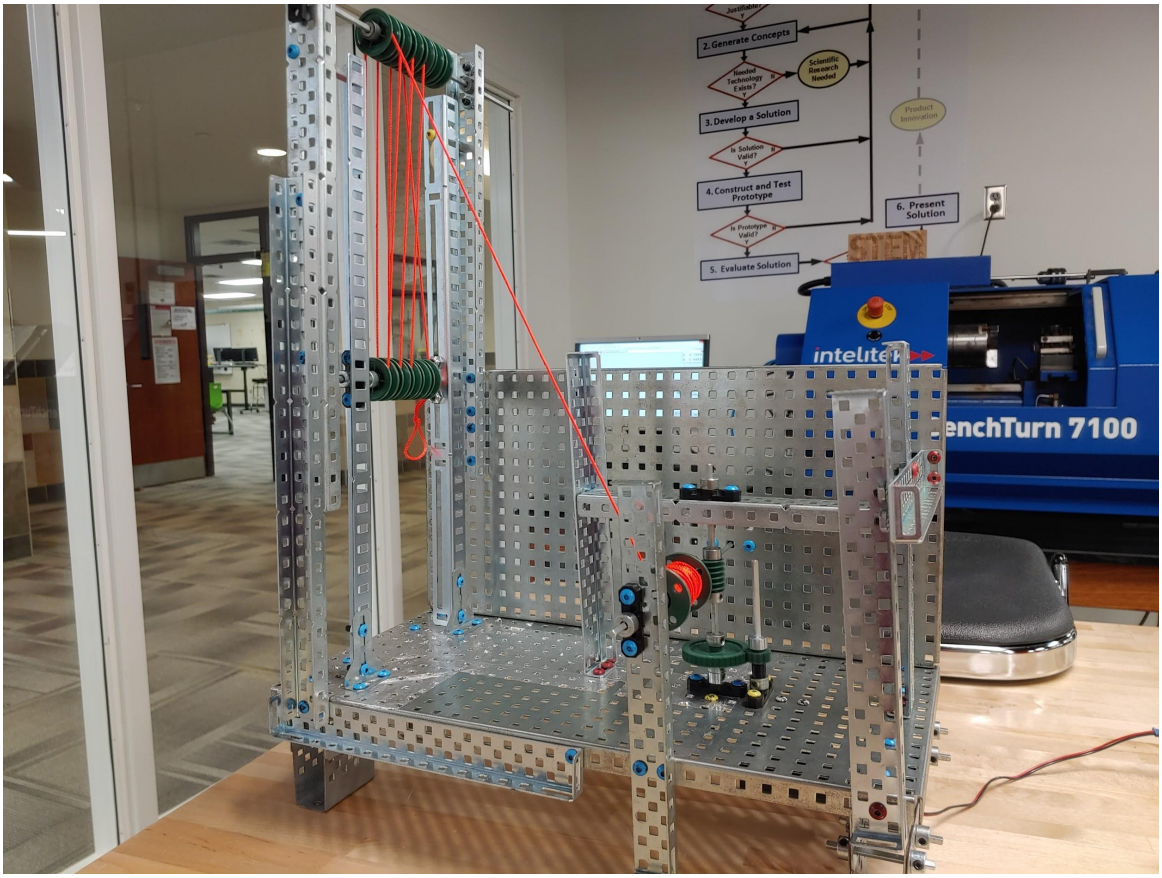
1.1.6 VEX Project



Block 1 POE

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Shakopee High School

February 18, 2020

Abstract

Our client, Wile E. Coyote is an honest, hardworking man. He emigrated from the nation of Looney Tunes to the Grand Canyon in order to create a good future for his family. However, after his wife passed away, he was the only one providing for his 10 year old son and 7 year old daughter. As financial issues rose, Coyote had to take a second job of capturing the wanted fugitive Road Runner. Unfortunately, Coyote's rock trap failed at the perfect opportunity. Coyote then went to inspect his trap for defects. Regretfully, the trap activated when Coyote was in the vicinity. The strings holding the rock snapped and it fell on Coyote. We are tasked with slowly lifting the rock 6 inches off his chest so he can slide out safely. If we don't rescue him in 4 minutes he will bleed out. We needed to save this living role model and icon before it was too late. His kids need a father. Our task was to somehow lift the rock up safely so that Coyote could slide out and be rescued. To accomplish this, we used a compound machine that included 4 simple machines. We decided that a pulley system for lifting the rock was the best solution and soon started working. But first we had to prepare quickly for annotating and documentation. After many prototypes and difficulties we had our final solution:

Our input effort was a gear train that was connected to a screw that would then turn another gear. This gear would turn a wheel and axle with rope. This rope then pulled a block and tackle pulley system which was connected to the rock.

The results of this product were quite successful. The compound machine was able to consistently and smoothly lift the rock in 4 minutes and 4 seconds. In addition to this, all design constraints listed in the procedure were met.

While the machine may not save other lives, we were able to save Coyote who is a great father. Along the way of building this one time rock scenario solution, we encountered many issues. To solve these issues, we applied the engineering design process. At the time these problems seemed unresolveable, however, with thinking and teamwork we were able to find a suitable solution. We learned the importance of this teamwork and the design process in creating any solution.

Concepts:

This project required multiple concepts in order to function.

- Teamwork: As this was a large project, teamwork was crucial to accomplish multiple tasks. By assigning group roles, all three of us were able to work more efficiently. We are also able to give constructive criticism and communicate issues with one another.
- Simple and Compound Machines: This project is based on PLTW's 1.1 Mechanisms unit. Essentially, the six simple machines (Gears, Screw, Pulleys, Inclined Plane, Wedge, Wheel and Axle) were required to move an object 6 inches in 4 minutes. However, these individual mechanisms needed to be interacting. This means that the entire solution had to be a compound machine. Not only did we need to know how the 6 simple machines operated, we also needed to know how they interacted with one another.
- VEX: The components for the project are all made of VEX parts which included the 6 simple machines. Our team had to familiarize ourselves with the specialized parts to build the product.

- Design Process: The design process is a set of outlining steps to creating an appropriate solution. It ensures that the progression of the project goes more smoothly and allows us to create a better solution.
- Documentation: Essentially, this process is taking notes and annotating the steps and progression of the project. This allows us to prove what and how we accomplished a solution. It also allows us to see what is working and can also be referred to if something is wrong.
- Calculations for Mechanical Advantage: These are calculations of the percent efficiency of the entire system. The ratios of MA for each individual mechanism was needed to calculate the final efficiency of the solution.

Materials List:

Vex:

- 2 base plates
- 1 motor
- 2 12th tooth gear
- 1 36th tooth gear
- Metal Axle Rods
- Various VEX screws
- Bearing Plates
- Many collar fasteners
- 1 Screw Gear
- 7 Pulley Wheels
- Winch Drum/Spool
- Orange String
- Various Structural Support metal beams
- VEX Cortex

Software:

- VEX RobotC

Tools:

- 5/64 Screwdriver
- 3/32 Screwdriver

Procedure:

After Wile E. Coyote's rock trap failed, he checked the trap to see what went wrong. However, the strings holding the rock snapped and it fell on Coyote. We are tasked with slowly lifting the rock 6 inches off his chest so he can slide out safely. If we don't rescue him in 4 minutes he will bleed out.

Design Constraints

- The applied effort force will be provided by 1 - Vex motor 393 with a 12-tooth gear
- The final design must include a minimum of four DIFFERENT mechanisms including;

lever, wheel and axle, inclined plane, screw, a gear system; a belt and pulley system; and/or a sprocket and chain system.

- Each simple machine must have a greater than or less than 1:1 MA. (no fixed pulleys, 3" axle driving 3" wheel)
- No more than 4 total gears/sprockets will be allowed in the design
- No more than 1 Screw gear will be allowed in the design
- The mechanism must not exceed the size of 2 VEX base plates
- The system must carefully move(push, pull, lift or lower) an item (TBD) a distance of 6 inches,in the time closest to 4 minutes

We then used a decision matrix and reasoning to choose and evaluate our designs

Decision Matrix: 1 = bad, 10 = good

	Complexity (interacting mechanisms)	Build Difficulty	Flexible/Adjustable Time	**# of simple machines**	Total
Idea 1	8	8	8	3	27
Idea 2	7	7	4	3	21
Idea 3	4	4	7	4	19
Idea 4	3	2	3	4	12
Idea 5	4	3	3	4	14
Idea 6	**7**	**8**	**9**	**5**	**29**

Idea 1: It is relatively simple in both the complexity and build difficulty of the machines. It is just a gear train being powered by a screw which means times can be adjusted. However, after reflection, only 3 simple machines are in the design meaning it cannot be used. The wheel and axle at the motor does not count.

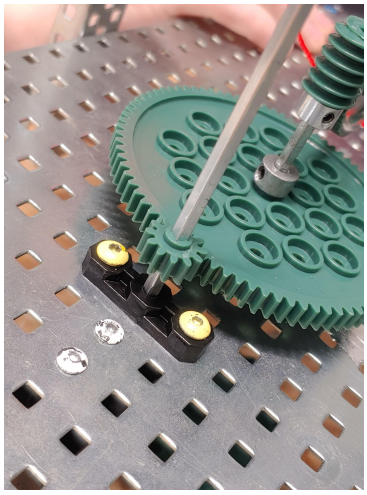
Idea 2: It is also relatively simple in both complexity and build difficulty. Instead of the screw driving the train, the train drives the screw. This creates lesser time flexibility as the screw is being driven. In addition to this, only 3 simple machines are in the design meaning it cannot be used. The wheel and axle at the motor does not count.

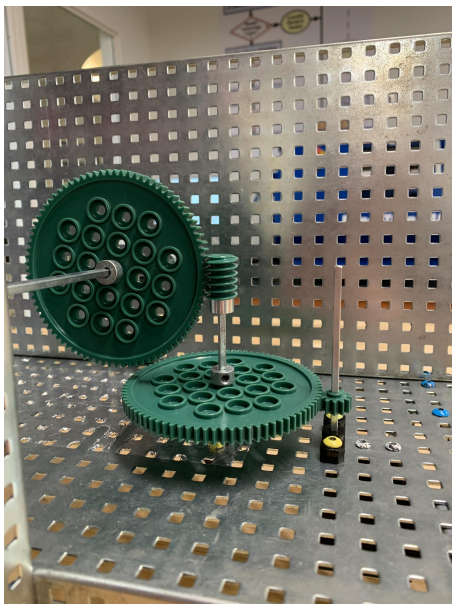
Idea 3: This design is complex. It requires a conversion of rotational movement into a screw with linear movement. Our expertise in this area is lacking. This linear movement also pushes a wedge and the wedge complicates time flexibility and the complexity of the overall design. This means that the build would be more difficult to accomplish.

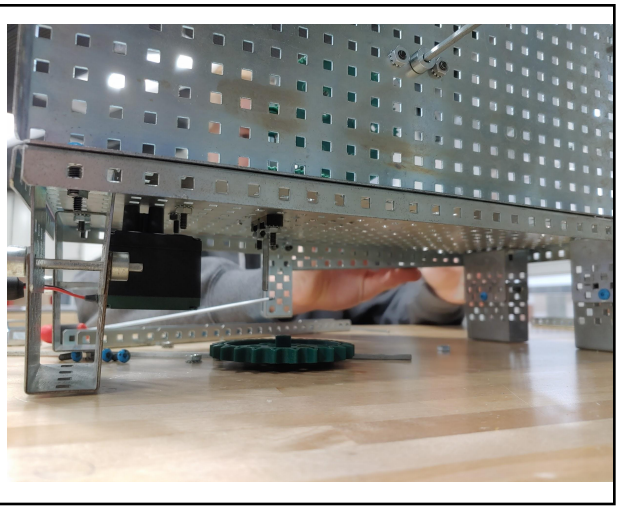
Idea 4: Relies on the 2nd class lever to move the pulley. This is unreliable, complex and difficult to make. The lever system also means that time constraints are less adjustable. Overall, this is too complex and difficult for the time allotted.
Idea 5: Uses the 3rd class lever to move the pulley. It has the same problems as Idea 4 but uses a gear train instead of a gear sprocket system meaning it is a little bit simpler.
Idea 6: The idea is really just a long gear train. It is not that complex but requires a wheel and axle to a sprocket system. This makes it not that difficult to build and allows us to switch gears to change timing. Because of this relative simplicity, Idea 6 was picked.

Testing Mechanisms and Prototype I

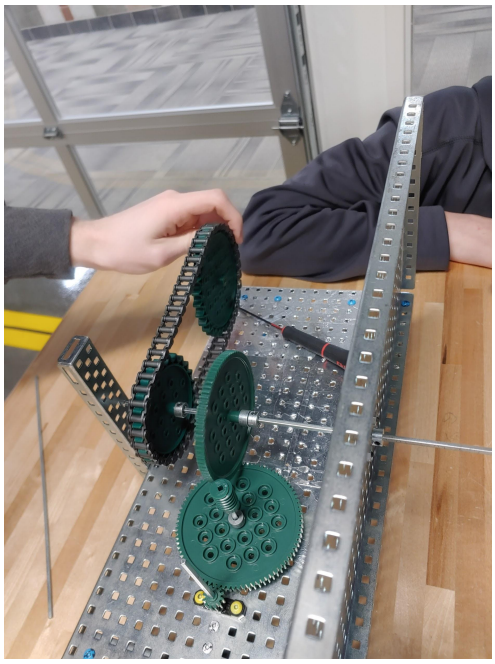
After choosing Idea 6 we began to play around with some of the simple machines and mechanisms.

2-7-2020	
Tested and observed how the 12 tooth gear worked and how it would affect the system.	

Discovered: - Sprocket: needs to be on the same axle as the regular gears for it to connect - Screw gear: can be vertical and is super slow - 12th tooth gear: is the input and motion needs to be converted from it	

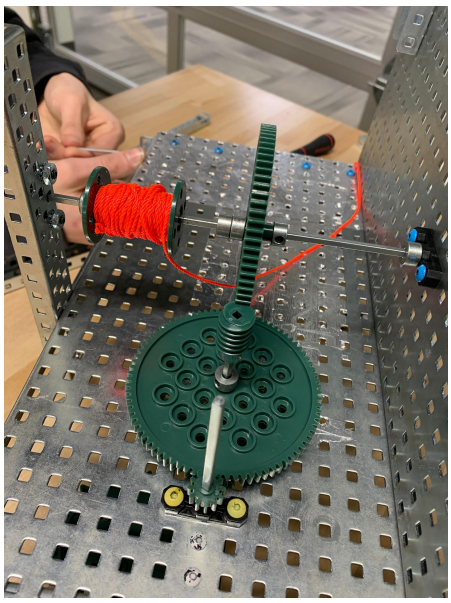
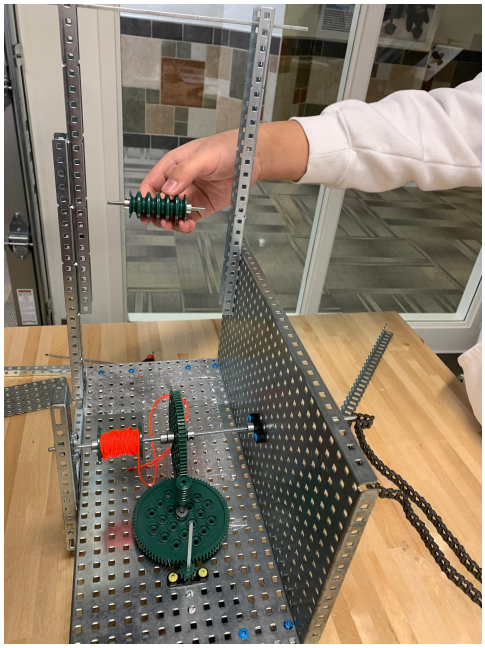
Remade testbed for vertical flexibility and added a motor on the bottom.	

After experimenting, we began construction on our first prototype.

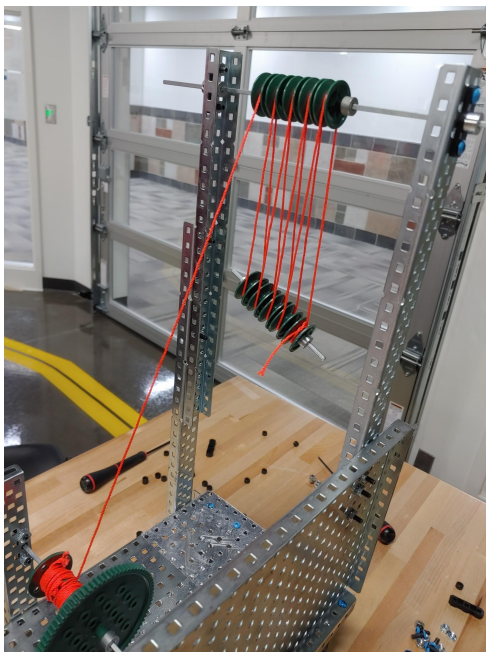
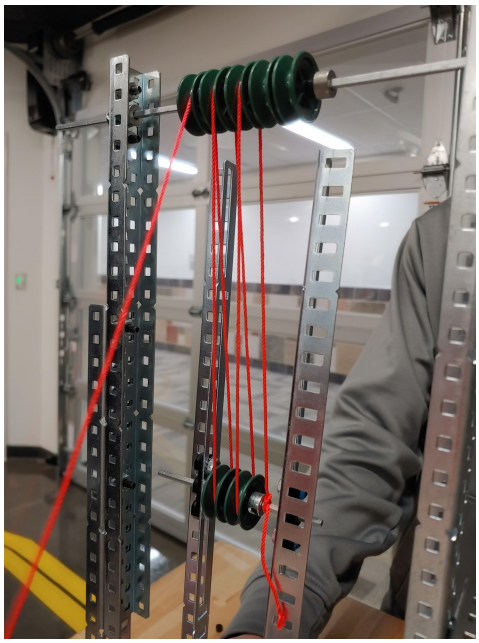
2-10-2020	
Original Idea: 12 tooth gear turns another horizontal gear which turns a vertically positioned screw. The screw mechanism then turns a different vertical gear. On the same axle (wheel and axle) a sprocket system would be powered from the vertical gear. This would then turn a pulley system. However, We discovered that the 12 tooth gear and screw count as gears. Redesign for Idea 6 needed since only 4 gears are allowed and the current was 6.	

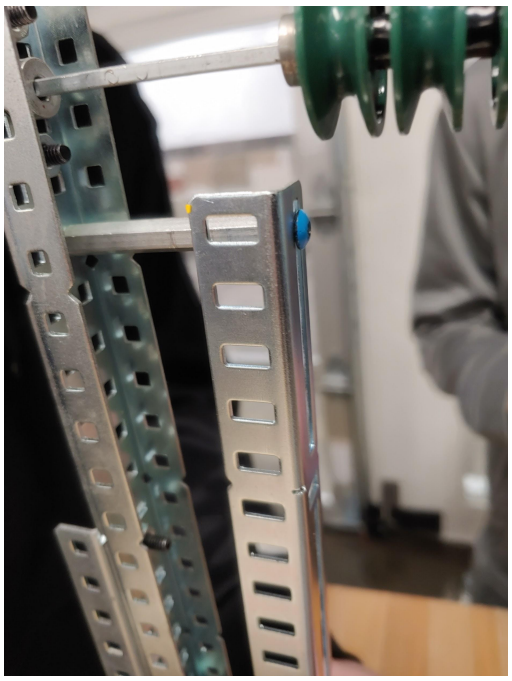
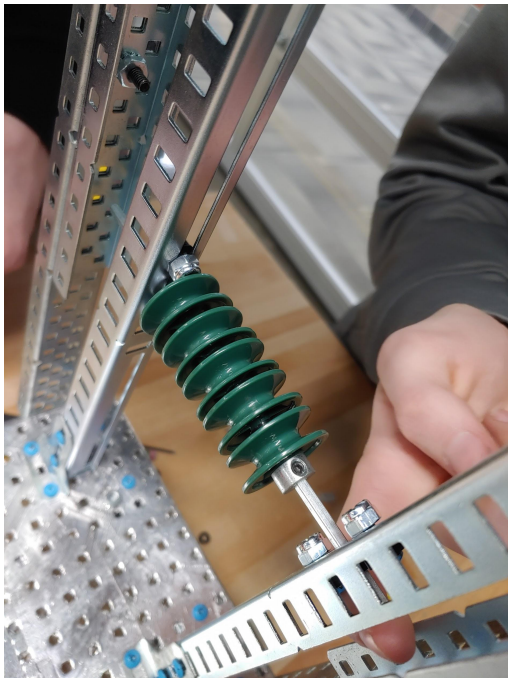
Redesign and Prototype II

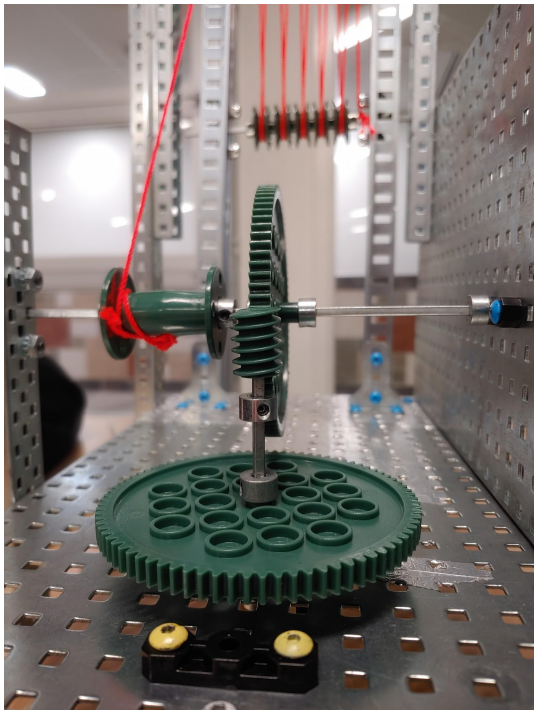
2-10-2020	

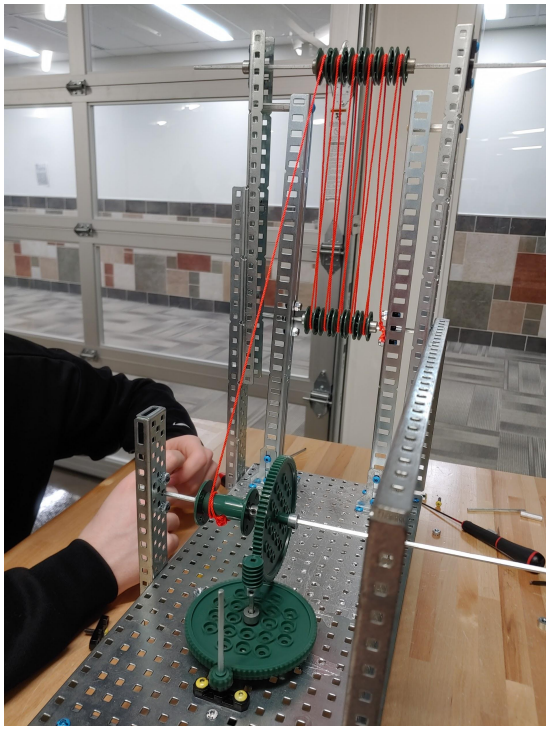
New constraints: 1 more different machine needed - Added Wheel and axle (spool) that turns the pulley instead of sprockets - 4 simple machines present and we continued to the pulley system	
Rough Prototype created - Not yet tested - More upward vertically added for the pulley system. The plan was to add the pulley at the top and have a lower pulley/block and tackle at the bottom.	

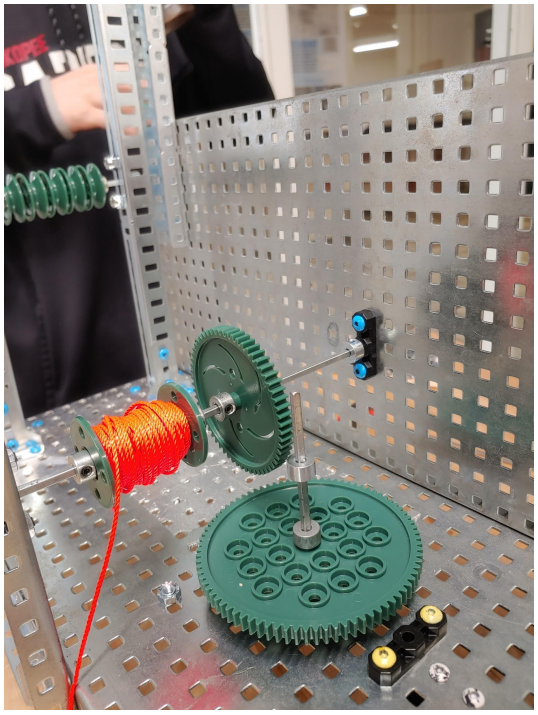
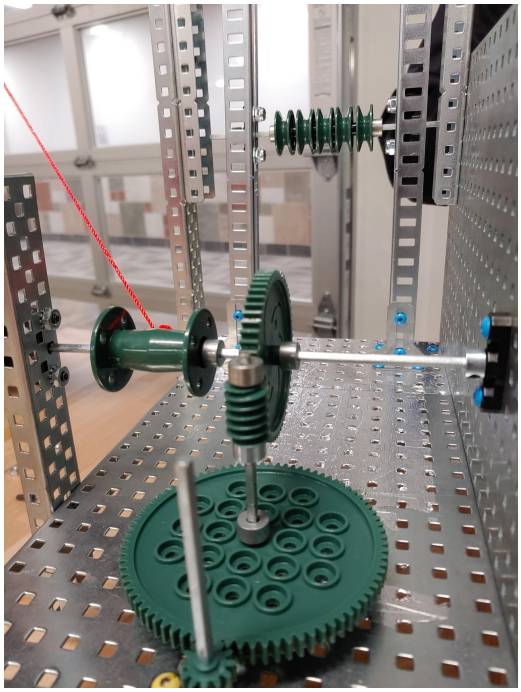
2-11-2020	
Joey commented that spacers were needed between the pulley wheels. If no spacers are there, then the pulley wheels will turn the same direction. Thanks, Joey.	

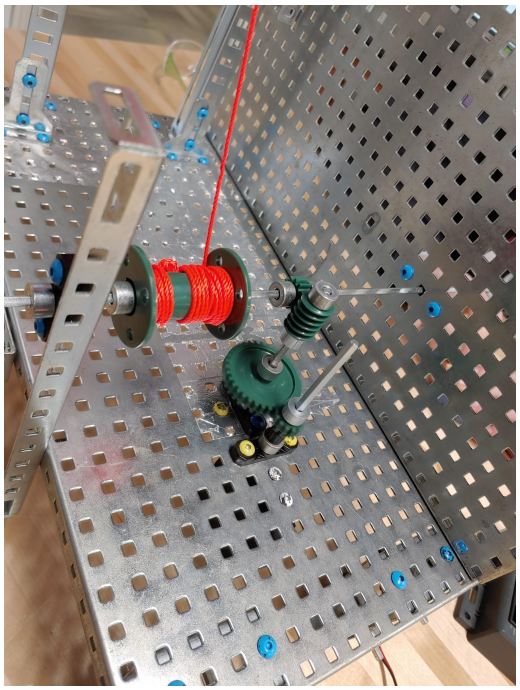
Discovered that the lower pulley system (the movable section) became uneven when the effort was inputted from the top. However, multiple pulley wheels were still desired since they can be adjusted for time constraints.	
Solution for uneven pulley created by using two vertical slotted legs and bearing plates. The lower pulley section/system is now able to move up and down evenly due to it being held by the legs (axle moves).	

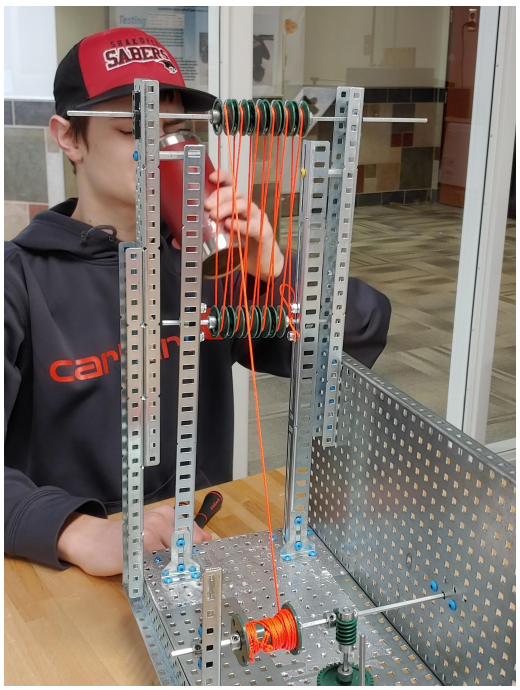
Problem: Vertical slotted legs were unstable and would not reliably hold the lower pulley system. - Solution: added threaded, screwable tubes that attach to the vertical slotted legs to the structure that the upper pulley is attached to. Makes the vertical slotted legs stable.	
Lower pulley Axle was too long and was trimmed down my Mr. Mainhardt	

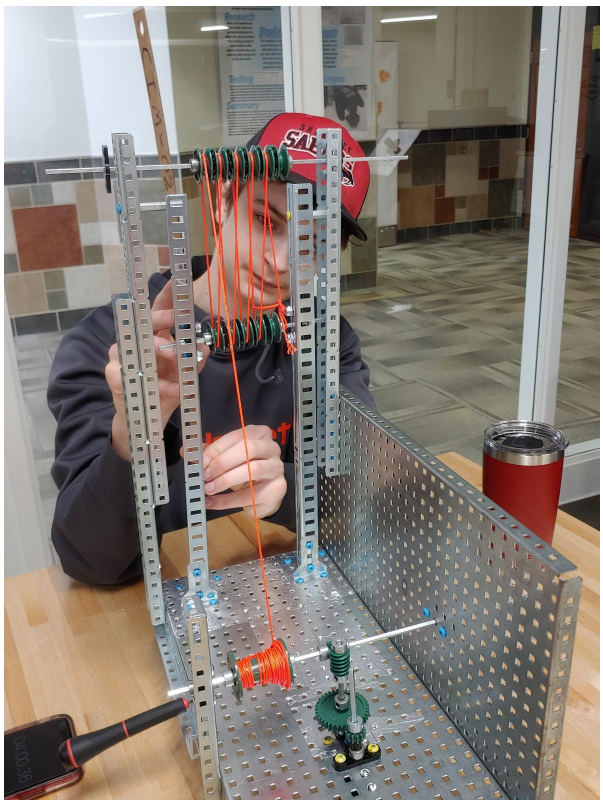
Problem: The screw comes off after longer rotations. Axle needs to be adjusted so that the upper collar has enough space to stop the screw from flying off.	

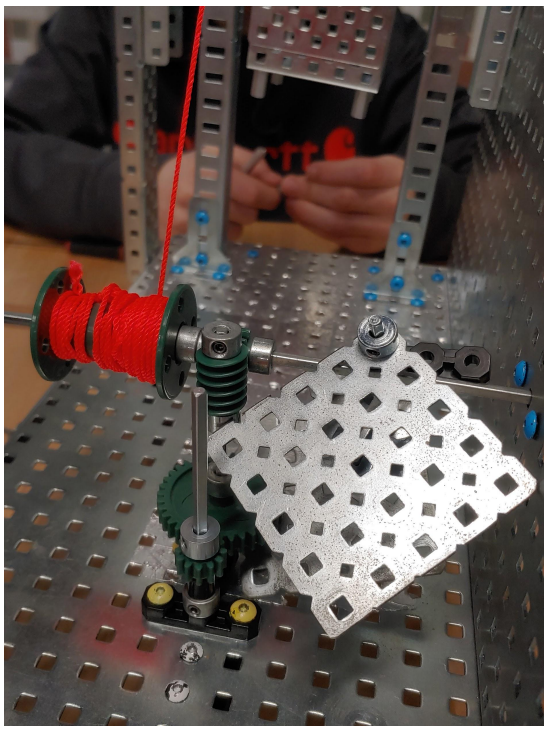
2-12-2020	
First Test: The machine takes too long for it to move the pulley up. Way over 4 minutes	

Changed last output gear to a smaller gear, added longer string since it is going to be moving faster - The axle for the output gear also had to be adjusted - 2nd test: Still took too long to move 6 inches	
The screw was also adjusted to not fly off. We moved the screw axle down so that the collar was able to fit on the top.	

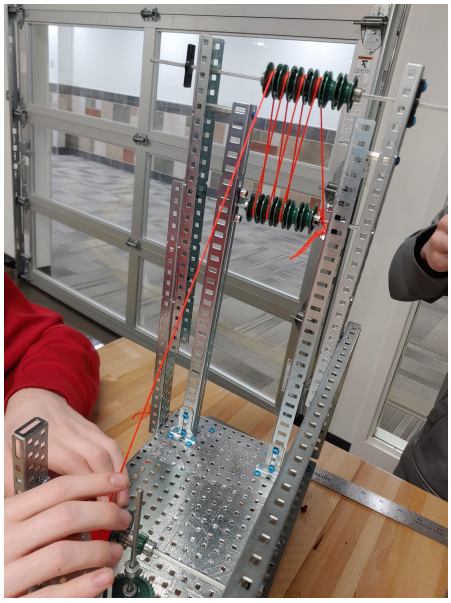
Input and output gears changed to a smaller size to get closer to 4 minutes - Changed the positions of the gear axles and added more axle supports so that the screw and gear would mesh correctly. Very time-consuming. - Awaiting further testing	

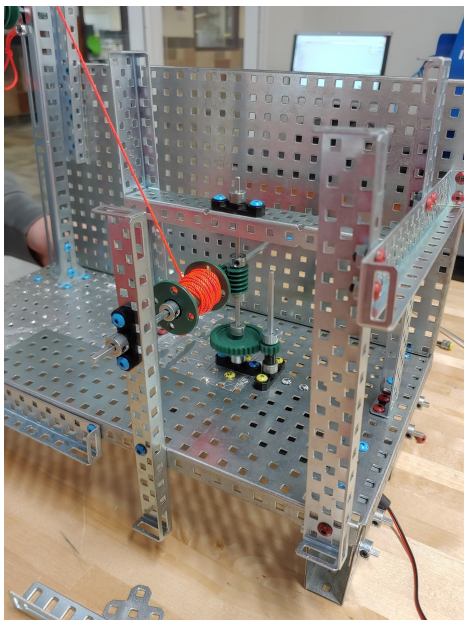
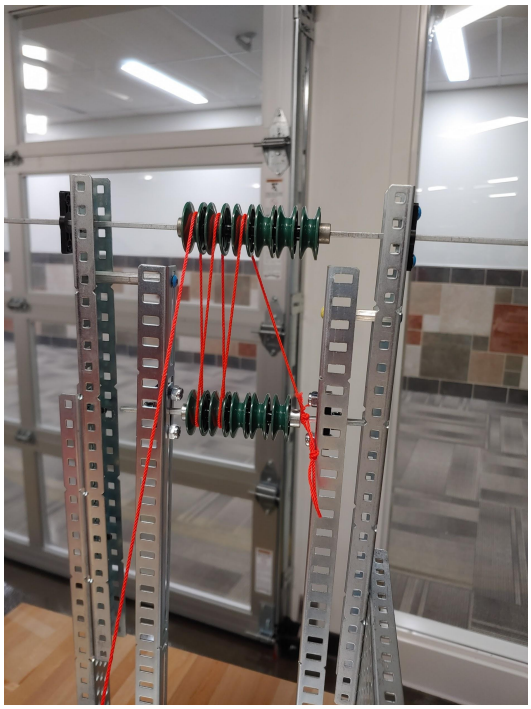
2-13-2020	
Test 3: The 5 pulleys on the top and bottom pulley took too long to pull up. In 4 minutes it only went 3 inches.	

Test 4: 5 pulleys on the top and 4 on the bottom was a little too slow. In 4 minutes it moved 5 inches	
Testing with Resistance Force: Test 5 We completely forgot to add resistance force for the pulley. We had to figure out how to add some weight to the pulley. 4 pulleys on top 3 on the bottom. The lower pulley reached six inches but the resistance, since it was lower than the pulley, did not reach the 6 inches.	

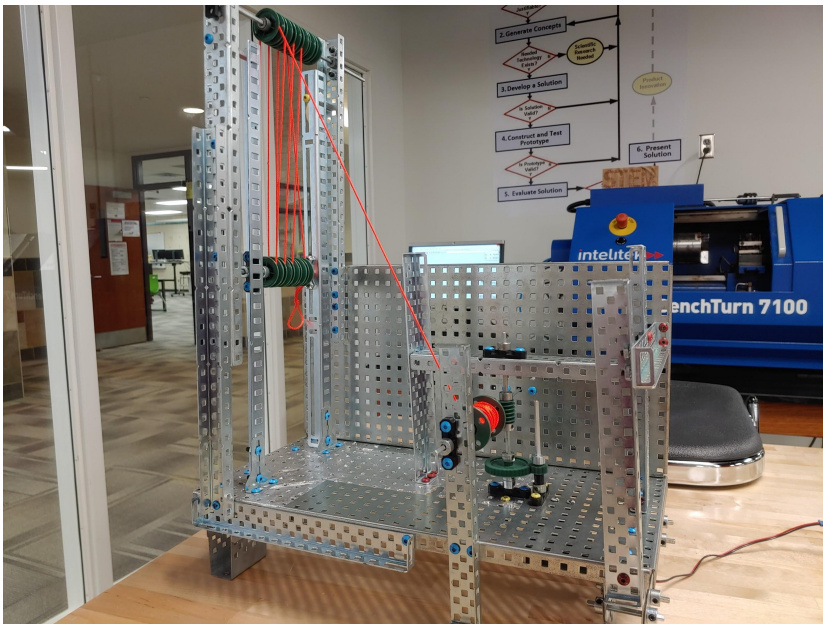
Screw started slipping: Joey helped us add a plate behind the screw to stop it from slipping.	

Final Product

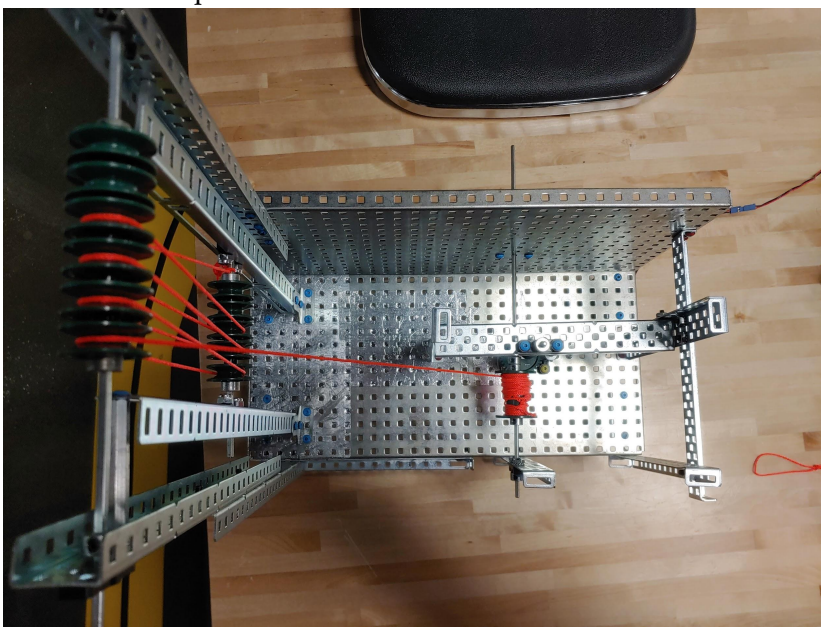
<u>**2-18-2020**</u>	
We discovered that a resistance force is not needed. Tested without resistance: 4 pulleys on top 3 on the bottom: took 4 minutes and 30 seconds	

Need a better screw slipping solution. Old solution was not reliable and inconsistent. The screw slipping also affected the overall time of the pulley lifting. Added axel holding system for the screw's axle. The system also needed more stable support so other bars were attached.	
Test: 3 pulleys on top, 2 on the bottom. Time: 3 minutes 15 seconds	
Test with screw slip solution and 4 on top and 3 on bottom: 4 minutes 6 seconds	
Another Test: 4 minutes and 4 seconds	
Final Product Complete!	

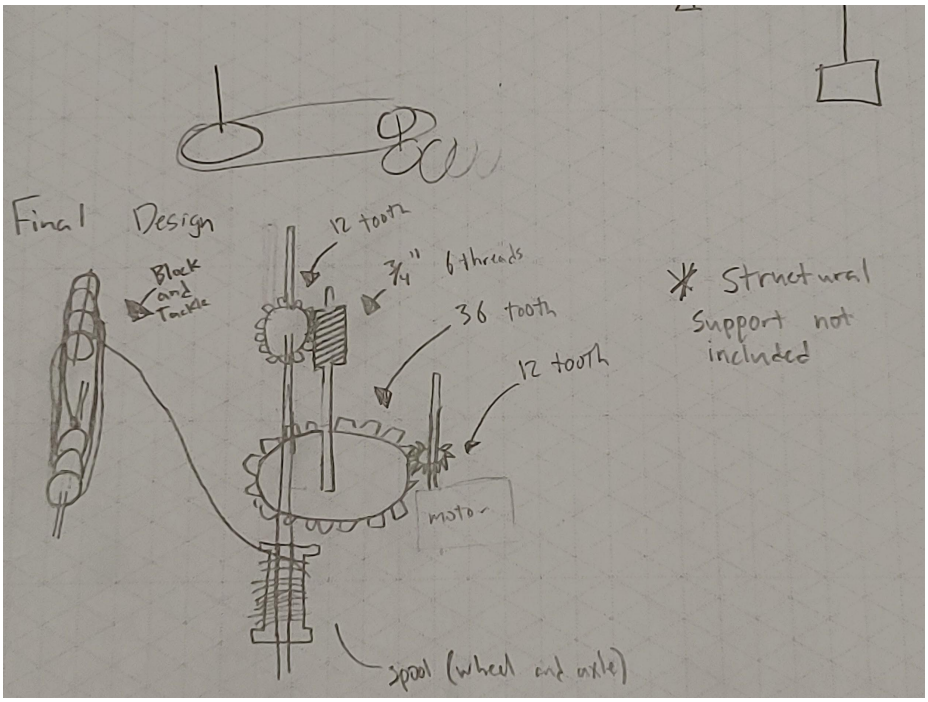
final Picture Side View:



Final Picture Top View:



Final Product Sketch:

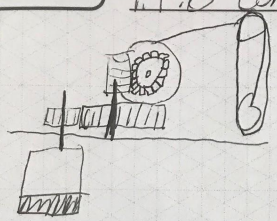


Final MA Calculations:

TITLE

1.1.6 Compound Machine IMA

27



$IMA_{total} = IMA_1 \cdot IMA_2 \cdot IMA_3 \ldots$

$IMA_{total} = 3 \cdot 12 \cdot 1 \cdot 7$

$\boxed{IMA_{total} = 252:1}$

Gear Train 1
12 tooth to 36 tooth

$\frac{GR}{1} = \frac{n_{out}}{n_{in}} = \frac{36}{12} = 3$

$\frac{IMA}{1} = \frac{d_{effort}}{d_{resist}} = \frac{1.5}{0.5} = 3$

36 tooth to worm gear

$\frac{IMA}{1} = \frac{d_{effort}}{d_{resist}} = \frac{1.5}{(0.75/6)} = 12$

12 tooth to wheel an axle

$\frac{IMA}{1} = \frac{d_{effort}}{d_{resist}} = \frac{0.5}{0.5} = 1$

Block and tackle

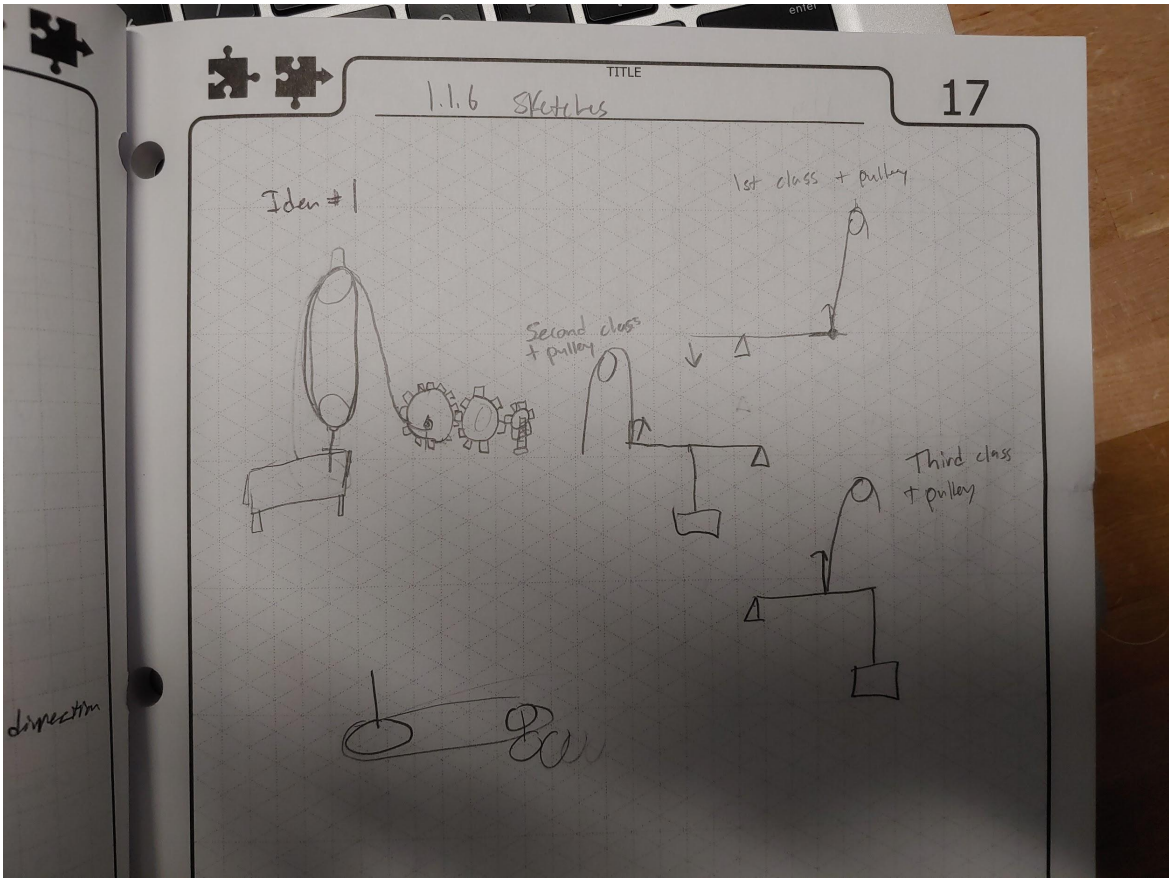
$\frac{IMA}{1} = \frac{\text{\# of strands}}{\text{opposing load}} = 7$

DESIGNED BY: [signature] DATE 2/19/20

WITNESSED BY: [signature] DATE

PROPRIETARY INFORMATION
All information is the property of, and solely owned by the Designer.

Concept Sketches



Problem Statement:
After Wile E. Coyote's piano trap failed, he checked the trap to see what went wrong. However, the strings holding the piano snapped and it fell on Coyote. We are tasked with slowly lifting the piano 6 inches off his chest so he can slide out safely. One of the legs landed on his arm and if we don't rescue him in 4 minutes he will bleed out.

Coding P.

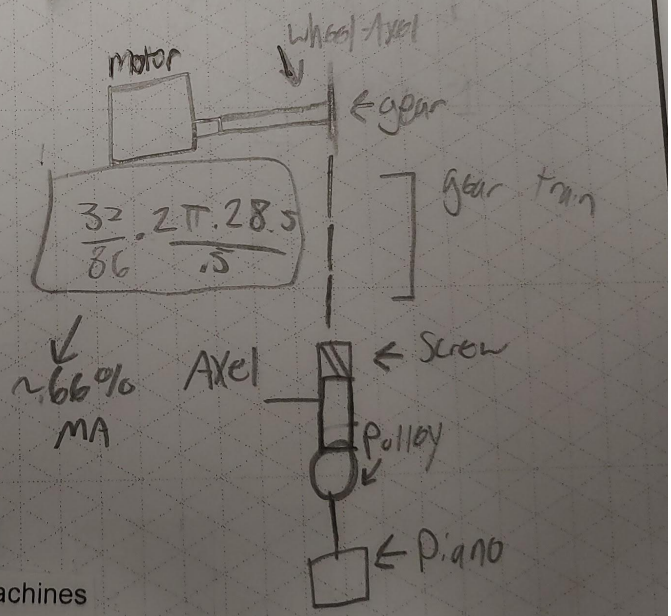
← In tyler's Notebook

Idea 1:
Pulley at the end: lifts the piano up
Gear Train: turns the axle the pulley is (
Screw: turns gear train
Wheel/axle: driver

Coding

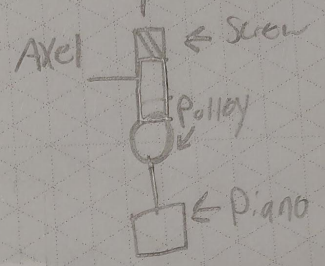
Idea 2:
~~Block and tackle~~ Pulley at end to lift piano
Screw spins string for the pulley
Gear train turns screw
Wheel and axle turns, starts gear train

Idea 3:
Wedge: gets pushed the piano by other machines
Screw: pushes the wedge at in a linear action by using a rod

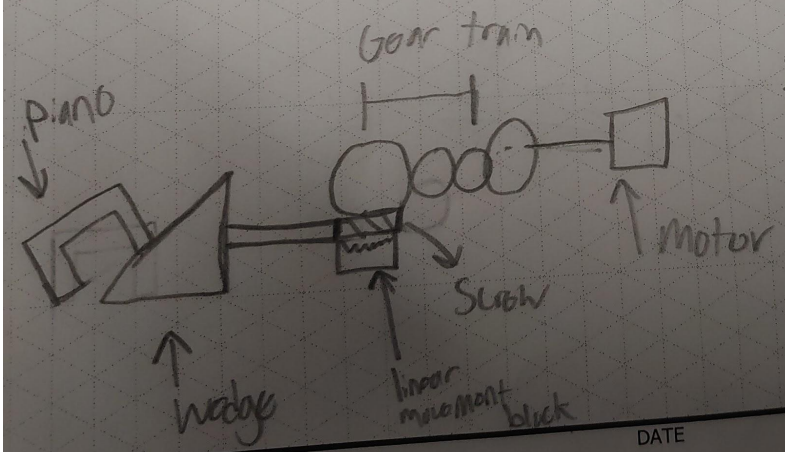


Screw spins string for the pulley
Gear train turns screw
Wheel and axle turns, starts gear train

~.66% MA



Idea 3:
Wedge: gets pushed the piano by other machines
Screw: pushes the wedge at in a linear action by using a rod
Gears: turn the screw
Wheel and Axle : the input to the gear



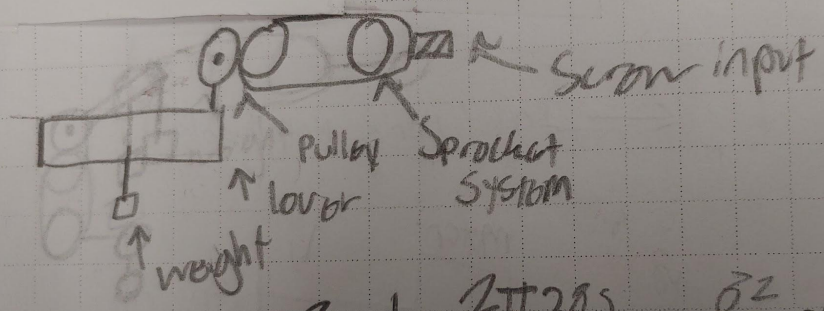
$\frac{32}{86} \cdot \frac{2\pi \cdot .285}{.5} \cdot$ wedge friction

.66 · wedge friction
≈ MA

DATE

PROPRIETARY INFORMATION

Idea 4:
Lever (2nd class): Will be lifted at the one end by pulley. Weight will be at the middle
Pulley(?): the pulley is attached to the lever
Sprocket (chain): the chain will turn the pulley
Screw: input, powers sprocket

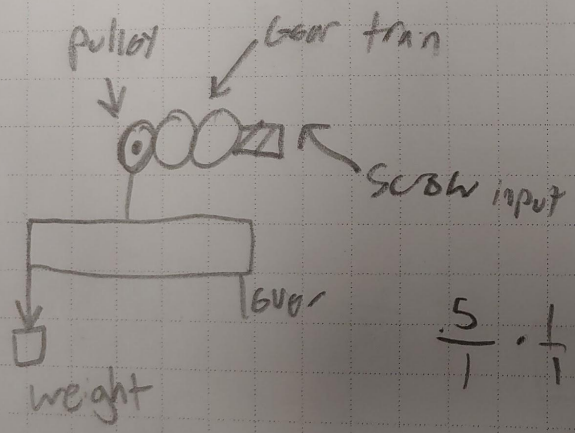


$$\frac{2}{1} \cdot \frac{1}{1} \cdot \frac{2\pi \cdot 28s}{s} = \frac{82}{36} = \sim 46\%$$

estimated

Idea 5:
Lever (third class): lifts piano
Pulley: lifts middle of lever

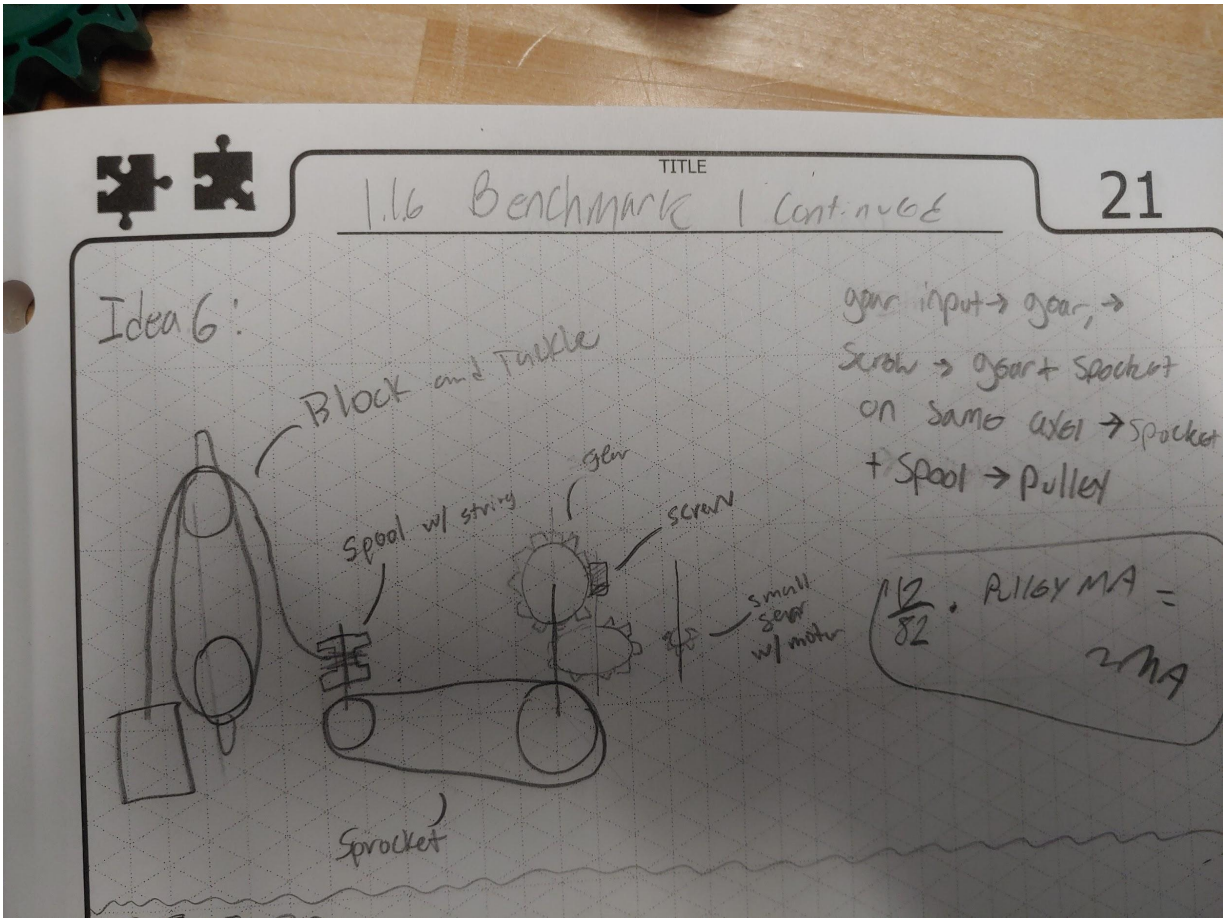
Idea 5:
Lever (third class): lifts piano
Pulley: lifts middle of lever
Gear train: pulls string on pulley
Screw: spins gear train



$$\frac{.5}{1} \cdot \frac{1}{1} \cdot \frac{2\pi \cdot 265}{15} = \frac{83}{82} =$$

$\sim 4\%$

est. η_{tot}



Conclusion

Our final product turned out well, we lifted the object in 4 minutes, and 4 seconds. It was a good solution since it was able to consistently lift the object in 4 minutes. We were able to do this because we discussed problems and solutions to those problems as a team. Everyone was open minded and was able to voice their own opinion and ideas. We even listened to other people outside of our group. This communication meant that we resolved issues as they popped up. If we were to perform the project again we would design our compound machine so that we had a system that we could fine tune more. By doing this, we could get closer to exactly 4 minutes. However, our machine's time greatly fluctuated when we altered a gear size or added or removed pulleys from the block and tackle. Our machine was also time consuming to work with at the end because of the many components that needed to be tweaked or adjusted. If given more time, we could try to make it more simpler to work with. Overall, however, we are quite happy with our solution.

References

Compound machines VEX. (2013, August 5). Retrieved February 7, 2020, from https://www.youtube.com/watch?v=1kuK2EIf4w0