FINAL PROJECT PRESENTATION

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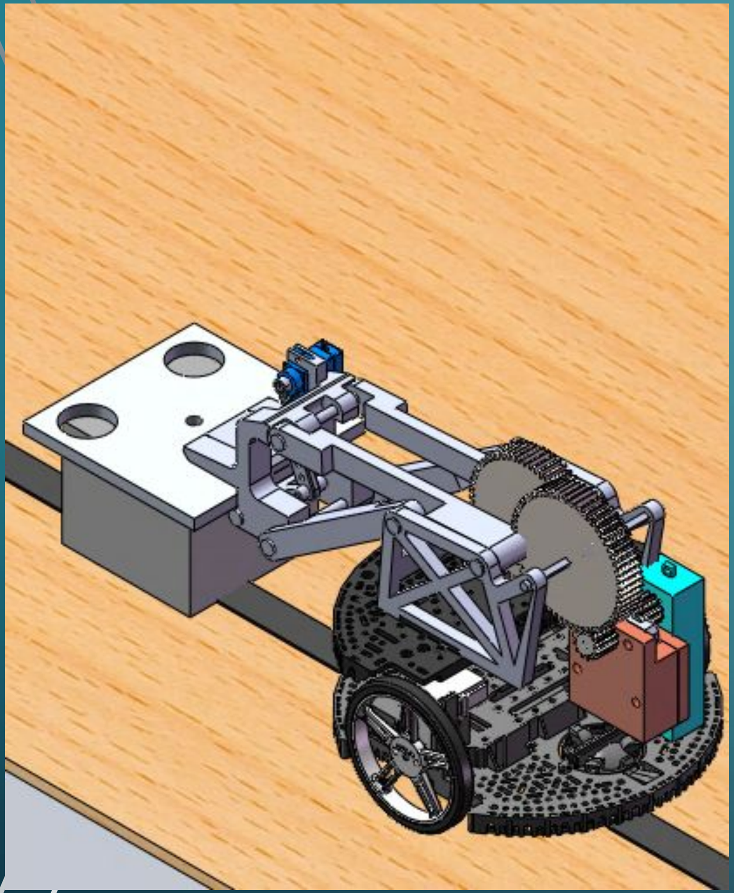
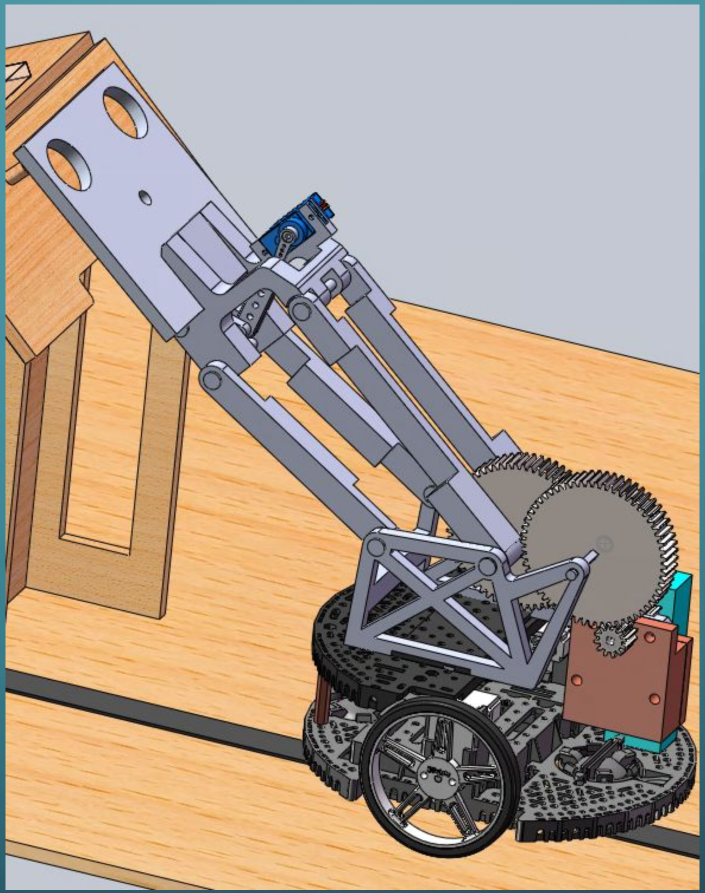
SUMMARY OF CHANGES

- Labeled reaction forces on FBDs for four bar and fixed moment equation (8-10)
- Input motor speed matches motor speed at max torque (15) and calculated new omega 2 value based on new input motor speed and recalculated velocity at solar panel (16)
- Included a full diagram of the gripper (17) and fixed torque calculations at servo horn (20)
- Included only one FBD of each gear per slide (21-24)
- Added factor of safety calculation for gears (25)
- Flowchart slide renamed, minor errors corrected in diagram, and summary of sensors moved to separate slide with accompanying images and updated text descriptions (27-28)

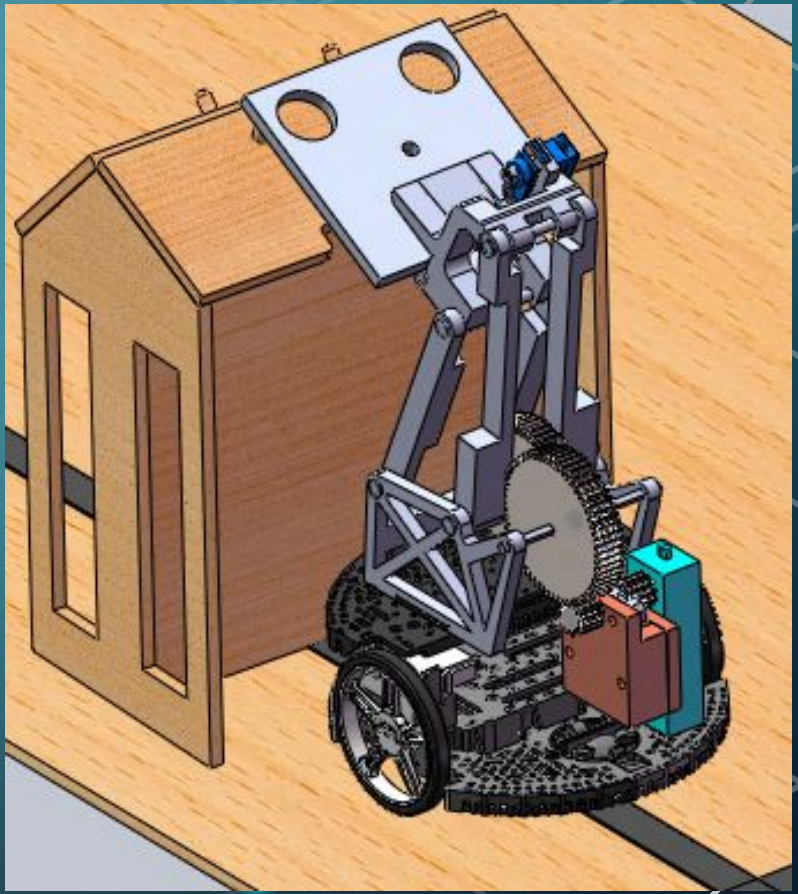
THE CHALLENGE



Position 1: collecting the plate

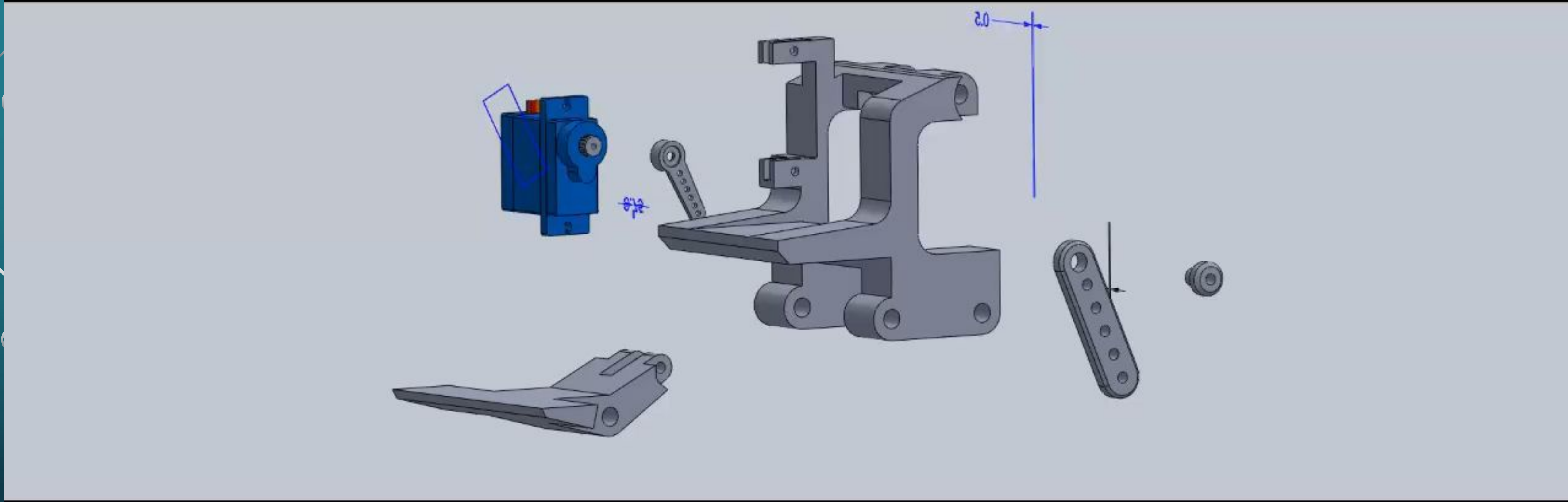


Position 2: placing the plate at 45°

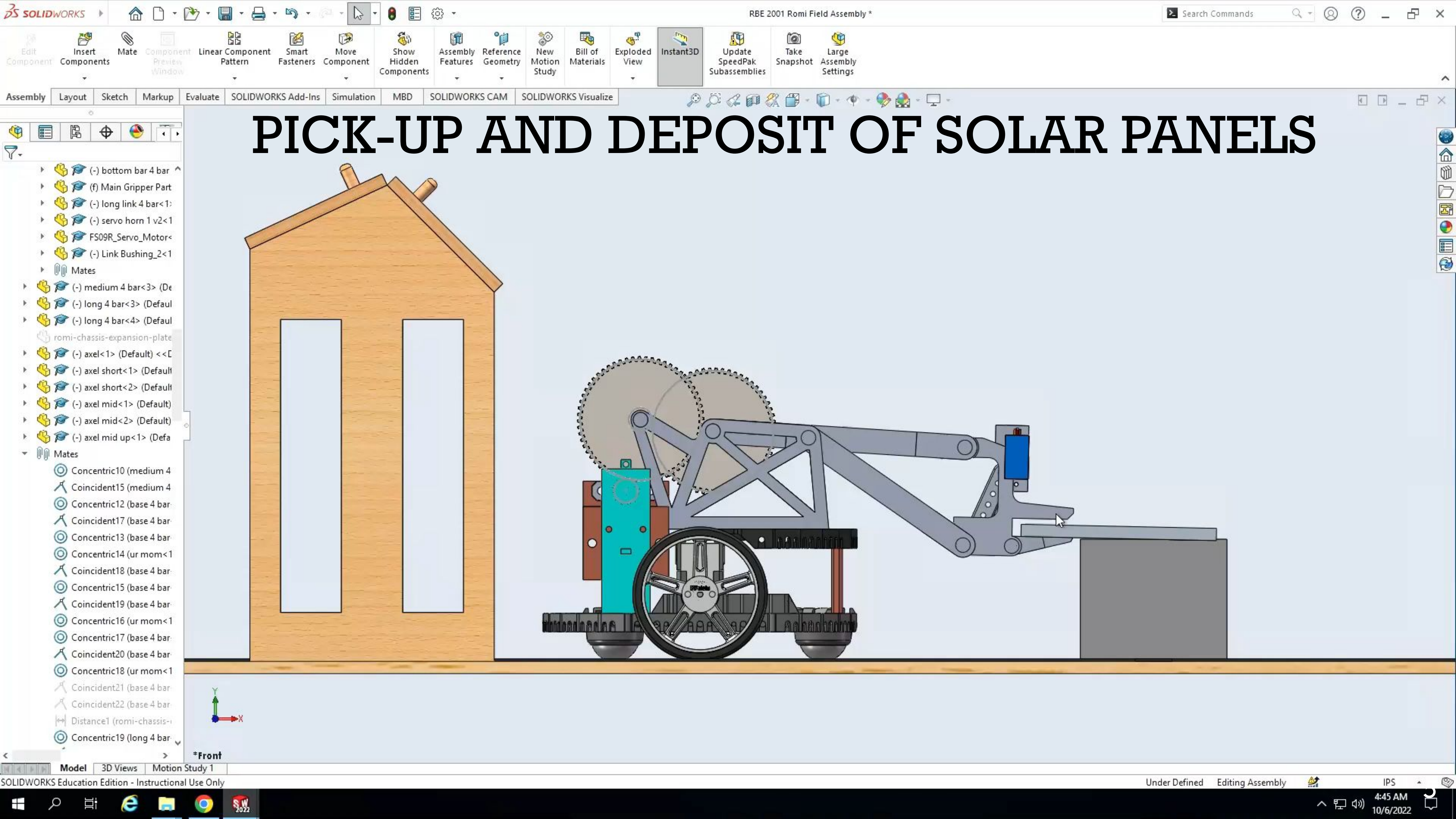


Position 3: placing the plate at 25°

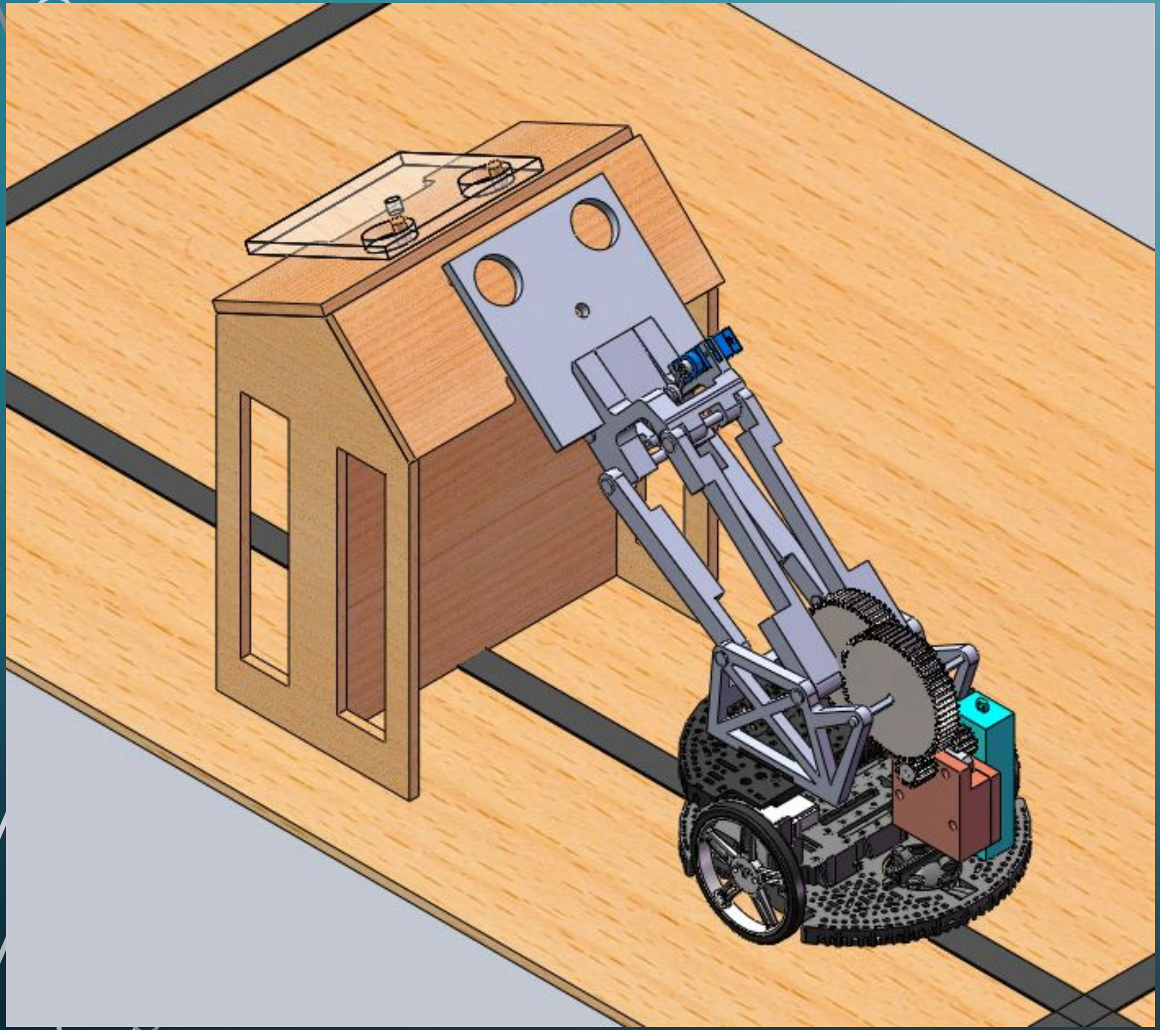
ASSEMBLY ANIMATION



PICK-UP AND DEPOSIT OF SOLAR PANELS



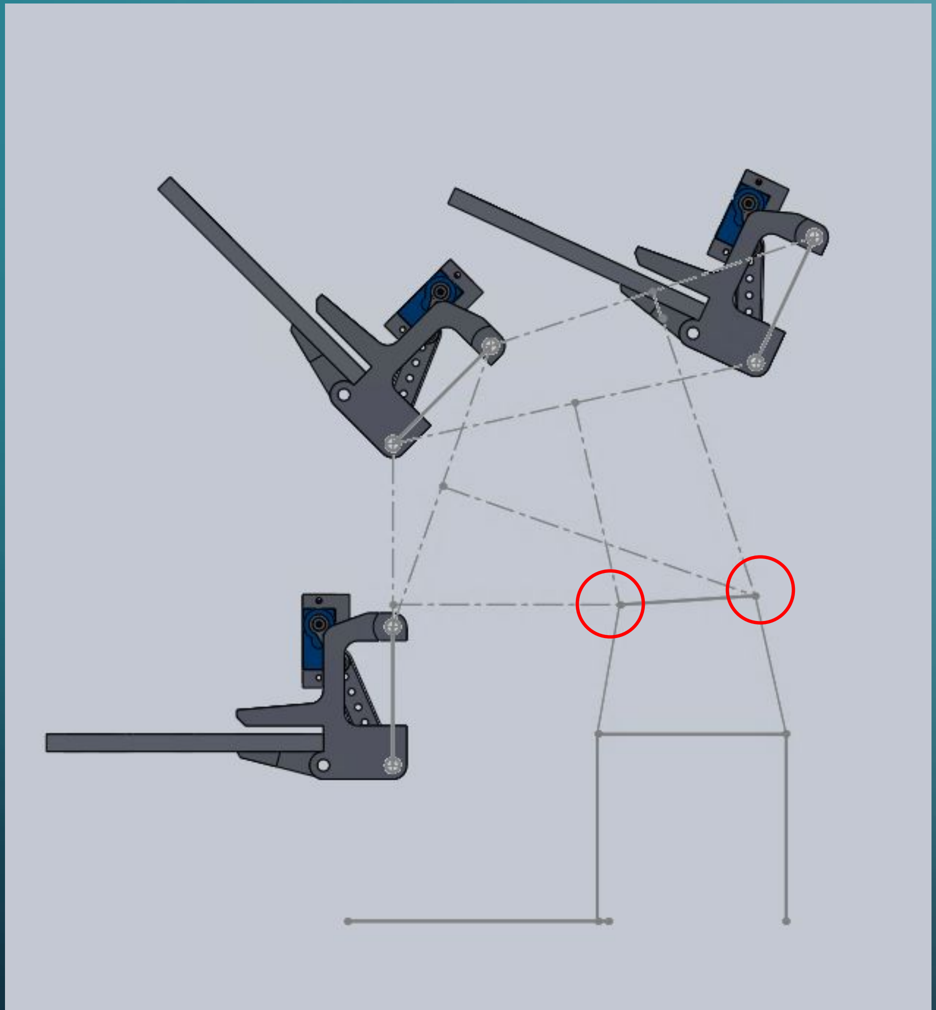
SOLID WORKS MODEL

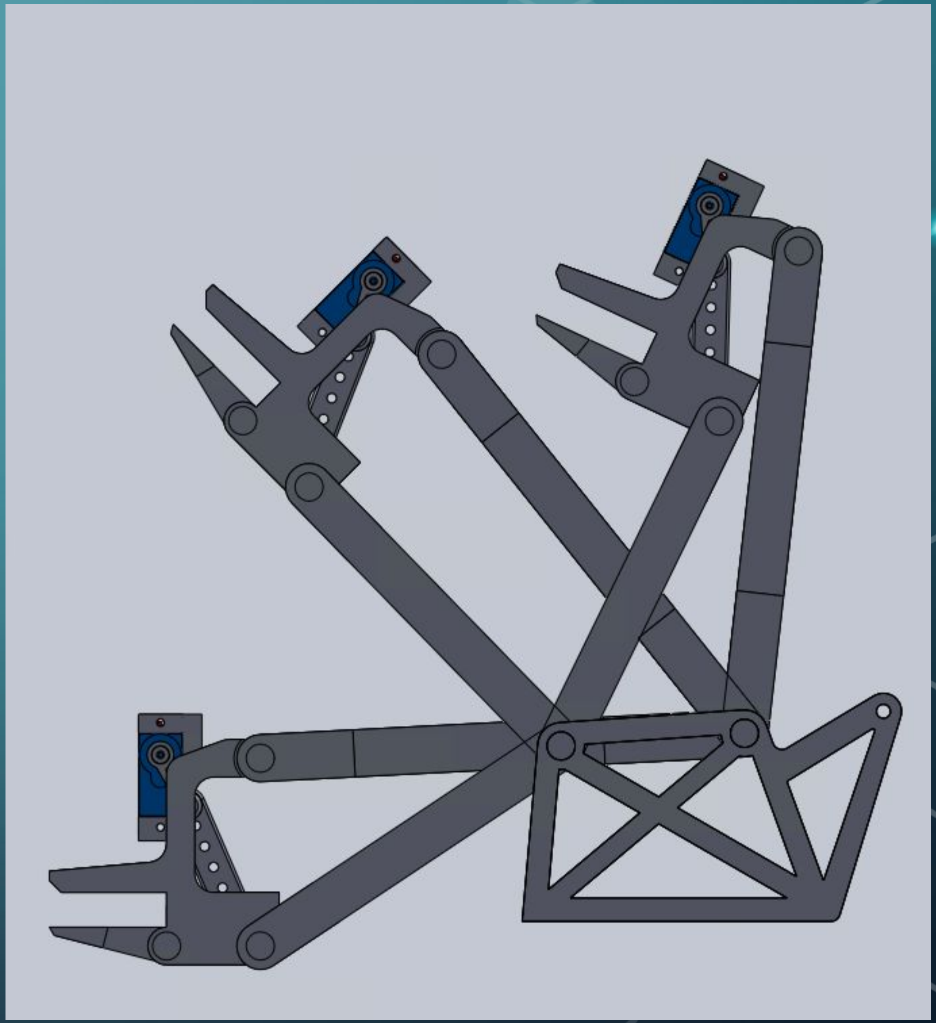


Here is a SolidWorks model of our robot.

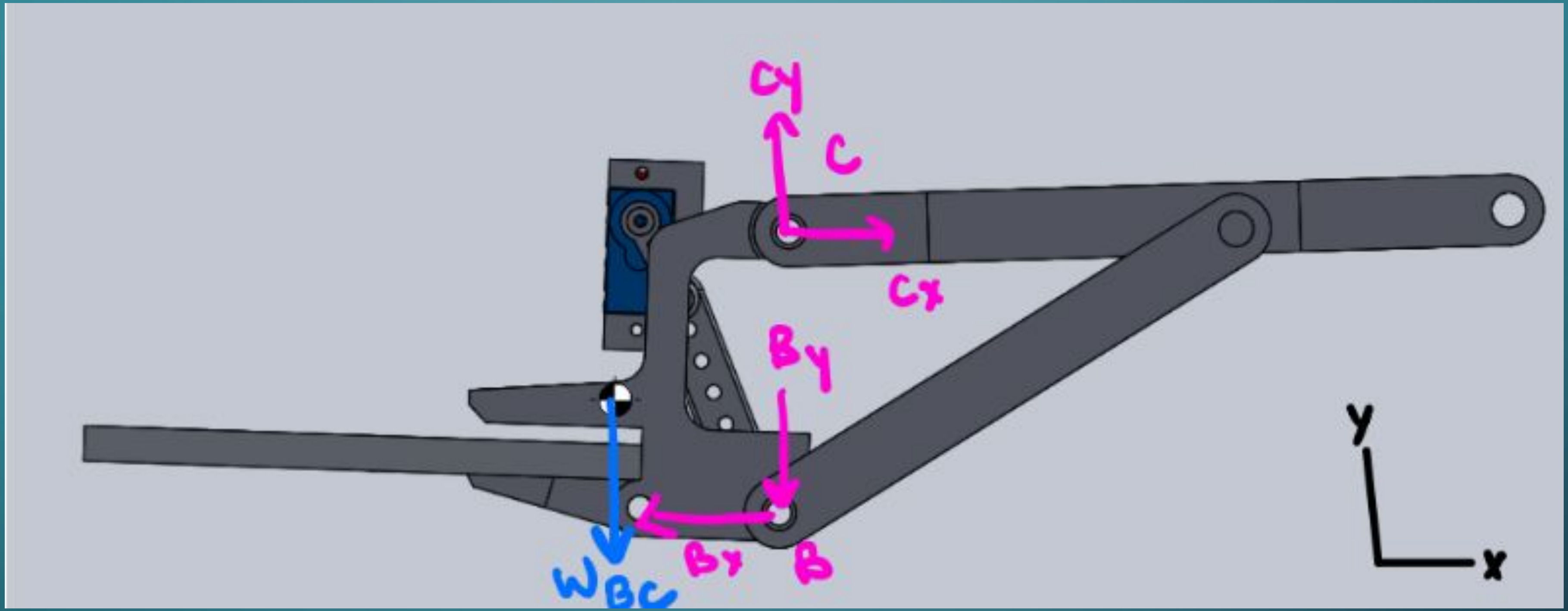
Including the 4 bar, the transmission, and the custom made gripper

SKETCH TO DETERMINE 4 BAR LENGTHS





FORCE ANALYSIS – FBD OF COUPLER

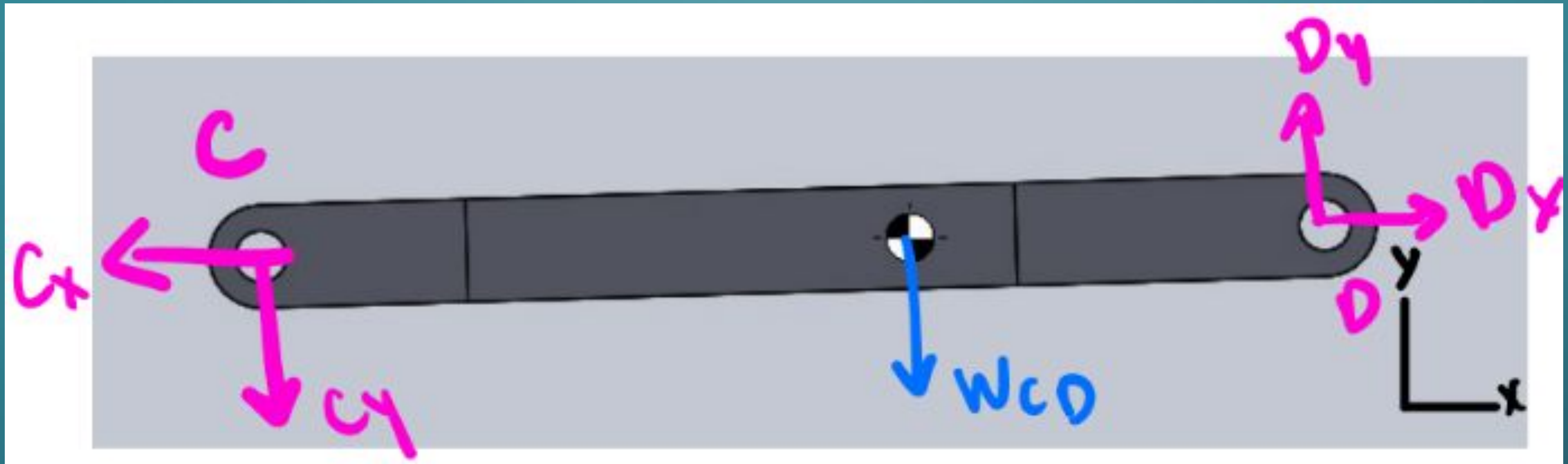


$$\Sigma F_x = 0 \qquad 0 = -B_x + C_x$$

$$\Sigma F_y = 0 \qquad 0 = -W_{BC} + C_y - B_y$$

$$\Sigma M_B = 0 \qquad 0 = W_{BC} \cdot (x_B - x_W) - C_x \cdot (y_C - y_B) + C_y \cdot (x_C - x_B)$$

FORCE ANALYSIS – FBD OF ROCKER

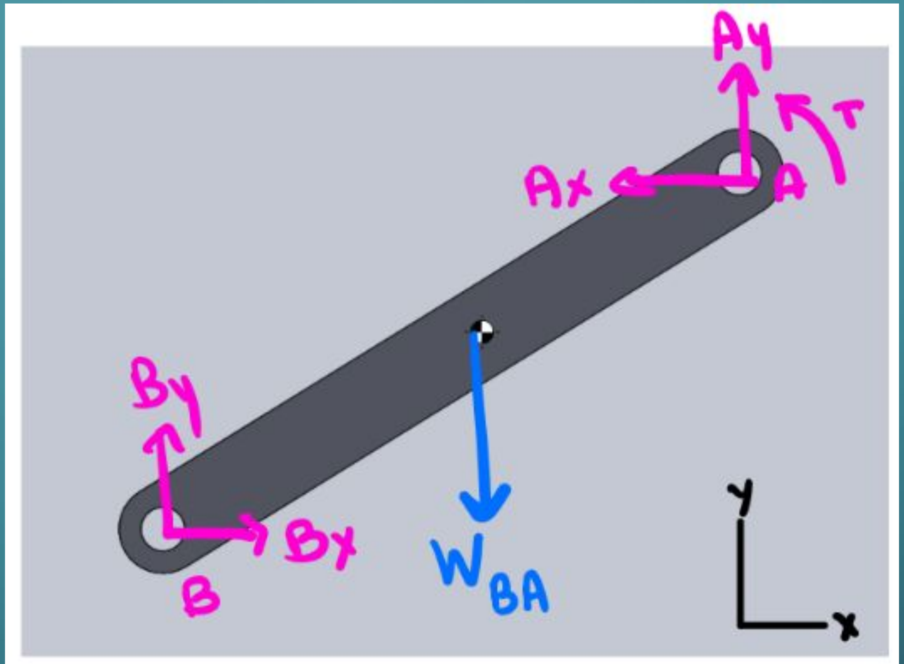


$\Sigma F_x = 0 \qquad 0 = -C_x + D_x$

$\Sigma F_y = 0 \qquad 0 = -C_y + D_y$

$\Sigma M_D = 0 \qquad 0 = C_x \cdot (y_C - y_D) + C_y \cdot (x_D - x_C)$

FORCE ANALYSIS – FBD OF CRANK



$$\Sigma F_x = 0 \qquad 0 = -A_x + B_x$$

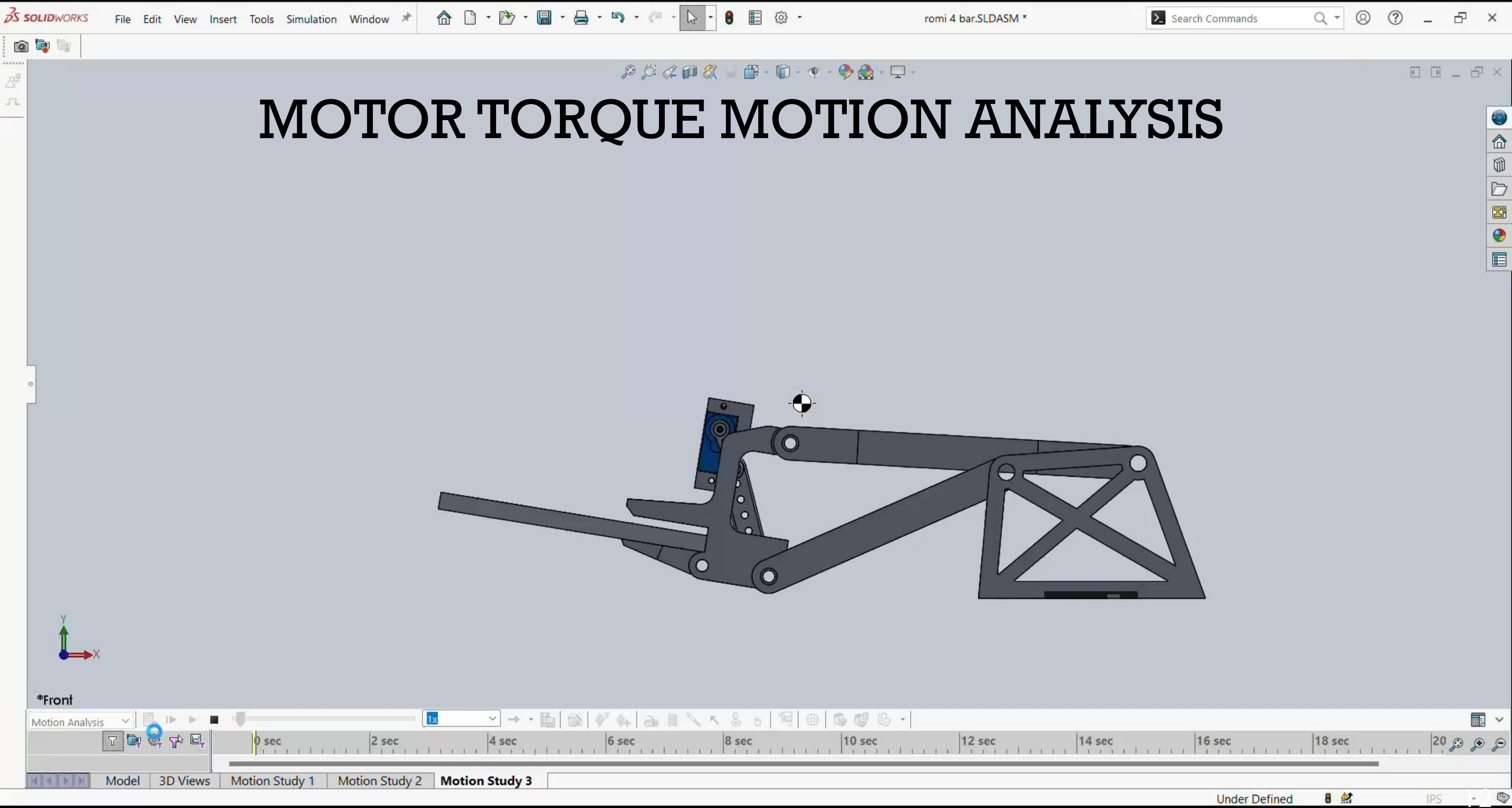
$$\Sigma F_y = 0 \qquad 0 = A_y + B_y - W_{BA}$$

$$\Sigma M_A = 0 \qquad 0 = T_A + B_x \cdot (y_A - y_B) - B_y \cdot (x_A - x_B) + W_{BA}(x_A - X_{W2})$$

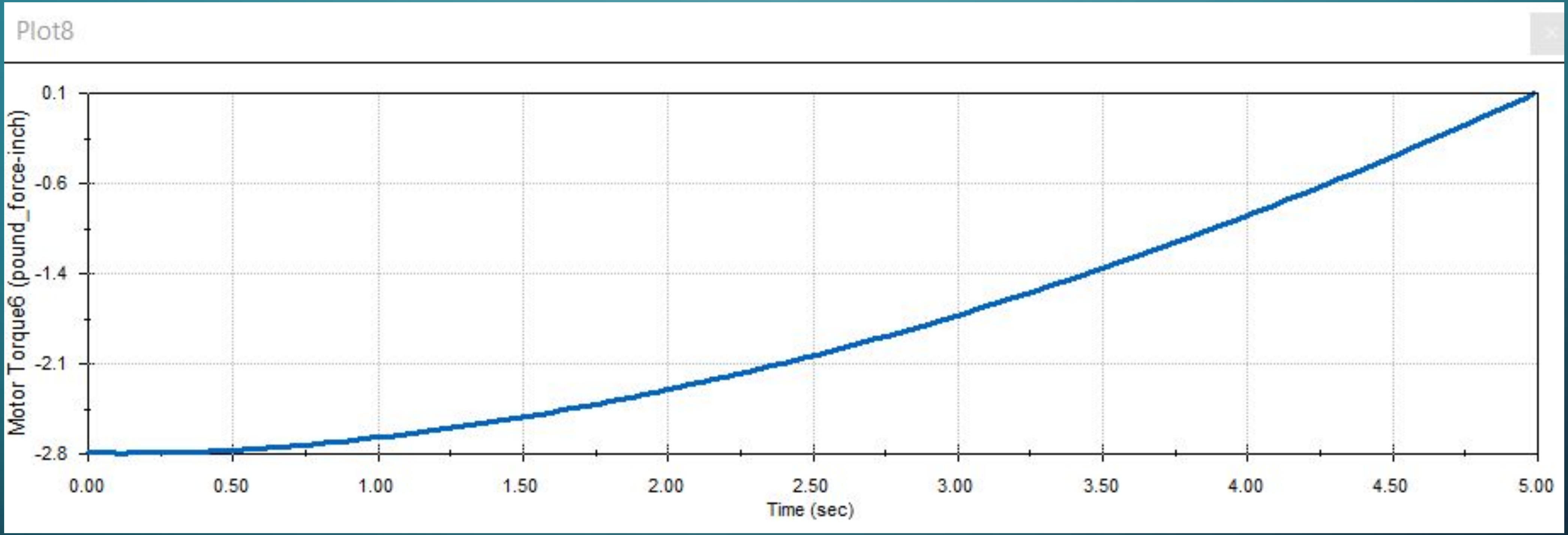
FORCE ANALYSIS – MATHCAD

$$\begin{pmatrix} SA_x \\ SA_y \\ SC_x \\ SC_y \\ SB_x \\ SB_y \\ SD_x \\ SD_y \\ ST_A \end{pmatrix} := \text{Find}(A_x, A_y, C_x, C_y, B_x, B_y, D_x, D_y, T_A)$$

$$\boxed{ST_A = -2.823\ \text{in}\cdot\text{lbf}}$$


MOTOR TORQUE MOTION ANALYSIS
SOLIDWORKS
File Edit View Insert Tools Simulation Window
romi 4 bar.SLDASM *
Search Commands
*Front
Motion Analysis
1x
0 sec 2 sec 4 sec 6 sec 8 sec 10 sec 12 sec 14 sec 16 sec 18 sec 20
Model 3D Views Motion Study 1 Motion Study 2 Motion Study 3
Under Defined
IPS

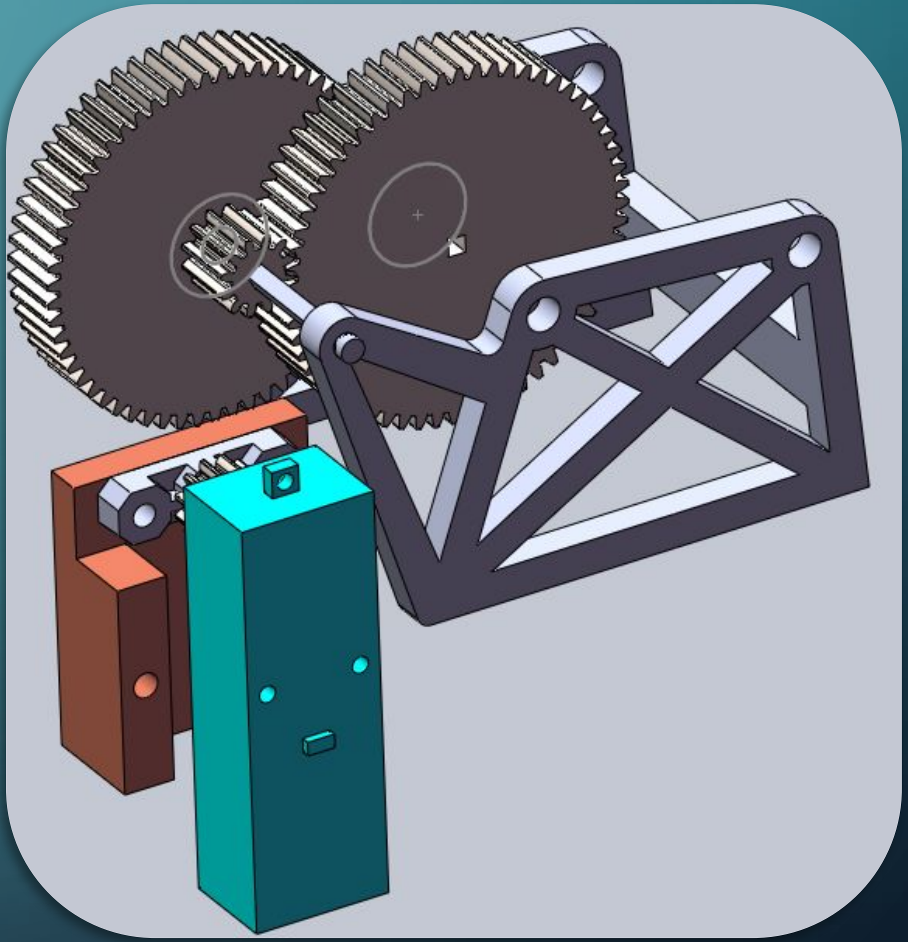
MAXIMUM MOTOR TORQUE



Max Torque: 2.8 in-lbs

TRANSMISSION

- Torque required: 2.8 in-lbs
- 100% PWM Stall Torque : 0.792 in-lbs
- 18% of Stall Torque required : 0.138 in-lbs
- 25:1 Gear Ratio for Precision Control
- 2-stage transmission
- Efficiency per stage: 90%
- Transmission efficiency: 81%
- $0.138 * 25 \ * 0.81 = \ 2.8$ in-lbs



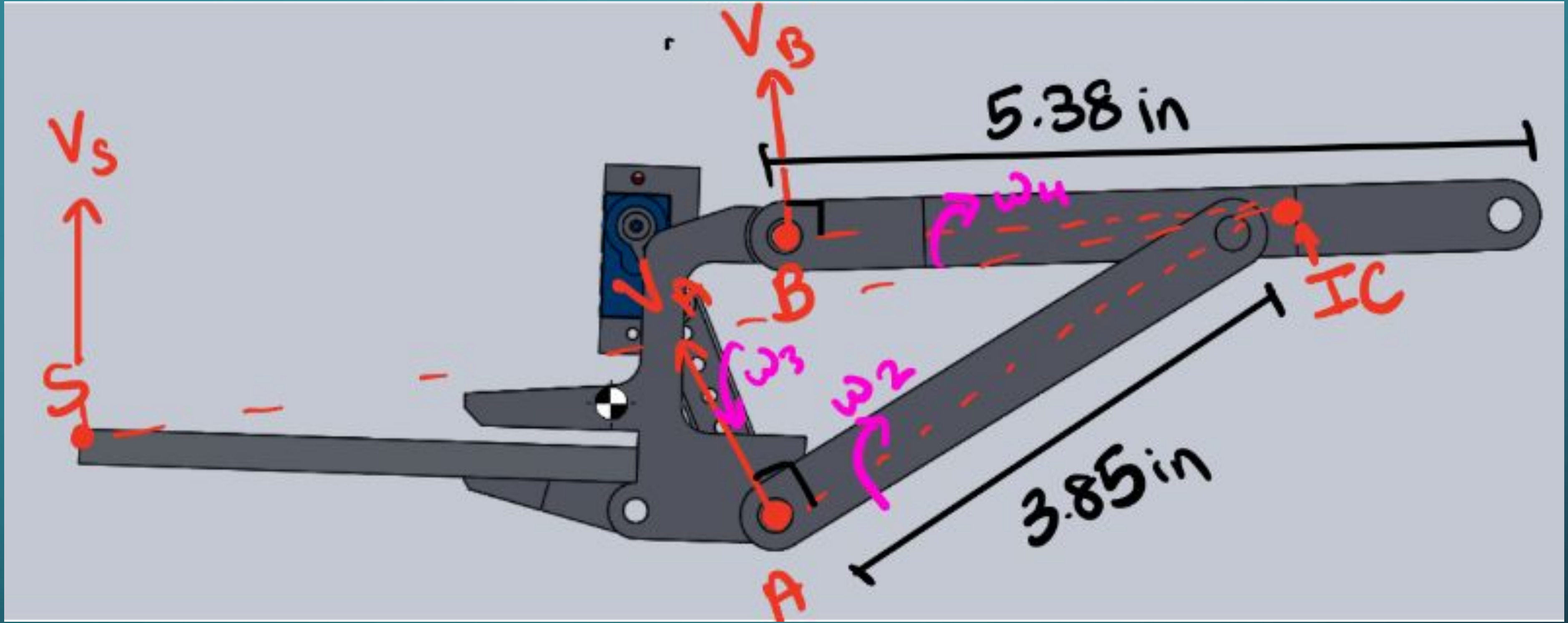
BLUE MOTOR CURRENT AT MAXIMUM TORQUE

- Current = -.0016(Speed) + .2953
- Stall Current = .2953
- Speed at Max Torque = 108 rpm
- Current at Max Torque = .12 A

OMEGA 2 CALCULATION

- No load speed = 135 rpm
- Input motor speed = 108 rpm
- Output transmission speed = 4.32 rpm
- Omega 2 = .45 rad/sec

CALCULATION OF SPEED AT PANEL

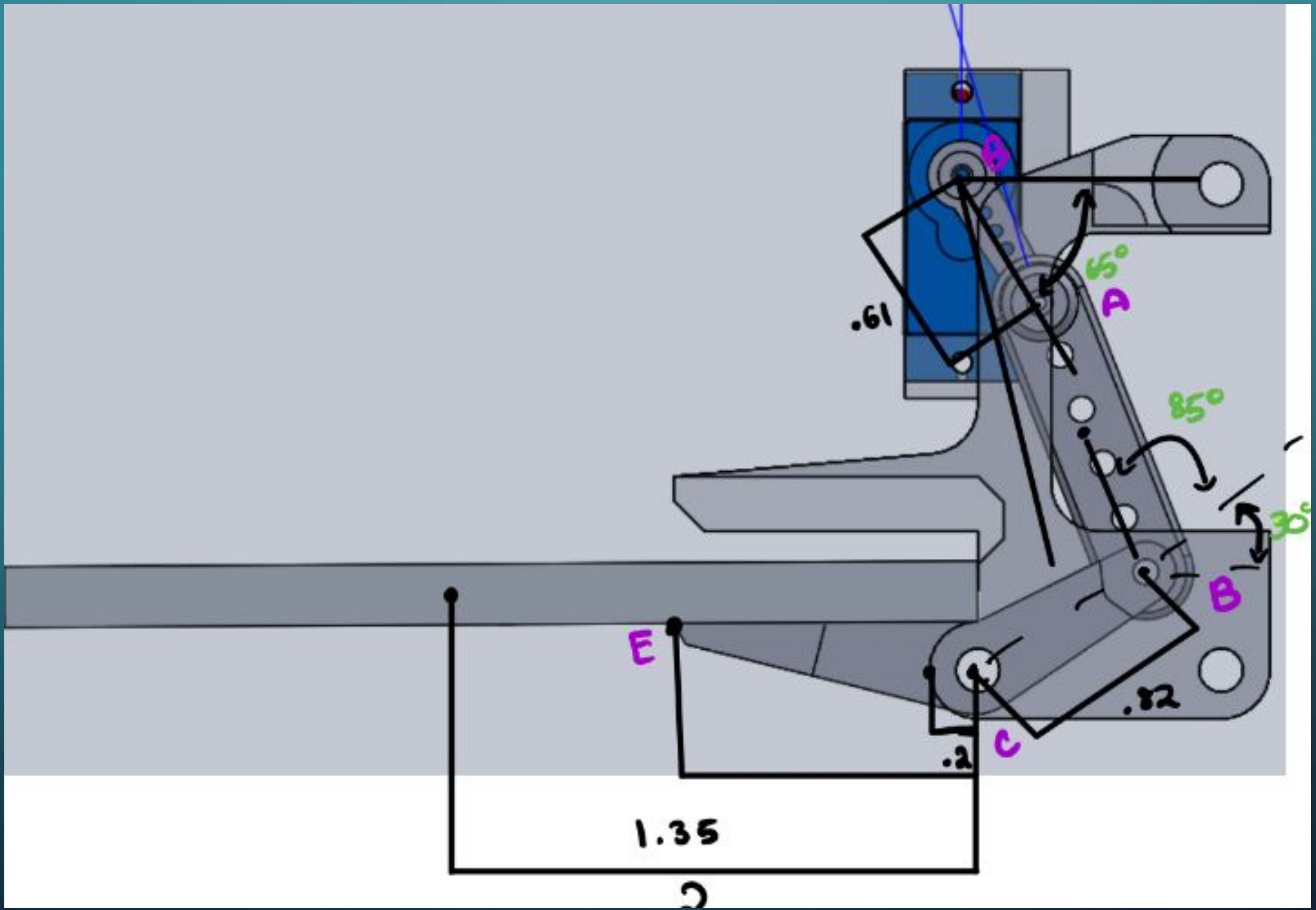


$$V_A = \frac{\omega_2}{3.85\,\text{in}} \qquad \omega_3 = \frac{V_A}{I_cA}$$

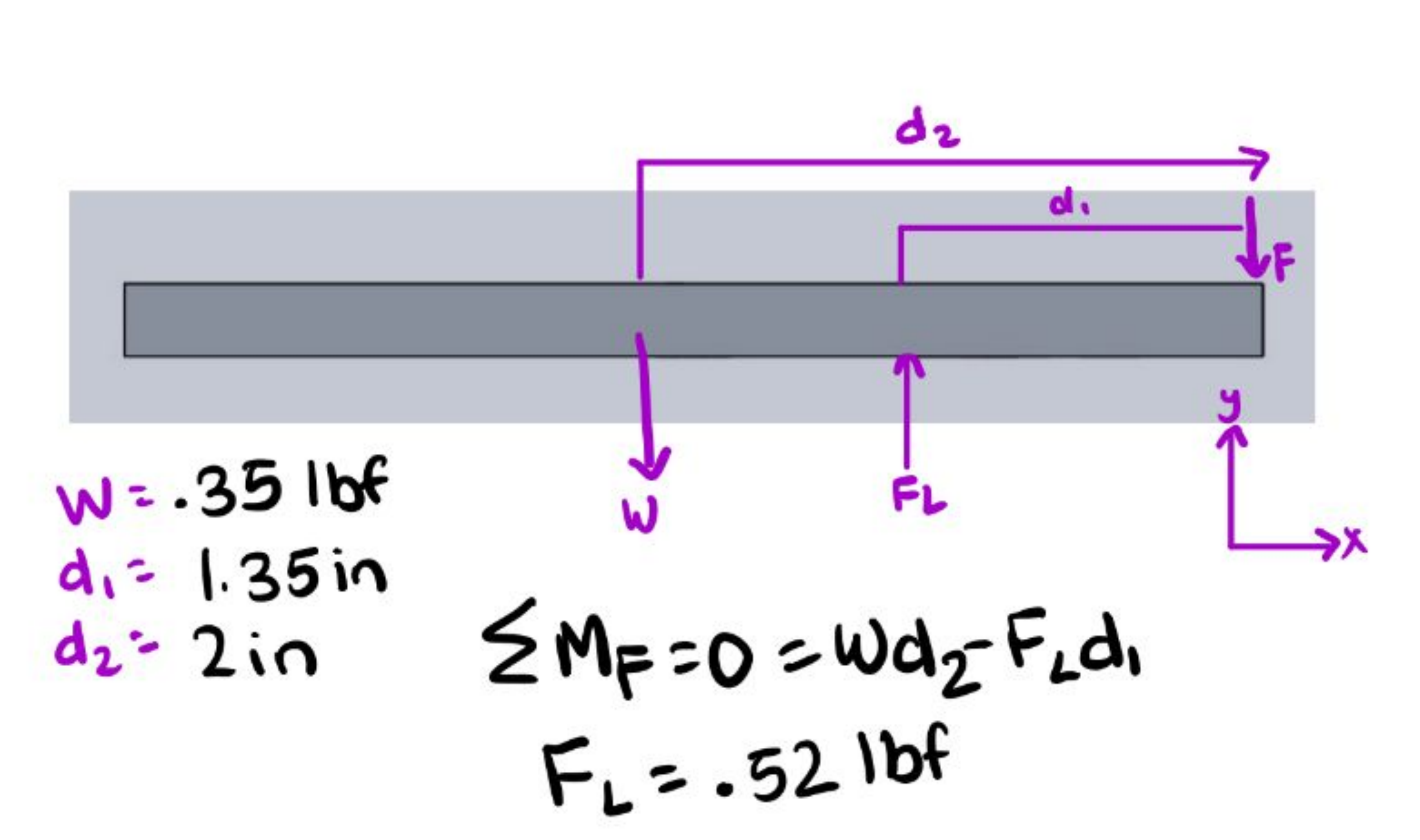
$$V_B = \omega_3(I_cB) \qquad V_S = \omega_3(I_cS)$$

$V_A = .12$ in/sec
$\omega_3 = .027$ rad/sec
$V_B = .099$ in/sec
$\boxed{V_S = .18 \text{ in/sec}}$

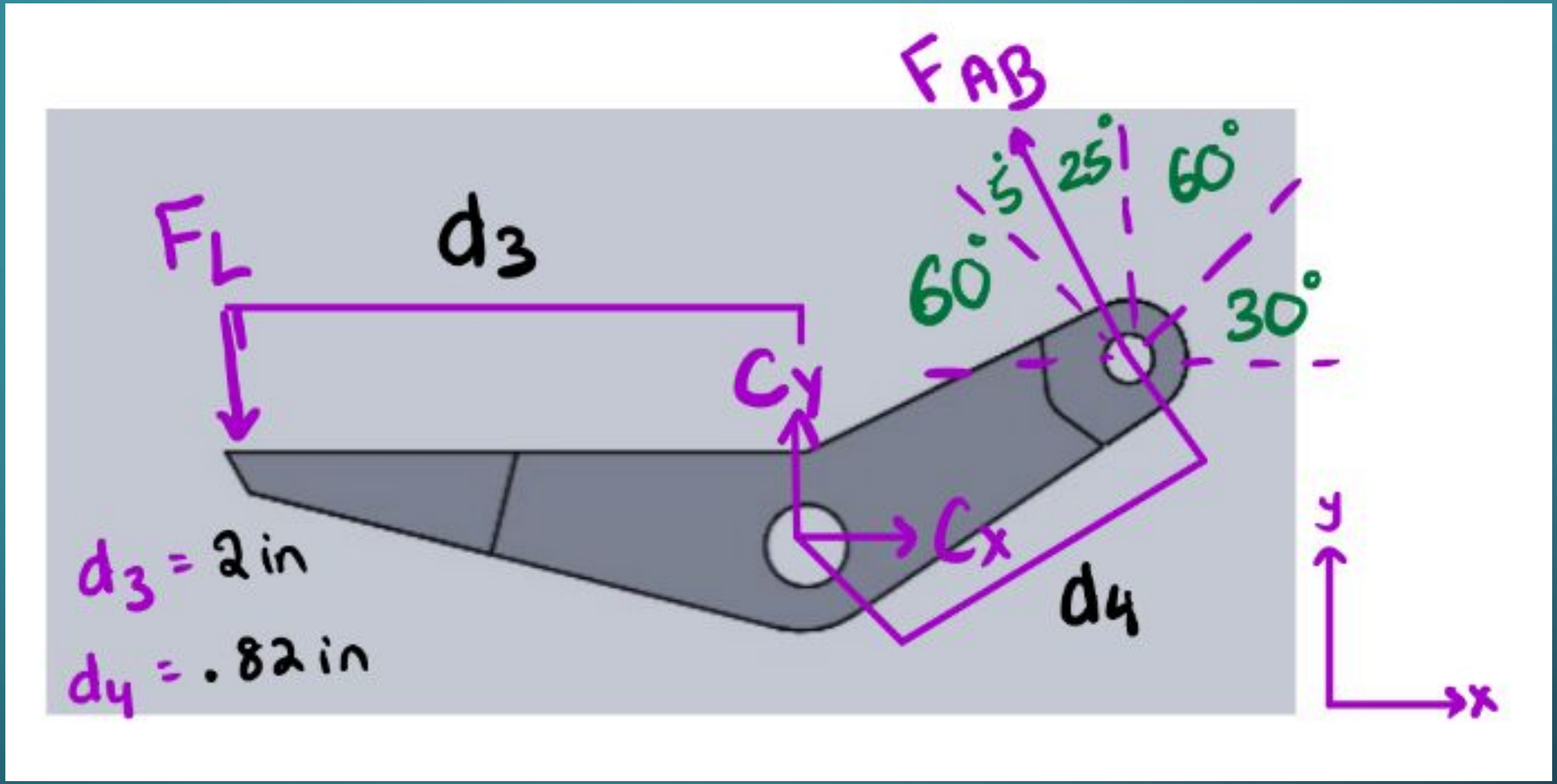
FORCE ANALYSIS – GRIPPER



FORCE ANALYSIS – FBD OF COLLECTOR



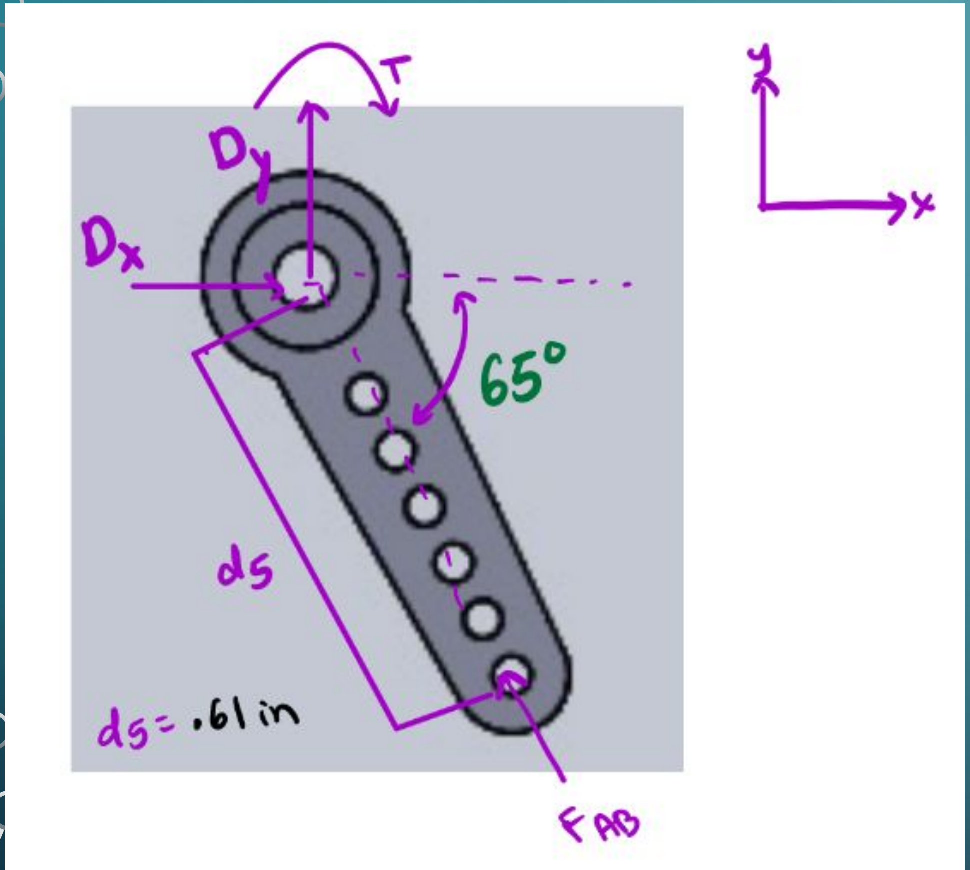
FORCE ANALYSIS – FBD OF LOWER JAW



$$\sum M_c = 0 = F_L d_3 + F_{AB}\cos(5^\circ)\, d_4$$
$$\sum F_x = 0 = C_x - F_{AB}\cos(25^\circ)$$
$$\sum F_y = 0 = -F_L + C_y + F_{AB}\sin(25^\circ)$$

$$F_{AB} = -1.28\ \text{lbf}$$
$$C_x = -1.161\ \text{lbf}$$
$$C_y = 1.06\ \text{lbf}$$

FORCE ANALYSIS – FBD OF SERVO HORN



$$\Sigma F_x = 0 = D_x$$

$$\Sigma F_y = 0 = D_y$$

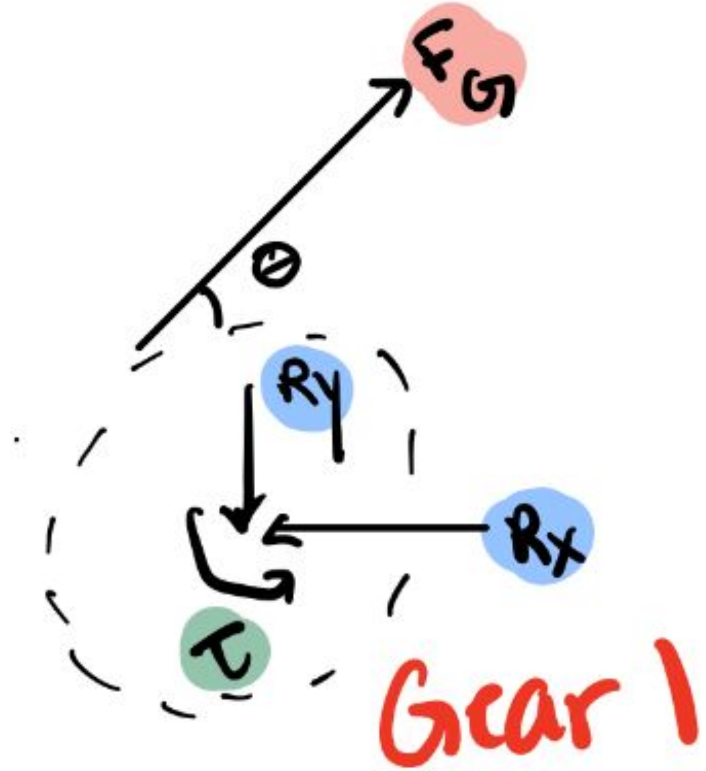
$$M_D = (.61)\cos(65°) - (.61)\sin(65°) - T$$

$D_x = 0$ lbf

$D_y = 0$ lbf

$T = 0$ in-lbf

FORCE ANALYSIS – FBD OF GEAR 1



$$\Sigma F_x = 0 = F_G \cos\theta - R_x$$

$$\Sigma F_y = 0 = F_G \sin\theta - R_y$$

$$\Sigma M = 0 = F_G \cos\theta(\Delta y) + F_G \sin\theta(\Delta x) - T$$

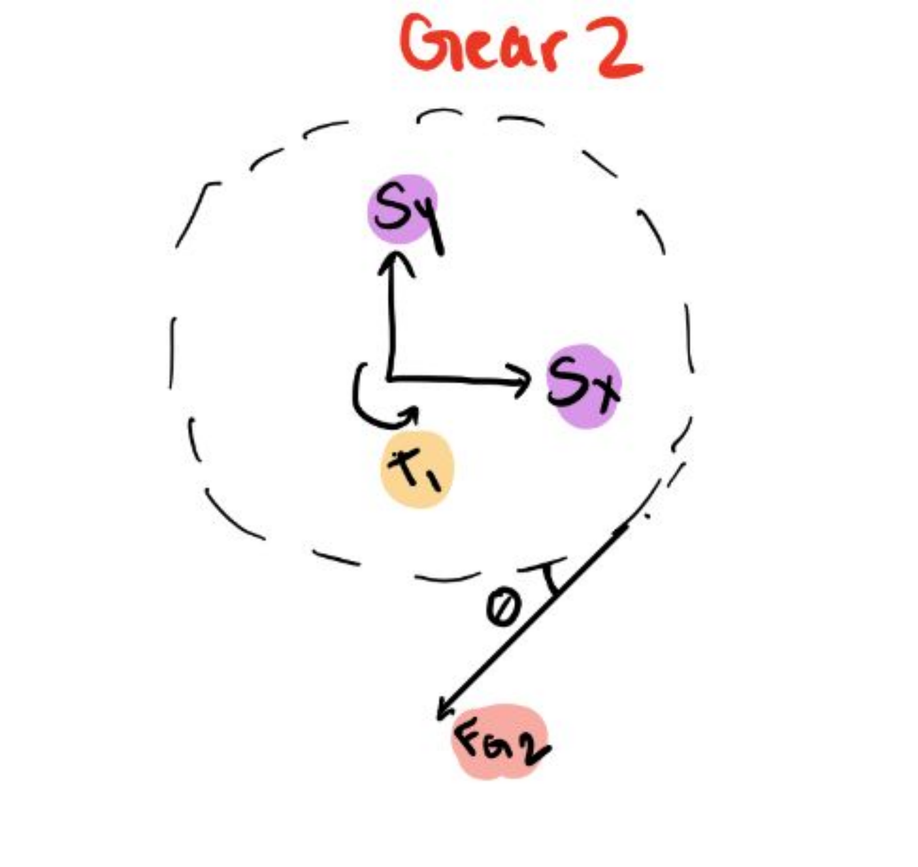
$R_x = .235\ \text{lbf}$

$R_y = .085\ \text{lbf}$

$F_G = .25\ \text{lbf}$

$T = .25\ \text{in-lbf}$

FORCE ANALYSIS – FBD OF GEAR 2



$$\Sigma F_x = 0 = S_x - F_{G_2}\cos\theta$$

$$\Sigma F_y = S_y - F_{G_2}\sin\theta$$

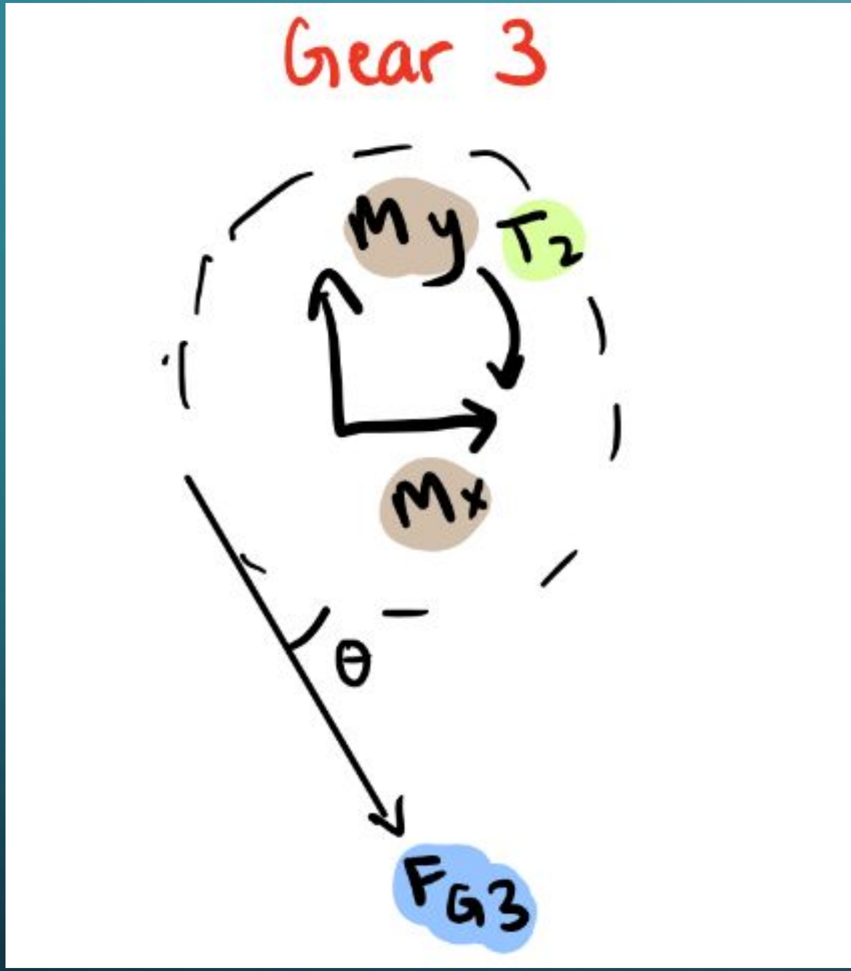
$$\Sigma M_{G_2} = -F_{G_2}\cos\theta\,\Delta y + F_{G_2}\sin\theta\,\Delta x - T_1$$

$S_x = .24$ in-lbf

$S_y = .085$ in-lbf

$T_1 = .162$ in-lbf

FORCE ANALYSIS – FBD OF GEAR 3



$$\Sigma F_x = 0 = M_x + F_{G3}\cos\theta$$

$$\Sigma F_y = 0 = M_y - F_{G3}\sin\theta$$

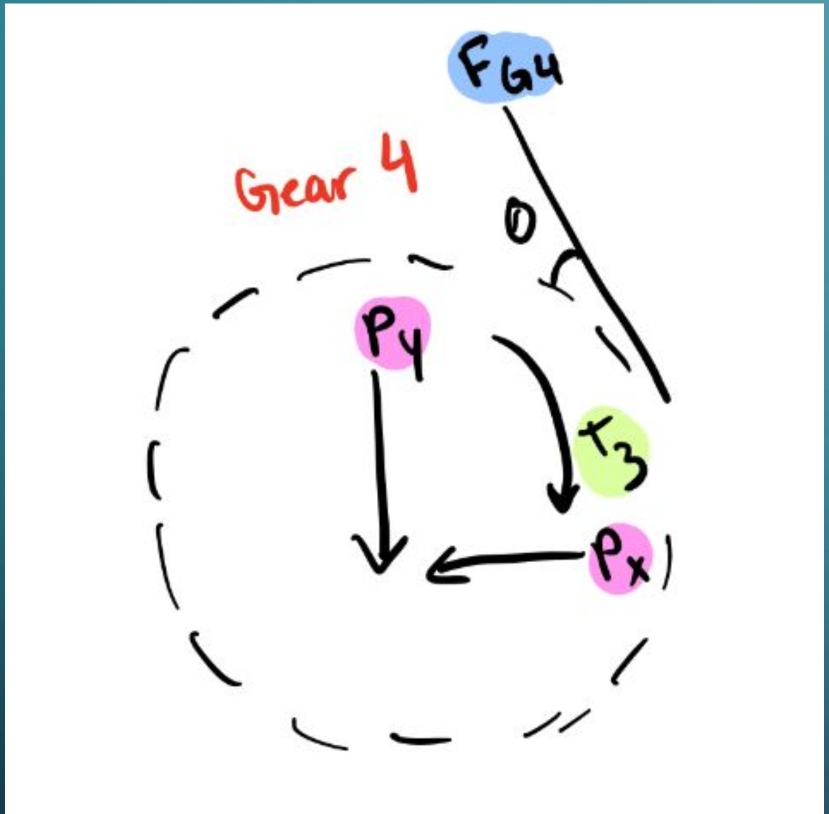
$$M_{G3} = F_{G3}\cos\theta\,\Delta y - F_{G3}\sin\theta\,\Delta x + T_2$$

$F_{G3} = 7.2$ lbf

$M_y = 2.45$

$M_x = -6.77$

FORCE ANALYSIS – FBD OF GEAR 4



$$\Sigma F_x = 0 = -P_x - F_{G4}\cos\theta$$

$$\Sigma F_y = 0 = P_y - F_{G4}\sin\theta$$

$$\Sigma M_{G4} = -F_{G4}\cos\theta\,\Delta y - F_{G4}\sin\theta\,\Delta x + T$$

$P_x = -6.77$

$P_y = 2.448$

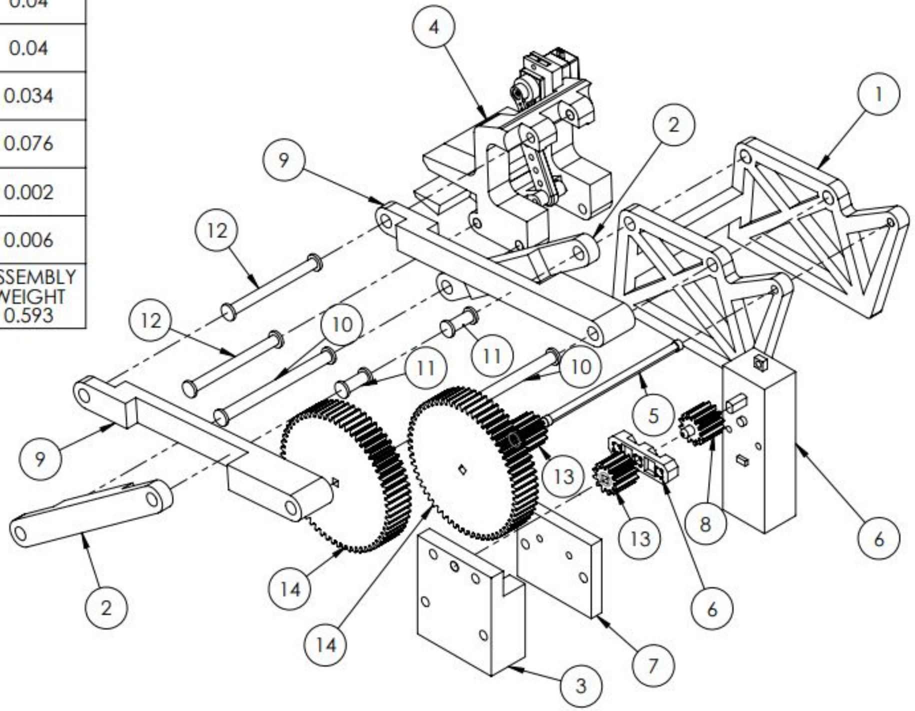
$T_3 = 4.64$

GEAR FACTOR OF SAFETY

P of Vex Gears: 24 teeth per inch
Pitch diameter of 60 tooth Vex gear: 2.5 in
Force on tooth = Output torque/(pitch diameter/2) = 2.8 in-lb / (2.5in/2) = 2.24
Area of gear Tooth = Thickness of tooth * Width of tooth
Tooth thickness = pi/2p = pi/48
Width of tooth (from measurement) = .5 in
Area of gear tooth = (pi/48) * .5 = .0327 in^2
Working shear stress = F/A = 2.24lbf/.0327 in^2 = 68.50 psi
Material of vex gears (from website): acetal plastic = shear stress of 9800 psi
FOS = Max shear stress/working shear stress = 9800psi/68.50psi = 143

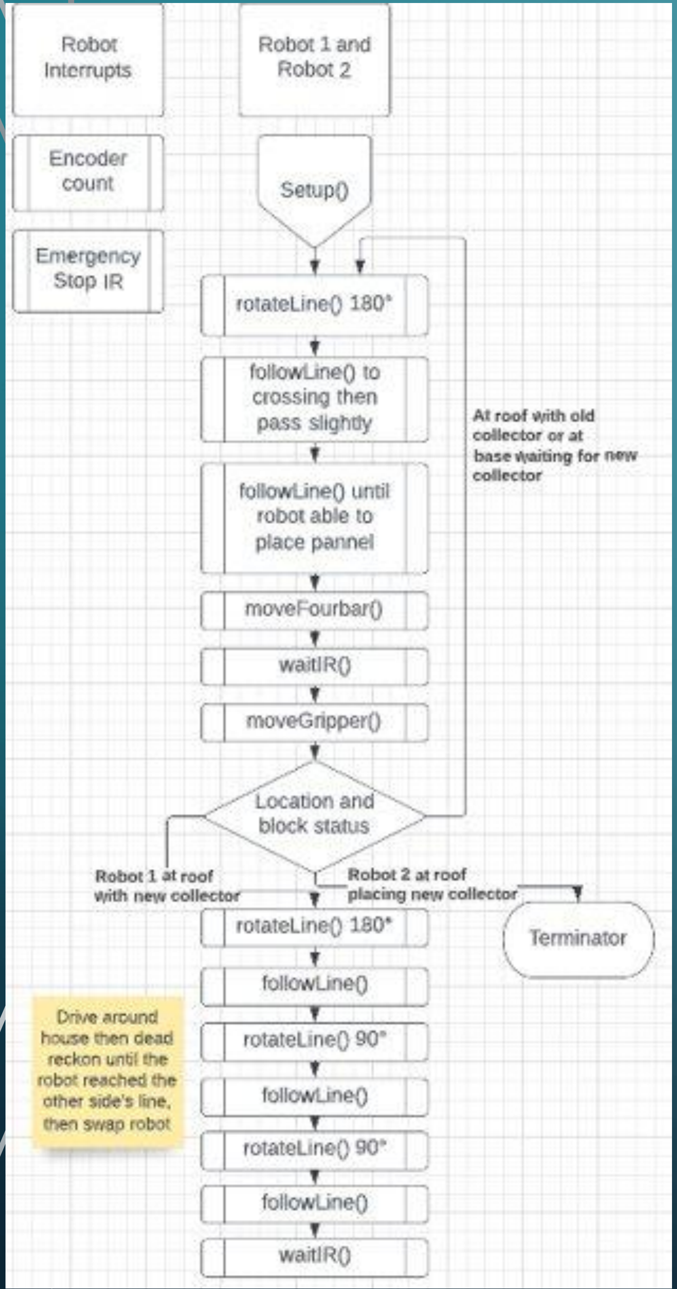
FOUR BAR AND TRANSMISSION BILL OF MATERIALS

ITEM NO.	PART NUMBER	QTY.	MATERIAL	UNIT COST	EXT. COST	UNIT WEIGHT (LBS)	EXT. WEIGHT (LBS)
1	FOURBAR_BASE	1	PLA	$1.50	$1.50	0.105	0.085
2	SHORT_BAR	2	PLA	$0.36	$0.72	0.025	0.05
3	GEAR_MOUNT	1	PLA	$0.03	$0.03	0.002	0.002
4	GRIPPER_ASM	1	PLA + ELECTRONICS	$4.59	$4.59	0.126	0.126
5	VEX_SHAFT	1	ALUMINUM	$0.75	$0.75	0.03	0.03
6	BLUE_MOTOR	1	ELECTRONICS	$6.50	$6.50	0.1	0.1
7	MOTOR_MOUNT	1	PLA	$0.05	$0.05	0.001	0.001
8	GEAR_12T_EXT	1	PLA	$0.05	$0.05	0.001	0.001
9	LONG_BAR	2	PLA	$0.57	$1.14	0.04	0.04
10	LONG_SHAFT	2	ALUMINUM	$1.00	$2.00	0.04	0.04
11	SHORT_SHAFT	2	ALUMINUM	$0.25	$0.50	0.017	0.034
12	MEDIUM_SHAFT	2	ALUMINUM	$0.80	$1.60	0.038	0.076
13	GEAR_12T	2	PLA	$0.02	$0.04	0.001	0.002
14	GEAR_60T	2	PLA	$0.04	$0.08	0.003	0.006
					ASSEMBLY COST $19.55		ASSEMBLY WEIGHT 0.593



TEAM_14	FOURBAR	SCALE: 1:2	10/6/22

PROGRAMMING FLOWCHART



Function descriptions

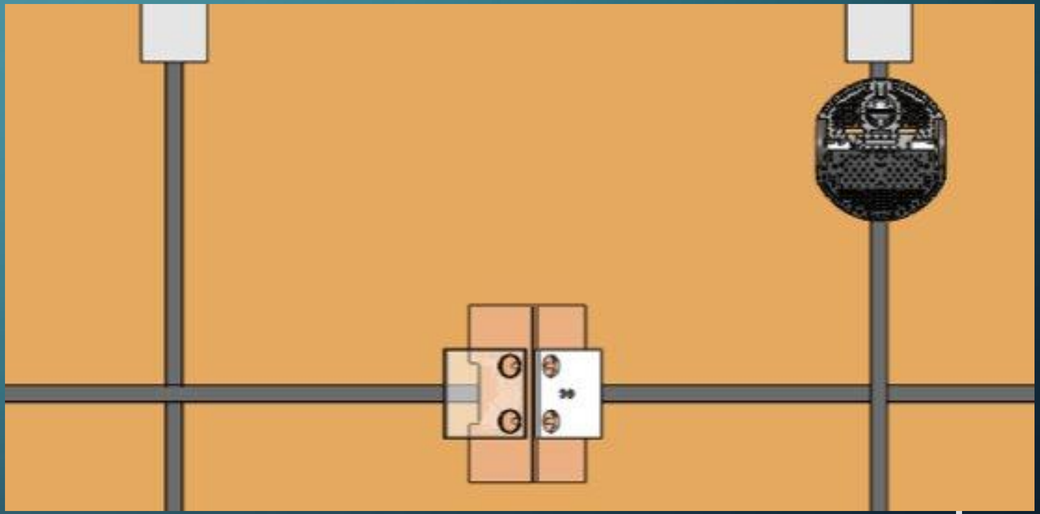
rotateLine(): rotate off the line with dead reckoning. then check when both reflective sensors detect the line (either 90° or 180°)

followLine(): use proportional control to set motor power based on which reflective sensor detects the line until both detect the crossing line or a distance supplemented with ultrasonic distance sensor

moveFourbar(): rotate the fourbar to a predefined height
1 = ground
2 = slightly above steep roof
3 = place on steep roof
4 = slightly above shallow roof
5 = place on shallow roof

moveGripper(): open and close gripper if the change in the pot's reading reflect servo movement, otherwise emergency open
1 = closed
2 = open

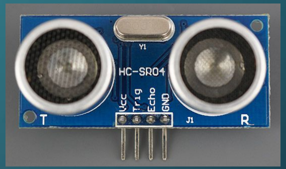
waitIR(): waits for a specified IR input before continuing program



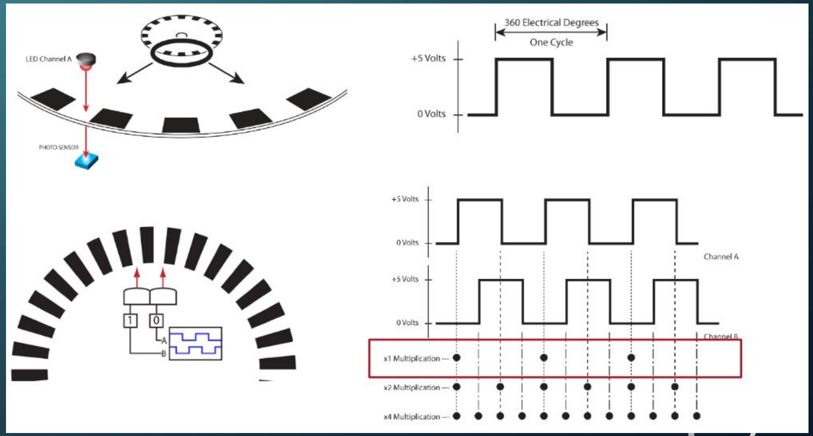
SUMMARY OF SENSORS

- IR sensor
  - Emergency stop
  - Resume robot operation

- Reflectance sensors
  - Line following and rotation using proportional control



- Ultrasonic sensor
  - Detects distance to center vertical panel and uses proportional control to move toward it, then stop



- Blue motor internal quadrature encoders
  - 540 tick resolution / revolution
  - Rotates four bar to certain position using proportional control, then stop
- Drive motor internal encoders
  - Dead reckoning to drive a certain distance when unable to use other sensors
- Servo internal potentiometer
  - Determines if the servo is moving correctly and reaches the right position

THANKS!

Any questions?