Amplifying the Force in a Motor

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ABSTRACT

Mechanical systems are used everywhere. They are present in transportation, factories, tools, and other necessities, but these necessities would not run nearly as well without mechanical advantage. Mechanical advantage is a method used to increase force efficiency and optimization in mechanical systems that include levers, wedges, inclines, screws, gears, and pulley systems. The value calculated from mechanical advantage is an idealistic value that does not include friction, meaning the calculated value is higher than expected. This project focuses on using an Arduino motor and LEGO parts as the foundation to determine how much friction and other forces decrease mechanical advantage. The information about these forces can then be applied to a larger mechanical system to achieve the most optimized force efficiency.

Mechanical Advantage (MA) of the System

$$\text{Ideal MA}_{\text{Gears}} = \frac{\Delta Teeth_{Driven}}{1\ Revolution_{Driver}} = \frac{1}{1} = 1$$

$$\text{Ideal MA}_{\text{Pulley}} = String\ Number = 1$$

$$\text{Ideal MA}_{\text{System}} = 2$$

$$\text{Actual MA}_{\text{System}} = \frac{Force_{Out}}{Force_{In}} = \frac{339}{282} = 1.2$$

Solving for Force of Friction (f) in the system

$$mg = (\rho RT)A - f$$

m = max weight lifted ($339 * 10^{-3}$kg)
g = acceleration due to gravity ($9.81 \frac{m}{s^2}$)
ρ = exhaled air density ($1.15 \frac{kg}{m^3}$)
R = ideal gas constant ($8.314 \frac{J}{{}^\circ K * mol}$)
T = exhaled air temperature (34°C or 307.15°K)
A = area of plunger face ($2.01 * 10^{-4} m^2$)
f = force of friction in system (to be solved kg$\frac{m}{s^2}$)

$$339(10^{-3}) = (1.15 * 8.314 * 307.15)(2.01(10^{-4})) - f$$

$$f = 0.25N \approx 0.056lbf$$

Units for solving f

$$\text{kg}\frac{m}{s^2} = \left(\frac{kg}{m^3} * \frac{J}{{}^\circ K * mol} * {}^\circ\text{K}\right) m^2 - \text{kg}\frac{m}{s^2}$$

$$J = \text{kg}\frac{m^2}{s^2} \quad 1\ mol = 6.022 * 10^{26} kg$$

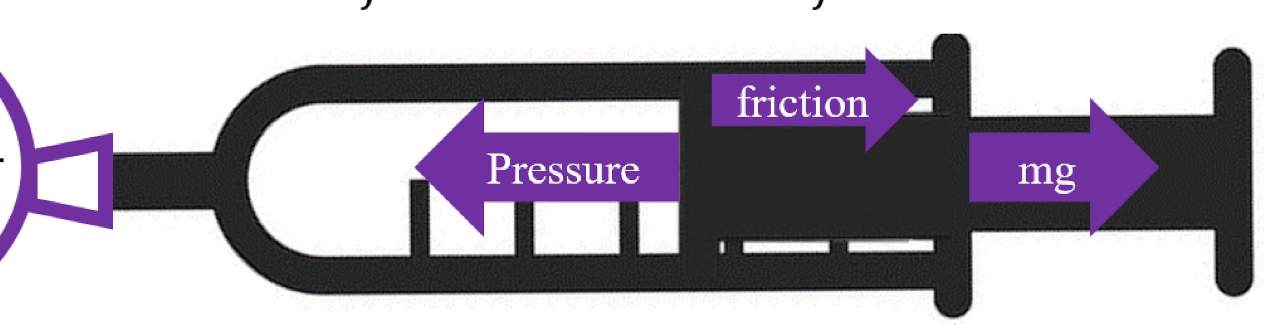

Figure 2. Calculations

METHODS

- **Measured the weight a standard Arduino motor can lift**
- **Built a gear and pulley system using LEGOs and measured the weight the motor can lift**
- **Attached a balloon and syringe to the system and found the friction within the syringe**
- **Used the same power (3.5V) for the motor during all trials**

RESULTS

- **Initial Motor weight lifted……………………………..282g**
- **Motor weight lifted using gears and pulley……..339g**
- **Ideal Mechanical Advantage…………………………..2**
- **Actual Mechanical Advantage………………………..1.2**
- **Friction in system………………………..0.25N or 0.056lbf**

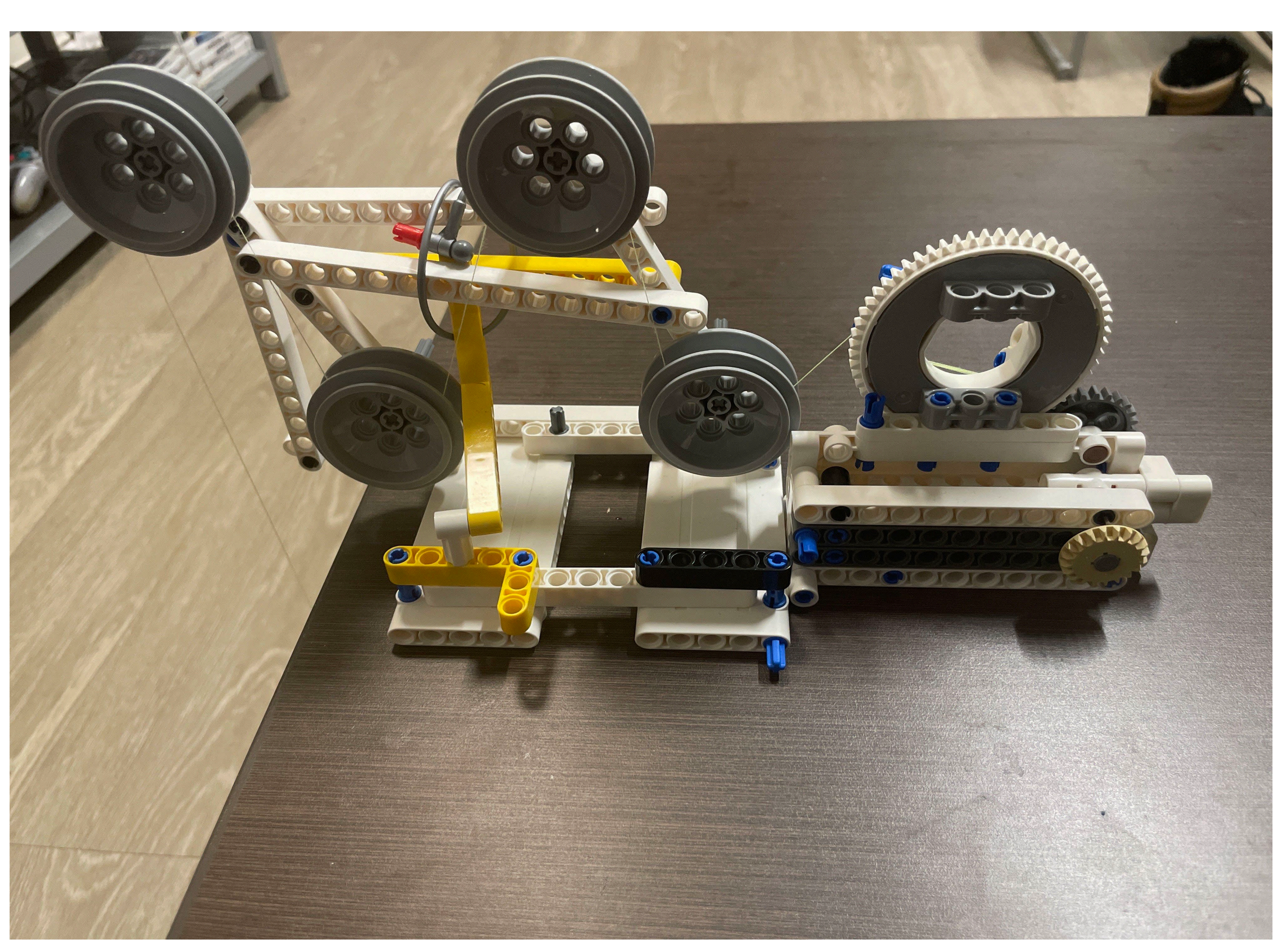

Figure 1. LEGO Pulley and Gear System

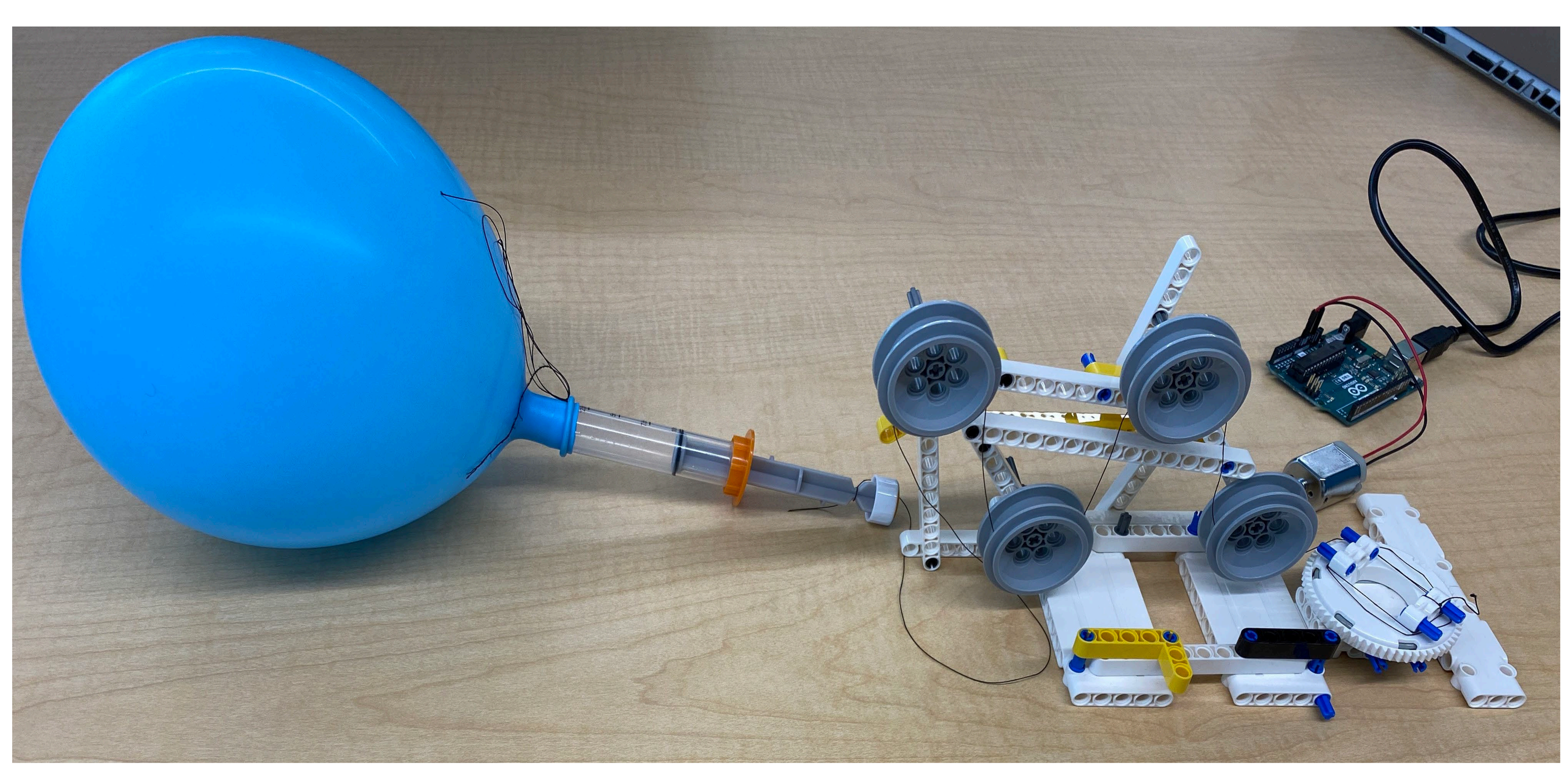

Figure 3. Syringe and Balloon with Pulley and Gear System

CONCLUSION

The tests proved that using a gear and pulley system improved the output of the motor and that friction decreased mechanical advantage. The pulley was able to lift more load while decreasing the force needed, and using a worm gear in the system helped create more torque in lifting the load. The main issue with the experiment was the strength of the LEGOS; a group member had to hold the pulley system together to prevent breaking. The experiment could be improved by using stronger materials and different shaped LEGO pieces so that they would not be misaligned, and using more strings could also increase the mechanical advantage of the pulleys.

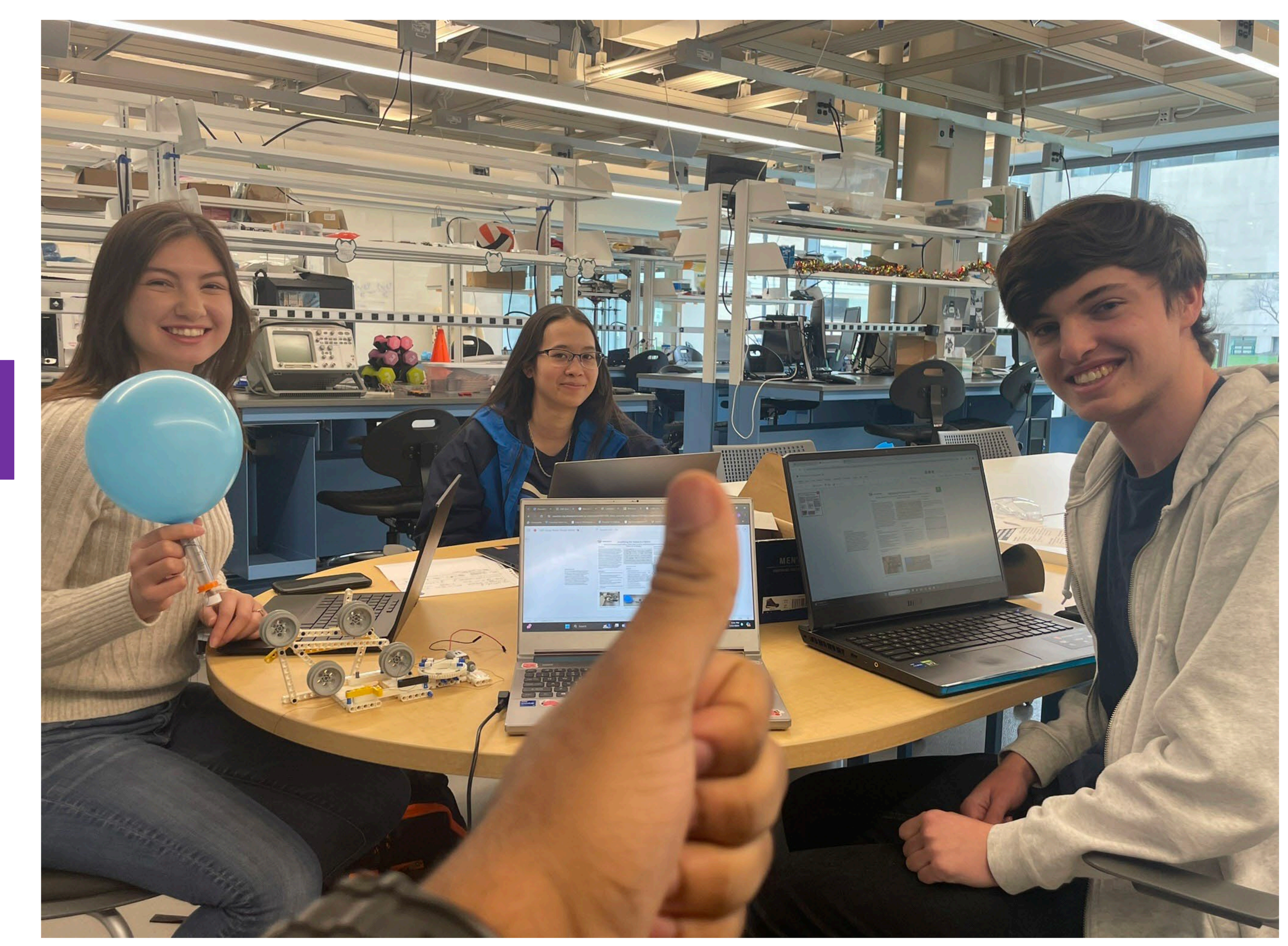

Figure 4. Group Photo with the Gear and Pulley System

References

[1] "Powerful Pulleys - Lesson," *TeachEngineering.org*. https://www.teachengineering.org/lessons/view/cub_simple_lesson05#:~:text=With%20a%20pulley%2C%20the%20trade
[2] Khan Academy, "Torque," *Khan Academy*, 2019. https://www.khanacademy.org/science/physics/torque-angular-momentum/torque-tutorial/a/torque
[3]
"Gears: Lift It Up! - Activity," *TeachEngineering.org*. https://www.teachengineering.org/activities/view/nyu_gears2_activity1#:~:text=It%20is%20important%20to%20keep (accessed Mar. 22, 2024).

Acknowledgments

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