
    Serial.println("Stabilizing...");
    count++;
    }
  else{
    calcVoltage = voltsMeasured * (5.0 / 1024.0);
    dustDensity = 0.17 * calcVoltage - 0.1;
    if (count < 15){
      runningSum += dustDensity;
      runningAvg = runningSum/(count-7);
      Serial.println("Stabilizing...");
      count++;
      first = dustDensity;
    }
    else{
      Serial.print("Dust Density = ");
      Serial.println(dustDensity); //mg/m3
      if ((dustDensity < (runningAvg-0.05)) && (dustDensity < (first-0.03))){
        plasCount++;
        Serial.println("+ plastic!");
        }
      else{
        runningSum += dustDensity;
        runningAvg = runningSum/(count-7);
        count++;
        }
      Serial.print("Running Average = ");
      Serial.println(runningAvg);
      Serial.print("MicroPlastic Count = ");
      Serial.println(plasCount);
      Serial.println("");
      first = dustDensity;
    }
    delay(1000);
  }
}
```

Ferrofluid Pump

```
const int motor= 10; //motor connected to digital pin 10

void setup(){
  pinMode(motor, OUTPUT); //sets the digital pin as output
}

void loop(){
  digitalWrite(motor,HIGH);
  delay(5000); //turns motor on for 5 seconds -> can change this value based on number of
microplastics
  Serial.println("Ferrofluid Pump Done!");
  digitalWrite(motor,LOW);
  delay(30000); //turns motor off for 30 seconds
}
```

Stirrer Servo

```
#include <Servo.h>
Servo servo;
int angle = 10;
void setup() {
  servo.attach(8);
  servo.write(angle);
}
void loop()
{
  for(angle = 10; angle < 180; angle++)
  {
    servo.write(angle);
    delay(15);
  }
  for(angle = 180; angle > 10; angle--)
  {
    servo.write(angle);
    delay(15);
  }
}
```

Data

1. Milk Carton Cap

2/24

Trial	# Plastics in Water	# Plastics Detected	Pump Mode (0/1/2/3)	Total Priming Time (min)	# Plastics Primed
1	1	1	1	2:29	1
2	3	4	1	2:52	3
3	5	1	1	2:52	4
4	7	0	0	2:09	0
5	9	4	1	2:52	8
6	11	8	2	3:07	11
7	13	11	3	3:21	12
8	15	2	1	2:51	15

2.

2. Milk Carton

2/26

Trial	# Plastics in Water	# Plastics Detected	Pump Mode (0/1/2/3)	Total Priming Time (min)	# Plastics Primed
1	1	1	1	2:51	1
2	3	4	1	2:51	3
3	5	2	1	2:52	4
4	7	0	0	2:08	0
5	9	1	1	2:51	7
6	11	3	1	2:51	9
7	13	5	1	2:52	12
8	15	1	1	3:21	11

3.

3. Styrofoam

2/26

Trial	# Plastics in Water	# Plastics Detected	Pump Mode (0/1/2/3)	Total Priming Time (min)	# Plastics Primed
1	1	3	1	2:50	1
2	3	3	1	2:50	3
3	5	0	0	2:09	0
4	7	2	1	2:52	7
5	9	2	1	2:51	9
6	11	4	1	2:51	11
7	13	2	1	2:51	13
8	15	1	1	2:50	13

4.

4. Water Bottle

2/27

Trial	# Plastics in Water	# Plastics Detected	Pump Mode (0/1/2/3)	Total Priming Time (min)	# Plastics Primed
1	1	0	0	2:08	0
2	3	1	1	2:51	3
3	5	7	2	3:08	5
4	7	3	1	2:50	6
5	9	1	1	2:51	9
6	11	12	3	3:21	11
7	13	4	1	2:49	12
8	15	35	3	3:21	15

5.Control

2/24

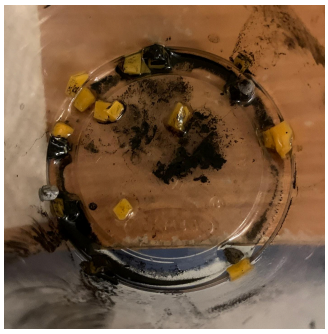
Trial	# Plastics in Water	# Plastics Detected	Pump Mode (0/1/2/3)	Total Priming Time (min)	# Plastics Primed
1	0	0	0	2:07.78	n/a
2	0	0	0	2:05.80	n/a
3	0	0	0	2:08.65	n/a
4	0	0	0	2:05.71	n/a
5	0	0	0	2:05.68	n/a

Observations

2/24-2/27

- Overall, the plastics that were a little thicker were the ones that were detected most accurately
    - Milk Carton Cap + Styrofoam
- Thinner plastics seemed to absorb ferrofluid easier and end up sticking to the magnet easier
- Although water bottle detected most amount of plastics overall, the last trial was an outlier, so that does not mean it was necessarily accurate
- Styrofoam ended up sticking to the stirrer
    - This is because the stirrer is plastic, so over time, it may have also gotten magnetized after being stuck in the ferrofluid for so long
- Box broke halfway through 3rd trial, had to restart with a black box
    - Since it wasn't clear, it was difficult to see whether the ferrofluid got to all areas of the box
- Ferrofluid pump also would sometimes stop pumping
    - This is when the ferrofluid was too sludgy, tilting it so that all the liquid would fall to one end seemed to do the trick
- The device did a good job of priming the plastics overall, more statistics about this can be seen in slide 8 of the project presentation
- The ferrofluid was really messy, I had to use several paper towels and a tarp to maintain the mess
- All the fluid was dumped into containers, will be disposed of like motor oil, Plastics will be cleaned and reused for future testing

<Ferrofluid-infused Water Containers>



<Primed Plastics>

Link to full Lab Notebook:
https://docs.google.com/document/d/1kv3oSB2gn5UvnaqXBy-ne0oSiddQBvhLo5ghdzVM-QE/edit?usp=sharing