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5/19-5/22

5/19:

11 am: Came in for a meeting with Professor Forman. (Delegated tasks, figured out very general processes and flows for the day-to-day lab)

11:30 am: Checked keys on doors to instructional lab, wind tunnel, and access to Wilsdorf.

12: Began overviewing/organizing the task that I will be working on (Mech Lab Gear Train Testing) and setting up a timeline for the steps that need to be completed and when they need to be completed.

Aiming to complete task 1 by June 16th,

ROUGH SCEDHULE:

Week 1 (May 19th – May 22nd):

- Organize and set a schedule for the rest of the week. Deliverables for the end of each week, and what is hoped to be accomplished.
- Go over objectives and make sure that each one is understood and how different concepts are incorporated into the lab
- Look over old lab and data to understand how it can be fixed.
- Research and brainstorm ideas for new lab that also involves dynamic approach instead of only static

Week 2 (May 25th – May 29th):

- Develop idea for the new lab: What it looks like, how it will complete the objectives, and how it will work.
- Does it minimize safety? Is it compact/portable? Is it reproducible at a low cost?

Week 3 (June 1st – June 5th):

- CAD designs and drawings
- PASCO data acquisitions
- Lab testing

Week 4 (June 8th – June 12th):

- Finish leftovers from week 3
- Student handout with procedure and objectives (draft)

Week 4.5 (June 15th – June 17th):

- Extra for any pushover steps that have not been completed (ASEE Delios maybe... also can work on while out of town)

5/20: Finished going over previous lab and understanding its objective, as well as the difference needed to improve the lab to also incorporate a dynamic approach.

Came up with multiple ideas for new lab, and decided on one as the main focus to go ahead with if approved by Professor Griffiths

Also attended the 2026 RCCADS Workshop that Professor Forman invited us to.

Potential Ideas for a real world application:

Wind Turbine: Ideal, most preferable because of personal enjoyment as well. Gear box?

Conveyor Belt: Interesting, however, replicating and getting the belt may be difficult. Slipping, Belt Stretch.

Crane Hoist System: Also more ideal because of simplicity, gear application? Very similar to current lab but hanging mass allowed to fall allowing a dynamic approach rather than simply a static one.

Automotive Transmission: How would hanging mass be incorporated? Gearbox probably too complicated.

Robotic Arm: Complicated, many different areas that can be replicated in the lab.

Decided on **Wind Turbine**, meaning the planetary gear system. If not attainable then try the crane hoist system as just a more advanced version of the static lab to incorporate dynamic elements and calculations.

Thought up a design for the lab which needs to be sketched.

5/21:

Further research on parts and gear system. Ideas for how the lab can be carried out and what could be goal of it.

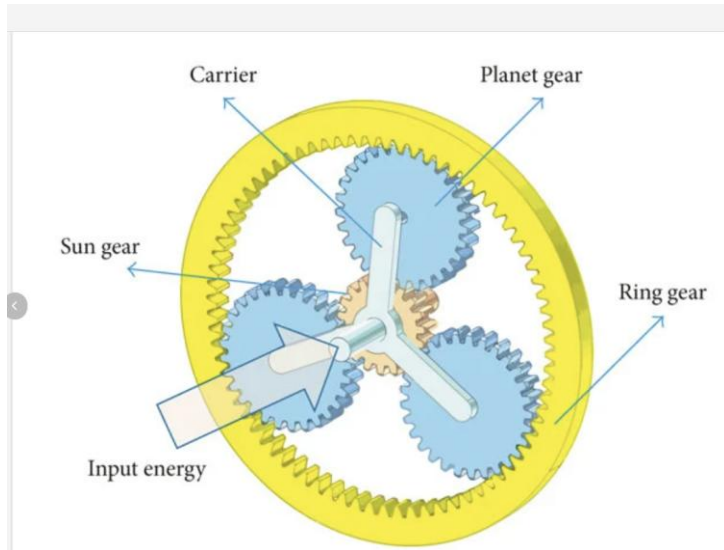


Figure: Ideal Planetary Gear System to model

Began making sketches for the part

CAD designs for all three gear parts (Sun, Planets, and Ring)

- Used the toolbox feature in SolidWorks and edited the module, thickness (gear width), and pitch angle so that they were the same for every gear. Also made sure each specific gear had the correct number of teeth that I wanted to use (5:1 ratio).

Began the CAD for the carrier

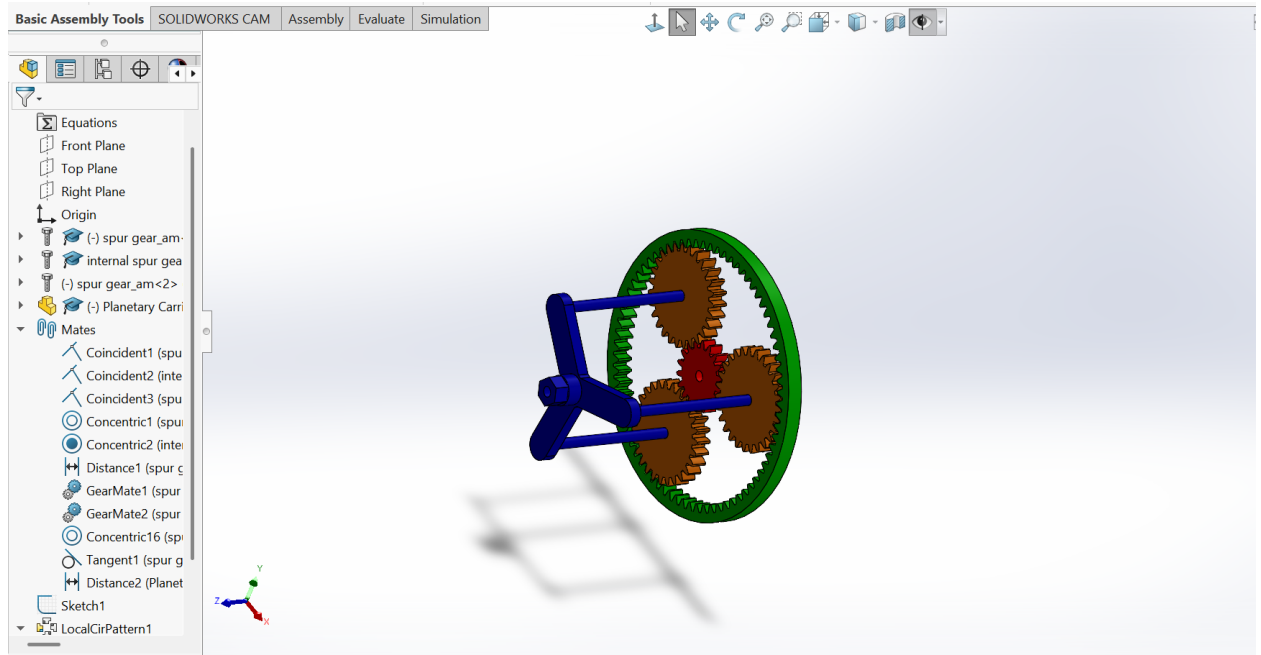
- Using a picture of a carrier that was the most similar to the kind of carrier I wanted to use, I began the CAD for that. Lots of dimension work necessary in order to ensure that it fits on ring stand similar to one used for the static lab. Took measurements of previous gears and holds to find the proper tolerances and size for the connecting parts.

Dimension work in order to make rough sketches and to do the CAD

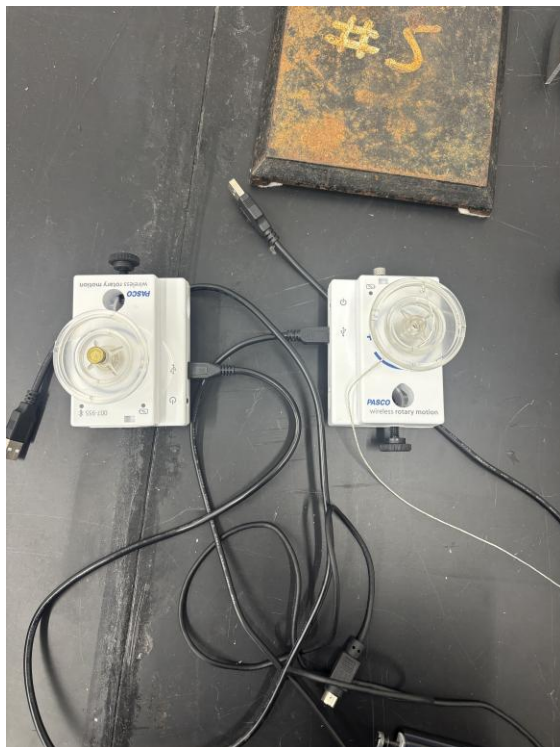
5/22:

Continued to CAD the models.

- Finished the first draft of the carrier.
- Began the assembly, ran into difficulties with sizing and after about an hour realized it was because I had switched the number of teeth for me sun and for my planet.
- Finished the assembly



Went to see if we had Pasco rotary motion sensors (Needed for testing and for future labs if lab works)



Now need to work on the proposal for Professor Griffiths.

If the lab is feasible... If so: (GENERAL ROUGH DRAFT OF LAB PLAN) - does not need to be all written

- How the lab is going to complete the different objectives

- What would need to be bought or what we have (Pasco sensors, different clamps)
- How the lab measures specific variables, and how they will be collected

UPDATED PROJECTED SCHEDULE

Week 2 (May 25th – May 29th):

Get Prototype done:

- Finish with lab plan so know what testing for and how to do it
- Finish all of the CAD designs and drawings
- (Pin system??)
- Figure out how pin system will work and if things need to be printed + edits to gears
- Test the print to see structure/durability/fit (most likely carrier is best piece to test)
- Create the entire system on lab stand by end of week

Week 3 (June 1st – June 5th):

- Continue with printing and setting up if needed
- Set up Pasco part so that testing the system can begin
- Troubleshoot and fix anything that doesn't run smoothly or properly
- Run trials and collect data (FULL LAB run-through)

Week 4 (June 8th – June 12th):

- Finish the lab run-through
- Analyze the data and fix where appropriate (data is not accurate or what I want)
- Create the entire lab procedure and lecture notes (model after labs that I've taken)
- CAD drawings??

Week 4.5 (June 15th – June 17th):

- Overlap space for anything not completed

5/25 (Memorial Day):

Had to do work in Wilsdorf because I could not access Mech Building.

Worked on a design brief and overview of my proposal for what the new lab should look like.

Design Brief:

Objective: To refine a previously existing gear train lab to transform the lab procedure from only a static one to one that involves dynamic testing and replicates real-world system behavior.

Design Requirements:

Must fulfil lab objective (Replicate real-world system).

Builds upon previous lab. Can be used for student-led investigations

Must be tabletop and portable.

Must be easy to set up and take apart.

Cost: Reasonable, most materials already acquired and budget is flexible (limitless).

Safety: Minimizes safety risks in terms of hanging mass and rotation. End-of-travel impacts and uncontrolled motion.

Potential Design Concepts:

1. Wind Turbine
2. Conveyor Belt
3. Crane Hoist System

The main problem with the conveyor belt was the belt aspect of it. First that would require additional cost for something that would work well with a tabletop lab setup, which would not be too difficult but certainly was not the most ideal. Second, a big problem with pulleys with belts is that they can slip, which would affect the accuracy and be inconvenient for the students.

For the crane hoist, the idea itself was not bad and honestly might be the best and easiest to pull off, however it was still a little too boring. This idea is my main fallback idea if the wind turbine gets rejected, but in terms of developing the lab it would be very similar to the current static lab, the hanging mass would just be moving and falling instead of what it does currently. It would use some kind of compound gear train similar to the one currently, and would incorporate the real-world aspect for the angular acceleration, torque application, and moment of inertia.

Main Preliminary Concept: Wind Turbine:

Of these design systems, before creating concepts for the other two, I decided to go with the wind turbine. Overall it was the one which made the most sense to do when considering feasibility and replication, and it was also the one which interested me the most, meaning it would be the most enjoyable to work on.

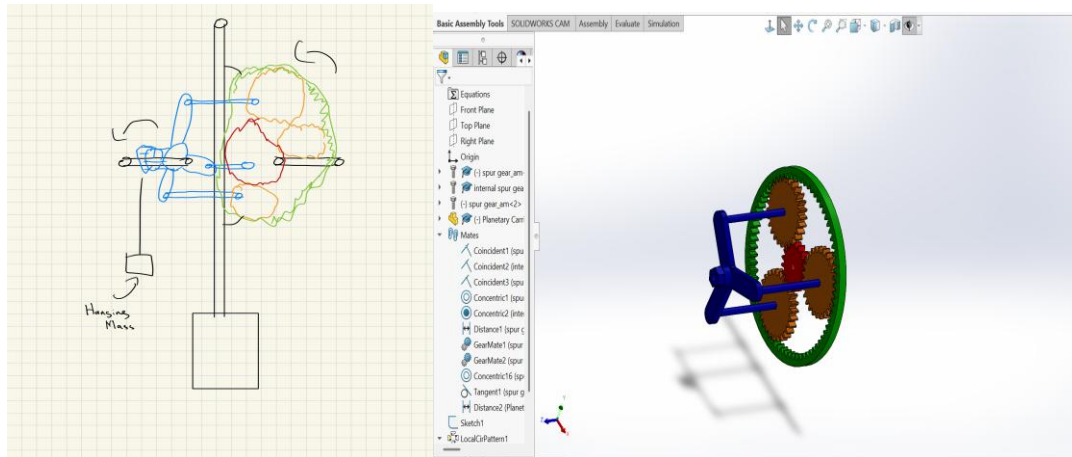
The wind turbine uses a planetary gearbox, which is not difficult at all to replicate for a lab, but is also different enough from the old lab that it would require new designs and gears. It is cost efficient because there is nothing that needs to be bought additionally (as of right now) to collect the necessary data to pull off the lab. The hanging mass can be easily incorporated into the design, and would represent the wind that starts the process to generate energy from the turbine. It could also be easily designed for modularity so that the students can change the gear ratios and configurations in order to see changes in their data and what they are testing for.

The Pasco sensors needed for the lab are rotary motion sensors which I checked for and we had.

Preliminary Lab Procedure:

LAB SETUP: Using the image of the planetary gear system (CAD for it shown above), the gear system would be connected to the lab stand via two shafts which are in line with each other but not connected. The shaft on the left will be connected to the carrier for the planetary gear system and will also hold the hanging mass carrier which will be on the main carrier. The shaft on the right is connected to the sun gear and will hold the all of the actual gears for the gear system which are connected to the sun gear.

Here is a rough sketch of the lab setup alongside a copy of the gear system in SolidWorks. The two shafts (input and output) are shown in black.



Measurements: Two Pasco rotary motion sensors are required per setup, one on the left input shaft and the other on the right output shaft. Both of these would measure the angular velocity at the input and output simultaneously as the hanging mass is released and either comes to a stop or reaches its terminal velocity. This would show up as a graph together so the difference can be easily seen. Angular acceleration can also be obtained from this graph.

Modularity: This will be the most difficult part to pull off, but the gear and setup would be designed so that different parts of the gears (sun, ring, planets) would be locked so that the gear ratio would change and the data would look different, allowing the student to learn more about the lab objective and have a hands on way to do it.

Improvements: While the old lab was effective, it was boring. It measured one static force value while the entire system was at equilibrium. This lab measures the entire time history of the dynamic event, from release until the hanging mass comes to a stop.

Timeline: *See highlighted schedule*

5/26:

Had Tuesday check in meeting with Prof Forman and Prof Griffiths.

Presented Wind Turbine design brief and overview of what the plan was. Design was good, however there were many things that were uncertain and may not have been completely feasible. Such as: Due to the torque load is it possible for my carrier shafts to support the planets? How am I going to make it modular, very complicated to do that in order to have the simplest way for students to take it apart and attempt different gear ratios.

Prof Griffiths suggested it was best to maybe stick with a compound gear train for the sake of simplicity and allowing the students to be able to understand what they are doing. (Still needs to be a prelab and post-lab so working with things that the students will know how to do would be ideal).

For the compound gear train: Need to have a way to calculate power, have a known moment of inertia and torque application.

Figuring out a way to combine the elements of lab 05 with lab 07 is what was suggested by Prof Griffiths.

- Rotational Dynamics Gear Train Lab

5/27:

Start with research for new lab idea (Rotational Dynamics Gear Train) and different ways that this can be pulled off.

Call with Prof. Griffiths to go over the design and requirements a little further.

- Need to do the calculations for the lab and design first before actually making
- What do I think will happen with the design.
- What needs to be where to get proper measurements
- Flywheel at the end of the

Spent a lot of time trying to visualize the redesign and could not quite think of how I could pull it off. Talked to Nick and Prof. Griffiths who helped me come up with many good ideas. Struggled a lot with how I was going to connect everything.

Also spend a lot of time with Magen, Nick, and Kemal looking at the wind tunnel hex design. Explored the machine shop downstairs and more in the wind tunnel room.

5/28:

Continued research and design thinking

- Figured out a potential way to connect the rotary motion sensor to shaft using couplers
- Looked into couplers and how that would work
- May need different pasco sensor, with larger rotating shaft then the current one
- Did some flywheel research and figuring out how to incorporate it into the system and what it would do.

Design idea

- Horizontal instead of using vertical lab stand
- Need to make gear box/frame to hold everything that is also portable and tabletop
-

Began to start some calculations in order so that the gearbox would work correctly.

- Used the same gears from one of the previous lab setups: used the same pressure angles, calculated the new module from the pitch that was given. Calculated pitch diameter from there.

- Measured the shaft length and diameter, plan to use these same shafts in the prototype and need the measurements for the frame

5/29:

Continued with calculations for dimensions of different components and moment of inertia.

- Needed to figure out the moment of inertia of the whole system without the flywheel to determine realistic constraints to put on the flywheel to ensure the system runs properly
- Also need to figure out how the hanging mass and the pulley affect this, not sure but further research on this.

Further research on what needs to happen to make this possible to work: what I need to calculate/know

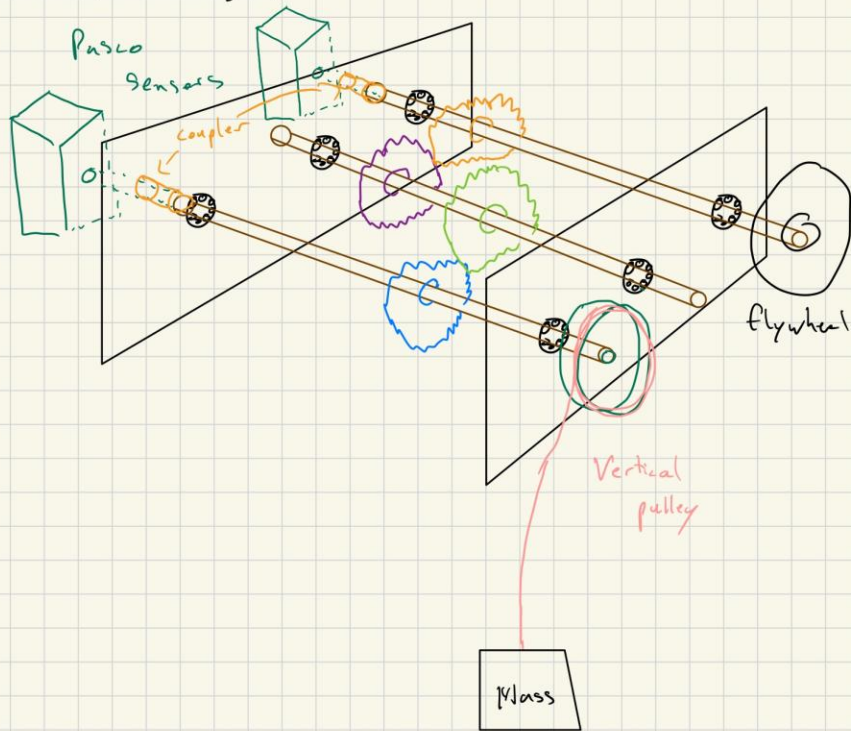
Sketched a design for the entire system along with the frame

- Further research into how the flywheel will be incorporated
- Further research into how to connect sensor to shaft with coupler and began thinking about ideas for how the vertical pulley can be attached to the design.

6/1:

Updated design drawing a little bit & Continued with the calculations

Frame / Stand Design:



Component Calculations

Gear 1: $N=18$, $d=14.5$, $m=2.54$, $d=14.52\text{mm}$
 Gear 2: $N=24$, $d=14.5$, $m=2.54$, $d=14.54\text{mm}$
 Gear 3: $N=24$, $d=14.5$, $m=2.54$, $d=14.52\text{mm}$
 Gear 4: $N=24$, $d=14.5$, $m=2.54$, $d=14.52\text{mm}$

Using current gears so 2 gears from middle (12 teeth)
 Gear 1: 12 teeth
 Gear 2: 12 teeth
 Gear 3: 12 teeth
 Gear 4: 12 teeth

Shaft: Length = 206mm, diameter = 7.92mm

Distance between shafts: $d_{12} = r_1 + r_2 = \frac{14.52 + 14.52}{2} = 14.52\text{mm}$
 $d_{23} = r_2 + r_3 = \frac{14.52 + 14.52}{2} = 14.52\text{mm}$

Moment of Inertia Calculations: ($I = \frac{1}{2}MR^2$ for shaft & gears)

Mass of shaft: $m_s = 2.54$, $R_s = 0.0254$
 Mass of gear 1: $m_{g1} = 1.8$, $R_{g1} = 0.018$
 Mass of gear 2: $m_{g2} = 1.8$, $R_{g2} = 0.018$
 Mass of gear 3: $m_{g3} = 1.8$, $R_{g3} = 0.018$
 Mass of gear 4: $m_{g4} = 1.8$, $R_{g4} = 0.018$

Radius of shaft: $R_s = 0.0254$
 Radius of gear 1: $R_{g1} = 0.018$
 Radius of gear 2: $R_{g2} = 0.018$
 Radius of gear 3: $R_{g3} = 0.018$
 Radius of gear 4: $R_{g4} = 0.018$

$I_1 = I_{\text{shaft}} + I_{\text{gear 1}} = \frac{1}{2}(m_s R_s^2) + \frac{1}{2}(m_{g1} R_{g1}^2) = 7.24 \times 10^{-6} \text{ kg}\cdot\text{m}^2$
 $I_2 = I_{\text{shaft}} + I_{\text{gear 2}} + I_{\text{gear 3}} = \frac{1}{2}(m_s R_s^2) + \frac{1}{2}(m_{g2} R_{g2}^2) + \frac{1}{2}(m_{g3} R_{g3}^2) = 7.24 \times 10^{-6} \text{ kg}\cdot\text{m}^2$
 $I_3 = I_{\text{shaft}} + I_{\text{gear 4}} = \frac{1}{2}(m_s R_s^2) + \frac{1}{2}(m_{g4} R_{g4}^2) = 7.24 \times 10^{-6} \text{ kg}\cdot\text{m}^2$

Total: $I_{\text{total}} = I_1 + I_2 + I_3 = 2.172 \times 10^{-5} \text{ kg}\cdot\text{m}^2$

Calculating angular acceleration: (for a 200g hanging mass)
 $T = m(g - a) = 2(9.81 - a) = 0.476(9.81 - a)$
 $T = I \alpha$
 $0.476(9.81 - a) = 0.0245 \alpha$
 $4.67 - 0.476a = 0.0245\alpha$
 $4.67 - 0.476a = 0.0245a$
 $4.67 = 0.5005a$
 $a = 9.33 \text{ m/s}^2$

If pulley needs to be greater than this

Calculating angular acceleration: (for a 200g hanging mass)
 $T = m(g - a) = 2(9.81 - a) = 0.476(9.81 - a)$
 $T = I \alpha$
 $0.476(9.81 - a) = 0.0245 \alpha$
 $4.67 - 0.476a = 0.0245\alpha$
 $4.67 - 0.476a = 0.0245a$
 $4.67 = 0.5005a$
 $a = 9.33 \text{ m/s}^2$

for too large, ideally $\approx 5 \text{ rad/s}^2$
 - lower pulley radius
 - use less mass
 - add is helpful to slow down

Notes about the calculations

- Had to add numbers to the total inertia reflected to the output to account for the pulley that is not a part of the rotation
- Made the inertia of the Pasco rotor sensor negligible
- Calculated angular acceleration if we were using a mass of 200g. The number was far too big than that which would be acceptable for the Pasco sensors to properly be able to collect the data before the hanging mass hits the ground
- Numbers for inertia are not exact because I used the gears already printed. They have additional parts for the pulley attachment that would add to the mass, but not significant enough that it would affect what I am looking for. Once the lab seems like it can work, then I will use the exact numbers to create the lab that would be theoretically used in class.
- The total inertia is not including that of the flywheel. I needed the total without it so I could figure out how big I would need to make my flywheel so that it works well with the lab.

Worked on questions to ask Professor Griffiths during the Tuesday check-in meeting

Hoping to get approval on the design and progress so far, then will make an updated schedule for the future 2-3 weeks to complete the entire lab.

6/2:

Regular Tuesday Check-In meeting

Notes from meeting:

- Need to **bound the problem**: Create a maximum and minimum acceleration that can be used to help constrain what is being looked for.

- Maximum: The mass will be falling with a certain linear acceleration without any inertia, just gravity, and that will cause the output shaft to spin with a certain acceleration through the gear ratios.
- Minimum: What's the smallest acceleration that Pasco sensors will still be able to record. Also, the time that it would take for the mass to hit the ground, how long do I want that to be and what's the minimum acceleration for that.
- Use moment of inertia calculations to test flywheel weights and see what would give a low acceleration

Maximum acceleration (Upper Bound):

$$a_{max}(gravity) = 9.81 \text{ m/s}^2$$

$$\omega_{inputmax} = a_{max} / r_{pulley} = 9.81 / 0.02568$$

$$\Rightarrow 175.55 \text{ rad/s}^2$$

$$\omega_{outputmax} = \omega_{inputmax} \cdot e = 175.55 (0.25)$$

$$\Rightarrow 43.89 \text{ rad/s}^2$$

Minimum Acceleration (Lower Bound):

Drop Time: $t = 3 \text{ s}$ (Ideal for Pasco)

Height from table to floor: $h = 0.765 \text{ m}$

$$a_{min} = 2h/t^2 = 2(0.765) / 3^2 = 0.17 \text{ m/s}^2$$

$$\omega_{inputmin} = a_{min} / r_{pulley} = 0.17 / 0.02568$$

$$\Rightarrow 3.04 \text{ rad/s}^2$$

$$\omega_{outputmin} = \omega_{inputmin} \cdot e = 3.04 (0.25)$$

$$\Rightarrow 0.761 \text{ rad/s}^2$$

-
- Put equations into excel or MATLAB so that numbers can easily be changed and its possible to quickly see different outcomes for different inertias and gear ratios.
 - Trying to find the target moment of inertia to be used for designing the flywheel

Currently I have the calculations on the input acceleration without the flywheel added, it is too large. I also have calculated what the minimum input acceleration should be based on the lab setup with the table. I need to add the flywheel to the calculations for the input acceleration (using matlab) in order to see what flywheel weights would be ideal to give me a low acceleration closer to the minimum.

Made the first code that would be used in order to calculate what I need to calculate to make sure that it possible. Took a quick look at it and the different outputs, a lot of values need to be changed in order for it to start working the way that I want it to, and I also need to understand what the angular acceleration I am getting means.

Looked at the code to see the equations and walk through each step over again making sure everything made sense

Played around with the code to test difference values and see the different outcomes

- Mass of the flywheel
- Radius of the flywheel
- Mass of the hanging mass

Continued to listen to different parts of the recording to get an idea for the direction I should be headed in.

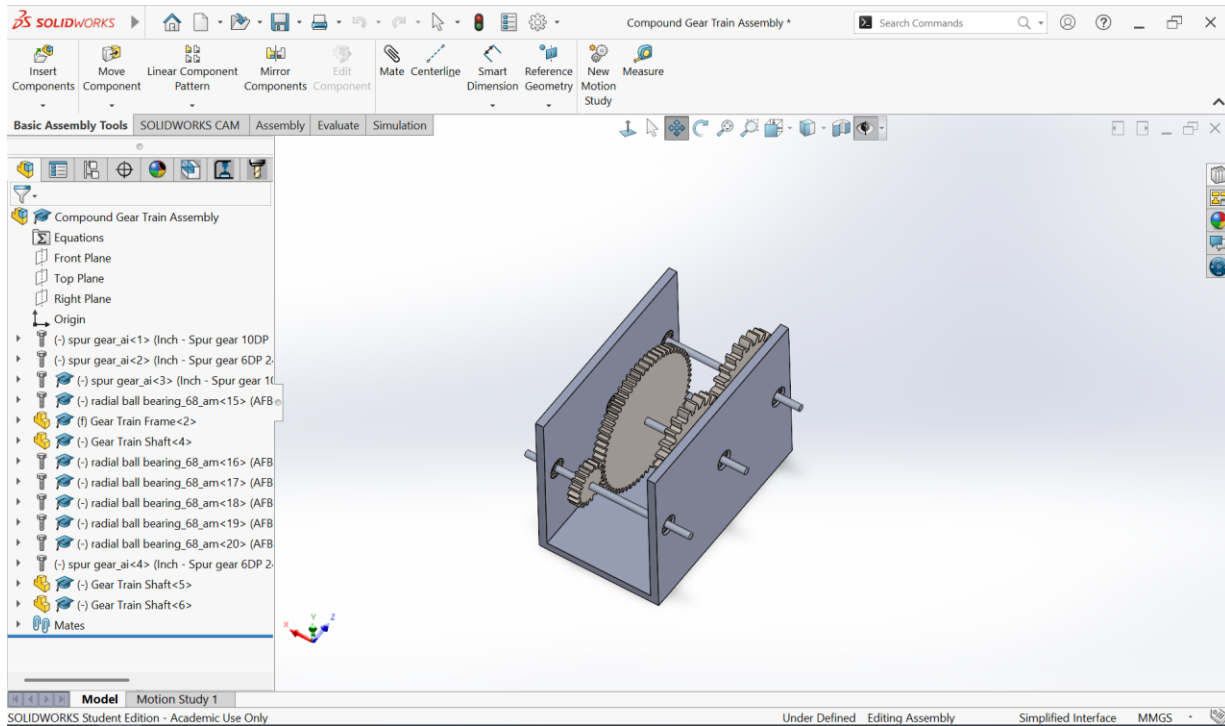
Began to CAD the design:

- Made the frame
- Made the shaft
- Made each of the gears
- Made ball bearing

I need to talk to Nick to see the material and correct sizes for the shaft and bearings so I can make the assembly as accurate as possible.

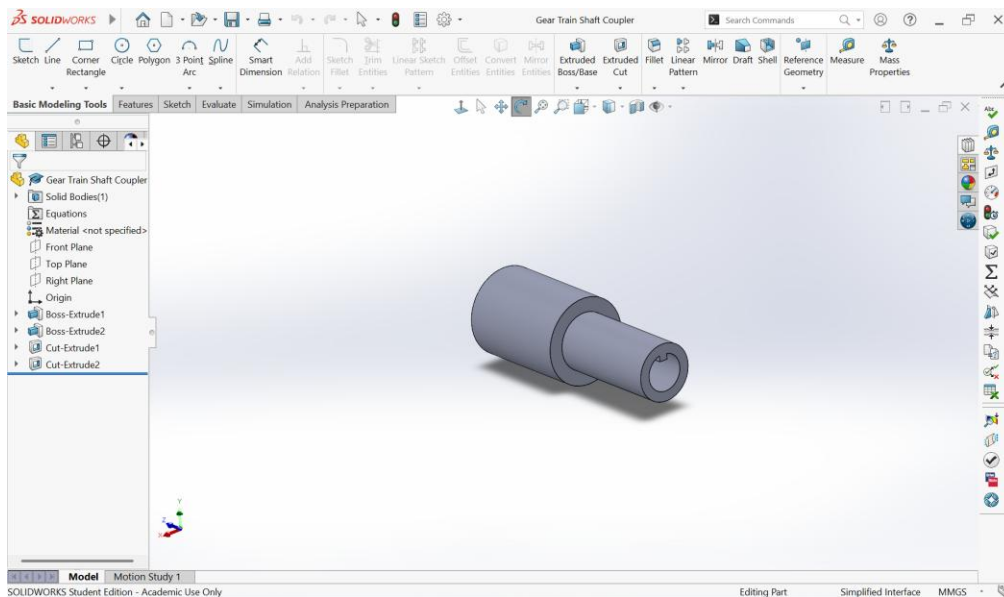
6/4:

Continued to work on the CAD designed. I finished the mates and the gear mates and everything was working well, but the shafts would not rotate with the gears they both had a separate rotation. At first I thought that this may have been because they were missing a mate but realized that I need to add something in order to actually connect them not just a concentric mate. Might have to add part to gear design that would allow me to use screws similar to the ones used in the previous lab in order to connect them.



Prof Forman came down for quick check in and I updated him on what I had been working on and what I plan to work on heading forward. Suggested that I try to see if teams has an ai summary for the transcript of the meeting.

Made a coupler for the shaft to the pasco sensor shaft. Measured the proper dimensions with a little bit of tolerance so that hopefully if the design is approved its a good fit on the first try.



Nick sent me the files for the previous parts that had been 3D printed, along with the link to the bearings that he used.

- Mainly just wanted to compare to the gears that I currently have, and if I need to add a connector that I can use to screw onto the shaft I now have a perfect frame of reference for that.

Idea for the modularity of the gears: use a shaft with a keyway and design the gear to fit this, so that they can slide on and off easily and be replaced. Instead of using screws that fit the gears to the shaft and make it a little difficult to simply take them on and off. The gears would have to be attached to the outside of the rod if the current design ends up being the actual one.



- Researched different ways a gear can be connected to the shaft to get some ideas for what could work best. Definitely something to spend more time on in the future as Professor Griffiths mentioned that it isn't a top priority right now and can be figured out later.

Did a whole lot of research on 3d printing and learning more about it because it is not something that I am too familiar with and is a very important thing to know and be skilled in at this stage.

6/5:

Continued with the CAD and solidworks simulation parts

Met with Professor Griffiths to give an update and what I had been working on and to have a shortsighted vision into the future. Thinking about going completely with the keyway idea, the only problem would be how it wears out over time due to the friction, however there is not a lot of force on there. Looking at McMaster-Carr as a resource to get that shaft from which already has the keyway in it. Also a good resource for getting CAD models that can be used.

Talked with Nick about the previous screws and threaded inserts that were used in the printed gears. Increased my general knowledge on screws and fasteners by a lot

6/8 and 6/9:

Continued working on calculations in order to figure out correct flywheel dimensions so that hopefully that part does not need any do overs. With the simulation that I had, I would need something like a flywheel with a 1.5-2.5 kg mass and a radius of about .08m that is driven by a hanging mass of .05kg in order for that mass to take around 1.5s to hit the ground, which seems way too big and does not sound right. So I need to check the

calculations to make sure that everything is done correctly and that the equations are correct. It was recommended by both Professor Griffiths and Professor Forman to start with the simplest case (which would be just the flywheel, pulley, shaft, and mass) and then move up to the reality with multiple shafts and different gear ratios.

For the design, talked with Prof Forman about how to make it as easy to replicate for other schools as possible. The main issue here was when looking at how the bearings were inserted into the housing previously, which looks as if they were machine pressed, and how that would be impossible with my U-shaped design. Brainstormed other ideas for getting the bearings to be stable in an easy way that can be copied without actually using anything to press them in with a machine. First step for all options would be making the hole diameter slightly bigger (thousandths) so that bearing does not need to be forced in.

- Can add a lip into the design so that bearing can't go completely through on that side (inside)
- Add a shaft collar to the other side so that shaft is secured on both ends of the housing and bearing can't go through that side

The only difficulty with the shaft collar is the friction it would generate once the shaft is rotating, but would that be significant enough to be worried about?

A new design option is instead of the U-shape, just simply making it one wall in the middle supported by a horizontal bottom floor with the same three shafts, but a reduction to just 3 bearings for each shaft.

- This allows the key shape design to actually be utilized
- Can now be machine pressed, but Prof Forman also suggested using two shaft collars on each side for it
- Would need some type of clamp to keep gears on shaft once they are keyed in from the outside (more friction?). Those might also just not be necessary, but a good insurance

When setting ideal drop time to 2 seconds at a height of .75m and using a mass of .25kg the necessary flywheel inertia was about $.25 \text{ kg} \times \text{m}^2$, which is insane and not realistic at all for this lab. Ideas to fix this issue are to either reverse the system, so that the output shaft spins faster than slower and effect of flywheel doesn't need to be reduced. Or use a rim style flywheel so that way there is almost double the inertia.

Flywheel Inertia Calculations Check: ($h = .75\text{m}$, $t = 2\text{s}$)

$$a = \frac{2h}{t^2} = \frac{2(.75)}{2^2} = 0.375\text{ m/s}^2 \rightarrow \text{ideal linear acceleration}$$

$$a = \frac{mgs^2}{I_{\text{total}} + mr^2} \rightarrow I_{\text{total}} = mr^2 \left(\frac{g}{a} - 1 \right)$$

$$I_{\text{flywheel}} = mr^2 \left(\frac{g}{a} - 1 \right) - I_{\text{pulley}} - I_{\text{shaft}}$$

$$= .5(.052)(.05588)^2 - .5(.024)(.00316)^2$$

$$\Rightarrow 0.0186\text{ kg}\cdot\text{m}^2$$

↑ largest flywheel would be if no gears involved

With Gears Involved: to find required flywheel on output

$$I_{\text{needed, input}} = m r_{\text{pulley}}^2 \left(\frac{g}{a} - 1 \right) = I_A + I_B \left(\frac{1}{4} \right)^2 + I_C \left(\frac{1}{4} \right)^2 + I_{\text{flywheel}} \left(\frac{1}{4} \right)^2$$

$$I_{\text{flywheel}} = \frac{m r_{\text{pulley}}^2 \left(\frac{g}{a} - 1 \right) - I_A - I_B \left(\frac{1}{4} \right)^2 - I_C \left(\frac{1}{4} \right)^2}{\left(\frac{1}{4} \right)^2}$$

$$= \frac{0.25(.05588)^2 \left(\frac{9.81}{.375} - 1 \right) - (8.61 \times 10^{-5}) - (5.15 \times 10^{-4}) \left(\frac{1}{4} \right)^2 - (7.23 \times 10^{-5}) \left(\frac{1}{4} \right)^2}{\left(\frac{1}{4} \right)^2}$$

$$\Rightarrow 0.25\text{ kg}\cdot\text{m}^2 \text{ (insanely large for this)}$$

The Red Text in the upper half should actually be indicating that that is the smallest the flywheel inertia would be without the addition of any gears for a drop time of 2 seconds.

6/10:

Research into why the number is so large: The system is a gear reduction, which means that the output shaft is spinning significantly slower than the input shaft. To be exact, the output shaft is spinning $18/64 = 0.28125$ times slower than the input shaft.

Calculating the angular speed for output shaft:

For $t = 2\text{s}$, $a = 0.375\text{m/s}^2$

$v = at = 2(.375) = 0.75\text{ m/s}$

$\omega_{\text{in}} = v / r_{\text{pulley}} = .75 / .05588 = 13.4\text{ rad/s}$

$\omega_{\text{out}} = 13.4(.28125) = 3.77\text{ rad/s}$

This output shaft speed is extremely slow, and because of this the inertia flywheel really does not play that big of a role in slowing down the shaft if it is on the output shaft, because the effect is over 3 times less than it would normally be.

Potential Options for fixing this massive flywheel issue:

1. See what reducing the hanging mass and the needed time to record the data would do
2. Use a rim style flywheel so that the moment of inertia changes (is that easy to make?)
3. Change gears around so that instead of a reduction it becomes an increase (would that help?)
4. Put the flywheel on the input shaft (kind of defeats the purpose)

Option 1: After changing the hanging mass to 0.05kg and the time for drop to 0.7s, the new needed flywheel inertia is $0.002768 \text{ kg} \cdot \text{m}^2$.

- This number is much more achievable, but are these requirements ideal for the lab, is a 0.05 kg mass too small?
- Can Pasco get accurate data recordings with only 0.7 seconds to collect

Ply wheel Inertia with less time & mass? ($m = 0.05 \text{ kg}$, $t = 0.7 \text{ s}$)

$$a = \frac{2h}{t^2} = \frac{2(0.75)}{(0.7)^2} = 3.06 \text{ m/s}^2$$

$$I_{\text{flywheel}} = \frac{0.05(0.0559)^2 \left(\frac{9.81}{3.06} - 1 \right) - (8.61 \times 10^{-5}) - (5.15 \times 10^{-4}) \left(\frac{9.81}{3.06} \right)^2 - (7.23 \times 10^{-5}) \left(\frac{9.81}{3.06} \right)^2}{(1/60)^2}$$

$$\Rightarrow 0.002768 \text{ kg} \cdot \text{m}^2$$

(Option 1 is just continuing to use the solid disk in a gear reducer system, but changing the mass and drop time to something that is not very realistic for a lab)

Option 2: If we use a rim-style flywheel, the inertia doubles allowing much less mass and a smaller radius to still reach the desired output. This also allows me to increase the hanging mass to make it more realistic for the lab and maybe even increase the drop time to 1 second.

- With a hanging mass of 0.05 kg, a flywheel mass of 0.5kg, and a radius of 80mm the drop time was about 0.7s, which is still good. If the flywheel mass is not too big already this is something that can be played around with in order to try and increase the hanging mass.

```

=== RESULTS ===
Hanging mass           = 0.050 kg
Pulley radius          = 0.0559 m
Linear acceleration     = 2.8268 m/s^2
String tension         = 0.3492 N
Input angular accel     = 50.5865 rad/s^2
Output angular accel    = 14.2275 rad/s^2
Drop height            = 0.750 m
Drop time              = 0.728 s

STATUS: OK - drop time is in a useful lab range.

```

Option 3: I made a new code that pretty much changed the system from being a gear reducer to being a gear increaser. The goal is that this would require the flywheel to have much less inertia in order to still have a significant effect on slowing down the dropping time of the hanging mass.

This option easily seems to be the most effective, after increasing the mass all the way to .200kg and with a much smaller flywheel of .25kg and a 0.05 m radius, the drop time was still over 1 second. There is so much room to adjust to make sure that I can find an ideal inertia. This was also with the solid disk style, which already requires more inertia than the rim style, so switching to a rim style for the increaser would allow the use of an even smaller flywheel.

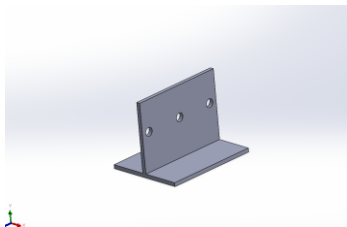
Solid Disk Style Results:

```
=== RESULTS ===
Hanging mass      = 0.200 kg
Pulley radius     = 0.0559 m
Linear acceleration = 1.1554 m/s^2
String tension    = 1.7309 N
Input angular accel = 20.6684 rad/s^2
Output angular accel = 73.4876 rad/s^2
Drop height       = 0.750 m
Drop time         = 1.139 s
|
STATUS: OK - drop time is in a useful lab range.
```

From everything that I have looked up the Pasco rotary motion sensor would definitely need more than 0.7 seconds in order to collect proper data, leaving option 3 as the best option and a potential for option 2 if there is room to increase the flywheel mass from 0.5kg.

After this switched modes to continue with some of the CAD ideas that were discussed.

- Trying a one plate housing design. This can be changed into two plates that are close together if necessary
- Am going to use keyed shafts
 - o Went on McMaster-Carr and found the aluminum keyed shafts and important it along with 608 bearings into SolidWorks so that I could use them for the new assembly



- Making the gear with a key, should I make the key apart of the gear or should I make the gear have a keyway itself, then design a universal key that fits in between. (Latter option leaves more room for mistakes with printing, going to try to make gear with key).

6/11:

Goal is to finish designing every part so I can send it in to be printed tomorrow and hopefully it will be available to me by Monday so I can start to put everything together and see what may need to be reprinted or what may need to be changed.

Talked to Prof Griffiths to update him about where I was and the problems with the inertia of the flywheel. He was completely supportive of me changing the system to a gear increaser instead of its current state as a reducer, and he was also in support of using the rim style flywheel so that it could be smaller yet still have significant inertia on the system. He suggested that I start printing soon, because there will be a lot of things that still need working out and will most likely need to be adjusted.

Designing today:

- Made 6 new gears. 2 Sets of the 18 teeth, 24 teeth, and 64 teeth, with one set being if the key was a part of the gear itself coming down from the bore, and the other set being if the gear had a keyway which another key could fit into
- Made a new pulley based off of the old one but with a keyway bore instead of the hex shape in the middle, other than that the same dimensions.
- Downloaded files from McMaster for both the keyway shaft and the key stock so that I can use those directly in my assembly
 - o For the key stock, I also designed one earlier because it was very simple and I may not want the exact dimensions of the ordered part.

Put in an order (courtesy of Nick) from McMaster Carr for the keyed shaft- 24inch and plan to split evenly into 3 shafts of about 8 inches (little less). Also ordered 12 inches of the key stock which will be cut into small segments of 1 inch. (These will be used in comparison to the 3d printed part to see which one works better for the lab).

Parts that I need to 3D Print:

- 4 Gears with Key
- 4 Gears with Keyway
- Keyway Pulley
- T Frame Design
- Shaft Coupler (for Pasco sensor)
- About 6 Key Stocks (One for each gear, then one for pulley and maybe flywheel)

Total: 17 items

Working on Flywheel

- Figuring out exact size that I want to start with (better to be on larger size if we want to cut)
- Trying to see if there are any good available pieces to buy
- If there is nothing to buy then trying to find something that I can download to SolidWorks and edit
- Figuring out the best material to use that gives me the proper moment of inertia
- Can I just use a pulley from McMaster ?

For starting to look and design parts, I am going to say the hanging mass in the experiment is 150g and that we are aiming for a flywheel with a mass of 0.25kg and a radius of 0.07m (or an inertia of $0.001225 \text{ kg} \times \text{m}^2$). This gives us a drop time of over two seconds and a linear acceleration of 0.27 m/s^2 which is good for the experiment.

6/12:

When I arrived, I went to talk to Hoyt about the 3D printing. All the printers were full, but he said as long as I verified that I had been granted access by Professor Dart (which I had from the work tag that was sent for Magen and me earlier, that I would be fine to use the printers.) Because he leaves at 12 every day, I won't be able to print today, but hopefully can send him the order and we can start the print early on Monday. The goal is to have the pieces hopefully by Tuesday so I can start an assembly. Hoyt also gave me some recommendations for how we could try to print the T-frame so that the holes are built in the best way possible because there were some concerns that Prof Griffiths expressed with how the print orientation may mess those up. On Monday I plan to go up and Hoyt will walk me through the printing process so I can also learn a thing or two. He also told me that for the things like gears and other parts, it should be easily possible to print them at the same time in the same printer, so hopefully that will help speed up the process.

Need to send in the work order with the different parts

Priority: (First 3 are honestly all of equal importance)

1. 4 Gears with the keyway
2. Pulley
3. T Frame
4. Coupler
5. 4 Gears with the key a part of bore
6. Key Stock (x6)

I have a friend who also works in a lab here who has a 3D printer at home, so I am going to try and send him the smaller parts to see if he can print those for me. Most likely the 6 key stocks and the coupler, and maybe the pulley if it seems possible.

For flywheel: Still aiming for a flywheel with a mass of 0.25kg and a radius of 0.07m (or an inertia of $0.001225 \text{ kg} \times \text{m}^2$). This gives us a drop time of over two seconds and a linear acceleration of 0.27 m/s^2 which is good for the experiment with a hanging mass of 200g

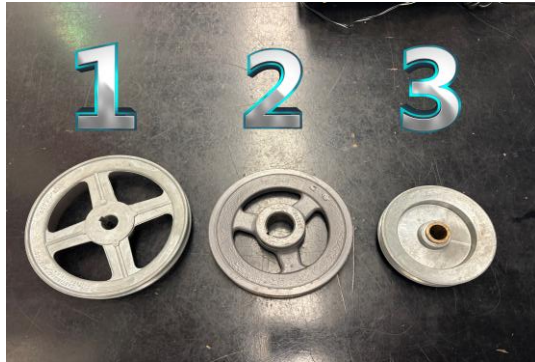
Nick told me that he had a lot of different parts and that I could potentially use some as a flywheel, so I went downstairs to take a look at those. They seemed promising

Flywheel 1: Mass = 0.5 kg, Radius = 0.075m, Drop time (200g) = 3.005s

Flywheel 2: Mass = .930 kg, Radius = 0.07 m, Drop time (200g) = 3.8s; Drop time (250g) = 2.4s

A little too heavy but, main concern is that it might cause imbalance in the system itself.

Flywheel 3: Mass = .360 kg, Radius = 0.05 m, Drop time (200g) = 1.765s; Drop time (150g) = 2.0s



Although the bore hole on all 3 is far too big, they all have screw slots that can be used to tighten them on the smaller shaft, and because I will probably not be able to order anything soon, this is a great option for testing how the gear train will behave with the hanging mass and knowing what flywheel mass I should aim for.

Went to the mail room to get the key stock and the keyed shaft. Both looked good but one concern I have is that the key stock is not really that tall, leaving not much room for the gear to work with. I may make the 3D printed key stock with a little more height to try and account for this.

Put in the order for the parts so hopefully prints can start on Monday and be ready by Tuesday

- Also sent some of the smaller parts to the friend so I can potentially have those by Monday

Began assembly for the parts in SolidWorks just to get a good idea for what the system will look like and to see a visual simulation of it while I wait to put it together.

6/14:

Started off with a meeting to give a quick update on what I have been doing and mostly what I want to get done before the end of the week. I need to pretty much print out everything and put it together, so I know what I need to change and can hopefully put together a functioning model before I leave or know what sizes I need to change to make the functioning model when I get back. Also need to cut the parts that got delivered.

- From Prof Griffiths: Need to make support for the sensors, also probably need a shaft adapter for the flywheel parts that I got for Nick to help them stick to the shaft.

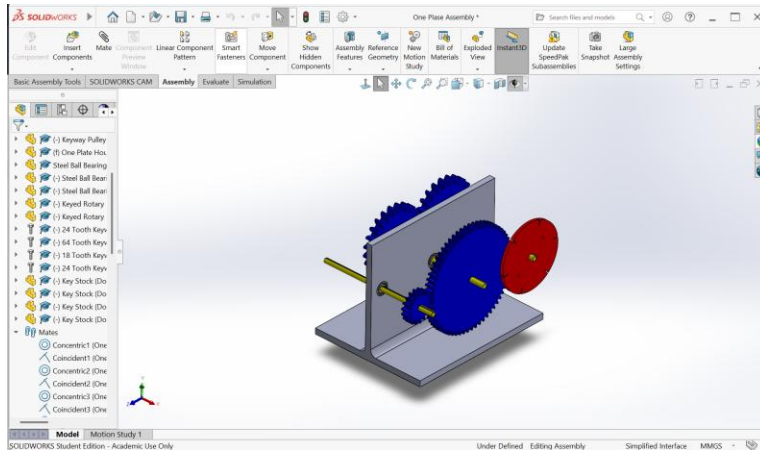
After meeting, Nick took me to go see Kemal, who cut my shafts into 3 parts around 8in each and my key stock into 6 parts about 2in each.

After this I collected the parts my friend had printed for me, which included the shaft coupler and 6 more key stock that were about 1in long each.

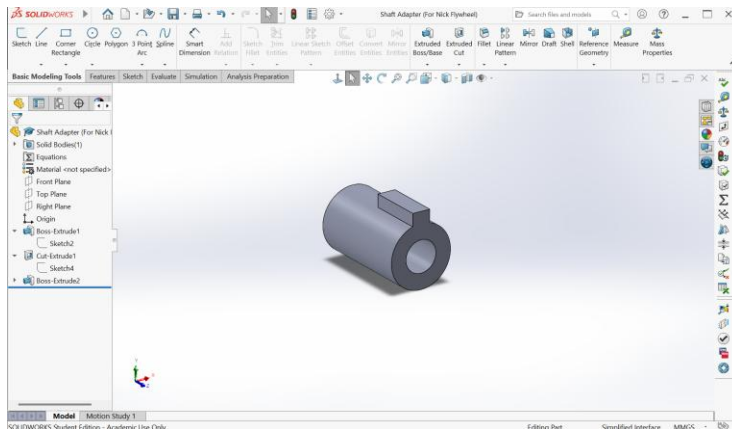
After this, I went to go too Hoyt, who walked me through 3D printing with my own parts. The ones I had for this first order included the T-frame design, 4 gears that needed the key stock to attach to the shaft, and the pulley. We printed the frame on its side for this first print to see if that would come out alright, and for the gears, we made it 100% infill only around the center where the key hole was, because that part would be experiencing the most force, and we did not want to risk it not being strong enough.

Tested the coupler for the shaft and sensor; it fit, but it was rather tight and also made the rotation not centered. Will probably need to redesign for a better test.

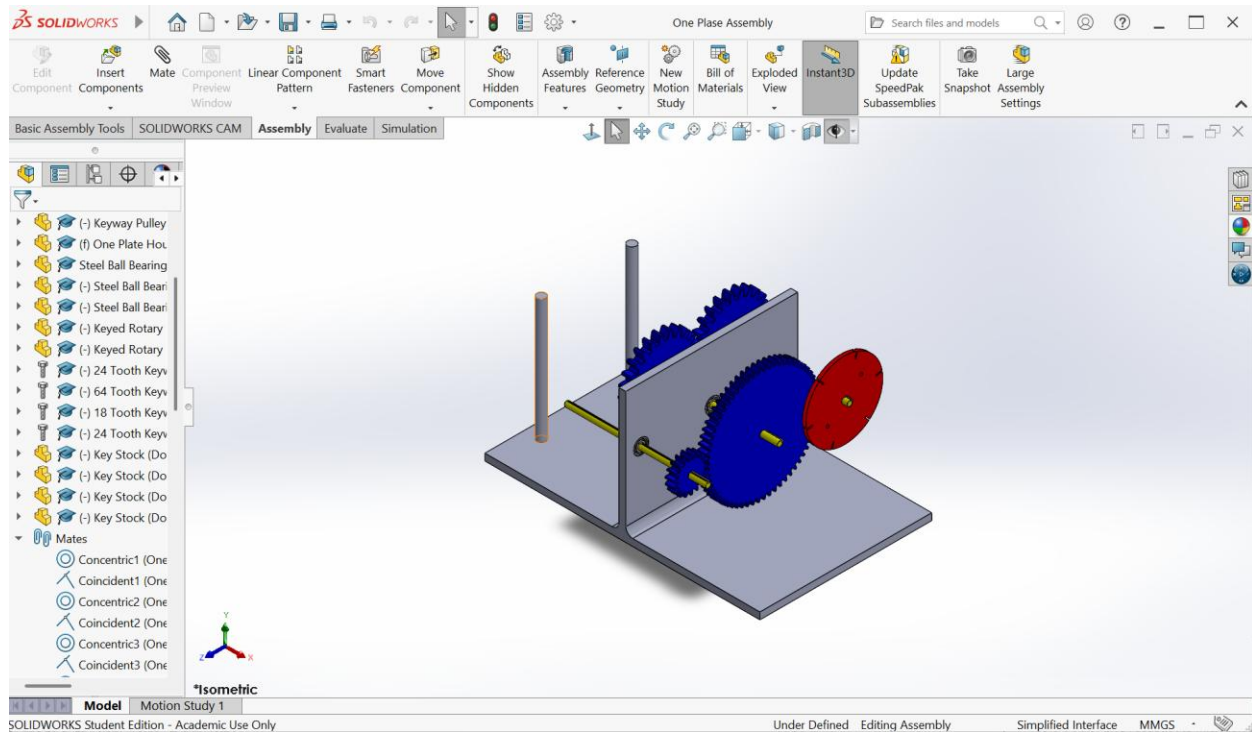
Completed the CAD assembly and ran a motion study just to see the components work together in real time. Hopefully I can use this to test out more studies and get a better visual simulation that will help me.



Modeled the shaft adapter to connect one of the flywheels I got from Nick to the shaft. Based on this design, it would have to go on the same side of the shaft as the 18 tooth gear, which is not that much of a problem but different from my original design idea. I made it with a key attached so that it can fit into the flywheel keyway easily and I modeled the rest of the design as a copy to my shaft coupler which worked decently but I changed some of the dimensions so that it would hopefully be a better fit.



Modeled some supports for the sensors for the T-frame design



Submitted order for 4 Gears with Key part, shaft adapter, and a new shaft coupler. Based on what I noticed from my 3D printed key stocks, I decided to make the new coupler with smaller dimensions and reduce the dimensions for the keystock part on my gears with the keystock as a part of the gear. I then added these all to a new order to print which I should hopefully have my Thursday.

6/17:

First went to collect that parts that I ordered yesterday and Hoyt invited my up to help print them. This contained the T-frame, 4 gears with the keyway slot, and the pulley.

Unfortunately, all of my holes and keyways were too tiny on the gears, and even the holes for the t-frame were too small. It was expected that things would not go perfectly on the first print, so I adjusted all of the dimensions and sent in another order for printing.

On the keyway gears and pulley:

- I changed the width from 0.09375 inches to 0.098 in
- I changed the height from 0.046875 inches to 0.05 in
- I changed the bore hole from 0.3130 inches to 0.3220 inches

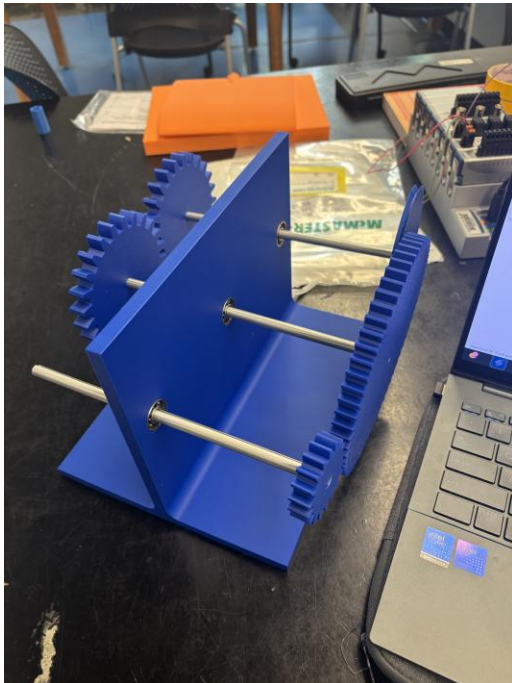
On the T-frame design:

- I changed the bearing holes from 22.02 mm to 22.15mm

I liked the structure of the T-frame design, it was bigger than I thought which was good because I was a little worried it would be too small, and the fillet on the sharp corners that I added looked really good and helped the entire thing to feel pretty durable.

Did a lot of flywheel research both general and related to my design. Continued to work on the flywheel in SolidWorks and test some of the downloaded files so that I can add it to my assembly and find something that would be a good base to change so that it can potentially be cutout for the future.

Used an arbor press to fit the bearings into the T-frame that I had already printed. With this design the bearings actually press fit perfectly into the frame, and I was able to set up a first prototype for the lab design by forcing the shaft into my gears that were too small.

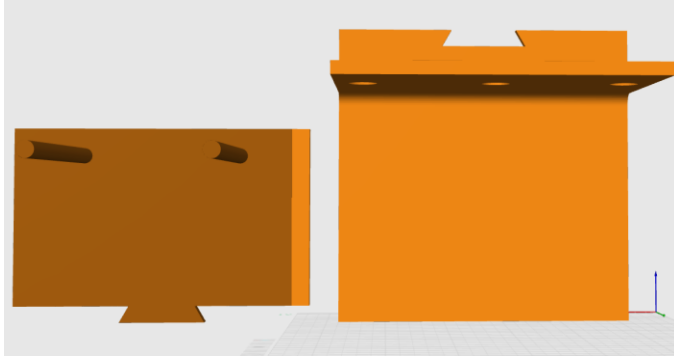


- Main concern is that T-frame may not provide enough balance to the shafts. They are already loose enough to slide in and out of the bearing with no concern, and I notice that they wobble very slightly while they are in place. The two plate design would solve this if it does prove to be a major problem.

6/18:

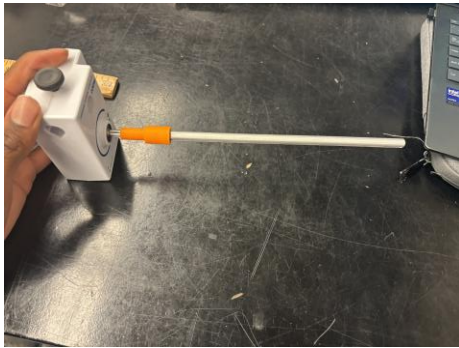
Realized that for my key gears that I plan to pick up today, I did not change the bore hole to 0.3220in like I did for the keyed ones once I realized my first print was too small. So, before picking up the gears with the key stock a part of them I submitted another order that makes the bore size larger so that hopefully Hoyt can submit the print before he leaves at 12 and I can have it by Friday.

Hoyt informed me that the new T-frame design that I had made, the one with the cylindrical supports for the sensor, was too big to print. He suggested that I use a dove tail so that I can split the frame into two parts, then assemble them after they print. This worked for me and I agreed, so that is the way that we are proceeding with the frame.



The shaft adapter was printed and collected today, and although the key size seems to fit the flywheel that I got from Nick, the bore sizes do not match up, and it does not fit even enough for me to jam it in. I need to redesign another one with a slightly smaller hole diameter.

The new shaft coupler that was printed seems to be working well. I am considering making another that is slightly looser at both the shaft hole and the hole for the sensor shaft, but this one looks good and is a tight fit which is what was desired.



Sensor shaft connected to gear train shaft via coupler

6/19:

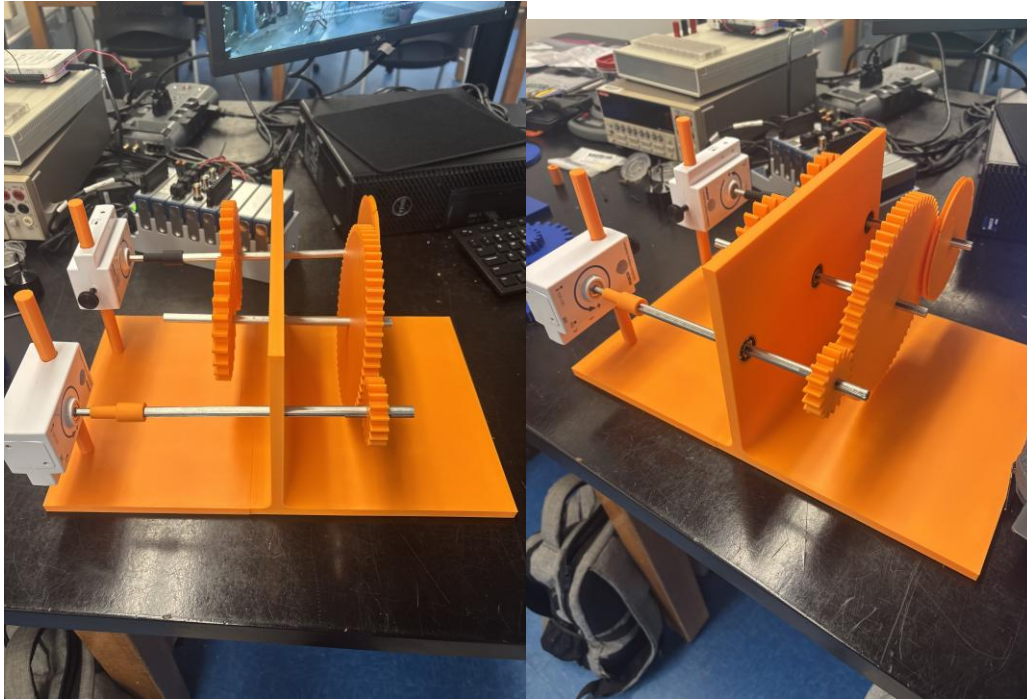
Was just planning to do some final touches and updates today because Hoyt told me that the orders would not be ready until Monday, but I got an email saying that both of my last orders which were my most recent ones were ready, so I came to see if the updated sizes were correct and if I could put everything together.

Thankfully the bearings that I had used the arbor press to get into my last T-frame design popped out easily, so I can use them in this new one.

For the initial fitting (Nothing connected just testing the shaft and gears):

- The keyed gears fit perfect and the key stock fits through it as well successfully connecting them to the rod and allowing them to rotate as one. The gear with the key
- The gear with the keys do not fit as well, while you can get the shaft in, the hole is big enough for the shaft to slide all the way through. I am going to try and use a file to see if I can help that and make it easier to slide through.

Because of this to put together a functioning prototype I need to use the keyway gears, which is the ones that I prefer anyways. Everything went together and fit, and the first official prototype has been put together!



A few notes:

- I had to use the old shaft coupler (black) to connect the second sensor because I had not printed two of the new ones that fit a lot better
 - o I will print another copy of the new coupler (orange) as well as a couple more slightly bigger as I discussed earlier.
- The gears on the shaft with the key stock move side to side very easily, so I will need to buy a shaft clamp or figure out a way to keep them in place
- While the input and output shaft are now very stable because of the sensors that are attached, the middle shaft is not completely stable. This may not be a big problem and doesn't affect the movement of the system right now, but may be something that needs fixing in the future.

To-do (before and when I get back):

- Design and put in print order for 3 more shaft couplers
 - o 1 as a copy of the current (orange) one, and 2 as the new bigger bore design
- Put in print order for new shaft adapter
- File down the gears with the key so that hopefully they may fit and I can test them
 - o If not, design a new key gear design that has a more room for the shaft (larger bore hole)
- Organize all of my files so I have a clear idea of where everything is and maybe also add them to the box file
- Continue to look at how I can design the flywheel and try to edit some downloaded files so that I can have something to model after.

Last things I did before leaving:

- Made a new shaft coupler
- Made a new adapter

- Made new keyed gears with bore size changed from .3220in to .3240in
- Did all the orders (3 couplers, 4 gears, 2 adapters)

7/14:

First day back, started off with the check in meeting. Showed Prof Griffiths and Forman my progress and what I had completed before I left for vacation, and gave them a run down of what I planned to get done in the future and what was left.

The last thing that I had gotten done was putting together a prototype for the entire gear train system. The prototype is on the table and available. The main things that need to be fixed are the middle shaft and figuring out a way to keep that stable, and figuring out a way to keep the gears in place on the shaft so they don't slide back and forth so easily. The best way to do this is to probably design something or order clamps like Prof Forman suggested (like gym bench clamps). I need to test the new shaft couplers to see which ones work best for my sensors. There should be two of each pair (4 total) that I can test to see which one I like best. I also need to make sure that my sensors are lined up properly which they seem to be but just to make sure. I also have printed 4 new key gears. I have 4 old ones that were just printed, so I will need to decide if these new key gears are better, or if I should just take a file and work on the old ones so that they work.

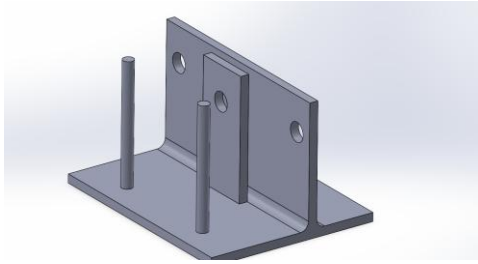
In terms of the future: The one thing I do need to work on is adding my flywheel to the design using the shaft adapter, then seeing how the system works and moves with that on. I then need to start testing, which I will definitely need to ask Professor Griffiths about the testing is first to figure out what I need to change, then to see if it tests for what I want and what other factors are involved, then to see if the lab goes how I want and can be carried out by a student.

After talking to both professors, a main thing that needs to be changed/improved is the overall sizing of the frame. There are a lot of different parts that can be cut off so that the whole design is more portable and looks a little better as well. A big part of this would be cutting down on the shaft size, because realistically there is no need for the shaft to be that big, I had just modeled it after the same size that the previous shaft was. Making the length smaller would also help how the lab itself gets carried out and allow the whole thing to run much more smoothly.

In order to keep my one plate design, the best solution for that would be to add another support that has a hole for a bearing in between the two poles for the sensor. It does not need to be large and it would just ensure that the middle shaft is stable, if making the shafts themselves smaller does not already solve that issue.

The new key gears that I printed out fit onto the shaft, but they were not as smooth as I wanted them to be or as the keyway gears were. Instead of reprinting, I think that I am going to stick with the keyway gears for now. They allow an easier removal of the gears and there is less worry about how the friction over time of taking the gears on and off the shaft will affect them.

Modeled a new frame design based on the recommendations from the meeting and different improvements I mentioned. Sent the part to be printed, and hopefully it will be available by Thursday.



7/15:

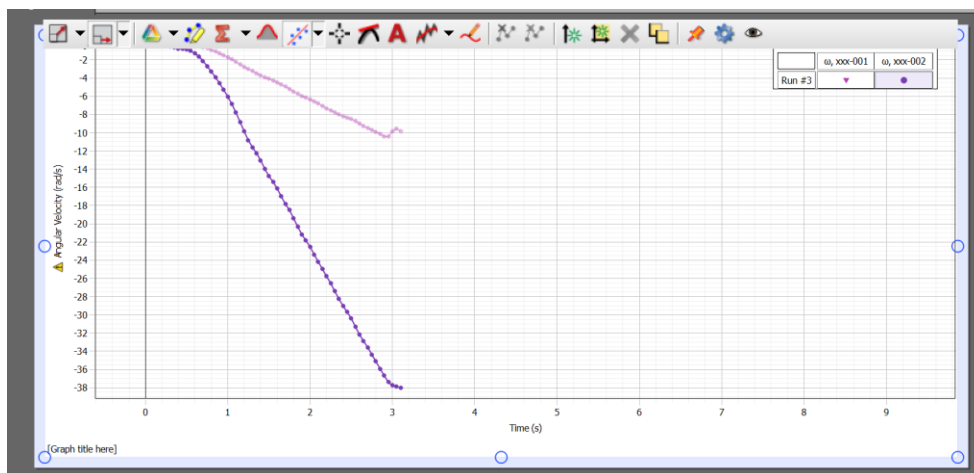
Order is processed and printing for the new frame design

I decided to take another look at the key gears and file them down so that they could potentially fit without having to worry about another reprint, and they did. So now I have two sets of gears, key and keyway, that work with my shafts and that I can use to test.

I put my prototype back together, because while I wait for the new design to be printed, technically the current one is fully operational although it needs a lot of improvements. So, I decided to test and see if the prediction that I had based on the simulation was accurate, and to see if the system would run somewhat smoothly. It did, and the drop time was 2.4 seconds versus the predicted 3.005 seconds that the MATLAB simulation said. This to me was a very good sign, there were many factors that may have slowed down the time by 0.5 seconds, such as friction that wasn't accounted for (I think this was the main reason), and also the fact that the radius of the flywheel I am using was not the exact number that was in the simulation due to it being hard to measure, and the radius plays a big role in the final drop time.

Another note is that for this simulation I used to key gears that I filed down earlier, I wanted to test and see how well they would work. They worked very well, and moved back and forth easily but were not as loose as the keyway gears. The pulley still used a key and keyway, but I think I may prefer these gears over the keyway ones.

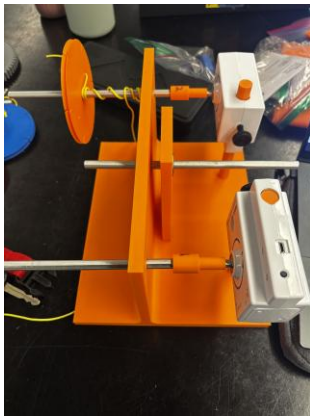
I ran the Pasco experiment for this setup, just checking to see if the sensors would record properly. Everything worked, and I was even able to measure the angular velocity and take the slope of that. Tomorrow I will be setting up the new frame hopefully and then truly evaluating the numbers I get to see if they are what I am looking for. Today proved that everything should be measurable and work properly.



This is what one of the trials looked like (the other two were similar). I realized that it has a negative slope because of the way my sensors were orientated, so on the actual trials that will be fixed but the data was collected smoothly.

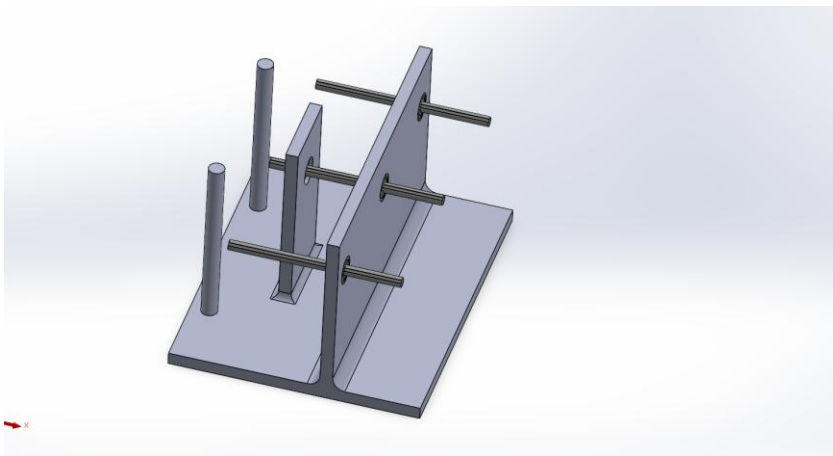
7/16:

Today I collected the new frame, but I ran into a pretty big issue. Because I was so focused on reducing the size of the system and cutting off unnecessary parts, I ran out of needed space. There was no room to add my gears on the side with the sensors and the support, because everything was too close together. This would prevent me from testing all together and is a direct result of me failing to make an assembly of the frame and shafts before printing. I rushed the process a little.



The design did seem much sturdier than the last, so that was a very good sign. The middle shaft looseness problem seems to be fixed with this design.

To not make the same mistake again, I made some adjustments in SolidWorks to fix the issue. I moved the support for the sensors back a little, and I also moved the support for the middle shaft further away from the main wall. This keeps the overall size of the design the same but will allow room between supports to add the gears in so I can run actual trials.

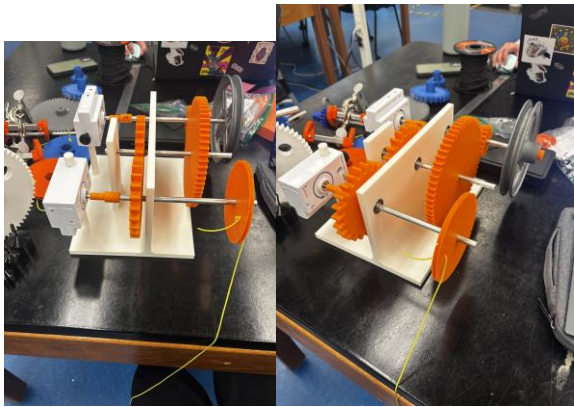


Fixed Design w partial assembly

I ordered the new frame, and hopefully I will be able to have and use that by Monday. For now, I will continue to use the first old design to see if I can collect some better data and get some more numbers to play with.

7/20:

Collected the new design which was ready for me to use and set it up by transferring the bearings and shaft from the previous design to this new one.



- For some reason in this design, the shaft that was connecting the 64 tooth gear to the 18 tooth one was a little too close. Not enough that the system wouldn't run but enough that it wouldn't run as smoothly as I would like.
- I had not touched this dimension since my first print of the frame, and this was not an issue for the other 3 old prints so I assumed that it was just a printing error and I put in another order for the frame to be reprinted.

Despite the flaw, I was able to test with this design anyways and I figured that the tests would still be useful and that the design flaw could just be an error.

I ran three trials of dropping the 200g weight from the system. For all the trials I tested I got a linear portion which represented the fall and it was enough that I could highlight and take the slope of in order to determine angular acceleration. The output shaft represented the line with the larger slope, while the input shaft was usually not quite as large.

	Trial 1	Trial 2	Trial 3
Angular Acceleration (Output Shaft)	19.5	84.6	87.3
Angular Acceleration (Input Shaft)	5.66	20.4	23.7

Using these values, I then can take the output angular velocity/input angular velocity to find the gear ratio for each trial.

Trial 1: $19.5/5.66 = 3.445$

Trial 2: $84.6/20.4 = 4.147$

Trial 3: $87.3/23.7 = 3.684$

Avg: = 3.76

The theoretical gear ratio for this lab was 3.556, so we have a percent error of 5.74%.

Having a percent error this small when running the experiment on a design that is not even the final design yet is a fairly good sign, and hopefully after running more tests it can become even more realistic.

7/21:

When going back and looking at the pasco trials, although there was enough time to record data, I think that there could still be some improvements in that area. The linear section that gets recorded is from about 1.2 to 2.0 seconds, sometimes less than that, so using a smaller weight could improve the recording time to make the data a little easier to extract.

Had the usual check in meeting at 10 and showed the progress that had been made so far up to the trials. I am going to do different tests of different things that I can measure to see what my data tells me about the system.

- Different weights
- Flywheel on the input shaft
- System running without any gears and just the flywheel
- Torque calculations

I also need to figure out ways that I can test the output torque without necessarily using a load cell or a pasco sensor to measure the actual shaft.

The most important thing in this lab to test for is the overall efficiency of it, which is figured out from comparing the input power to the output power and seeing if there is a significant difference between the two.

For a good amount of the day we met with Maria and I helped them work on providing a way to help the uva accelerate high school students have the best way to be able to design and test air foils using the sting attachment process Magen and David had been working on. Also learning how to create an airfoil from scratch in solidworks.

I ran trials with the 100g weight, and here are the results

	Trial 1	Trial 2	Trial 3
Angular Acceleration (Output Shaft)	4.95	5.27	6.27
Angular Acceleration (Input Shaft)	1.40	1.49	1.76

Trial 1: $4.95/1.40 = 3.535$

Trial 2: $5.27/1.49 = 3.536$

Trial 3: $6.27/1.76 = 3.562$

Avg: = 3.545

This gives a 0.3 percent error, which is significantly less than the 3.76 percent error when I tested with the 200g weights. From this I think that it is safe to say using a lighter weight is better to produce cleaner and more accurate data. The 100g dropped at a perfect time too and took a little over 2 seconds to hit the ground, which when testing felt like plenty of time.



Here are the two trials from the last two days. The top is one of the trials from today with the 100g weight and bottom is the trial from yesterday with the 200g weight. As you can see, the top is much cleaner and easier to extract data and obviously was a larger drop time.

In order to calculate power and see that, I am going to use the 100g trials to find my average output and input angular velocity from first finding the average in each of the three trials, then taking the overall average.

The first thing that I need to do is calculate the torque. The only thing I need to find is the input torque, then I can use the average gear ratio from my 3 trials to find the output torque.

Then using the angular velocity and torque for the input and output that I will have, I can then find the input and output power, then from there I can calculate the efficiency.

7/22:

Most updated frame is ready for pickup, but I think I may have figured out the issue and realized that I do not even need a new frame to fix it. I believe that problem is that my gears are on the wrong shaft, because based on their different sizes, the 24 to 24 connection needs to be at a different distance than the 64 to 18 connections. The difference is small (about 104 mm to 101mm), so it makes sense that the system would still run even if I messed up this part.

As it turns out, doing this means that I will be recording the data negatively due to the way that the sensors would rotate once I fix this, so I made the necessary adjustments by flipping the distance of the holes on my drawing and I sent this design in to print (which hopefully should be the last frame print I need to do for now).

I completed the calculations for the efficiency which I walked through the steps of how I would do that yesterday.

Torque Calculations (100% Trials)

	Trial 1	Trial 2	Trial 3
Avg. Output (100g)	10.166	10.717	12.260
Avg. Input (100g)	2.925	3.092	3.465

Angular Velocity

Total Avg Output: 11.047 rad/s
Total Avg Input: 9.342 rad/s

Find: Falling Mass Acceleration: Input shaft (ω): 1.40, 1.49, 1.76
Avg: 1.55 rad/s²

$a = \omega \cdot r = 1.55 (0.0895\text{m})$
 $a = 0.056614 \text{ m/s}^2$

Torque Calculations

Input Torque: $T \cdot r_{\text{pulley}} = m(g-a) \cdot r_{\text{pulley}}$
 $= 0.1\text{kg}(9.81 - 0.056614) \cdot 0.0895\text{m}$
 $T_{\text{input}} = 0.05433 \text{ N}\cdot\text{m}$

$T_{\text{output}} = T_{\text{input}} / e = 0.05433 / 3.345$
 $T_{\text{output}} = 0.01533 \text{ N}\cdot\text{m}$

Power Calculations

$P_{\text{input}} = T_{\text{input}} \cdot \omega_{\text{input}} = 0.05433 \cdot 9.342 = 0.50972 \text{ W}$
 $P_{\text{output}} = T_{\text{output}} \cdot \omega_{\text{output}} = 0.01533 \cdot 11.047 = 0.16935 \text{ W}$

$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \cdot 100 \Rightarrow \frac{0.16935}{0.50972} \cdot 100$
 $= 33\% \text{ (Pretty low)}$

The final efficiency was 33% (if my calculations were right),

which is not very good for a lab gear train.

I plan to run more trials with the frame setup that does not have the shaft spacing issue, and I am also going to make a code simulation in MATLAB so that I can just plug in the numbers from my different trials and see how the efficiency changes as quickly as possible.

Met with Prof. Griffiths to show the new progress and get a good update on what the next steps for the lab should look like.

He said that he was actually not too disappointed with the 33% efficiency result, because that actual shows that the design is doing something right rather than getting an efficiency of 100% or more which would be impossible and seriously wrong.

The main timeline and also sort of rough outline for what the students do is testing the setup without any gears and just the flywheel and torque from the pulley to determine the moment of inertia of the flywheel, then adding in the gearbox and using the gear ratios and things to provide a prediction and eventually find the efficiency of the entire design.

- Testing angular position, angular velocity, and angular acceleration versus time.
- Seeing different ways to find the power (directly from the angular velocity on pasco or another way)
 - o Prof Griffiths worried about the way pasco collects the data and if that would be the best way or if it would be too noisy.

I made a code that I could plug trial numbers into to help with the calculations to find efficiency so that I do not have to do it by hand every time, and to test it I plugged in the same numbers that I used for the hand calculation in the most recent image above. However, when I did this is got a 99% efficiency which was very

different obviously from the 33% efficiency I had previously gotten. A few hours ago this would have made me happy but after talking to Prof Griffiths I realize that this is not a good thing at all.

- It violates the second law of thermodynamics
- Its impossible, which means something in my trials or calculations was wrong, or my methods were wrong.

After some troubleshooting, I traced the problem down to the method I used to determine the output torque. All of the numbers and values I had gotten had been measured, none of them theoretical. However, by using the gear ratio in order to calculate the output torque. Because my gear ratio from using w-out/w-in is already extremely close to my actual gear ratio, the efficiency is always going to produce a number that is close to 1.

- The solution is to either change the formula I use to calculate efficiency, or actually measure the output torque from my system rather than using a formula to get it.

By doing the setup that Prof Griffiths wanted me to do and isolating the output shaft and running tests to figure out the inertia, hopefully that will solve both of these problems. I can use the inertia and angular acceleration measured to figure out the output torque, and then plug this back into the efficiency code.

7/23:

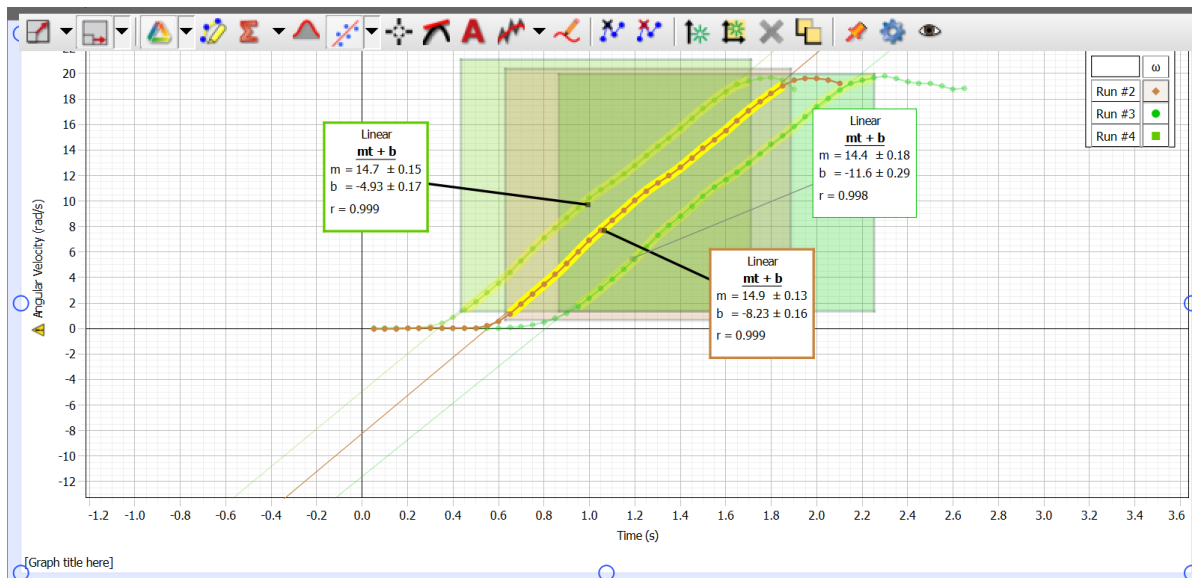
Running the isolated experiment, then rerunning the full experiment so that we can have more accurate numbers to use and plug into the efficiency calculator.

I updated my code so that it no longer uses the gear ratio to find output torque but instead uses the moment of inertia from the isolated testing and then the average angular acceleration from the full setup to then calculate the proper output torque.

The known torque for the isolated system is 0.0274 (Nxm), and the input torque for the full system is 0.054334 (Nxm).

For the isolated trials, my 3 angular acceleration values were 14.7, 14.9, and 14.4 which I will plug into the calculator and it will provide me the moment of inertia at the output by using the average of these three values and the known torque.

- **The output moment of inertia is 0.00186818 kg*m²**



Isolated flywheel testing data

For the rest of the day we went with Maria and met Prof. Forman at the CAB and got a tour of the entire place.

7/24:

To start the day, we met Maria up in the Capstone workspace and Hoyt gave us all a rundown on Bambu Studio and how to print a part, so we could better assist Maria this and next week with her class and the activity she wanted to do with them. We each printed our own parts to get a basic knowledge of how and what to do.

After this I collected my new and hopefully final design, and I put the bearings in with the shafts and attached the gears. Both problems were successfully fixed and this design allows the gears to mesh smoothly and the sensors to record the data positively.

- I am going to keep the isolated data the same with the last frame setup and only use this frame for the full testing.

Full Testing

Angular Velocity (rad/s):

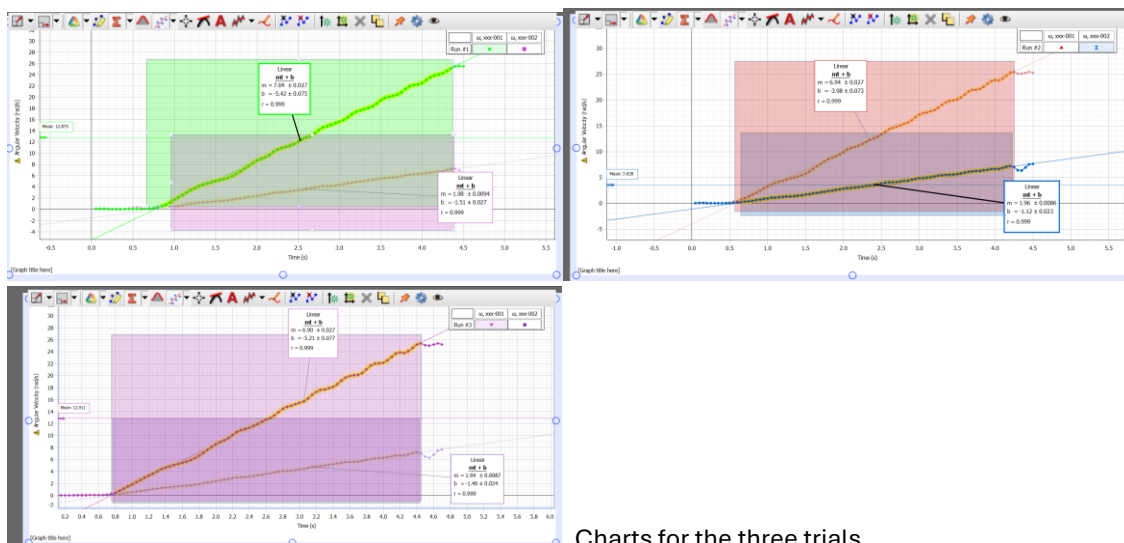
	Trial 1	Trial 2	Trial 3
Output Shaft	13.227	12.846	12.911
Input Shaft	3.786	3.628	3.600

Angular Acceleration (rad/s^2):

	Trial 1	Trial 2	Trial 3
Output Shaft	7.04	6.94	6.90
Input Shaft	1.98	1.96	1.94

After plugging these numbers along with the numbers from the isolated experiment into the efficiency calculator:

- The input power was 0.199009 W
- The output power was 0.168964 W
- And the final **efficiency = 84.90%**



Charts for the three trials.

7/27-7/28:

Really only brainstorming good ideas for how the lab could be carried out. What should the students be testing for and what would be the easiest but also most beneficial procedure.

7/29:

Went through a lab procedure that I generated to see how feasible and good it would be.

Had to calculate a theoretical input and output angular acceleration (what the students would have to calculate with some numbers provided).

- From the theoretical calculations:
 - Input angular acceleration of 1.636 rad/s^2
 - Output angular acceleration of 5.817 rad/s^2
- The values I got from my trials were 1.96 for input and 6.96 for output.
- The main issue with this is that it does not make sense for the calculated to be more than the theoretical, because factors like friction should actually be slowing my system down.
 - I believe this is due to the fact that the flywheel is not accurately modeled in my theoretical, and I had to use an estimation because I do not know the actual moment of inertia of my flywheel.

Another comparison the students would most likely make would be the torque ratio comparison.

- When it is calculated, the net output torque is $0.01504 \text{ N} \times \text{m}$
- The value is got experimentally was $0.013003 \text{ N} \times \text{m}$
- The input torque from the pulley and mass is $0.054206 \text{ N} \times \text{m}$