DEPARTMENT OF MECHANICAL ENGINEERING

TEAM 12

MagStab

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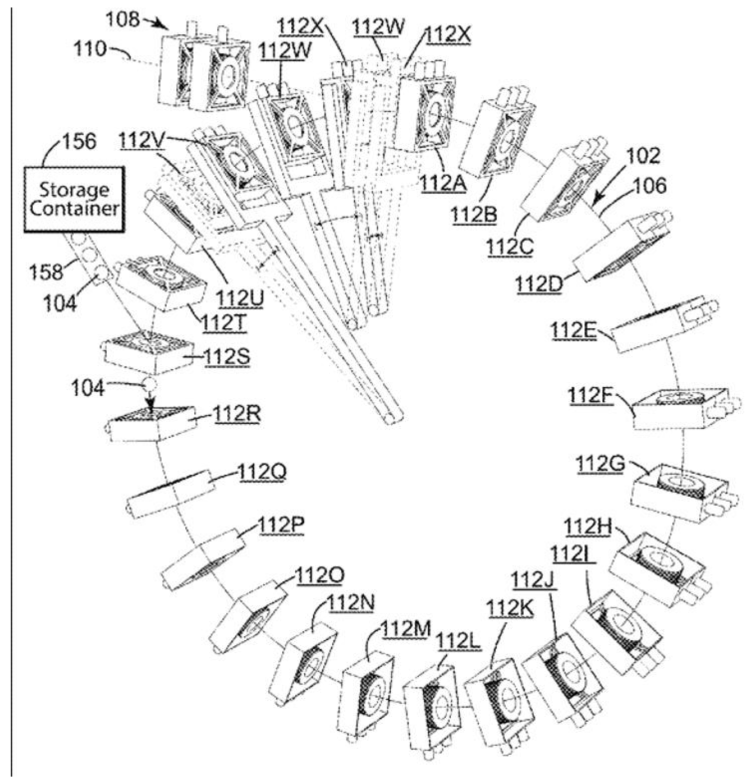
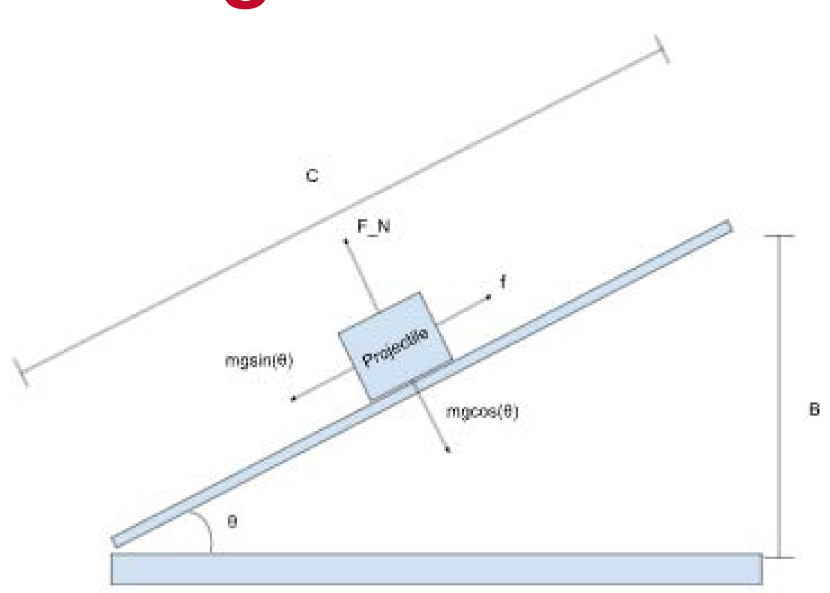
Problem Definition



Our stakeholder, James Lincoln, has developed a patent for a barrel-less electromagnetic coil gun that accelerates a projectile in a circular path through a series of solenoids. For our project, we were tasked with developing a system that uses electromagnets to stabilize and control the projectile's path during acceleration. To achieve this, we built a proof-of-concept prototype that uses electromagnets to control a radially charged projectile in a 2D plane based on a human input. Our magnetic stabilizers are designed with the intention of integrating them in-between the solenoids, controlling velocity and direction during acceleration.

Design Calculations & Analysis



$$\theta = arcsin(\frac{B}{C})$$

$$F_N = mgcos(\theta)$$

$$f = \mu_s F_N = \mu_s mgcos(\theta)$$

$$mgsin(\theta) = f = \mu_s F_N = \mu_s mgcos(\theta)$$

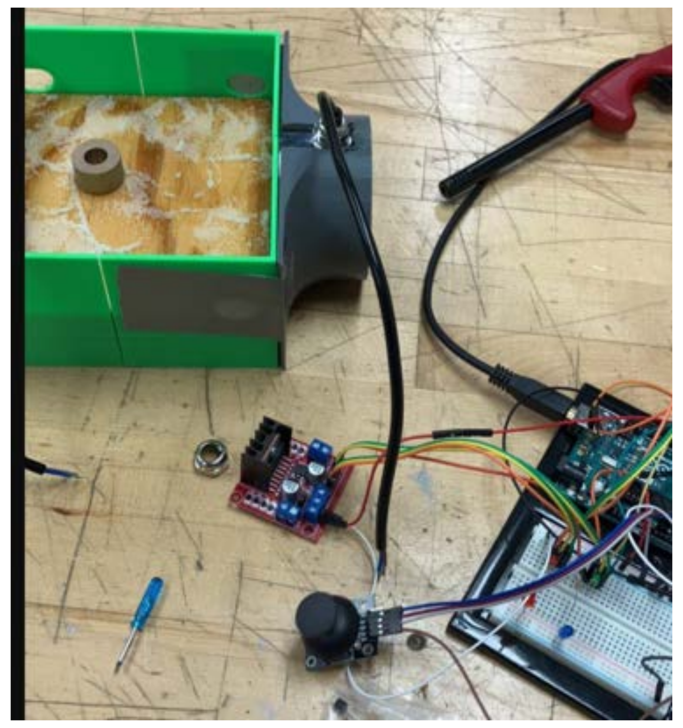
$$sin(\theta) = \mu_s cos(\theta)$$

$$\frac{sin(\theta)}{cos(\theta)} = \mu_s$$

$$\mu_s = tan(\theta)$$

$$\mu_s = tan(arcsin(\frac{B}{C}))$$

Used trigonometry and several rounds of testing to determine static friction for various projectiles on our low-friction surfaces, with a goal of minimizing total friction and simulating low gravity conditions.



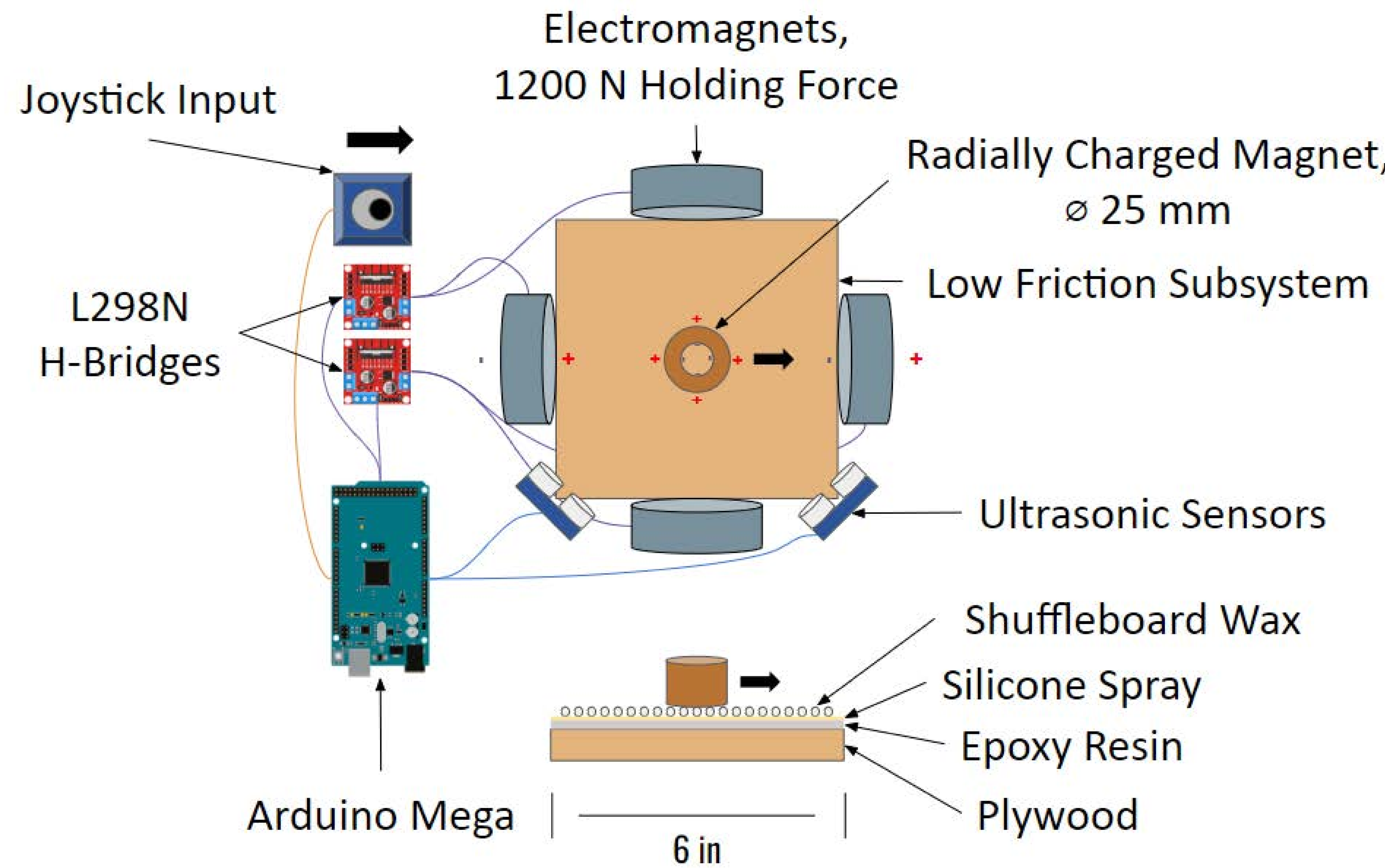
Design dimensions of apparatus dependent on electromagnetic (EM) field strength of each solenoid.

$$B = \mu NI/L$$

The greater EM field, the higher inductance, creating flyback voltage.

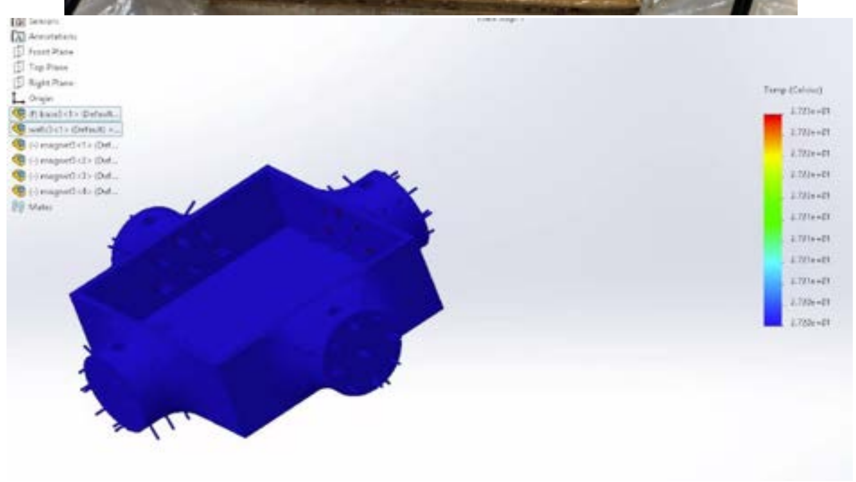
$$V_L = -L(di)/(dt) \quad L = \mu_0 N^2 A/l$$

Final Design



Our final design utilizes a set of four 12V, 1200 N Holding Force Electromagnets to control the position of a Radially Charged Magnet on a Low Friction Surface (CoF≈0.05). A user inputs a position to the Arduino Mega using the joystick. The Arduino then utilizes a pair of H-Bridges and an external power supply to appropriately adjust the voltages of each electromagnet to move the projectile. A pair of ultrasonic sensors provides feedback to the Arduino, verifying the projectile's position and preventing it from colliding with the PLA housing. This prototype demonstrates the ability to control and stabilize the position of a projectile in a 2D plane, providing a basis for future work in adapting the project to projectiles moving 3D space.

Prototype & Test Results



Components were found to heat due to the heat generation from current. A thermal analysis was done to ensure housing did not achieve over 60°C.

Low Friction Prototyping

Calculations		
Steel Washer	CoF, Avg	0.088
	CoF, 95% Upper	0.139
	CoF, 95% Lower	0.038
Neodymium Magnet	CoF, Avg	0.048
	CoF, 95% Upper	0.081
	CoF, 95% Lower	0.014
Nickel Coated Ring Magnet	CoF, Avg	0.051
	CoF, 95% Upper	0.063
	CoF, 95% Lower	0.038

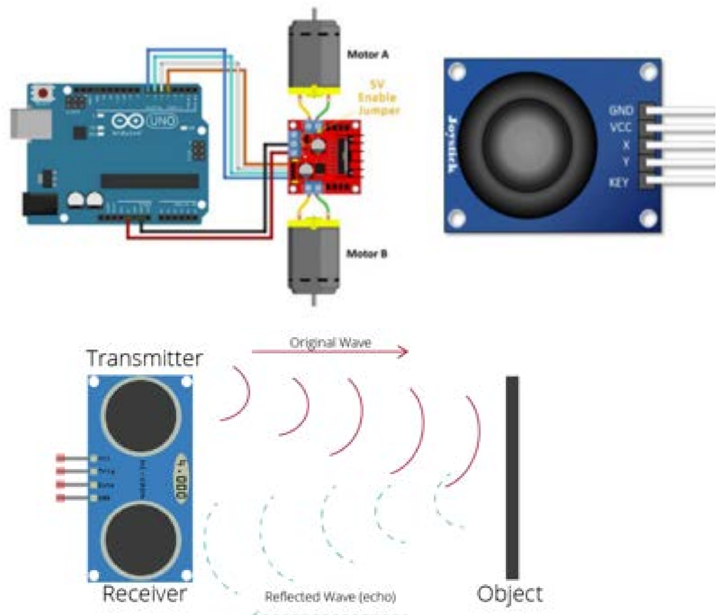
CoF ≈0.05 with test piece. Created 6''x6'' section based on EM selection. Same CoF.

Electromagnet Selection

Electromagnet	Holding Force (N)	Voltage (V)	Measured Current (A)	Calculated Power (W)	Maximum Effective Range (in)
	50	12	.15	1.8	N/A
	400	24	.4	10	4
	500	12	.2	2.4	4
	1200	12	1	12	5

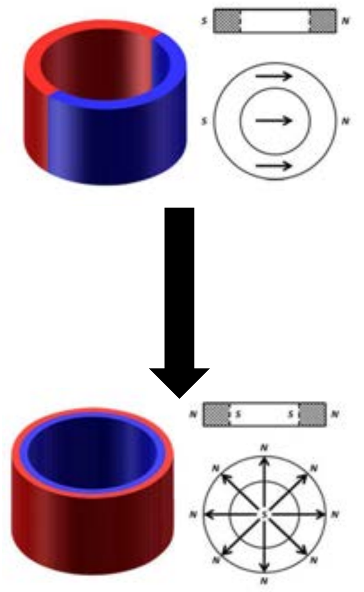
Tested electromagnet range, found 1200 N magnets offer optimal control.

Circuitry Prototyping



Developed EM actuation using H-Bridges, added Joystick & Ultrasonic Sensors for control & feedback.

Projectile Selection



Chose a radially charged projectile, avoiding initial orientation concerns.