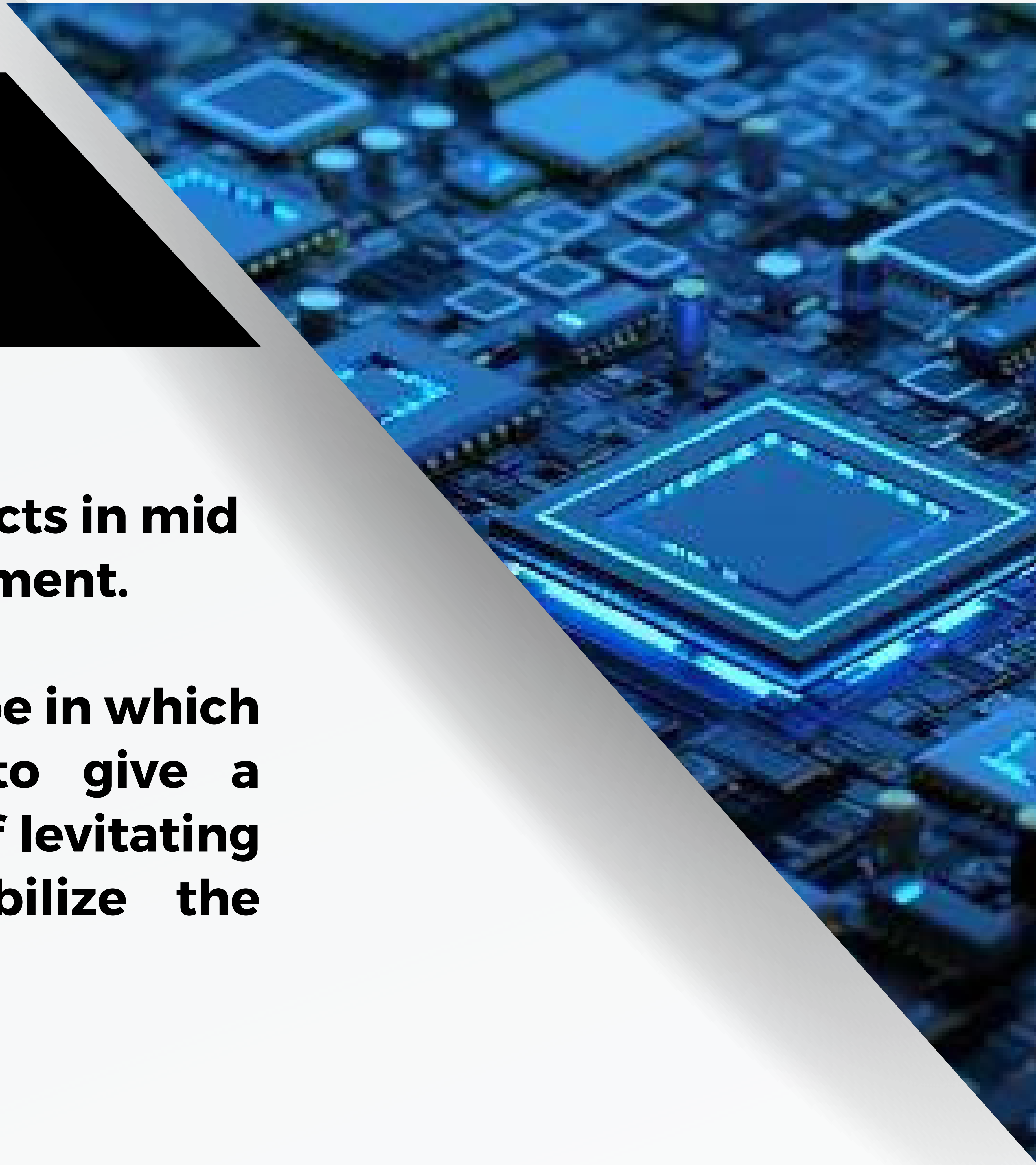
ECLUB

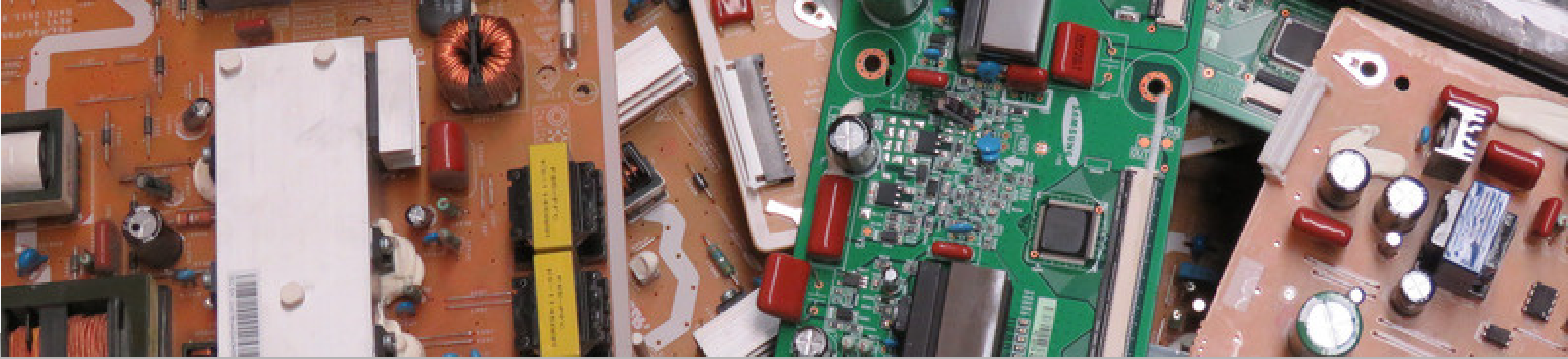
MAGLEV

PALTFORM

MAGNETIC LEVITATION



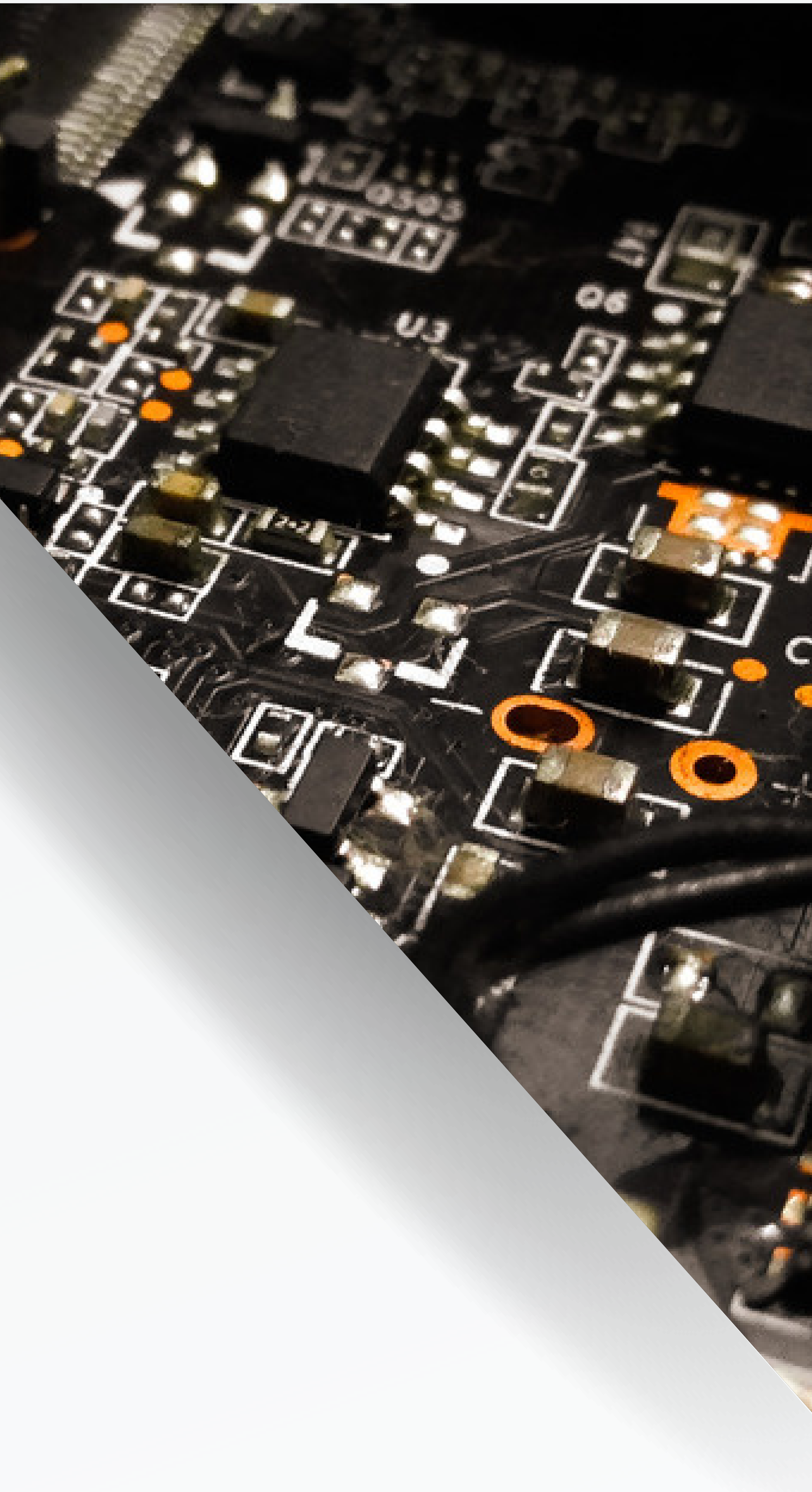
- Magnetic levitation is suspension of objects in mid air using magnetic forces in free environment.
- In our project, we are building a prototype in which we are using permanent magnets to give a necessary force to counter the weight of levitating magnet and electromagnets to stabilize the system.



AIM

The aim of this project is to levitate objects in the air stably by looking into various possible strategies.

We aim to design most feasible model for magnetic levitation by first building a small prototype and analyse it in order to scale it up to higher load capacities.



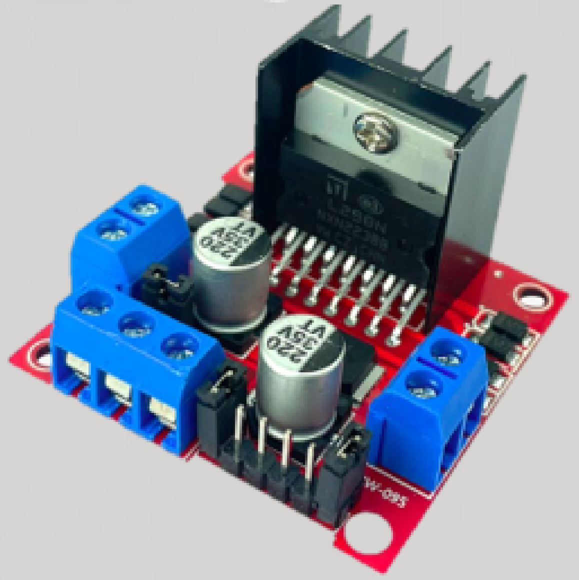
MAIN CHALLENGE

According to Earnshaw's theoram, two magnets cannot be floated by just putting them on top of one another with their repelling poles facing each other, since they will be in an unstable equilibrium.

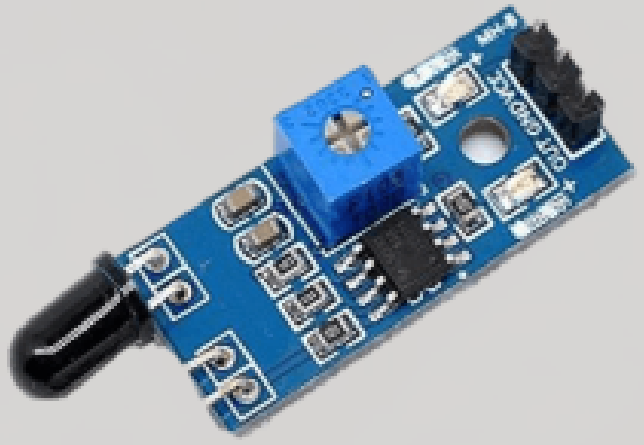
To counter this, we need a real-time self-balancing mechanism to sustain levitation.

Basic electronics

ULTRASONIC SENSOR



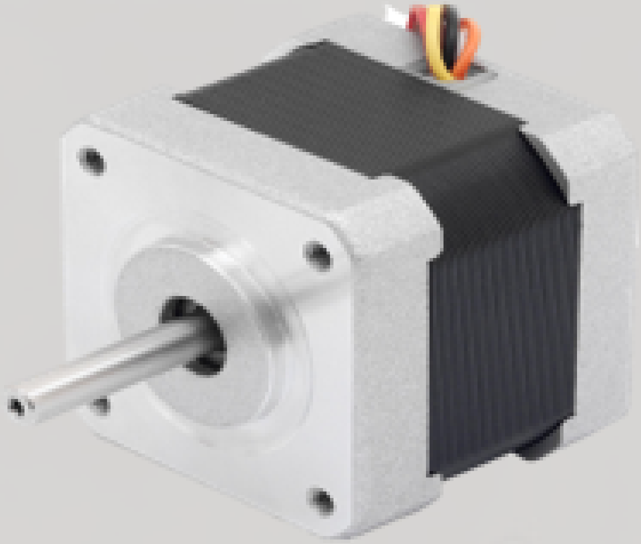
L298N DRIVER



IR SENSOR

SERVO MOTOR

DC MOTOR

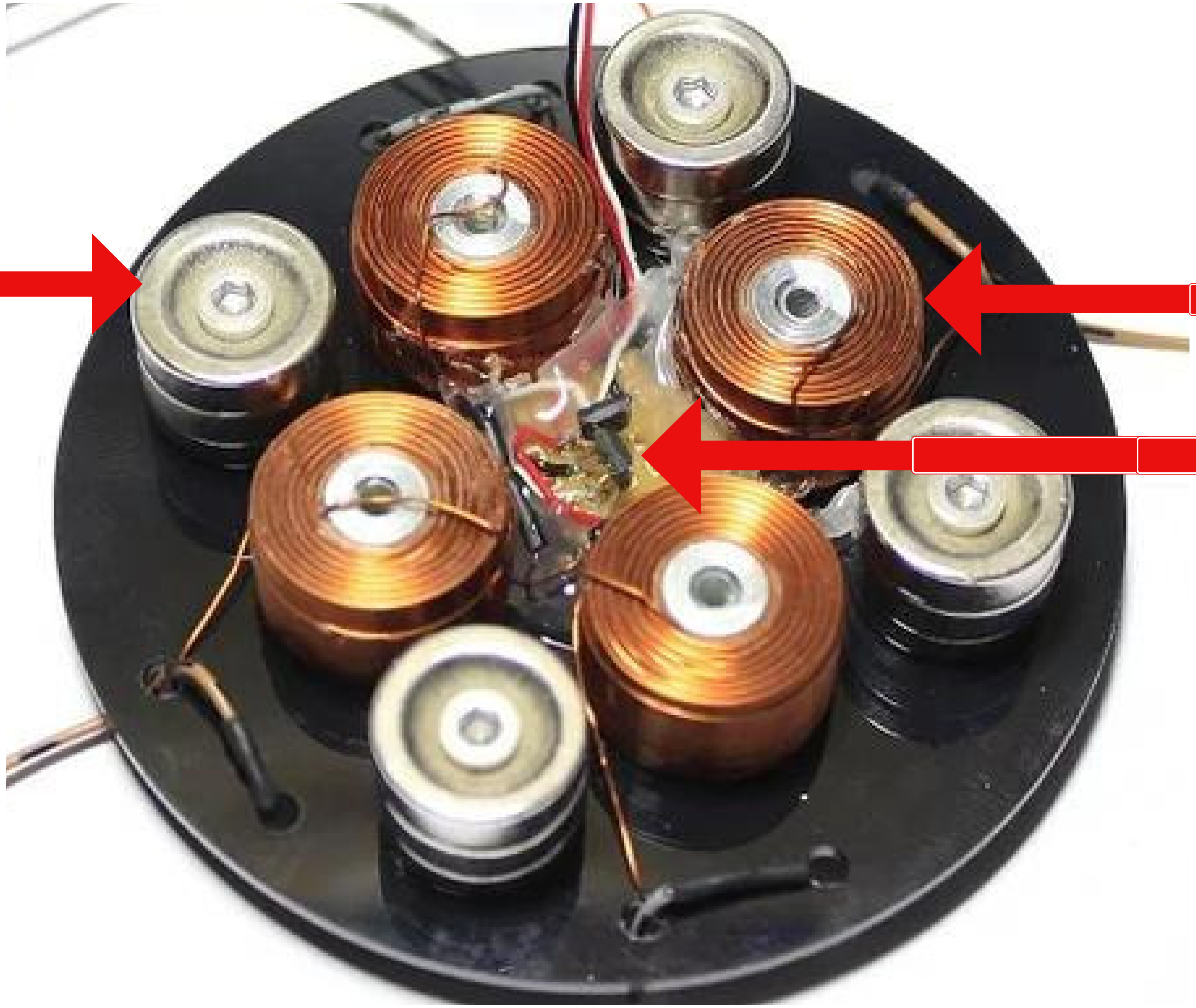


STEPPER MOTOR

FLEX SENSOR

Components we tinkered using Arduino in order to gain some hand on experience

INITIAL PROTOTYPE



WORKING MECHANISM

INPUT

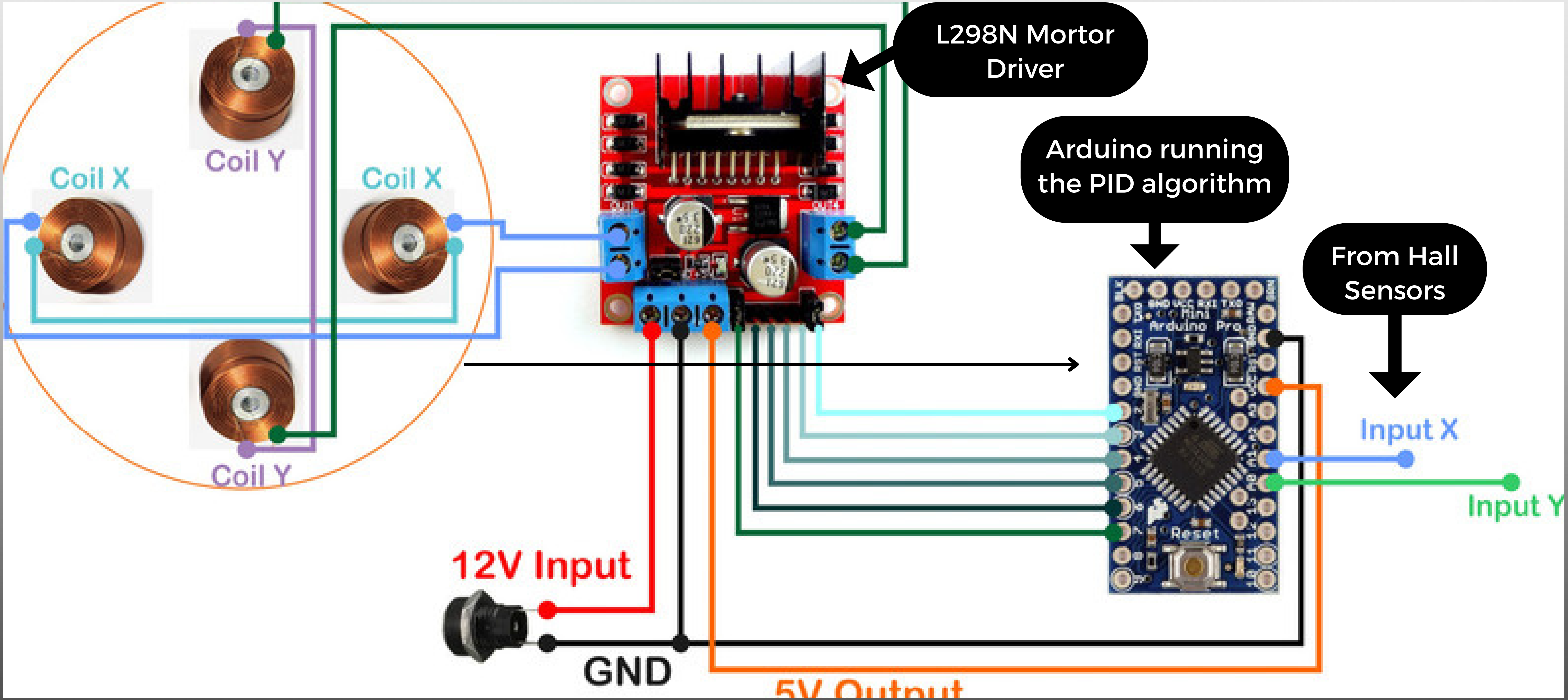
Two hall sensors will detect magnetic field in X and Y directions and send the values to arduino

PROCESSING

Using PID control, appropriate signal to change magnetic fields of electromagnets will be sent to L298 driver.

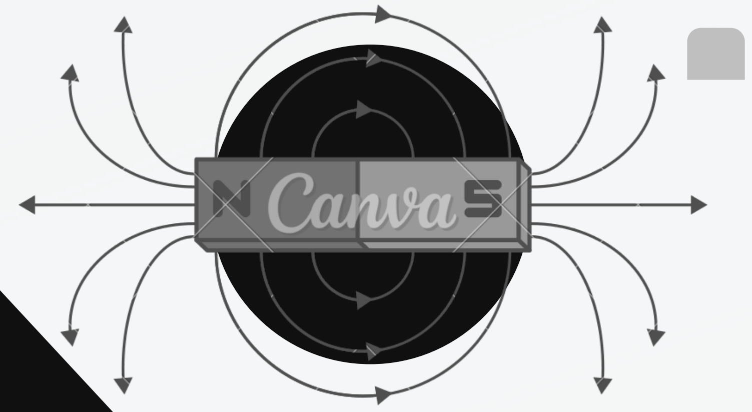
OUTPUT

L298 Driver will receive the signal from PID and accordingly adjust the electromagnets' field to balance the floating plate.

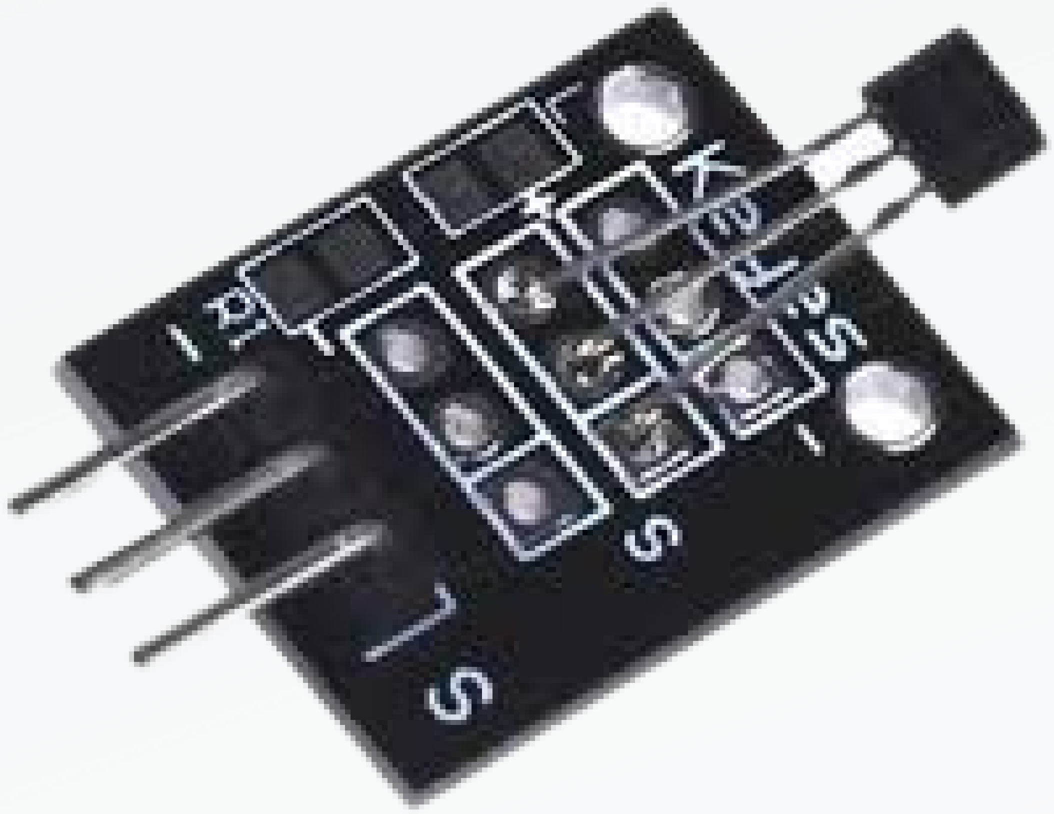


Coil Y
Coil X
Coil X
Coil Y
L298N Mortor Driver
Arduino running the PID algorithm
From Hall Sensors
Input X
Input Y
12V Input
GND
5V Output

HALL SENSOR



01 It is a sensor that detects the presence and magnitude of a magnetic field using the hall effect. Hall effect is the production of a potential difference in a conductor perpendicular to both the flowing current and the magnetic field.

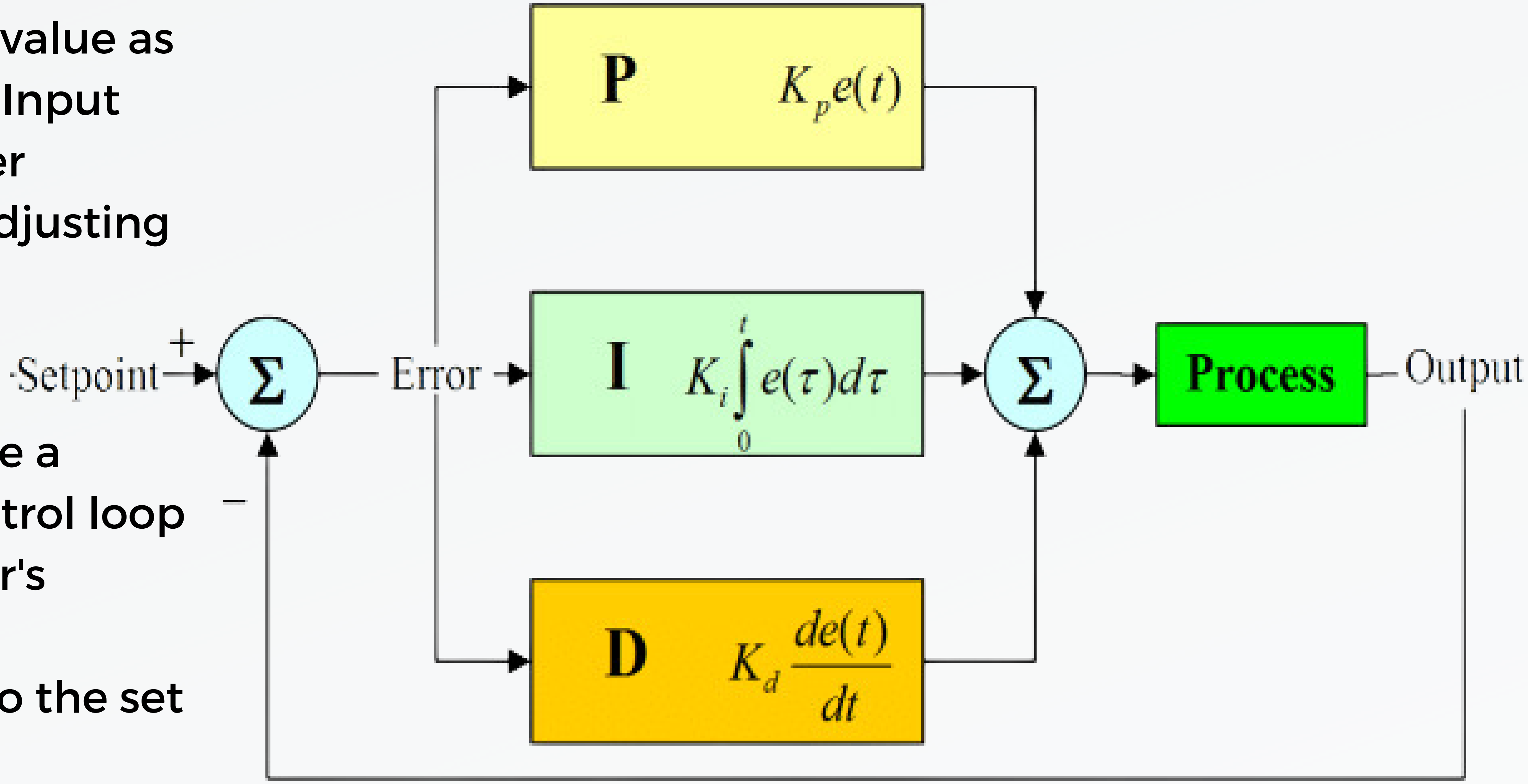


02 In our project, it is used to sense any change in the magnetic field corresponding to the change in the position of the levitating magnet. To sense that change in a magnetic field, we need two hall sensors - one for the X-axis and one for the Y-axis. It creates some output in terms of voltage when it senses the change in magnetic field which will be used as an input to the control mechanism.

PID

01 A PID controller calculates an 'error' value as the difference between a measured Input and a desired setpoint. The controller attempts to minimize the error by adjusting an Output.

02 We will be using PID libraries to write a program that implements a PID control loop which will read the Hall effect sensor's output to calculate error/change in magnetic field intensity compared to the set point magnetic field, calibrated at equilibrium position to again reach desired set point.

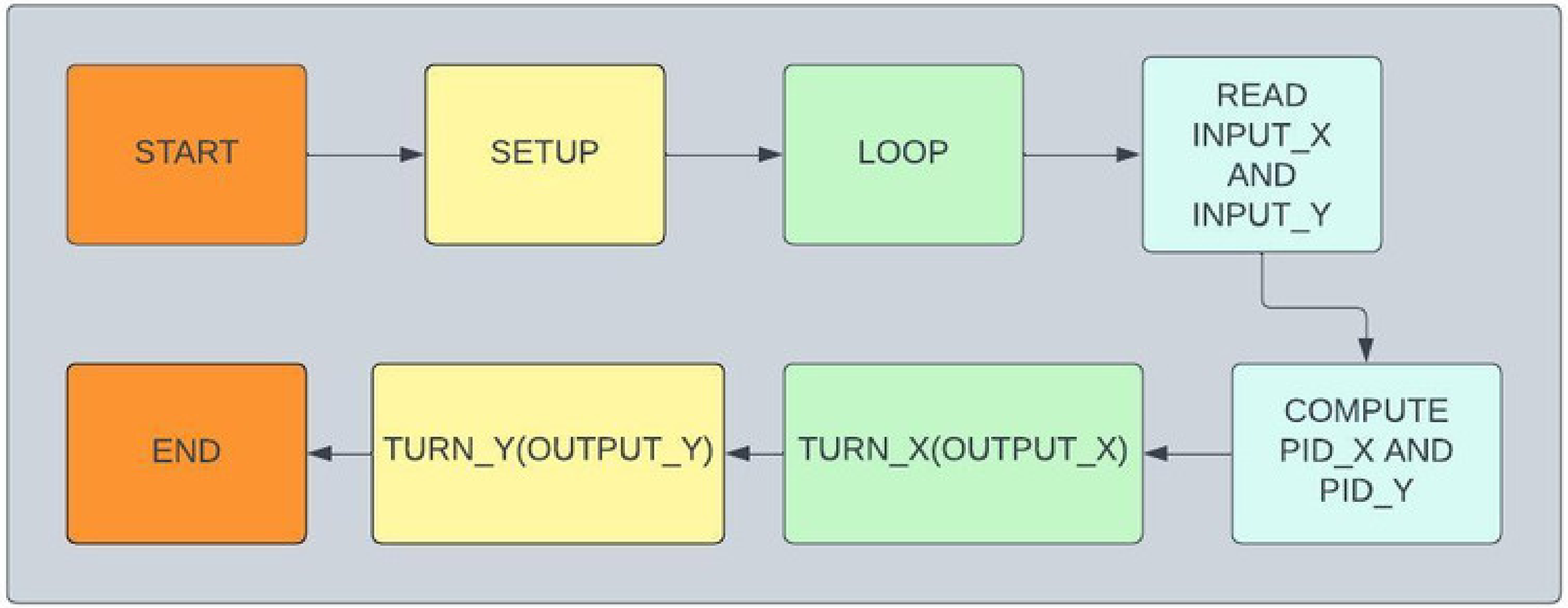


WORKING WITH PID

- Our code sets up two PID controllers for X and Y axes to control the position of a magnetically levitated object.

- The analog sensor inputs are used to read the object's position, and the PID controllers calculate the control signal to adjust the current speed and direction in both X and Y sets of electromagnets to maintain the object at the desired setpoint position.

- The set of electromagnets are controlled through the turn_X and turn_Y functions based on the PID controller outputs. The ultimate goal is to achieve stable levitation of the object in a magnetic field using this system.



UNDERSTANDING THE CODE

```
Setup:
   Set pin modes and initial values
   Set PID tuning parameters and limits
   Set PID sample time
   Set PID mode to AUTOMATIC
```

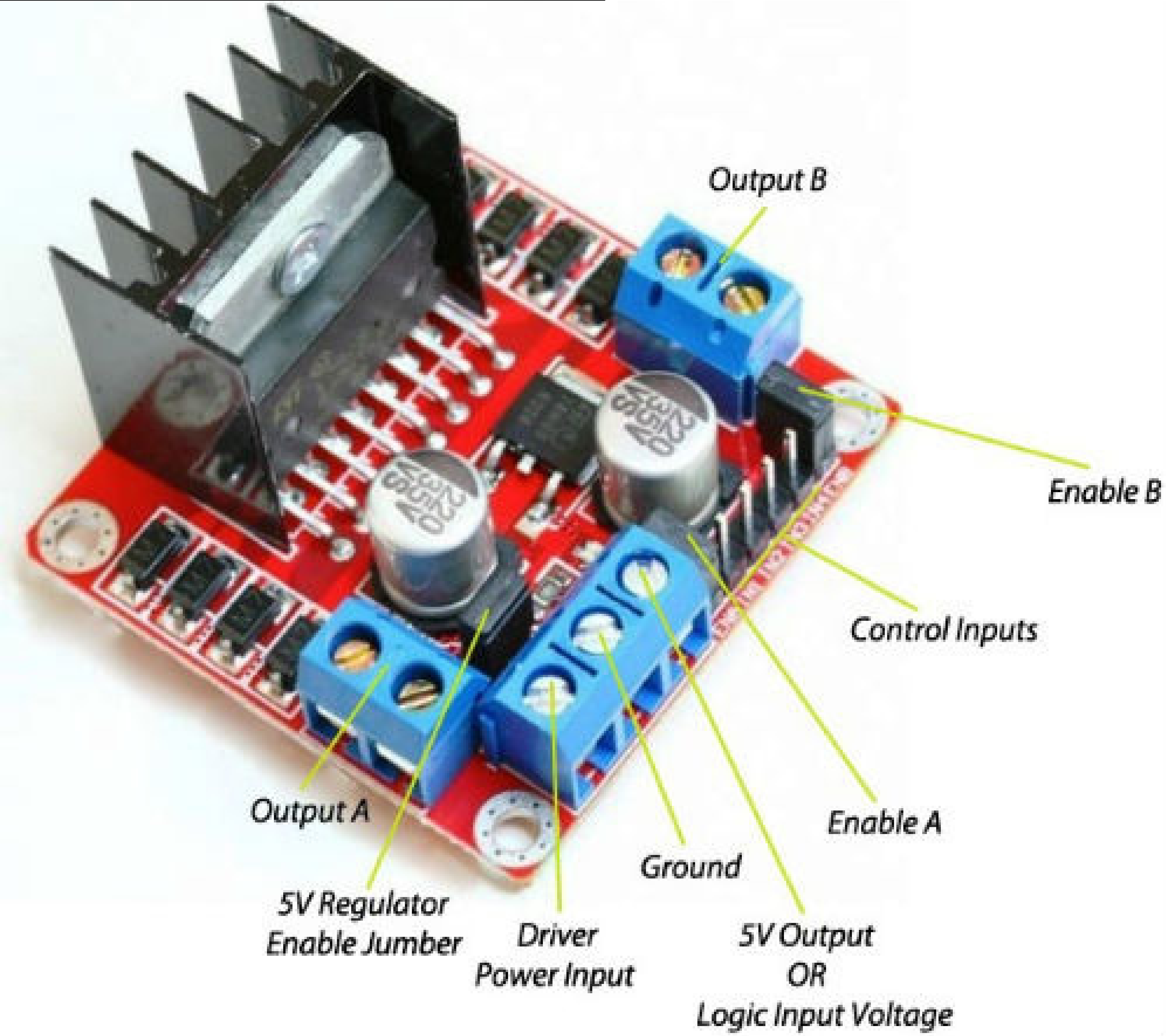
```
Loop:
   Read Input_X and Input_Y from analog pins A1 and A0
   Compute PID X and PID Y using PID algorithm
    control electromagnet-x through turn_X  function
    control electromagnet-y through turn_Y  function
   Repeat Loop
```

```
Turn_X:
   If a >= 0:
         Give clockwise torque about x-axis
   Else:
         Give anti-clockwise torque about x-axis

Turn_Y:
   If a >= 0:
         Give clockwise torque about y-axis
   Else:
         Give anti-clockwise torque about y-axis
```

L298N MOTOR DRIVER

- L298 Driver can control 2 motors simultaneously and change its direction and speed. We will be using it to control our electromagnets.
- One L298 can drive only two motors but as we are able to connect two electromagnets with one port we only require one L298 driver.

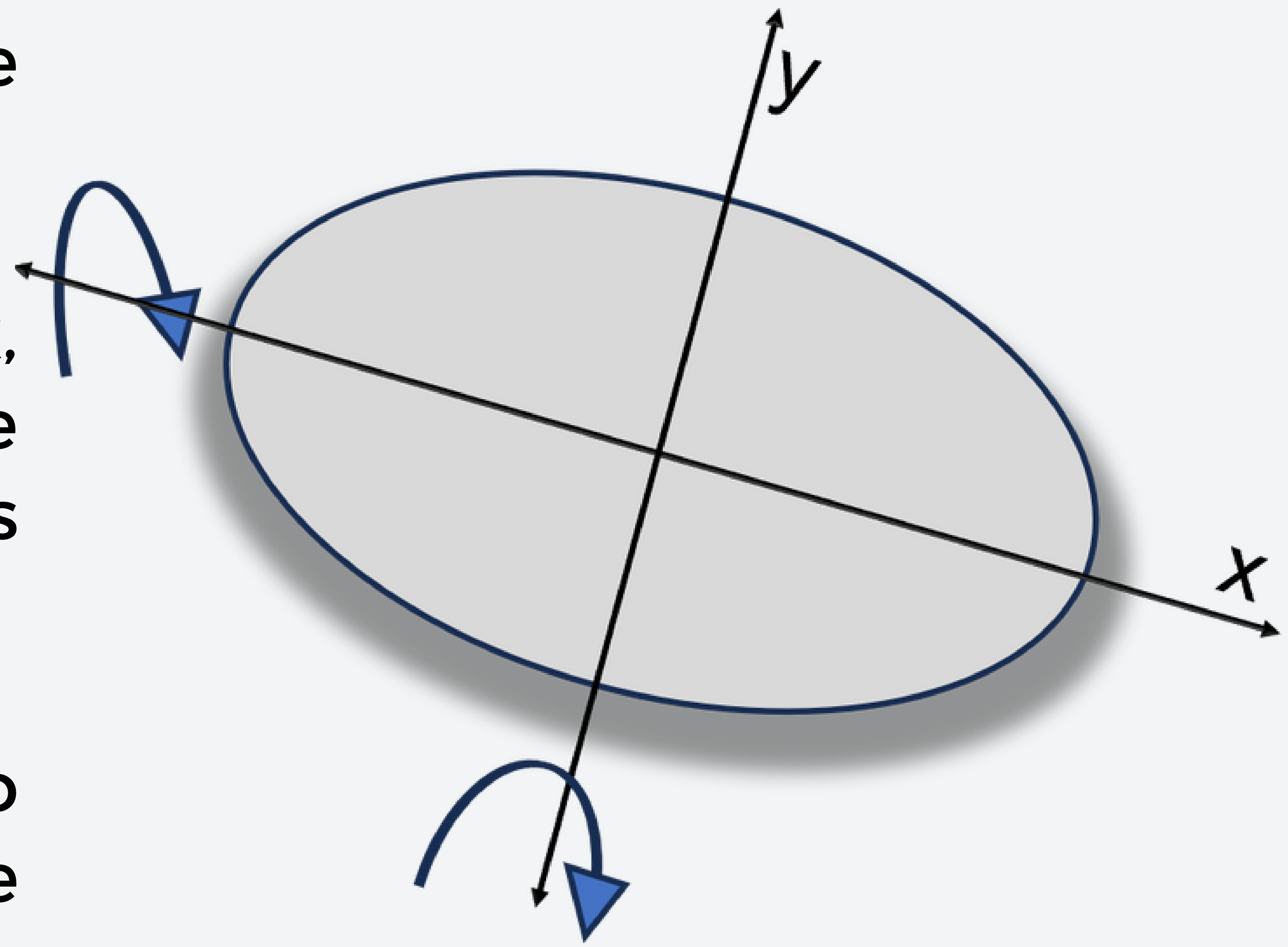


NATURE OF INSTABILITY

- Even after balancing it's weight with magnetic force we still have to counter the rotational instabilities.

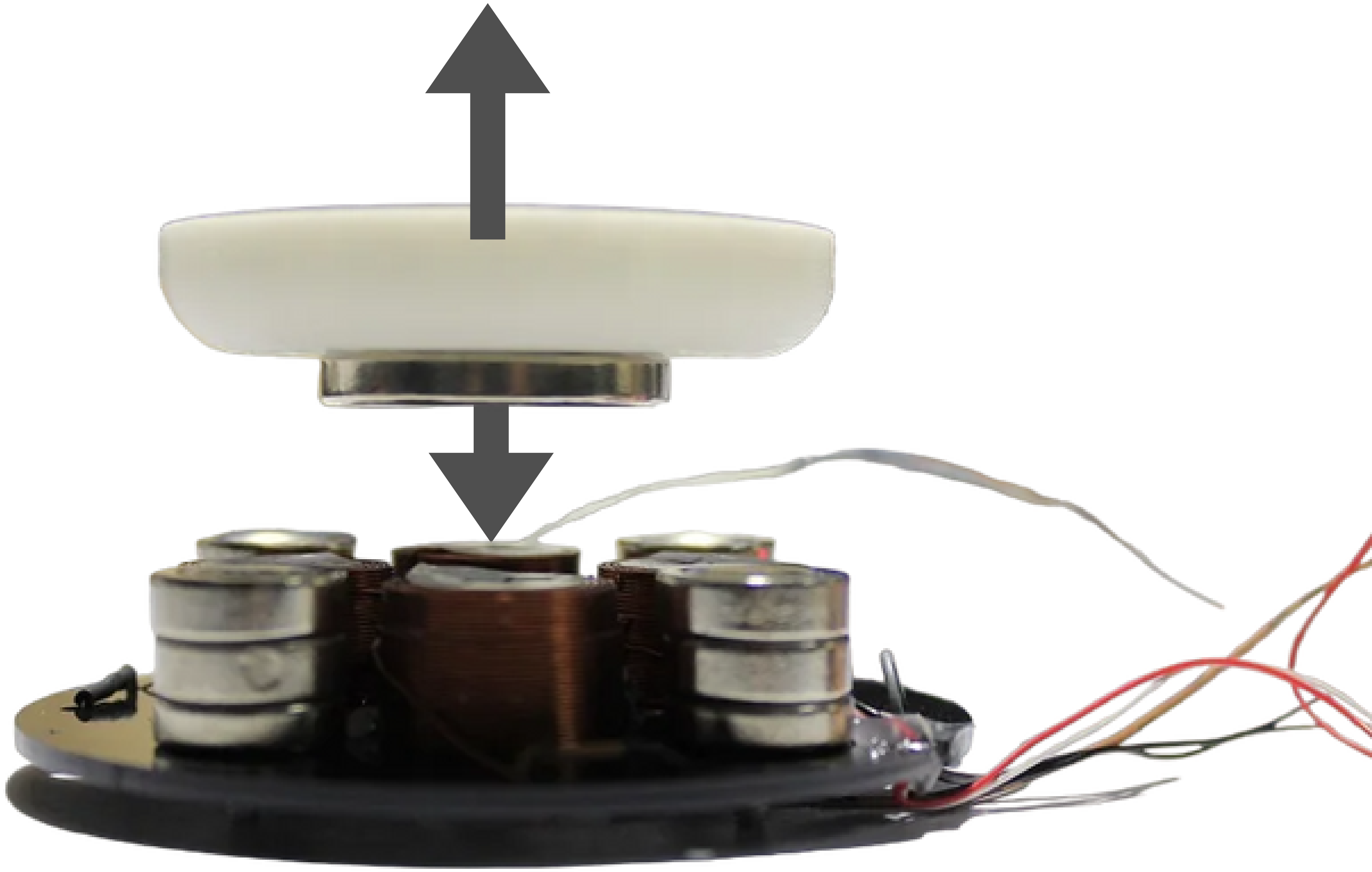
- The nature of instability is the torque generated in x, y and z direction, of which we don't need to care about the z component since the floating plate is free to rotate in the horizontal plane .

- Therefore, all the instabilities can be broken down to two perpendicular components of torque in the horizontal plane(x and y).

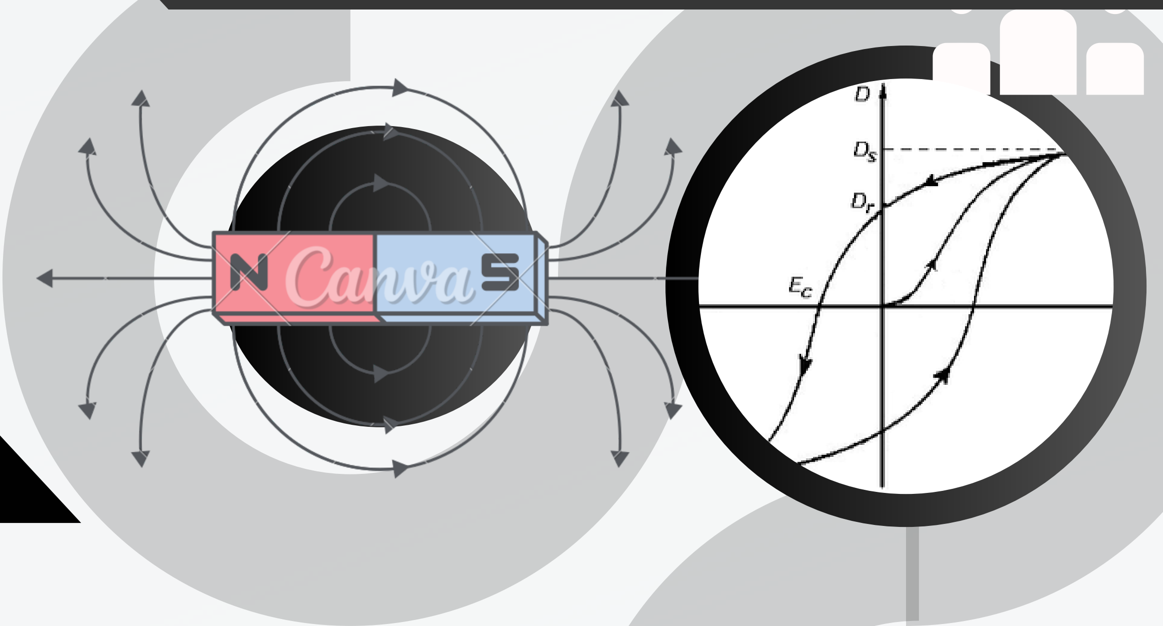


HOW STABILITY IS ACHIEVED?

- Two electromagnets are connected to the same port of L298 but with reverse connection.
- As they are connected with an opposite polarity that provides a torque counter to its direction of rotation that stabilizes it.
- When the floating plate disbalances in one direction equal and opposite torques are applied by the electromagnets.

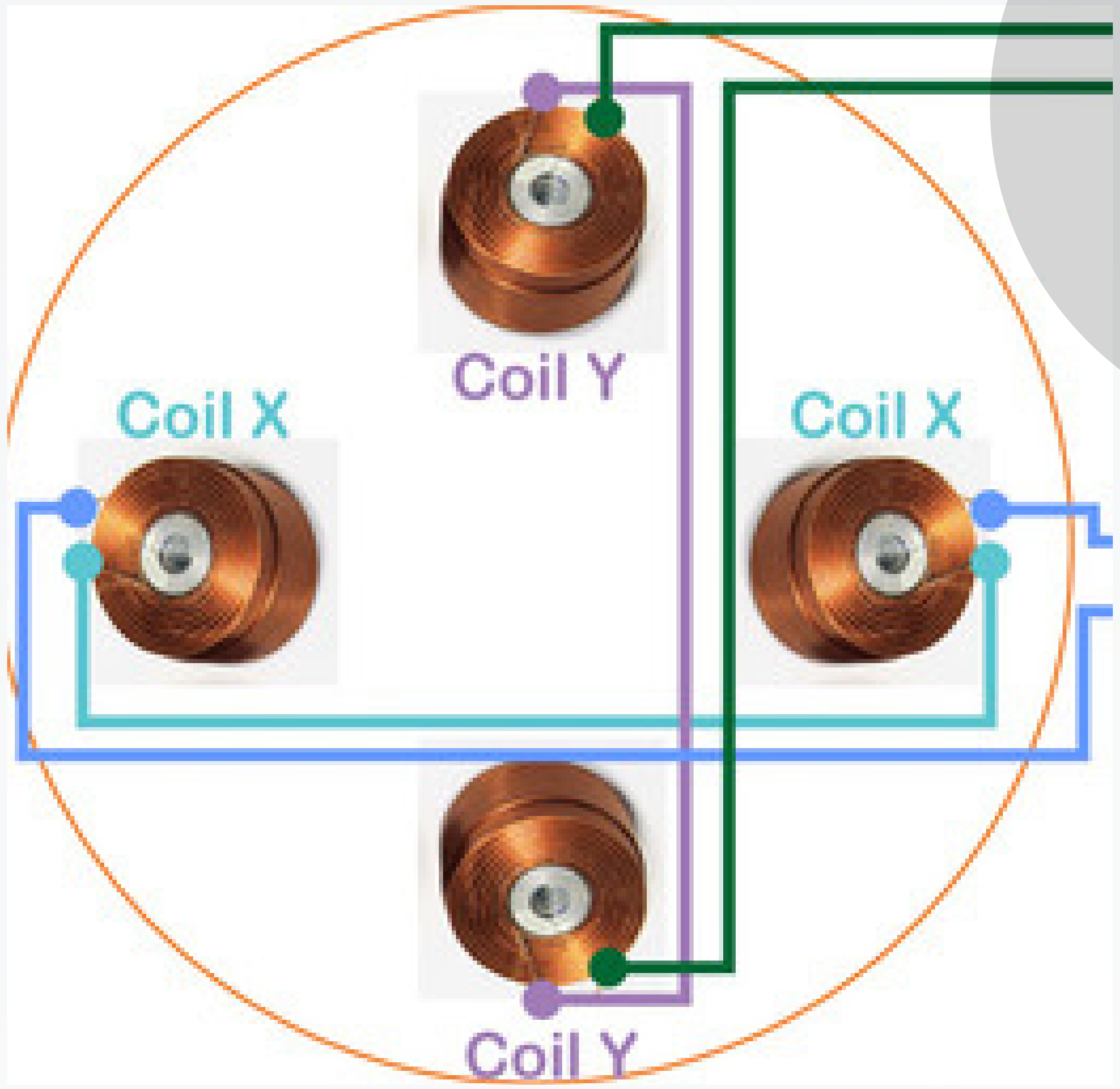


ELECTROMAGNETS



Why did we choose this arrangement?

Two pairs of counter polarized electromagnets in perpendicular direction are needed as we don't want them to produce any net force as its weight is already balanced. This configuration only produces torque to counter the rotational imbalance in both the horizontal axes.



CHANGE OF PLANS

- Initially, our plan was to replicate this design for the small prototype and then design and manufacture its scaled up counterpart.

- However, due to lack of funds and then logistical issues, we could not procure the required electromagnets and even faced challenges in finding ring magnets of the same dimensions.

- As a result, we have made the decision to do the thorough analysis beforehand and design and manufacture even the smaller prototype by ourselves.

DESIGNING ELECTROMANGETS

COILING

METAL CORE

HOUSING

COILING

01 Electromagnets usually consist of wire wound into a coil. In a coil of multiple turns of wire the magnetic field of the turns adds in the center of the coil, creating a strong field.

02 We will use electromagnets with number of turn equals to 480 as per given constraints.

03 The magnetic field of a finite solenoid is given by

$$\mathrm{B} = \frac{\mu_o n I L r^2}{2a^3}$$

where, L - length of the solenoid

r - radius of the solenoid

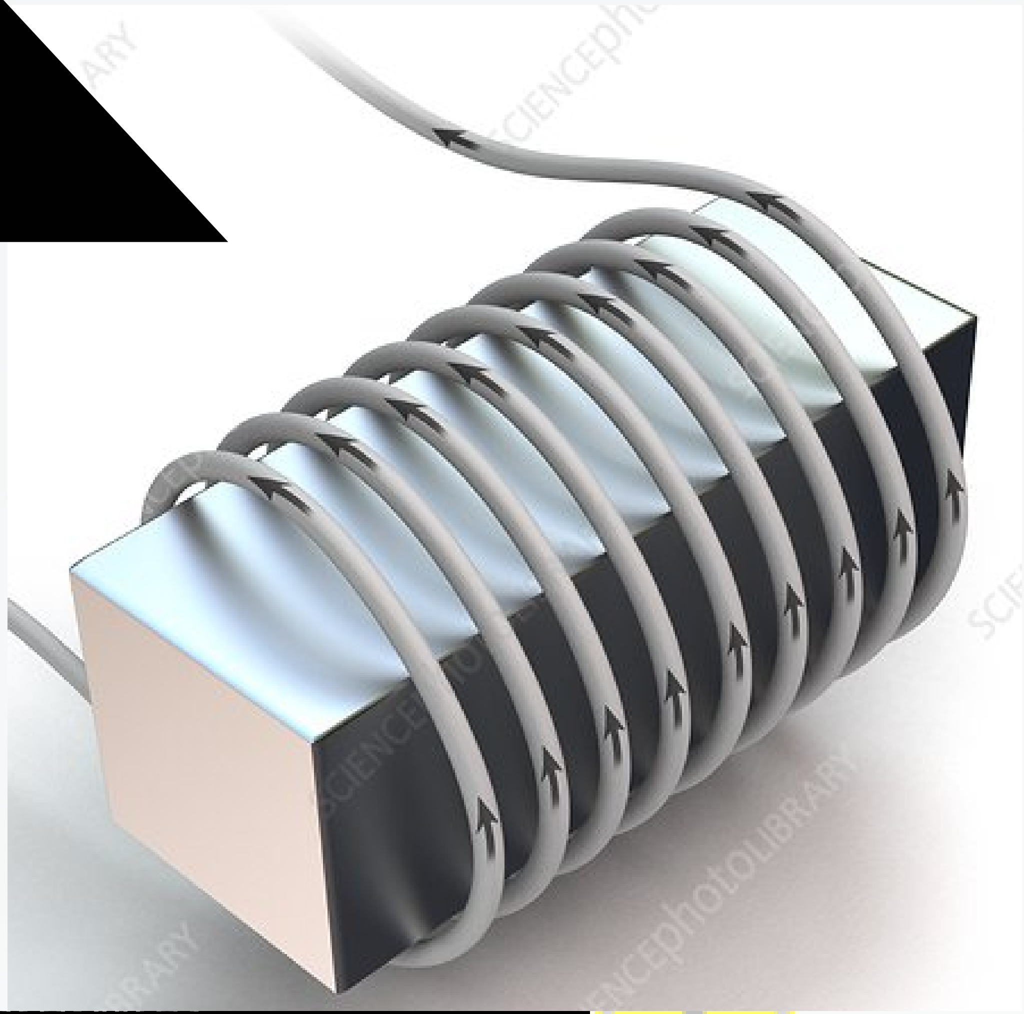
a - distance from the centre of solenoid

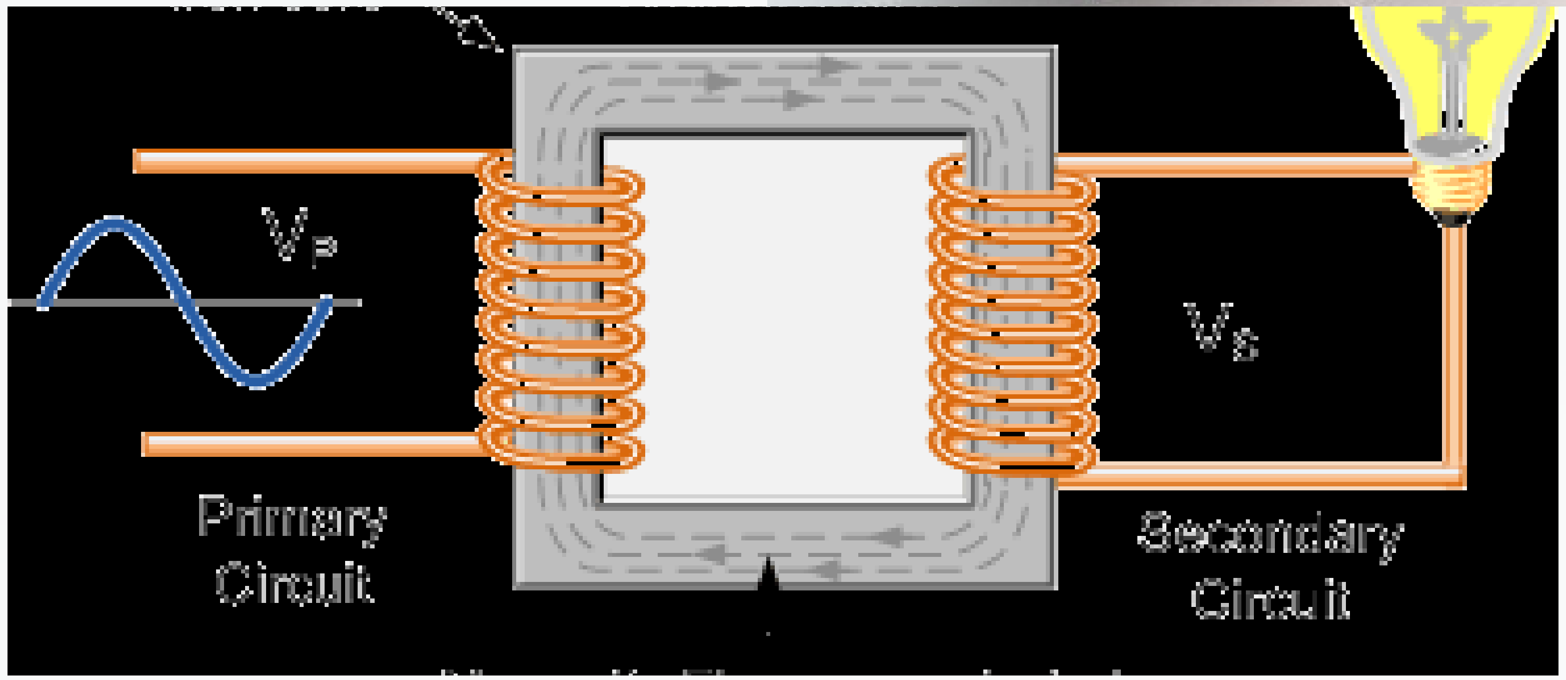
METAL CORE

01 As magnetic permiability goes up, hesterisis and other losses like eddy current also goes up which causes energy losses. Reducing retentivity also decreases permeability.

02 To resolve this we finally ended up with FSS(Ferite stainless steel) which has very high magnetic permiability but not that much . It is also the same material which is used in the transformer.

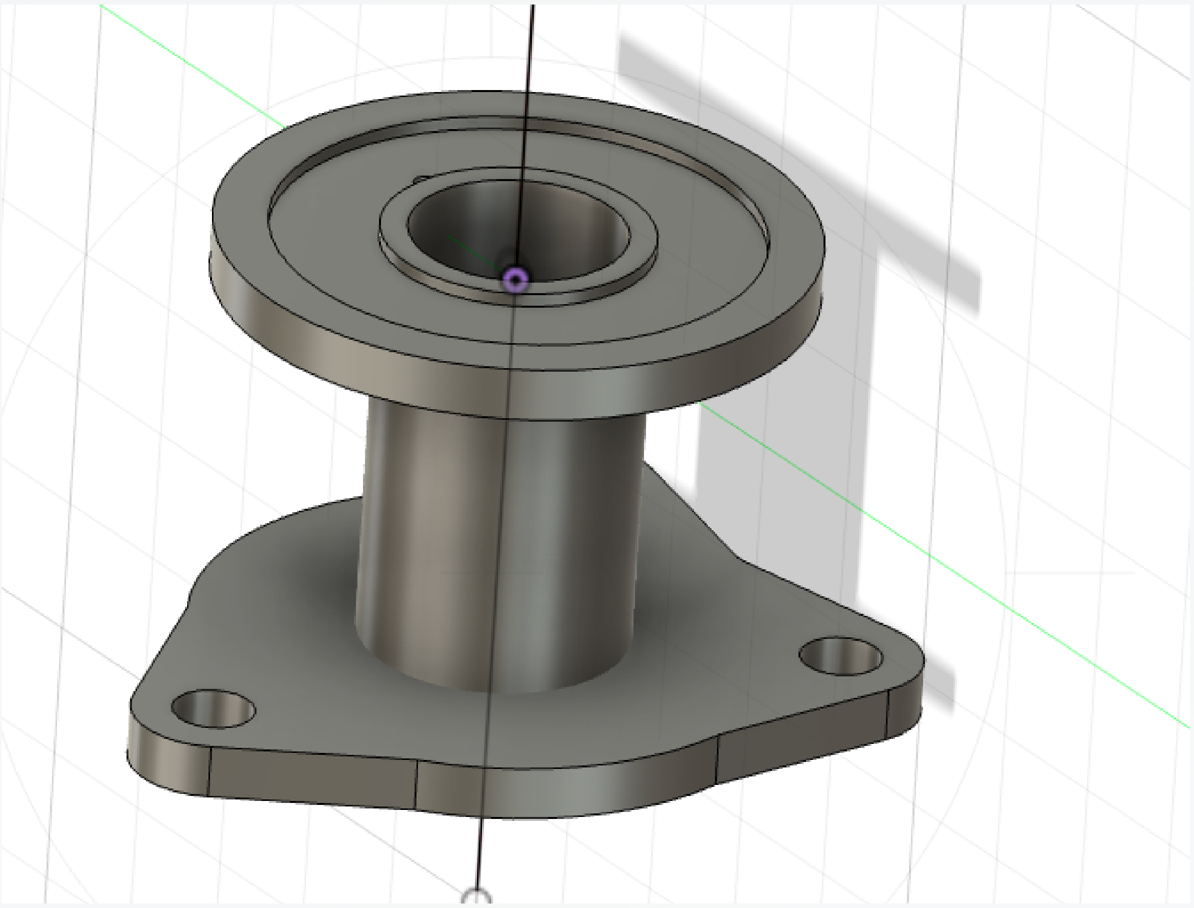
FSS rod (we are using)





Housing of electromanets

We need a body to hold the coil around the electromagnet and also to fit the electromagnets to the base plate.
We decided to use PLA to make the housing after confirming that it does not affect the magnetic field due to the coil.



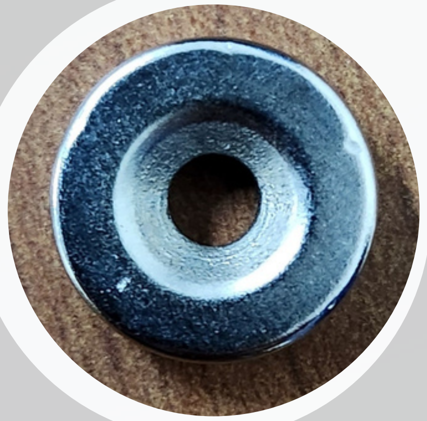
CAD DESIGN

3D PRINT

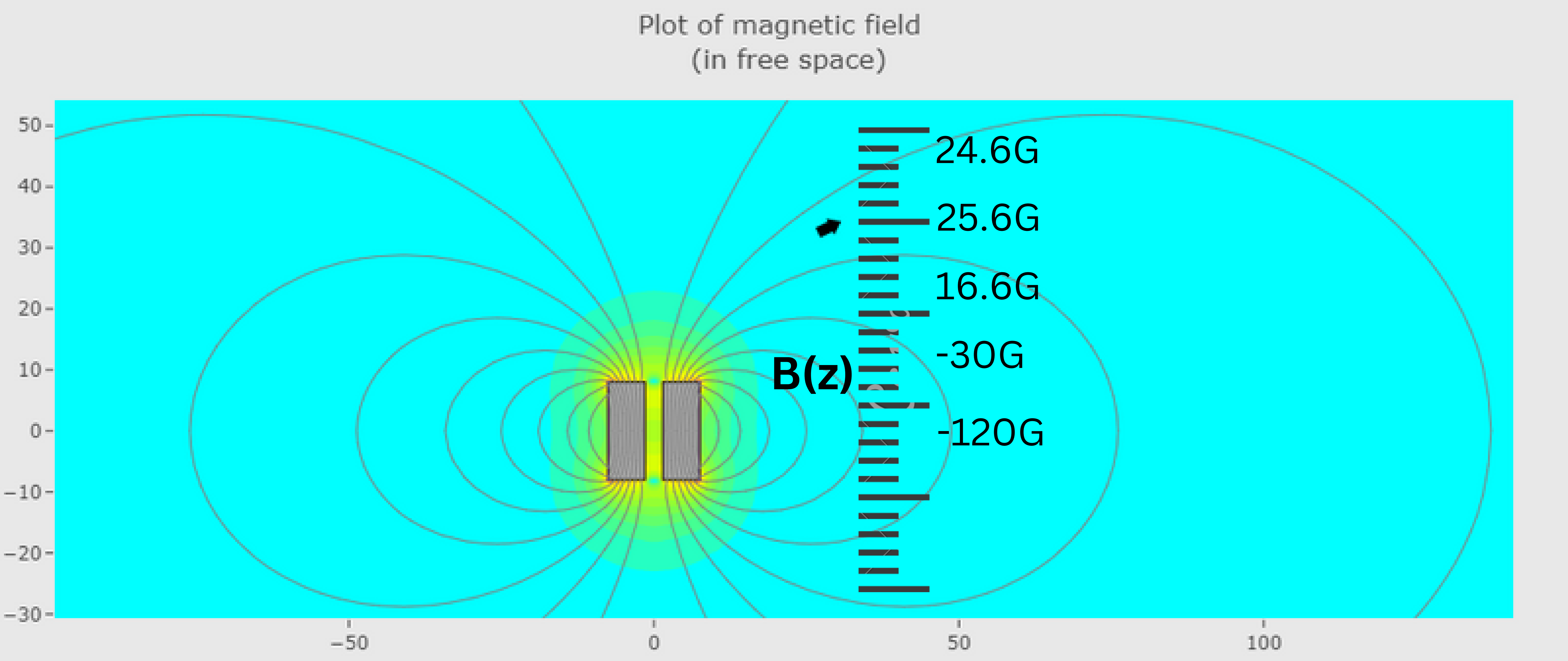
PERMANENT MAGNETS

01 Due to unavailability of desired magnets, we resorted to alter the design according to magnets available in market. we simulated the magnetic field of permanent magnets to determine diameter and stacking arrangement of permanent magnets required.

02 We analyzed the magnetic field of 4 stacks of big diameter magnets and 8 stacks of small diameter magnets and finalized 4 stacks of 15mm magnets

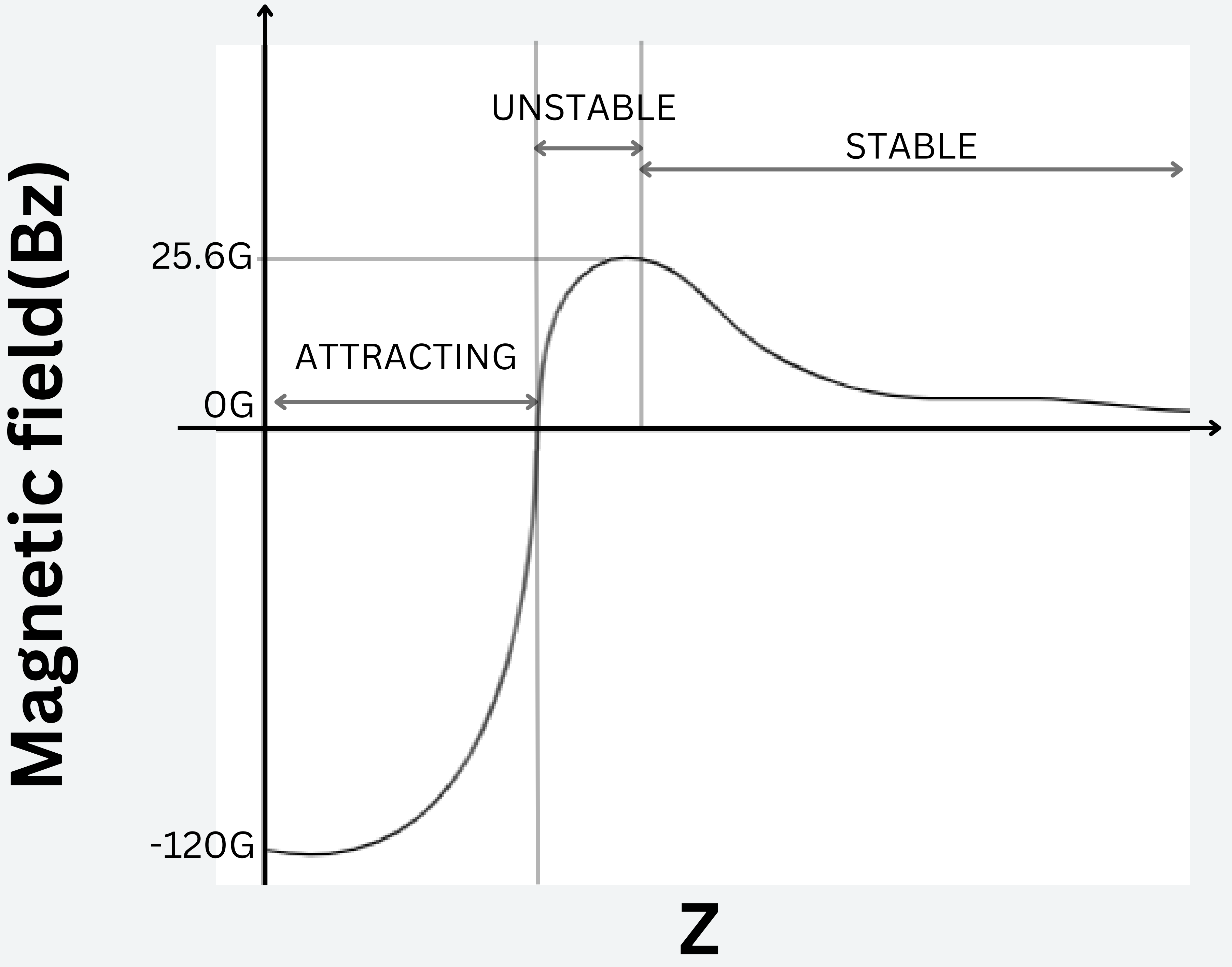


MAGNETIC FIELD OF PERMANENT MAGNETS



MAGNETIC FIELD V/S Z-COORDINATE GRAPH

The stable equilibrium region is the region above the point of maxima. The maxima depend on the configuration of the electromagnets. We want to decrease the height of maxima point

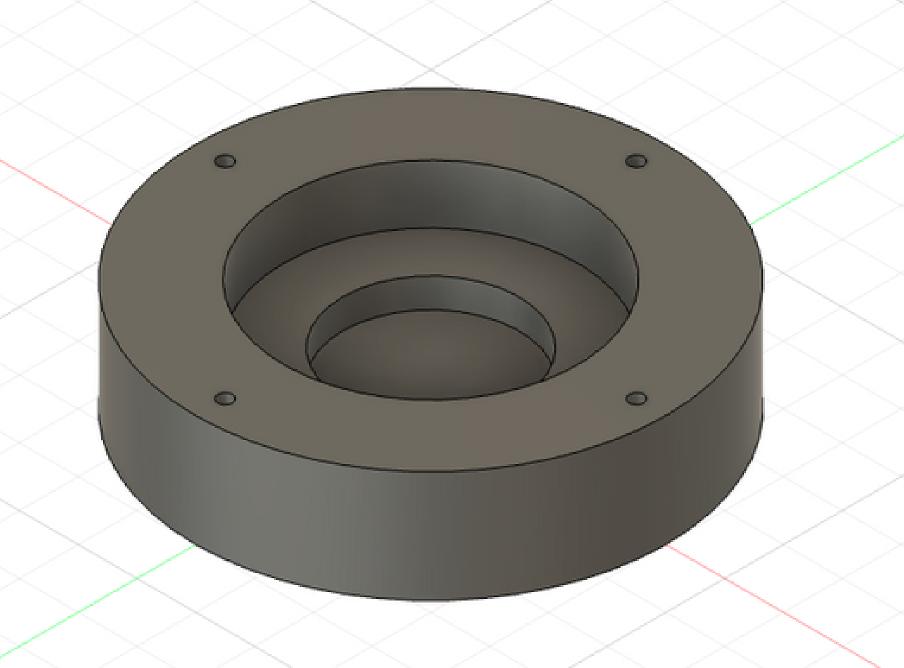


FLOATING PLATE

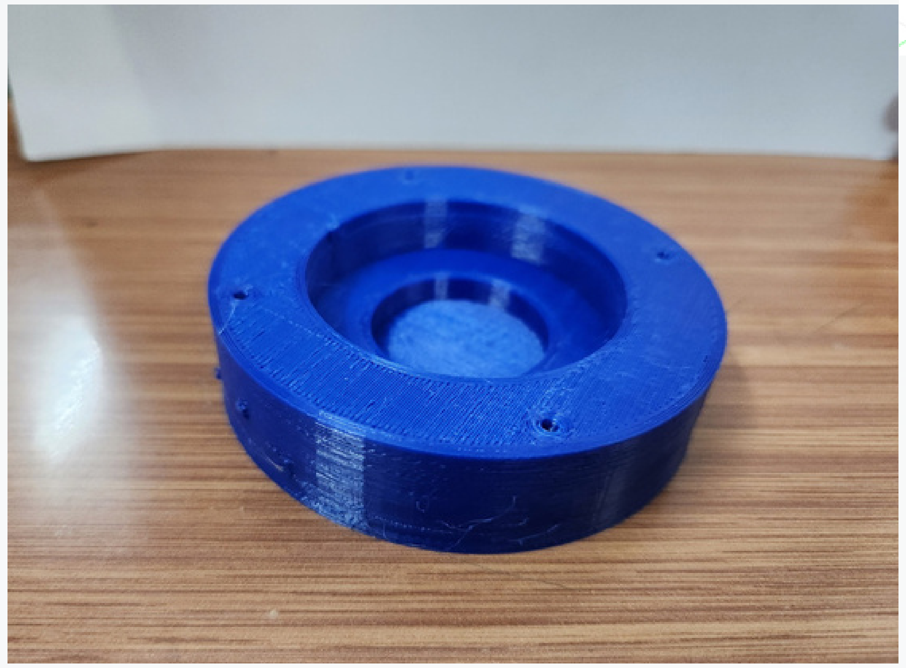
01 Floating plate will consist of strong permanent magnet made of neodymnium

02 We have ordered two magnets of different sizes so we can test and also increase our load capacity in future

03 This floating plate is designed in such a way that it can hold either or both the magnets.



CAD DESIGN



3D PRINT

LEVITATING MAGNETS

30x5 mm

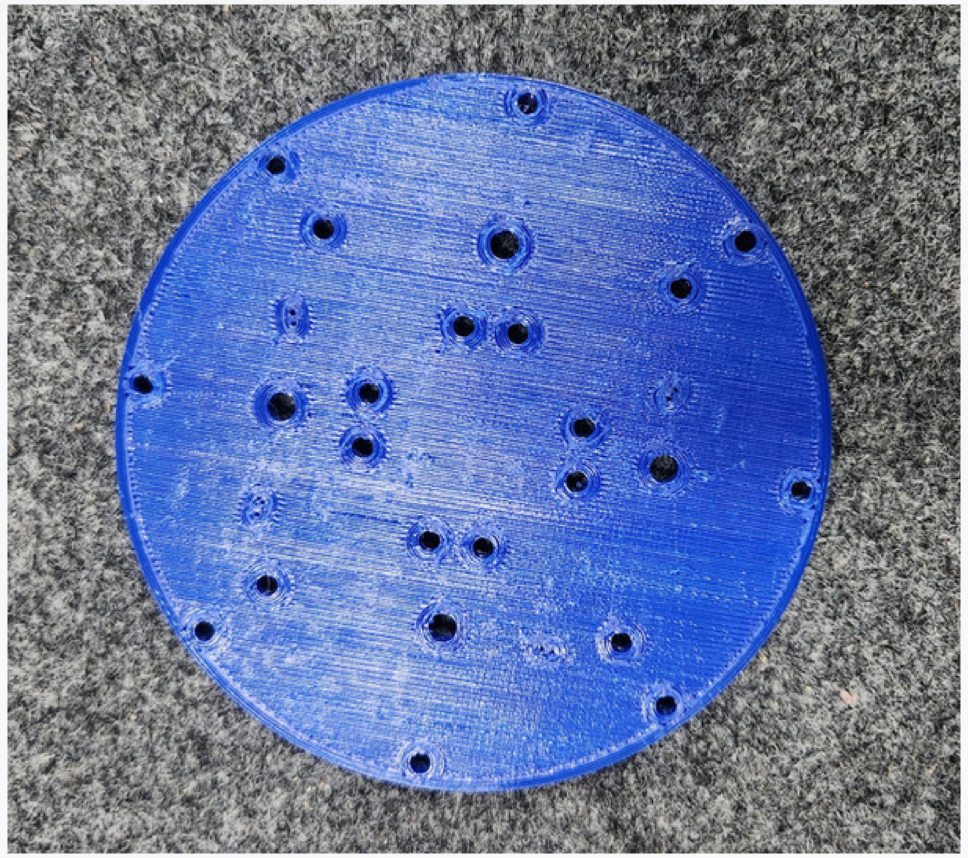
50x10 mm

BASE PLATE DESIGN

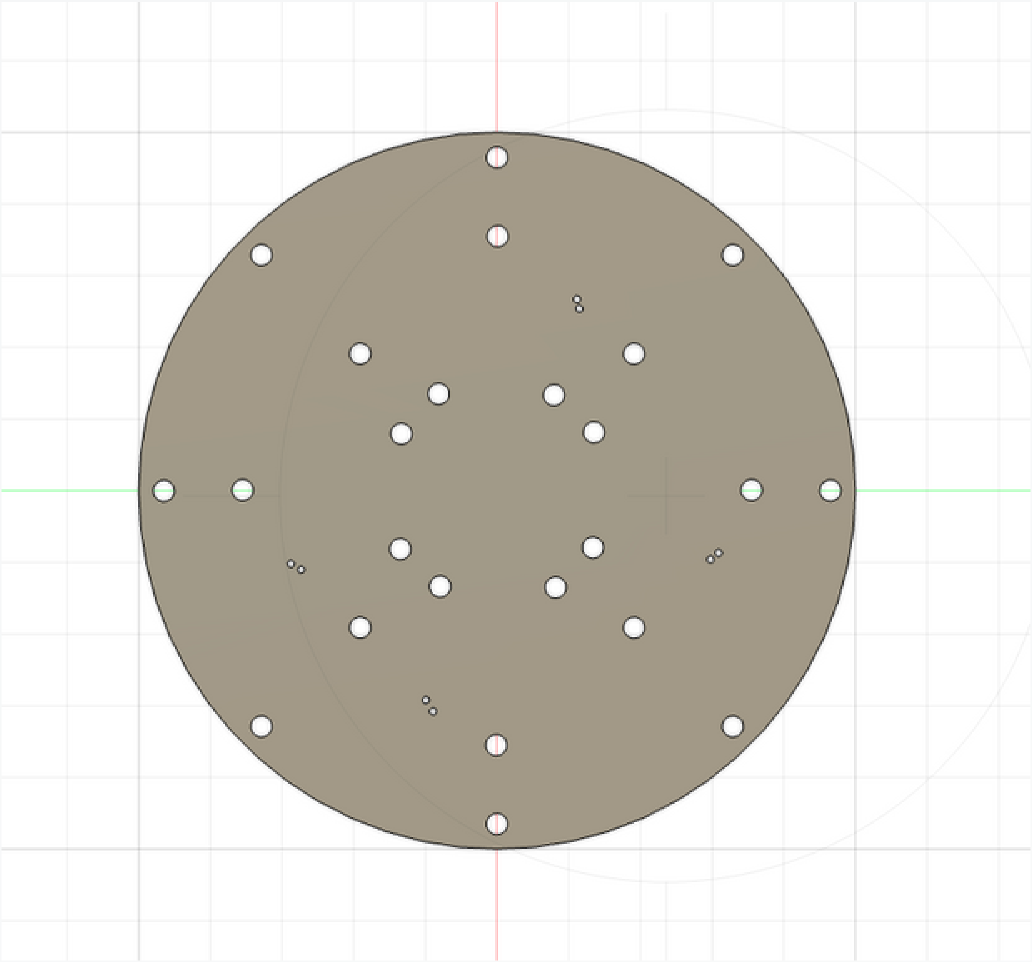
01 The Base plate is designed in such a way to minimize the distance between the permanent magnets from the centre.

02 We have two options, either we can use eight permanent magnets or we can use four permanent magnets .

03 This Base plate design helped us to decrease the distance of magnets enough that four magnets configuration has higher magnetic field strength.

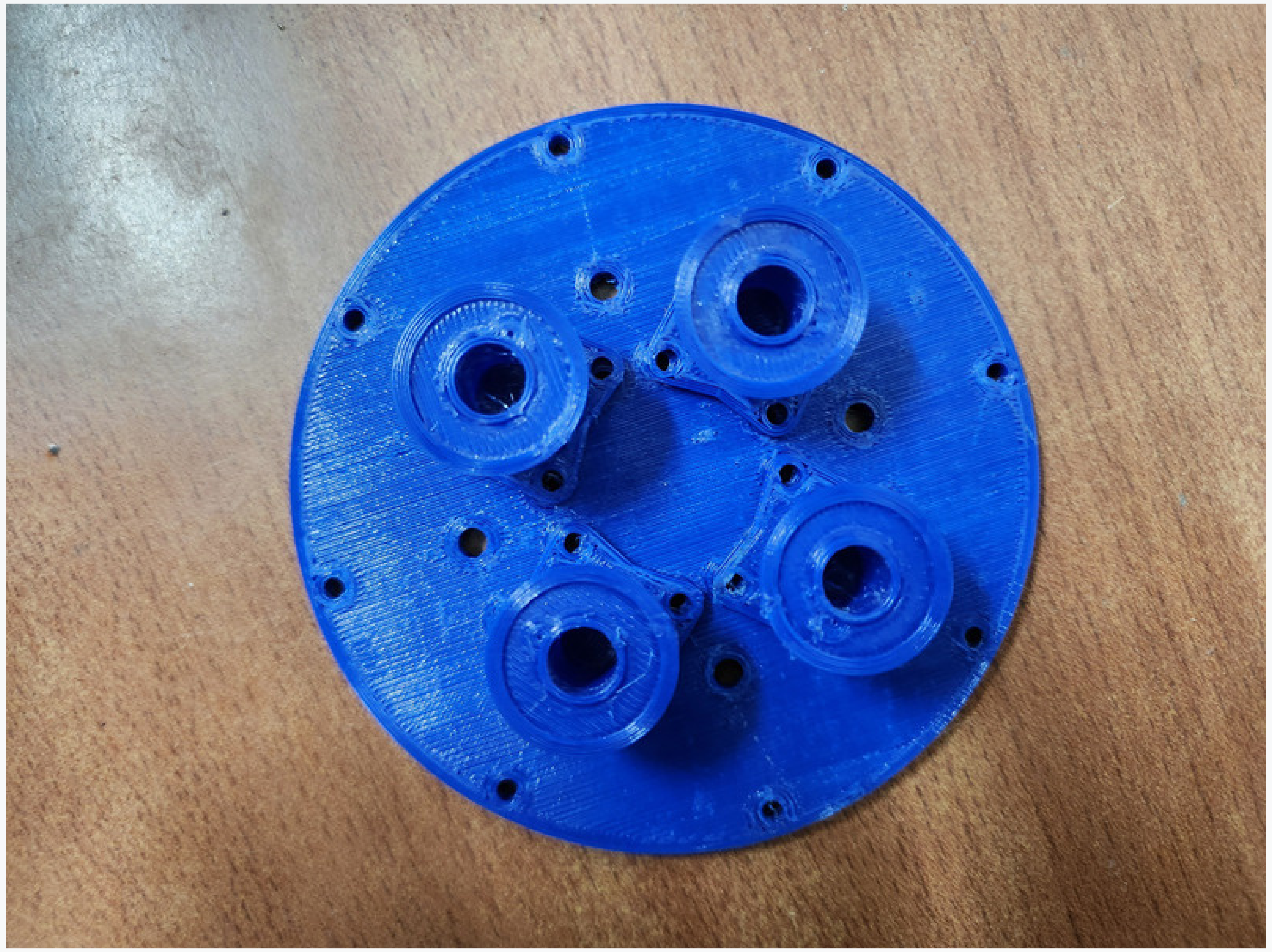


3D PRINT



CAD DESIGN

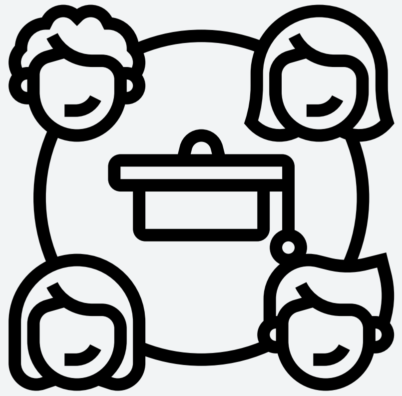
BASE MODULE



UPCOMING PLAN

We have reached the final stage of our project, having procured and manufactured all the necessary components.

We will complete the assembly shortly and then proceed to provide a live demonstration of the project at the SNT pavilion.



OUR TEAM

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Pranshu Kumar

Manisha Kaushal
Nandita Mittal
Abhishek Sahu
Devansh Dhookia

Thank You…