# Lab Report – Calculus-Based Physics II

# Project - Magnetic Levitation with Arduino

# Manchester Community College

Instructor: Dr. Negussie Tirfessa

Due Date: 05/03/2022

Prepared By: Thao Tran

Jennifer Vazquez

**Table of Contents**

II. Objective ........ 3
III. Theory ........ 3
IV. List of Materials and Principle ........ 4
V. Data ........ 4
VI. Calculations and Extension ........ 6
VII. Observations and Conclusions ........ 7
VIII. Work-cited ........ 8

## II. Objective

In this project, we will re-create an apparatus of Magnetic Levitation with an Arduino Uno board by applying magnetics' properties.

## III. Theory

- Magnetic Levitation is the repulsive or attractive force resulting gap from a magnetic field. Characteristic of the magnetic levitation model is the use of permanent magnet and electromagnet with PID control to maintain the wide gap between levitator and object levitation.
- A Hall-effect linear sensor, also known as a linear, is an analog device that varies its output voltage proportional to the magnetic field it is sensing. It is used for position detection of the object. (Principle)The output of the sensor is directly proportional to the magnetic field strength passing through it
- A Proportional, Integral, Derivative (PID) controller implemented on the Arduino micro-controller is used to control the current through an electromagnet based on the position and velocity of the magnetic object that is being levitated. In other word, it is used to control the ball position of the magnetic levitation system (MLS). The electromagnetic force of the MLS is controlled by sensing the position of the ball with the help of the Hall effect sensor.

**Formulas:**

- Gravity Force F=mg
- Magnetic force: F=ILB
- Number of turns:

$$\frac{Length}{\#\ of\ turns} = \pi D$$

- PID Controller Algorithm:

$$\mu(t) = K_p e(t) + K_i \int_0^t e(\tau)\, \mathrm{d}\tau + K_d \frac{d}{dt} e(t),$$

## IV. List of Materials and Principle

**List of materials:**

- Electromagnet
- Hall effect sensor (49E)
- Resistor x2 (1k ohm)
- Arduino board (Uno)
- Neodymium magnet
- Transistor (TIP 122)
- Power supply (5~12V)
- LED (Optional)

**Principle**

The magnet is positioned close enough to the electromagnet so that its magnetic field can interact with the magnet, but not so close that the magnet's own magnetic field is able to pull itself up to the electromagnet regardless of the power. A hall effect sensor is used to control the electromagnet so that when the magnet is too far away, the electromagnet will pull the magnet closer, but turn off when it gets too close, so that gravity can still pull it back down. It is placed underneath the electromagnet. Using the Arduino Uno, the electromagnet will turn on and off whenever the magnet passes a custom levitation point/ levitation value which is detected by the sensor.

If the analog value is greater than the levitation value, the electromagnet turns off. If the analog value is less than the levitation value, the electromagnet turns on.

Between each oscillation that the magnets go through, it creates a delay time between each time the electromagnet turns on and off, which creates an error overtime that does not allow the magnets to stay levitated. For this reason, a PID Controller is set to minimize the error, which maintains the magnets at the desired setpoint, or the levitation value that we set in the Arduino code.

## V. Data

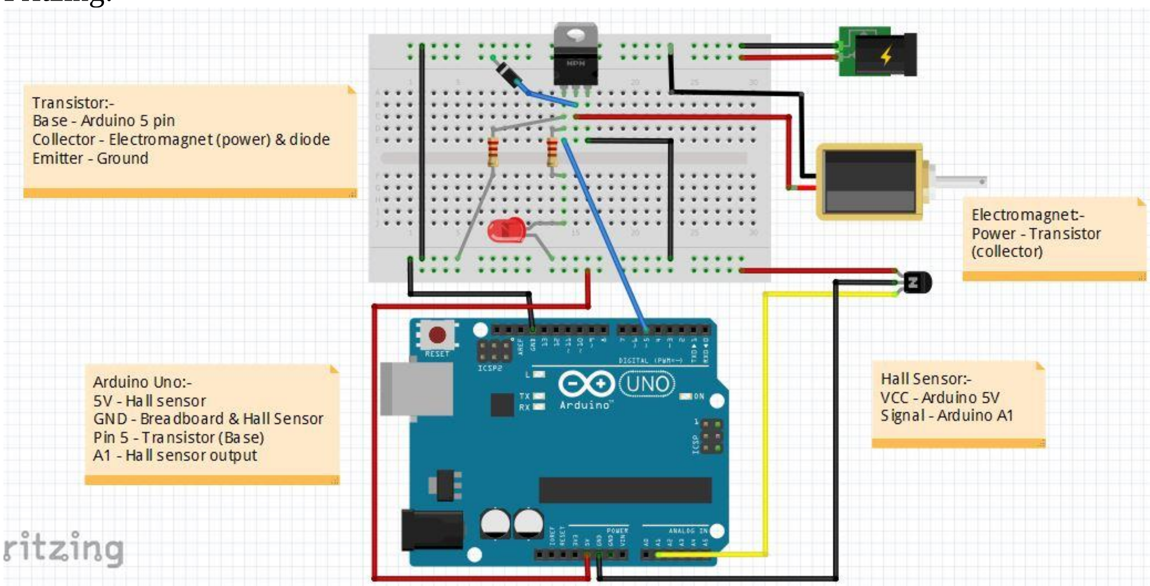
Table 1:

| | |
|---|---|
| **Levitation point** | 480 |
| **Kp** | 1.0 |
| **Ki** | 0.1 |
| **Kd** | 0.01 |

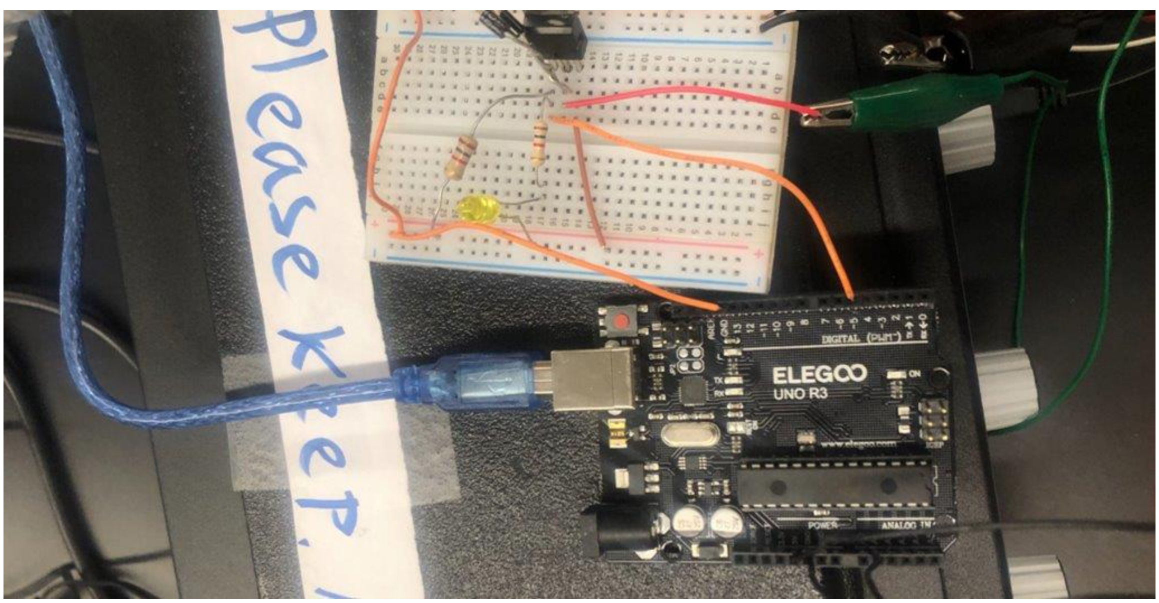
Table 2:

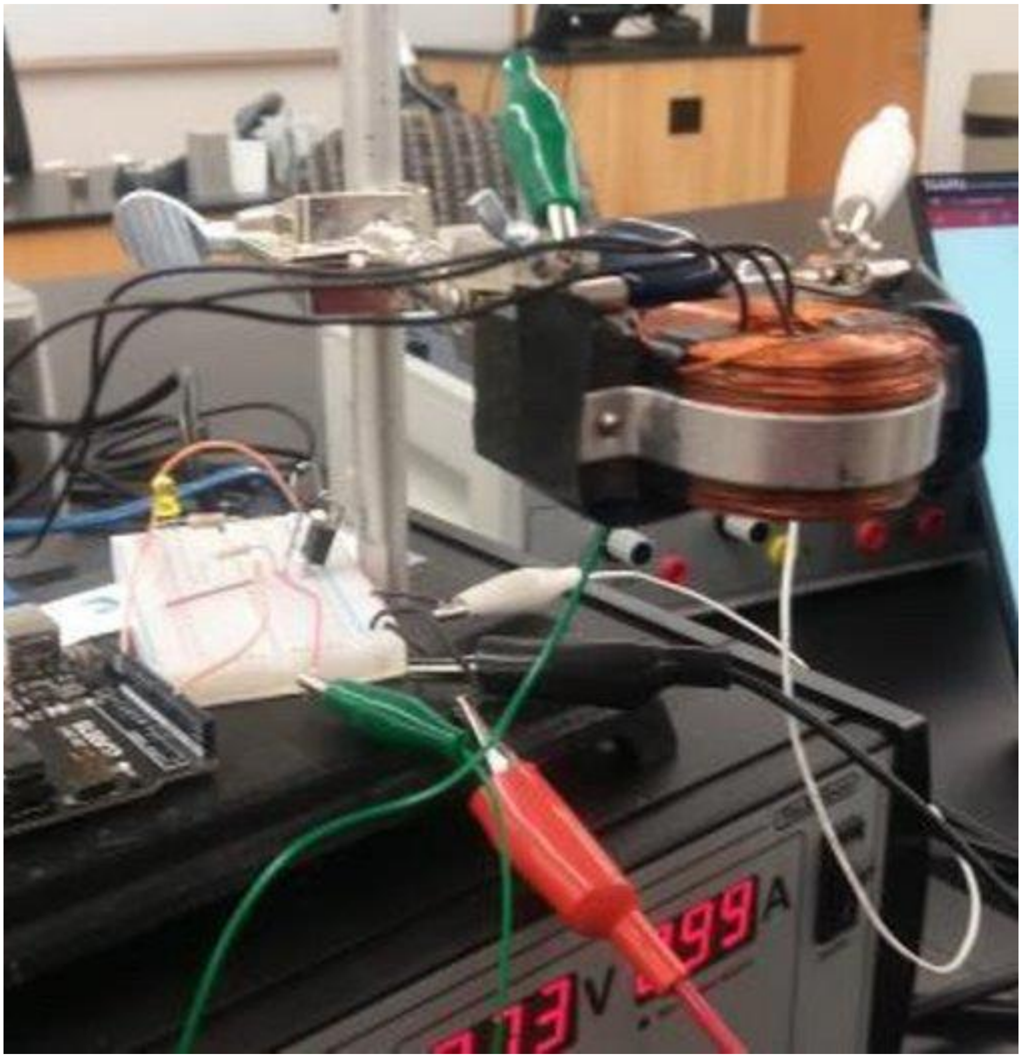
| | |
|---|---|
| **Small Magnet Mass** | 0.24g |
| **Big Magnet Mass** | 5.00g |
| **Magnetic Field** | 0.4644T |

Fritzing:




Setup:





## VI. Calculations and Extension

### 1. Calculate the force required to lift the magnet

where:

m=0.24g

g=9.81m/s^2

F=mg

F=(0.24g)(9.91m/s^2)

F=2.3544mN

F≈2.35mN

### 2. Estimate the number of turns in the coil

where: thickness of the wire = 0.6cm → 22 AWG

R=3.2ohm

Mean D=2.75cm

L=60.38m

$\frac{Length}{\#\ of\ turns} = \pi D = \frac{8.64cm}{\#\ of\ turns}$

22 AWG: $\frac{0.053}{m}$

# Of turns = $\frac{60.38}{0.0864}$

# Of turns = 698 turns when the wire/ is thin

$\frac{Area=2.26}{A.of\ coil}:\frac{2.83x10^{-5}m^2}{1.10x10^{-3}m^2}$

⇒ 38.96 turns = 38 turns

The estimate number of turns: 698 – 38 = 670 turns

**3. Calculate the required mass of the magnet to levitate**

Where: I=1.53A

Length=60.38m

B=0.4644T

g=9.81m/s^2

mg=ILB

m*9.81m/s^2 = (1.53A)(60.38m)(0.4644T) = 4.29E+2 N

m=4.37kg

## VII. Observations and Conclusions

Thanks to the base code written by The Assembly, we only need to input the levitation and the PID value. This value can be estimate using the monitor in the Arduino software.

**Attempt 1:**

The diode fried. It is because its maximum current is 1A, but we gave it around 2A. We fixed it by adding one more diode in parallel to increase the maximum current.

**Attempt 2:**

The magnet could not levitate because the magnet was too heavy. At 12V, the calculated force created by the electromagnet is 4.29E+2 N. Applying Newtons' Law, the maximum mass would be 4.37g. While the big magnet was 5g, it is a bit heavier to levitate, so we changed to a lighter magnet. This time, the magnet could bounce up and down between the thumbs. However, if we let it levitate by without holding it, it will fall down within a second.

Video: (2) Magnetic levitation with Arduino - YouTube

**Attempt 3:**

The magnet could not levitate for a long time. We checked the hall effect sensor. The hall sensor works by itself using the multimeter. However, when we checked it while it is connected to the Arduino board, we found that the left side of the board, which is the analog side already broken from the beginning, and that makes no current pass through the sensor.

We could not continue because the arrival date is after the presentation date. However, if the board could work properly, then the hall effect sensor could work, and the magnet would be able to levitate.

Overall, although we did not achieve the expected results, we learned a lot while doing the project and testing in each attempt. We learned how to use and how the electronic devices/ components work; how magnetics' properties are applied to make things levitate. The Arduino software is a good and fun software to use for programming small projects. However, it seems that the Arduino board is not durable since it quite affordable. In my experience, the Raspberry Pi is better, but it also means it is more expensive.

## VIII. Work-cited

Alex the Giant: Creative Commons tutorials are CC BY-SA 4.0, Magnetic Levitation - learn.sparkfun.com

Jsirgado, published on March 11, 2018: Magnet Levitation with Arduino - Arduino Project Hub, Magnet Levitation with Arduino - Arduino Project Hub

Sultan Mustufa Morbiwala: GitHub - The-Assembly/Magnetic_Levitation