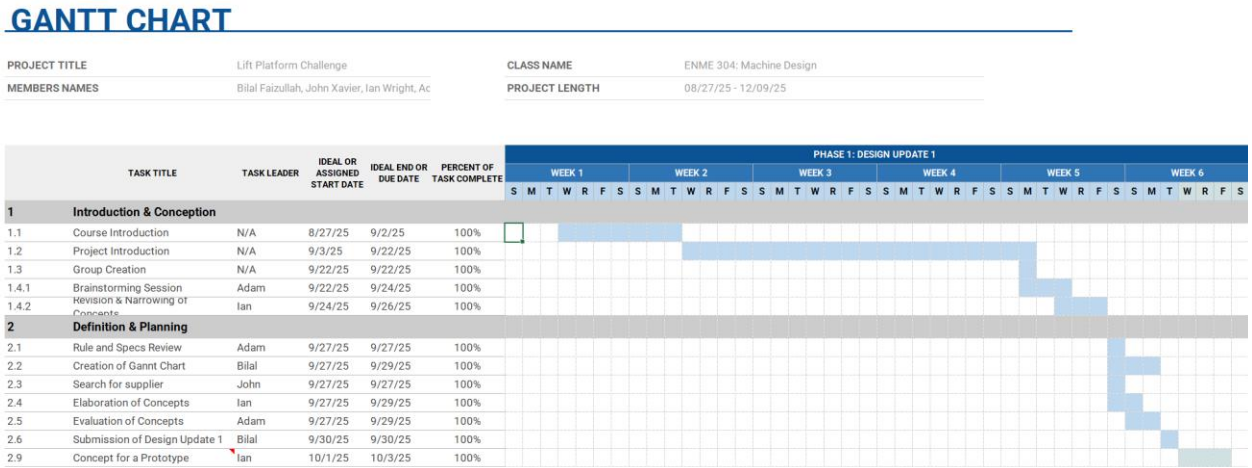
# ENME 304 Machine Design
# Design Update 2
# Professor Janelle Clark
# 10/26/25

Group 10 Members-
Adam Beall
Bilal Faizullah
Ian Wright
John Xavier

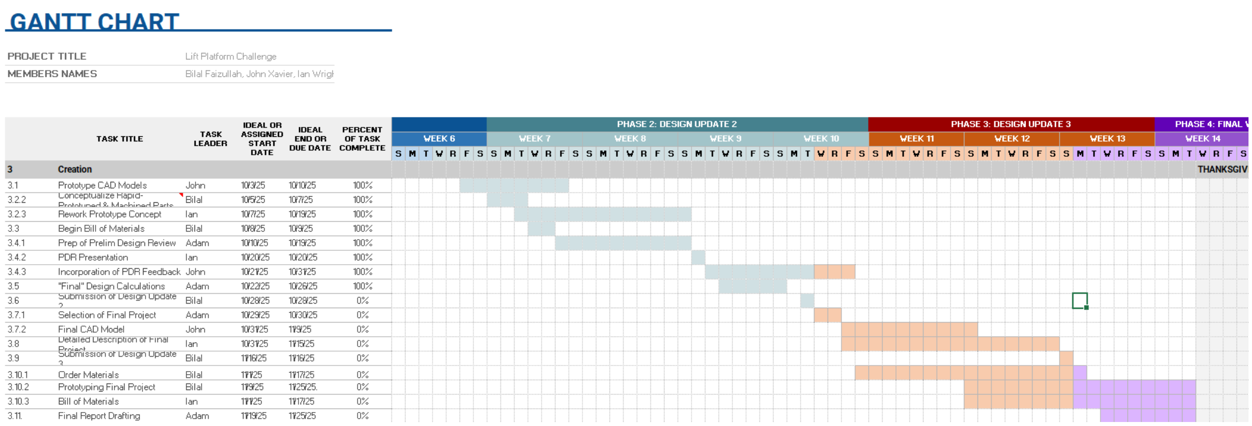
# Gantt Chart




| PROJECT TITLE | Lift Platform Challenge | CLASS NAME | ENME 304: Machine Design |
|---|---|---|---|
| MEMBERS NAMES | Bilal Faizullah, John Xavier, Ian Wright, Ac | PROJECT LENGTH | 08/27/25 - 12/09/25 |

| | TASK TITLE | TASK LEADER | IDEAL OR ASSIGNED START DATE | IDEAL END OR DUE DATE | PERCENT OF TASK COMPLETE |
|---|---|---|---|---|---|
| **1** | **Introduction & Conception** | | | | |
| 1.1 | Course Introduction | N/A | 8/27/25 | 9/2/25 | 100% |
| 1.2 | Project Introduction | N/A | 9/3/25 | 9/22/25 | 100% |
| 1.3 | Group Creation | N/A | 9/22/25 | 9/22/25 | 100% |
| 1.4.1 | Brainstorming Session | Adam | 9/22/25 | 9/24/25 | 100% |
| 1.4.2 | Revision & Narrowing of Concepts | Ian | 9/24/25 | 9/26/25 | 100% |
| **2** | **Definition & Planning** | | | | |
| 2.1 | Rule and Specs Review | Adam | 9/27/25 | 9/27/25 | 100% |
| 2.2 | Creation of Gannt Chart | Bilal | 9/27/25 | 9/29/25 | 100% |
| 2.3 | Search for supplier | John | 9/27/25 | 9/27/25 | 100% |
| 2.4 | Elaboration of Concepts | Ian | 9/27/25 | 9/29/25 | 100% |
| 2.5 | Evaluation of Concepts | Adam | 9/27/25 | 9/29/25 | 100% |
| 2.6 | Submission of Design Update 1 | Bilal | 9/30/25 | 9/30/25 | 100% |
| 2.9 | Concept for a Prototype | Ian | 10/1/25 | 10/3/25 | 100% |

Figure 1: First of three Parts of the Gantt Chart




| PROJECT TITLE | Lift Platform Challenge |
|---|---|
| MEMBERS NAMES | Bilal Faizullah, John Xavier, Ian Wrigl |

| | TASK TITLE | TASK LEADER | IDEAL OR ASSIGNED START DATE | IDEAL END OR DUE DATE | PERCENT OF TASK COMPLETE |
|---|---|---|---|---|---|
| **3** | **Creation** | | | | |
| 3.1 | Prototype CAD Models | John | 10/3/25 | 10/10/25 | 100% |
| 3.2.2 | Conceptualize Rapid-Prototyped & Machined Parts | Bilal | 10/5/25 | 10/7/25 | 100% |
| 3.2.3 | Rework Prototype Concept | Ian | 10/7/25 | 10/19/25 | 100% |
| 3.3 | Begin Bill of Materials | Bilal | 10/8/25 | 10/9/25 | 100% |
| 3.4.1 | Prep of Prelim Design Review | Adam | 10/10/25 | 10/19/25 | 100% |
| 3.4.2 | PDR Presentation | Ian | 10/20/25 | 10/20/25 | 100% |
| 3.4.3 | Incorporation of PDR Feedback | John | 10/21/25 | 10/31/25 | 100% |
| 3.5 | "Final" Design Calculations | Adam | 10/22/25 | 10/26/25 | 100% |
| 3.6 | Submission of Design Update 2 | Bilal | 10/28/25 | 10/28/25 | 0% |
| 3.7.1 | Selection of Final Project | Adam | 10/29/25 | 10/30/25 | 0% |
| 3.7.2 | Final CAD Model | John | 10/31/25 | 11/9/25 | 0% |
| 3.8 | Detailed Description of Final Project | Ian | 10/31/25 | 11/15/25 | 0% |
| 3.9 | Submission of Design Update 3 | Bilal | 11/16/25 | 11/16/25 | 0% |
| 3.10.1 | Order Materials | Bilal | 11/1/25 | 11/17/25 | 0% |
| 3.10.2 | Prototyping Final Project | Bilal | 11/9/25 | 11/25/25. | 0% |
| 3.10.3 | Bill of Materials | Ian | 11/1/25 | 11/17/25 | 0% |
| 3.11. | Final Report Drafting | Adam | 11/19/25 | 11/25/25 | 0% |

Figure 2: Second of three Parts of the Gantt Chart

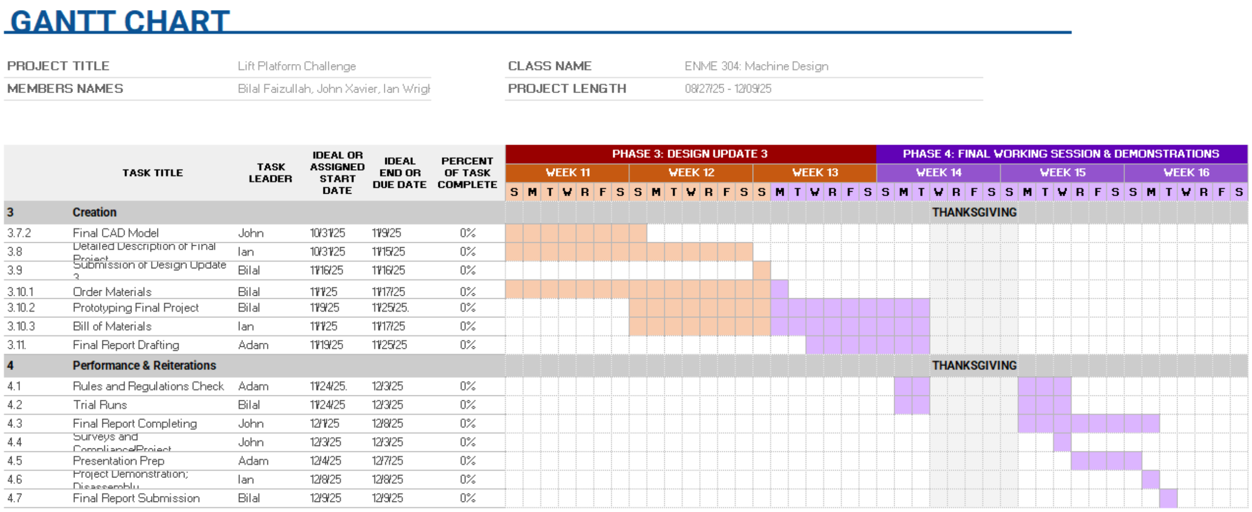



Figure 3: Second of three Parts of the Gantt Chart

# Bill of Materials

| | Item Name | Item Description | 3D Print Volume | Individual Cost | Quantity Needed | Total Cost |
|---|---|---|---|---|---|---|
| 1 | L Brackets | 7.9 inch L bracket with 10 drilled holes | N/A | $16.99 Pack of 4 | 2 packs | $33.98 |
| 2 | Washers | Spacer for Pivots under potion | N/A | $8.00 pack of 100 | 1 pack | $8.00 |
| 3 | Nuts #8-36 | Fastener for 8-36 Screws | N/A | $3.17 pack of 100 | 1 pack | $3.17 |
| 4 | Hex-Screw #8-36 7/8 inch long | | N/A | $10.46 Pack of 10 | 2 pack | $20.46 |
| 5 | Gear Train Bracket | | 14.49 in^3 | $0.82 per in^3 | 14.49 in^3 needed | $11.87 |
| 6 | 12 Tooth Plastic Gear | 12 tooth Plastic Spur Gear | N/A | $4.30 | 3 | $12.90 |
| 7 | 24 Tooth Plastic Gear | 24 tooth Plastic Spur Gear | N/A | $4.33 | 1 | $4.33 |
| 8 | 36 Tooth Plastic Gear | 36 tooth Plastic Spur Gear | N/A | $5.60 | 1 | $5.60 |
| 9 | 60 Tooth Plastic Gear | 60 tooth Plastic Spur Gear | N/A | $8.81 | 1 | $8.81 |
| 10 | Gear Train Shafts | Gear Shaft to Machine down to Proper size | N/A | $82.22 | 1 | $82.22 |
| 11 | Top Plate | Flat Top plate for scissor lift to hold objects | N/A | $12.21 | 1 | $12.21 |
| 12 | Step Down Shaft | axle for Central pivot and slides | N/A | $26.67 | 1 | $26.67 |
| 13 | Perferated Metal Flat | 3ft long sheet with perferated holes down it | N/A | $12.98 | 1 | $12.98 |

Figure 4: First of two Parts of the Bill of Materials

| Ordered | Arrived | Marerial | Part # | URL |
|---|---|---|---|---|
| No | No | Stainless Steel | N/A | https://www.amazon.com/Bracket-ULIFESTAR-Corner-I |
| No | No | Carbon Steel | 92141A223 | https://www.mcmaster.com/products/flat-washers/ger |
| No | No | Stainless Steel | 90480A185 | https://www.mcmaster.com/products/fasteners/threac |
| No | No | Stainless Steel | N/A | https://www.grainger.com/category/fasteners/bolts-sc |
| No | No | PLA | N/A | N/A |
| No | No | Durcan Acetal M90-44 Plastic | N/A | https://www.khkgears.us/catalog/product/DS1-12/ |
| No | No | Durcan Acetal M90-44 Plastic | N/A | https://www.khkgears.us/catalog/product/DS1-24/ |
| No | No | Durcan Acetal M90-44 Plastic | N/A | https://www.khkgears.us/catalog/product/DS1-36/ |
| No | No | Durcan Acetal M90-44 Plastic | N/A | https://www.khkgears.us/catalog/product/DS1-60/ |
| No | No | Carbon Steel | 8641T52 | https://www.mcmaster.com/products/step-down-shaft |
| No | No | Aluminum | N/A | https://www.amazon.com/Feelers-Aluminum-Plate/dp/ |
| No | No | Carbon Steel | 8641T2 | https://www.mcmaster.com/products/step-down-shaft |
| No | No | Steel | #69811 | https://www.lowes.com/pd/Hillman-0-094-ft-x-1-375-in |

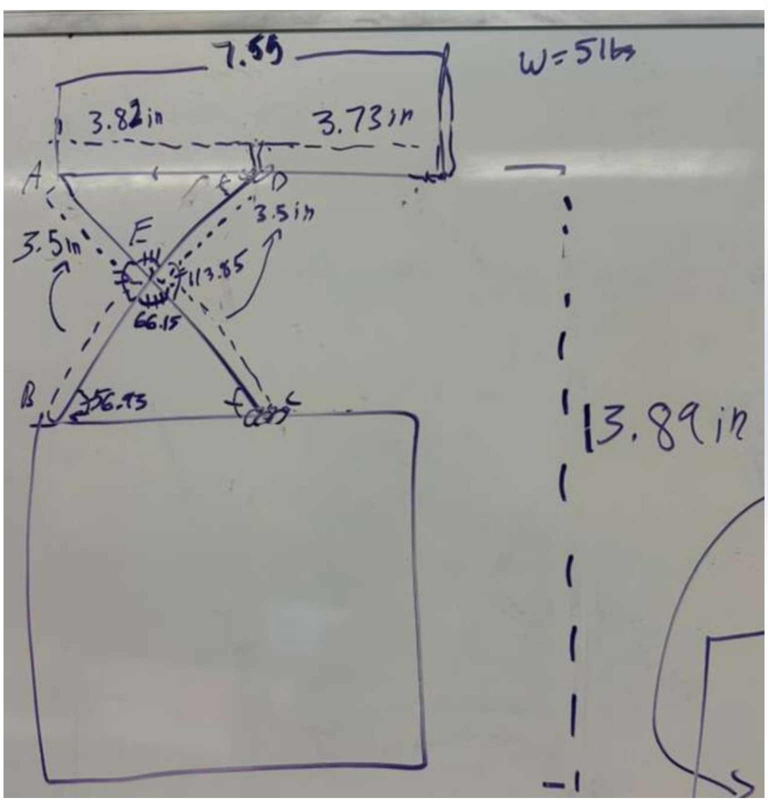
Figure 5: Second of two Parts of the Bill of Materials

# Statistical Analysis and FBD's

$$k_a = stiffness\ of\ shaft\ A, k_b = stiffness\ of\ shaft\ B, k_C = Stiffness\ of\ Shaft\ C, k_D = stiffness\ of\ shaft\ D$$

$$k_E = stiffness\ of\ shaft\ E$$

$\underline{k_A = 0.322 lb/in, k_B = k_C = 0.357 lb/in, k_D = k_E = 2.063 lb/in}$



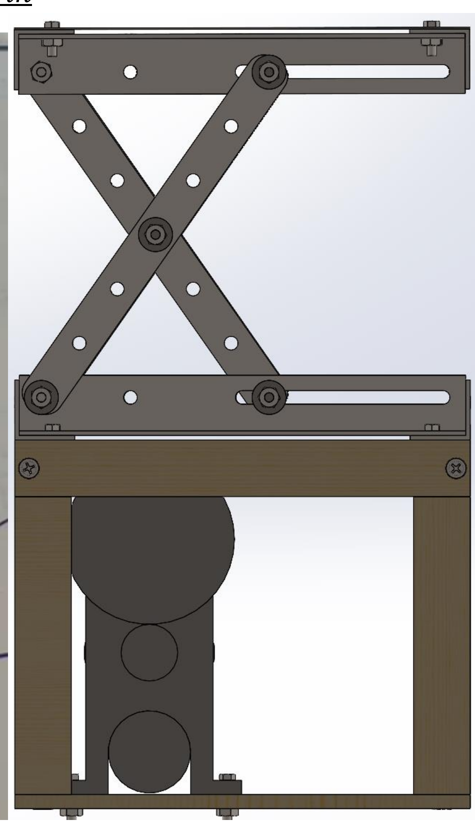



Figure 6 & 7: FBD of Scissor Lift and picture of the same view in Solidworks

$$\frac{V_{top\ plate} * \rho_{top\ plate}}{l} = .286lb/in$$

Angles between arms and horizontal surfaces discovered via: $cos^{-1}(\frac{3.82}{7}) = 56.93$, the angle between arms discovered via: $180 - 2(56.93) = 66.15$

Overall Length $l = 3.82 + 3.73 = 7.55$ in, distance between roller $R_2$ and the right end equals 3.73in, and the distance between the left end's $R_1$ and the $R_2$ is 3.73in.

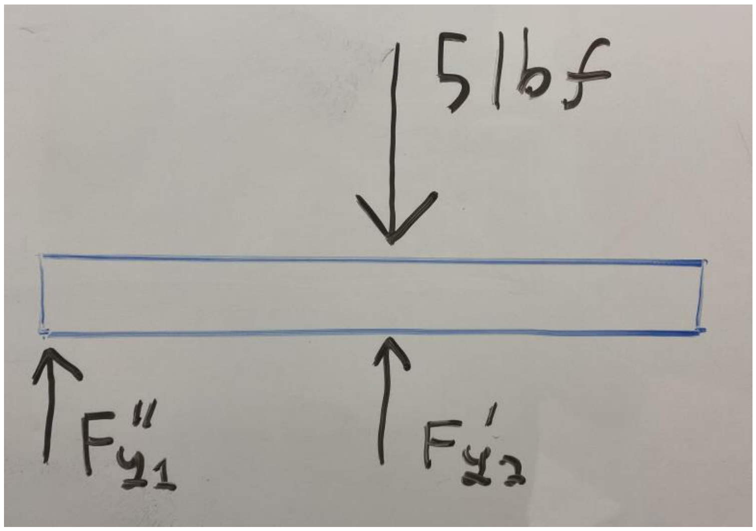



Figure 8 (Superposition 2): point load

Looking at the point load shown in Figure (Superposition 2):

Using Table A9, 10 where $l = 7.55, a = 3.82, b = 3.73$

Reaction forces for the left pin are $F_y' = \frac{fb}{l} = \frac{5(3.73)}{7.55} = 2.47$lbf and $F_x = 0$

Reaction forces for the roller is $F_{y2}' = \frac{fa}{l} = \frac{5(3.82)}{7.55} = 2.53$lbf

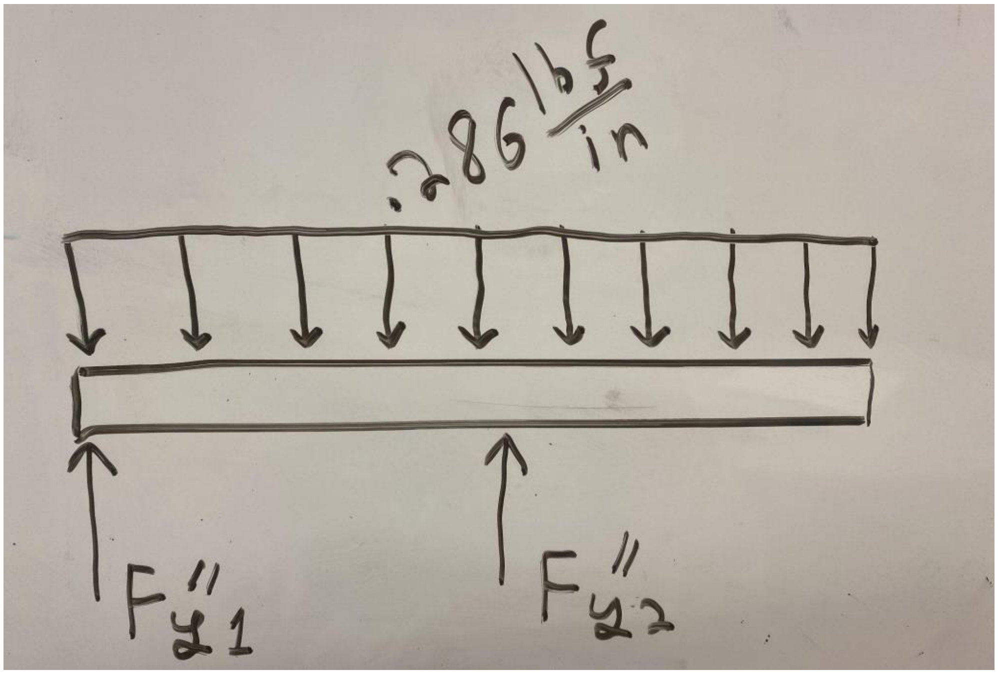



Figure 9 (Superposition 1): Superposition of the top plate uniform load

Forces from distributed .286lb/in load:
Looking at Table A9,7 where $w = .286, l = 3.82$
Reaction force $F_{y_1}'' = F_{y_2}' = \frac{wl}{2} = \frac{.286*3.82}{2} = 0.546lb$
Total forces

$$F_{y_1} = F_{y_1}' + F_{y_1}'' = 2.47 + 0.546 = 3.016lbf$$

$F_{y_2} = F_{y_2}' + F_{y_2}'' = 2.53 + 0.546 = 3.076$lbf

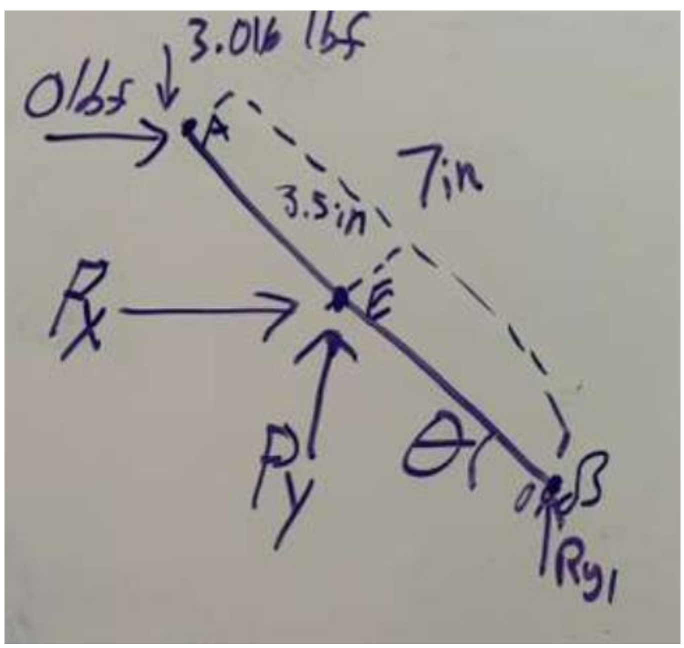


Figure 10: Free Body Diagram of First Arm

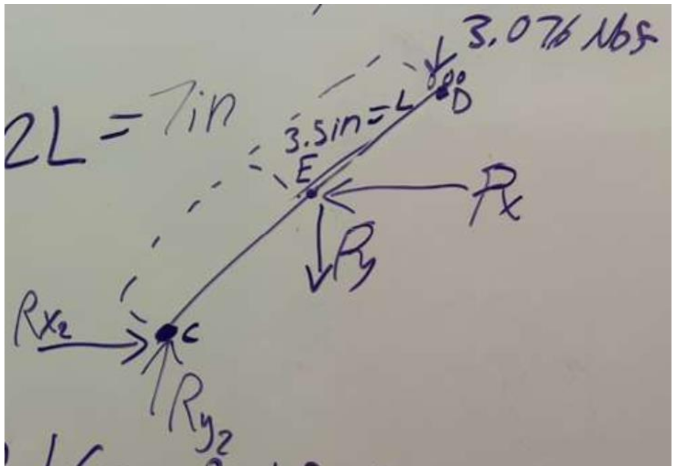



Figure 11: Free Body Diagram of Second Arm

$\theta = cos^{-1}(\frac{3.82}{7}) = 56.93$ degrees

$$\sum M_B = 0 = F_{y1}2Lcos(\theta) - P_yLcos(\theta) - P_xLsin(\theta)$$

$$0 = -F_{y1} + P_y + R_{y1}$$

$$\sum M_A = 0 = -F_{y2}2Lcos(\theta) - P_yLcos(\theta) + P_xLsin(\theta)$$

$$0 = -F_{y2} - P_y + R_{y2}$$

$$P_y = \frac{F_{y1}2Lcos\theta - P_xLsin\theta}{Lcos\theta} = 2F_{y1} - P_xtan\theta$$

$$P_x = \frac{F_{y2}2Lcos\theta + P_yLcos\theta}{Lsin\theta} = \frac{1}{tan\theta}(2F_{y2} + P_y) = \frac{2F_{y2} + 2F_{y1}}{tan\theta} - P_x$$

$$2P_x = \frac{2(F_{y2} + F_{y1})}{tan\theta}$$

$$P_x = R_{x2} = \frac{F_{y2} + F_{y1}}{tan\theta} = \frac{3.076 + 3.016}{tan(56.93)} = 3.97lbf$$

$$P_y = 2F_{y1} - P_xtan\theta = 2F_{y1} - (\frac{2F_{y2}}{tan\theta} + \frac{P_y}{tan\theta})tan\theta$$

$$P_y = 2F_{y1} - 2F_{y2} - P_y$$

$$P_y = F_{y1} - F_{y2} = 3.016 - 3.076 = -0.06lbf$$

$$0 = -F_{y1} + P_y + R_{y1}$$

$$R_{y1} = F_{y1} - P_y = 3.016 - (-0.06) = 3.076lbf$$

$$0 = -F_{y2} - P_y + R_{y2}$$

$$R_{y2} = F_{y2} + P_y = 3.076 - 0.06 = 3.016lbf$$

Summarized results from Free Body Diagram:

$$P_x = R_{x2} = 3.97lbf$$
$$P_y = -0.06lbf$$
$$R_{y1} = 3.076lbf$$
$$R_{y2} = 3.016lbf$$

Table A9: 14 (for the beams)

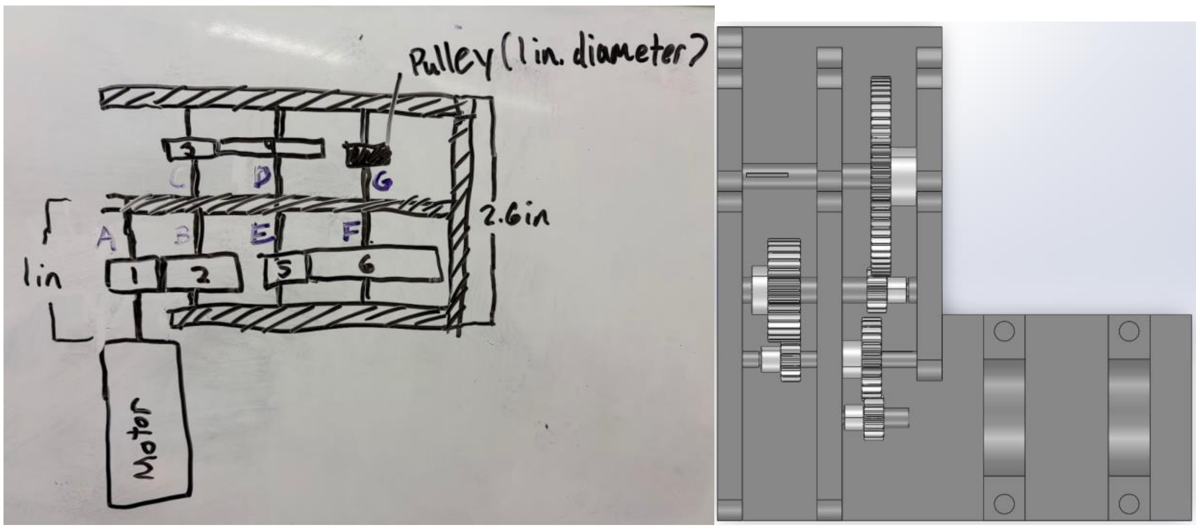



Figure 12 & 13: Top View of Gear Train Setup

Given 0.33 lbf-in rated load torque from motor and 2.45 A max rated load current. Direction given as clockwise and max allowed current is given as 2 amps.
$0.33 * \frac{2}{2.45} = 0.269$lbf-in for torque of the motor at 2 amps.

Table 1: The Torques, Forces, and Number of Gear Teeth for the 6 Gears.

| Number of Gear Teeth | Torques $T_{in} * \frac{N_G}{N_p} = T_{out}$ | Forces $F = \frac{2T}{d_p}$ |
|---|---|---|
| $N_1 = 12$ | $T_1 = 0.269$lbf-in | $F_1 = \frac{2T_1}{d_{p1}} = \frac{2*.269}{.472} = 1.140$lbf |
| $N_2 = 24$ | $T_2CCW = T_1 * \frac{N_G}{N_p} = .269 * \frac{24}{12} = .538$lbf-in | $F_2 = \frac{2T_2}{d_{p2}} = \frac{2*.538}{.945} = 1.139$lbf |
| $N_3$ =12 | $T_3CCW = T_1 * \frac{N_G}{N_p} = .269 * \frac{24}{12} = .538$lbf-in | $F_3 = \frac{2T_3}{d_{p3}} = \frac{2*.538}{.472} = 2.280$lbf |
| $N_4 = 36$ | $T_4CW = T_3 * \frac{N_G}{N_p} = .538 * \frac{36}{12} = 1.614$lbf-in | $F_4 = \frac{2T_4}{d_{p4}} = \frac{2*1.614}{1.417} = 2.278$lbf |

| | | |
|---|---|---|
| $N_5 = 12$ | $T_5 CW = T_3 * \frac{N_G}{N_p} = .538 * \frac{36}{12} = 1.614$ | $F_5 = \frac{2T_5}{d_{p5}} = \frac{2*1.614}{.472} = 6.839$lbf |
| $N_6 = 60$ | $T_6 CCW = T_5 * \frac{N_G}{N_p} = 1.614 * \frac{60}{12} = 8.07$lbf-in | $F_6 = \frac{2T_6}{d_{p6}} = \frac{2*8.07}{2.362} = 6.833$lbf |
| The Pulley | $T_{Pulley} CCW = T_5 * \frac{N_G}{N_p} = 1.614 * \frac{60}{12} = 8.07$lbf-in | $F_P = \frac{2T_P}{d_{pp}} = \frac{2*8.07}{1} = 16.14$lbf |

From textbook we used $F = \frac{2T}{d_p}$ where $d_p$ is pitch diameter and T is the torque
The torque on the pulley would match the torque on gear 6 due to being on the same shaft. This would mean that $T_{Pulley} CCW = 8.07$ lbf-in and lead to $F_P = \frac{2T_P}{d_{pp}} = \frac{2*8.07}{1} = 16.14$ lbf.

Table 2: Reaction Forces and Moments, Inertia, and Deflections of Shafts

| Shaft | $R_1 = R_2 = \frac{F}{2}$ | $M_1 = M_2 = \frac{FL}{8}$ | $I = \frac{\pi d^4}{64}$ | $y_{max} = \frac{-FL^3}{192EI}$ |
|---|---|---|---|---|
| A | $\frac{F_1}{2} = 0.570\ lbf$ | $\frac{F_1 L_1}{8} = 0.185\ lbf * in$ | $\frac{\pi {d_A}^4}{64} = 3.217 * 10^{-5}\ in^4$ | $\frac{-F_1 {L_A}^3}{192EI} = -4.051 * 10^{-5}\ in$ |
| B | $\frac{F_2}{2} = 0.569\ lbf$ | $\frac{F_2 L_2}{8} = 0.142\ lbf * in$ | $\frac{\pi {d_B}^4}{64} = 7.854 * 10^{-5}\ in^4$ | $\frac{-F_2 L^3}{192EI} = -7.545 * 10^{-6}\ in$ |
| C | $\frac{F_3}{2} = 1.140\ lbf$ | $\frac{F_3 L_3}{8} = 0.285\ lbf * in$ | $\frac{\pi {d_C}^4}{64} = 7.854 * 10^{-5}\ in^4$ | $\frac{-F_3 L^3}{192EI} = -1.511 * 10^{-5}\ in$ |
| E | $\frac{F_5}{2} = 3.419\ lbf$ | $\frac{F_5 L_5}{8} = 0.855\ lbf * in$ | $\frac{\pi {d_E}^4}{64} = 4.533 * 10^{-4}\ in^4$ | $\frac{-F_5 L^3}{192EI} = -7.851 * 10^{-6}\ in$ |
| F | $\frac{F_6}{2} = 3.417\ lbf$ | $\frac{F_6 L_6}{8} = 0.854\ lbf * in$ | $\frac{\pi {d_F}^4}{64} = 4.533 * 10^{-4}\ in^4$ | $\frac{-F_6 L^3}{192EI} = -7.845 * 10^{-6}\ in$ |
| G | $\frac{F_P}{2} = 8.070\ lbf$ | $\frac{F_P L_P}{8} = 2.018\ lbf * in$ | $\frac{\pi {d_G}^4}{64} = 4.533 * 10^{-4}\ in^4$ | $\frac{-F_P L^3}{192EI_G} = -1.853 * 10^{-5}\ in$ |

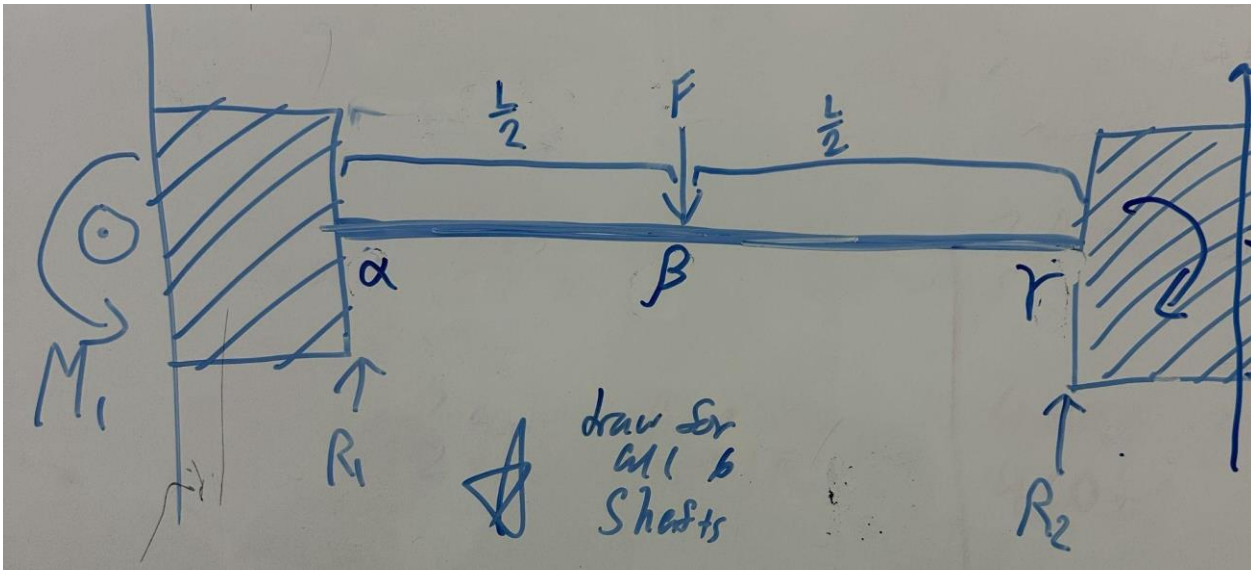



Figure 14: FBD For all Transmission Shafts

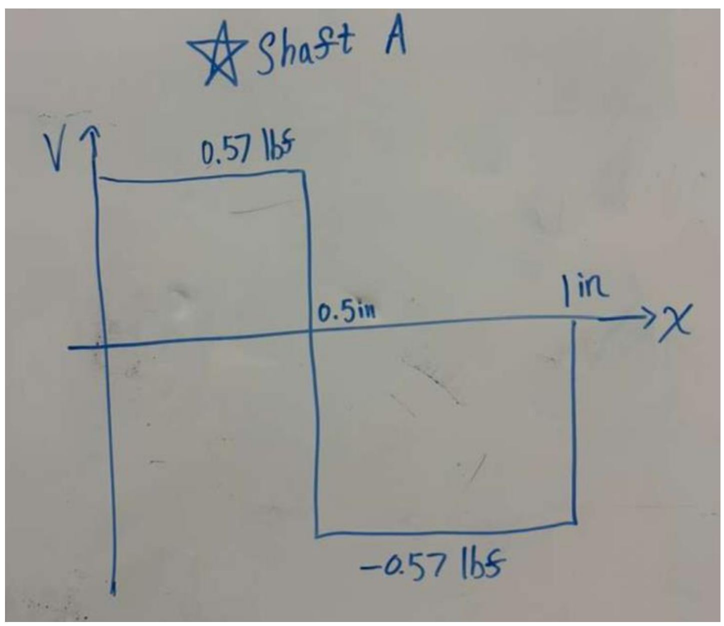



Figure 15: Shear Diagram of Transmission Shaft A

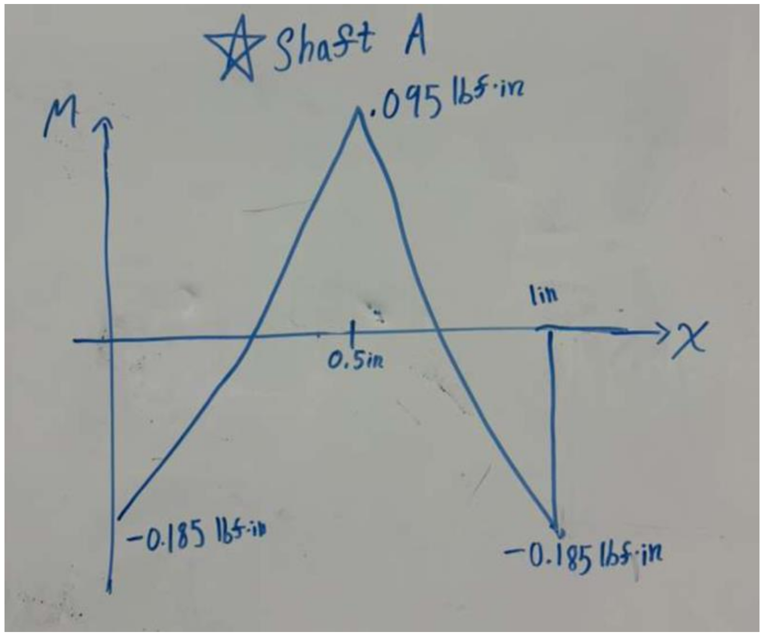



Figure 16: Moment Diagram of Transmission Shaft

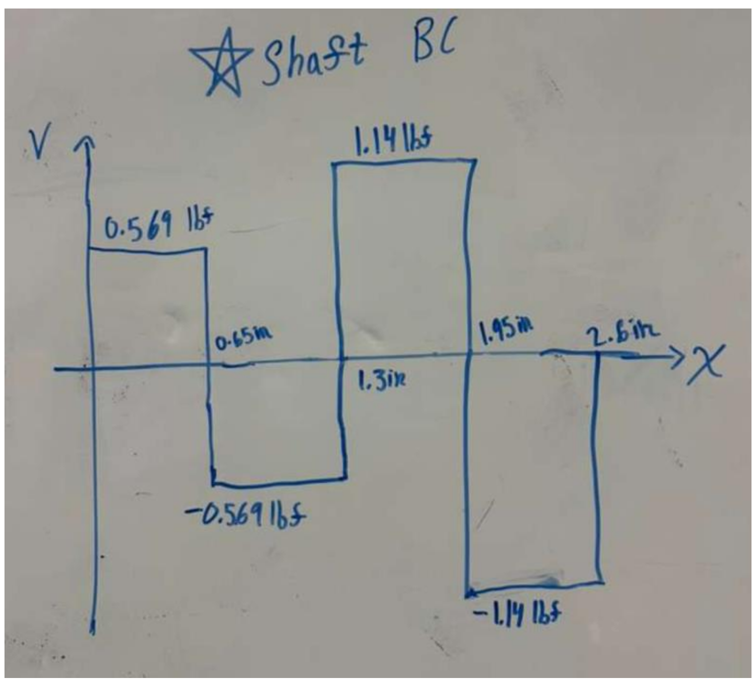



Figure 17: Shear Diagram of Transmission Shaft B-C

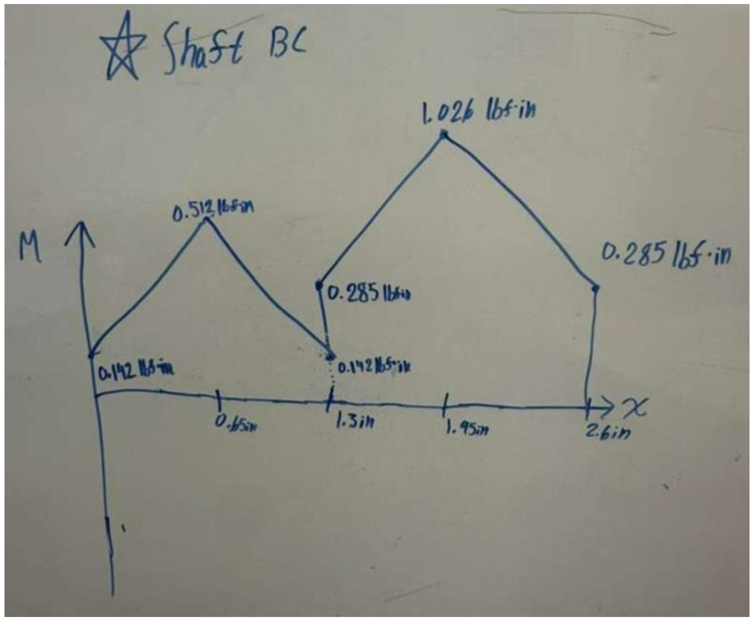



Figure 18: Moment Diagram of Transmission Shaft

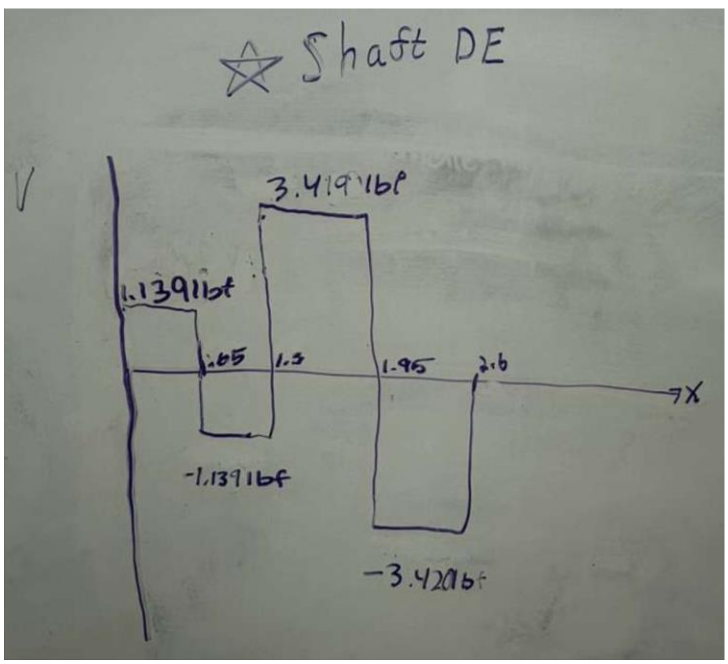



Figure 19: Shear Diagram of Transmission Shaft D-E

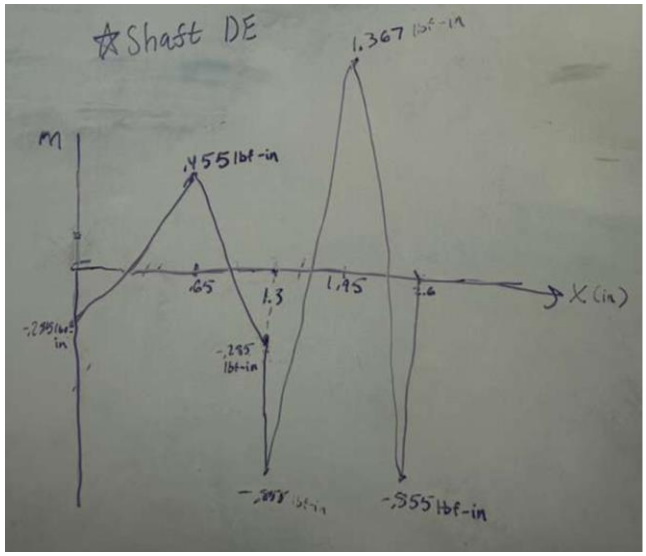



Figure 20: Moment Diagram of Transmission Shaft

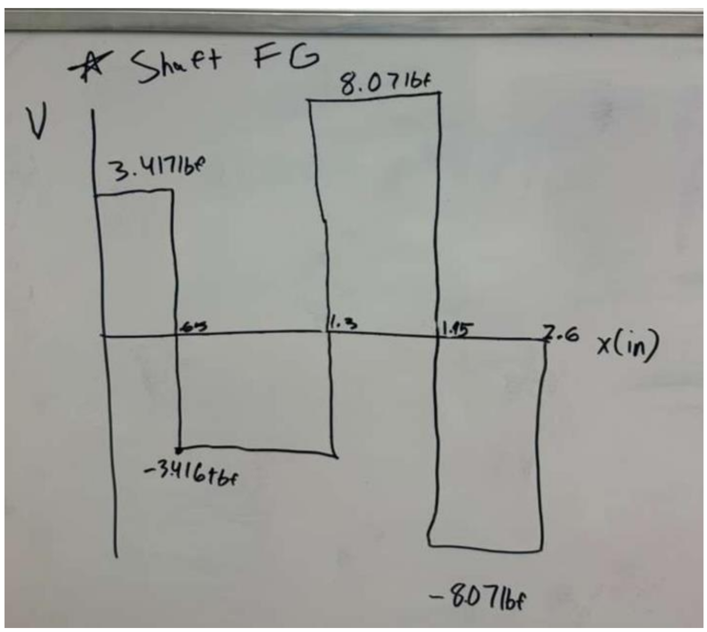



Figure 21: Shear Diagram of Transmission Shaft F-G

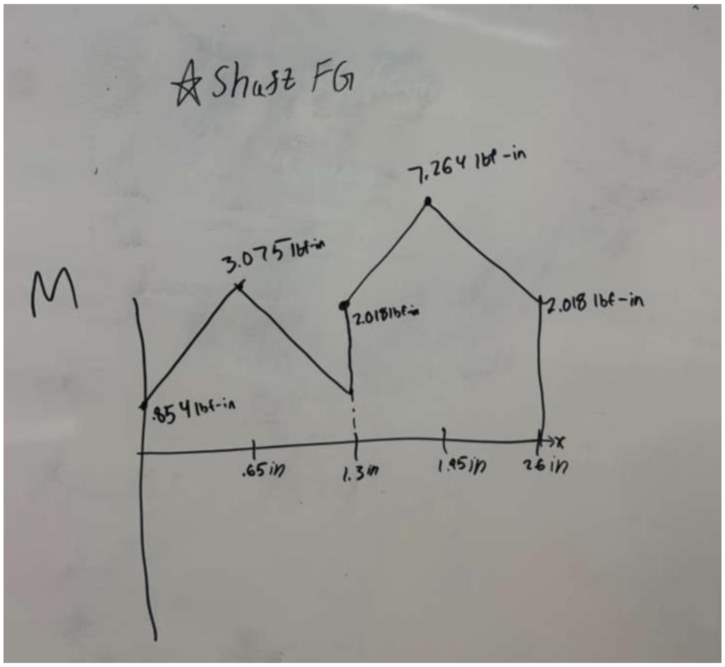



Figure 22: Moment Diagram of Transmission Shaft F-G

## **Mohr's Circle**

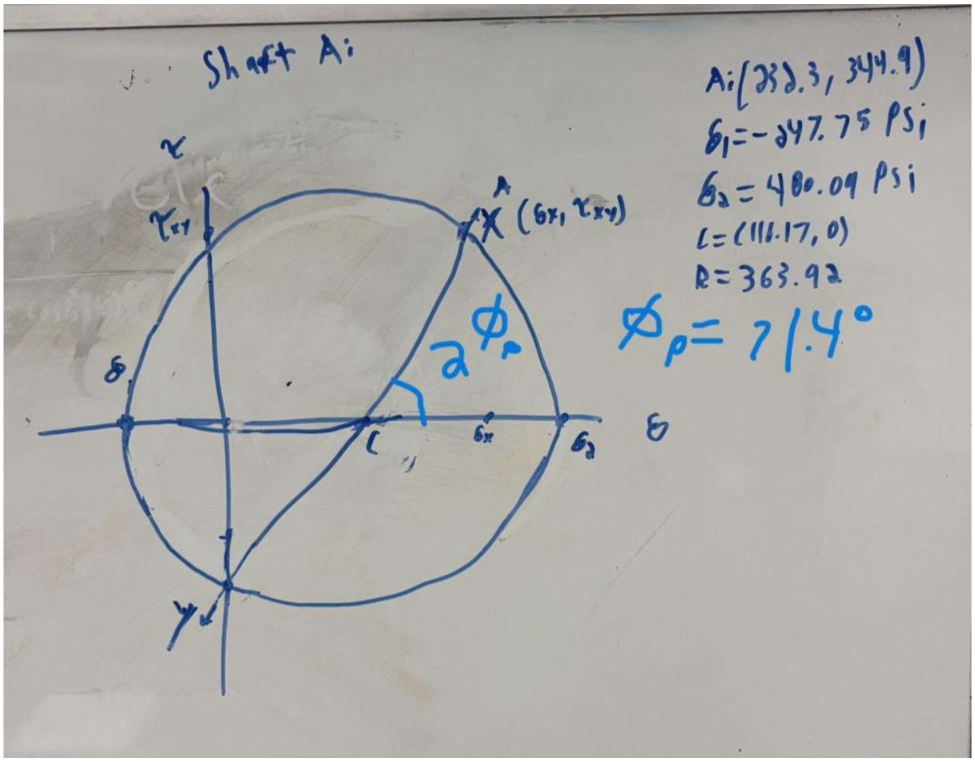



Figure 23: Shaft A Mohr's circle

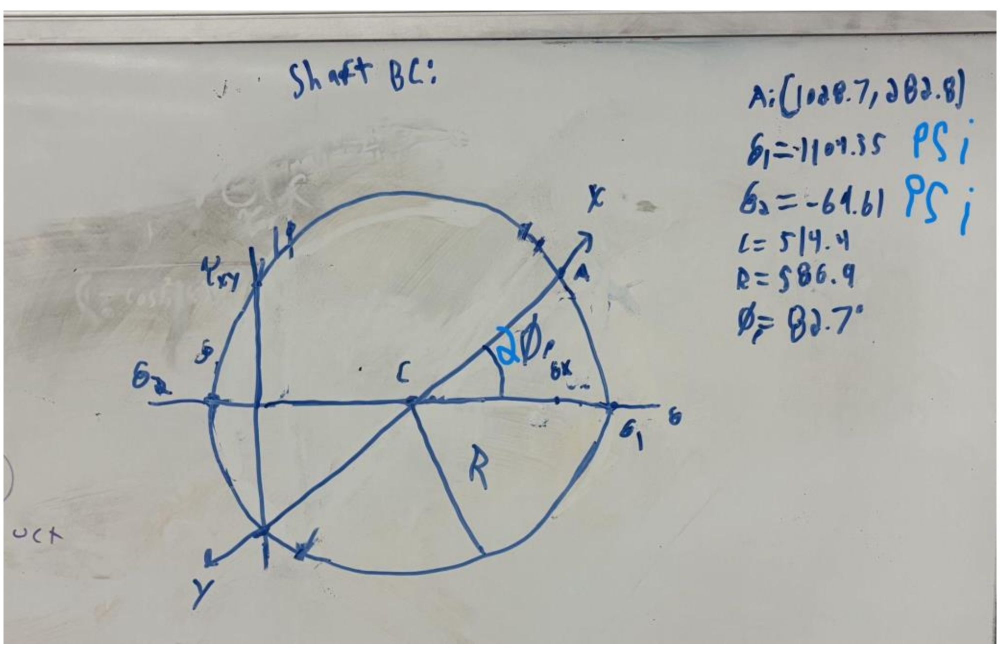



Figure 24: Shaft BC Mohr's circle

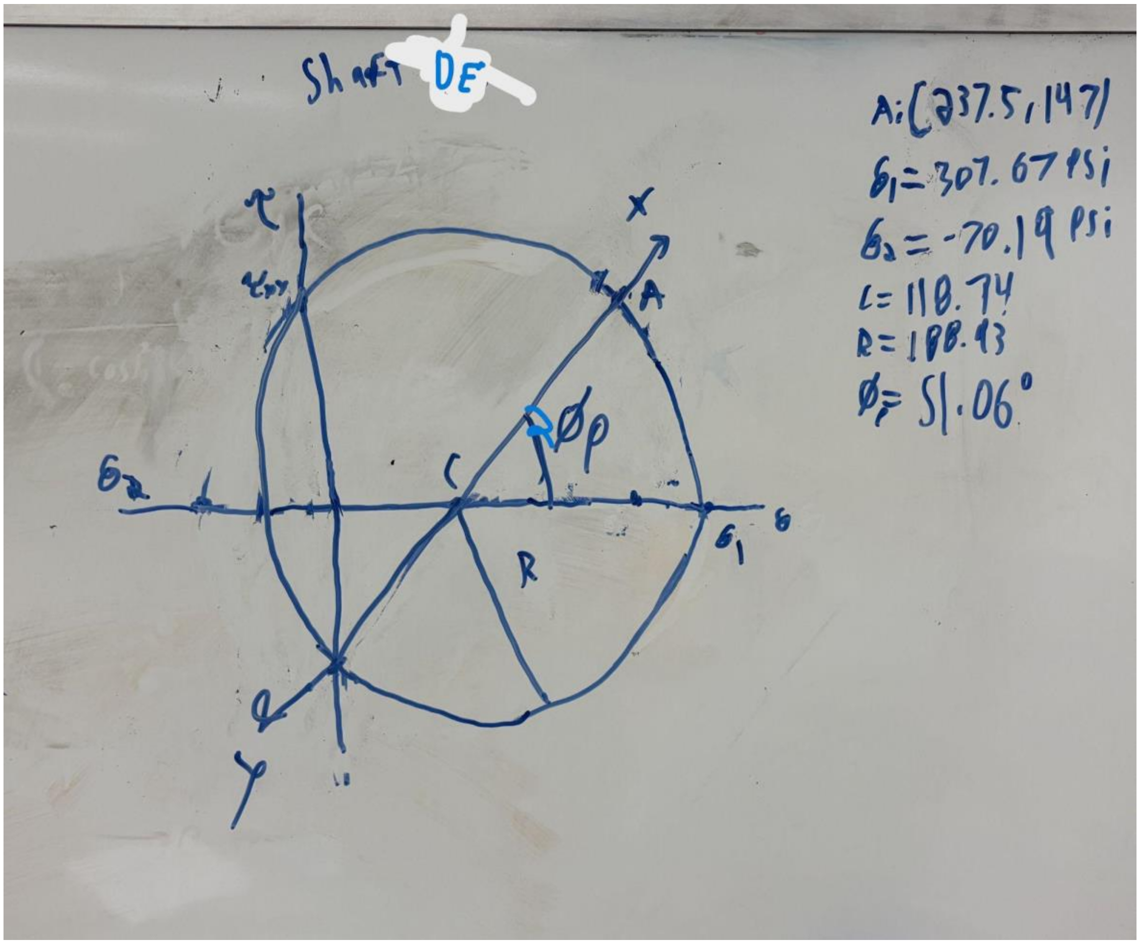



Figure 25: Shaft DE Mohr’s Circle

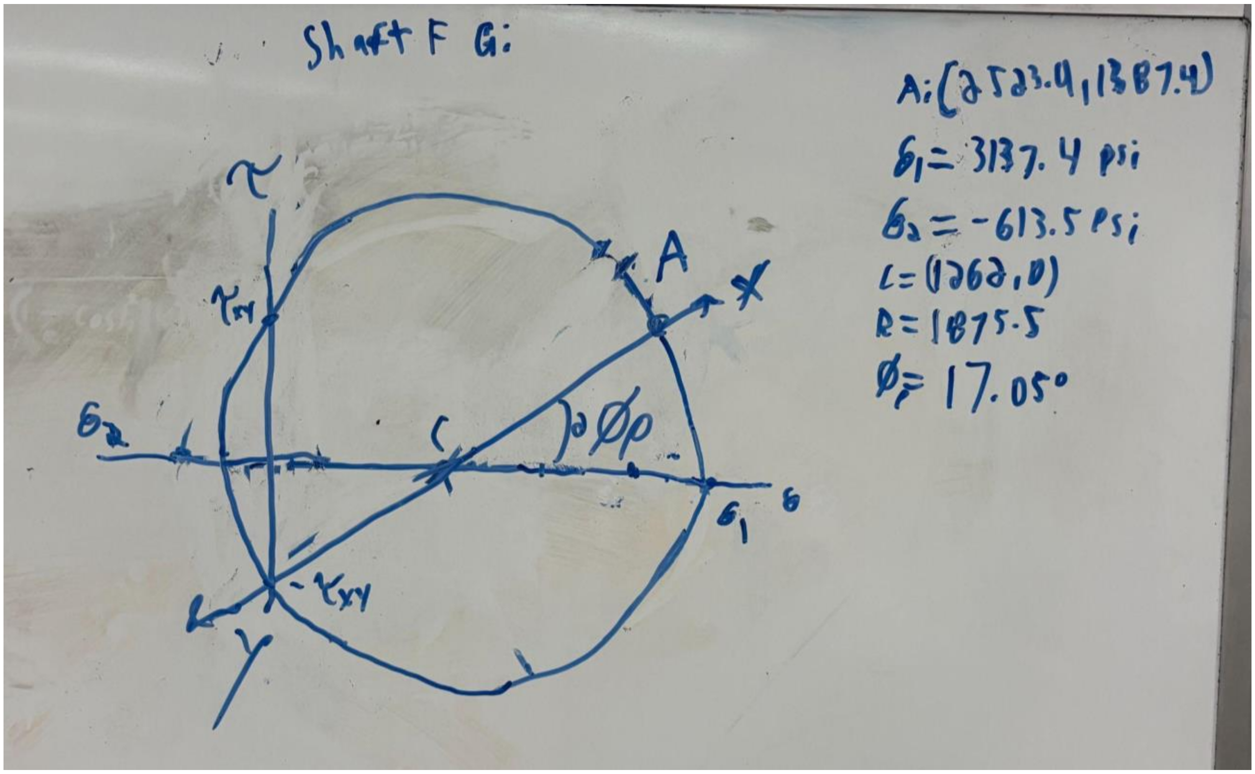



Figure 26: Shaft FG Mohr's Circle

Tolerances

For all of the holes and shafts in both the transmission and bracket, we are using a clearance close running fit. This means that the "symbols" we are using are from table 7-9 H8/f7. In all cases, the diameter of the hole, D, and shaft, d, are equal ($D = d$).

For the smallest transmission (0.16 inches):
According to Table 13- $\Delta D = 0.0007$ in and $\Delta d = 0.0005$ in
According to Table 14- $\delta_F = -0.0004$ in
$D = d = D_{min} = 0.16$ in
$D_{max} = D + \Delta D = 0.16 + 0.0007 = 0.1607$ in
$d_{max} = d + \delta_F = 0.16 + (-0.0004) = 0.1596$ in
$d_{min} = d + \delta_F - \Delta d = 0.16 + (-0.0004) - 0.0005 = 0.1591$ in

For the other small transmission (0.2 inches):
According to Table 13- $\Delta D = 0.0007$ in and $\Delta d = 0.0005$ in
According to Table 14- $\delta_F = -0.0004$ in
$D = d = D_{min} = 0.2$ in
$D_{max} = D + \Delta D = 0.2 + 0.0007 = 0.2007$ in
$d_{max} = d + \delta_F = 0.2 + (-0.0004) = 0.1996$ in
$d_{min} = d + \delta_F - \Delta d = 0.2 + (-0.0004) - 0.0005 = 0.1991$ in

For the larger transmission (0.31 inches):
According to Table 13- $\Delta D = 0.0009$ in and $\Delta d = 0.0006$ in
According to Table 14- $\delta_F = -0.0005$
$D = d = D_{min} = 0.31$ in
$D_{max} = D + \Delta D = 0.31 + 0.0009 = 0.3109$ in
$d_{max} = d + \delta_F = 0.31 + (-0.0005) = 0.3095$ in
$d_{min} = d + \delta_F - \Delta d = 0.31 + (-0.0005) - 0.0006 = 0.3089$ in

For the Diameter of the holes and shafts in the brackets (0.24 inches):
According to Table 13- $\Delta D = 0.0009$ in and $\Delta d = 0.0006$ in
According to Table 14- $\delta_F = -0.0005$
$D = d = D_{min} = 0.24$ in
$D_{max} = D + \Delta D = 0.24 + 0.0009 = 0.2409$ in
$d_{max} = d + \delta_F = 0.24 + (-0.0005) = 0.2395$ in
$d_{min} = d + \delta_F - \Delta d = 0.24 + (-0.0005) - 0.0006 = 0.2389$ in

Deflections Vs Tolerances

From the calculations above we can determine the tolerances of the holes and shafts that make up our scissor lift. This is important to make sure we identify the proper fit for our system so we don't lose efficiency due to a clearance issue. We have determined that our system would require a Clearance Close running fit because our system is under motion so we need a fit that can support this action while supporting a small to moderate force load. Due to our design abilities we have been able to design a system where the deflection of our transmission shafts under load will not cause tolerance issues because at the worse out lowest clearance is .0005 inches while our max deflection was $4.051 * 10^{-5}$ inches so we have plenty of room for our deflection to deflect without it impacting our system.