University of Idaho
College of Engineering

3-AXIS CENTER OF GRAVITY INSTRUMENT

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INTRODUCTION

- Center of Gravity
- Natural Frequency of Entire Device
- Strain on Server Rack Mount Ears

PROJECT REQUIREMENTS

MECHANICAL

- Automatic
- 50 lbs
- Re-creatable
- Stretch goal: Vibration Test

ELECTRICAL

- 120 VAC

SOFTWARE

- Average Cartesian CG

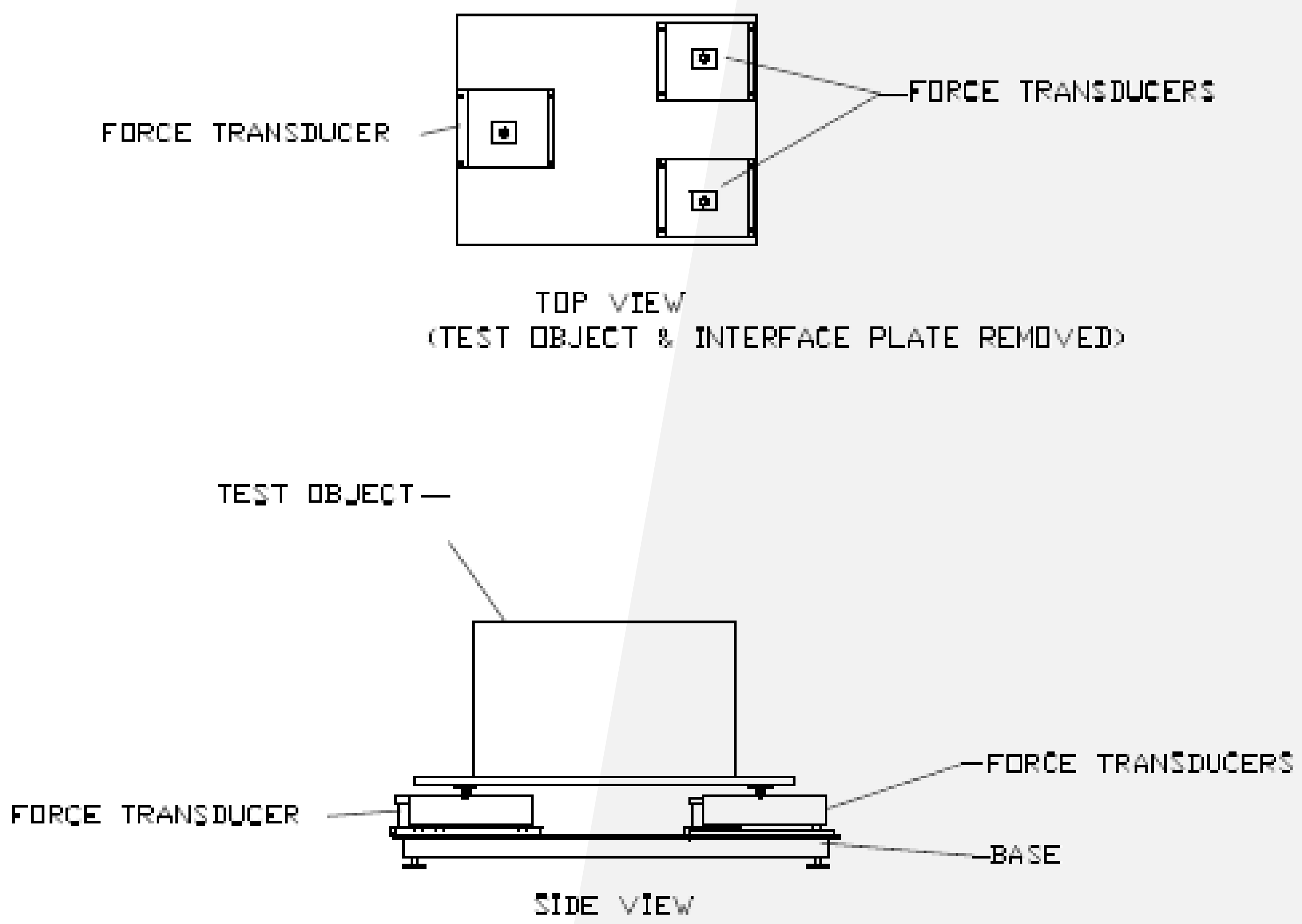
ENVIRONMENTAL

- 60 to 85°F

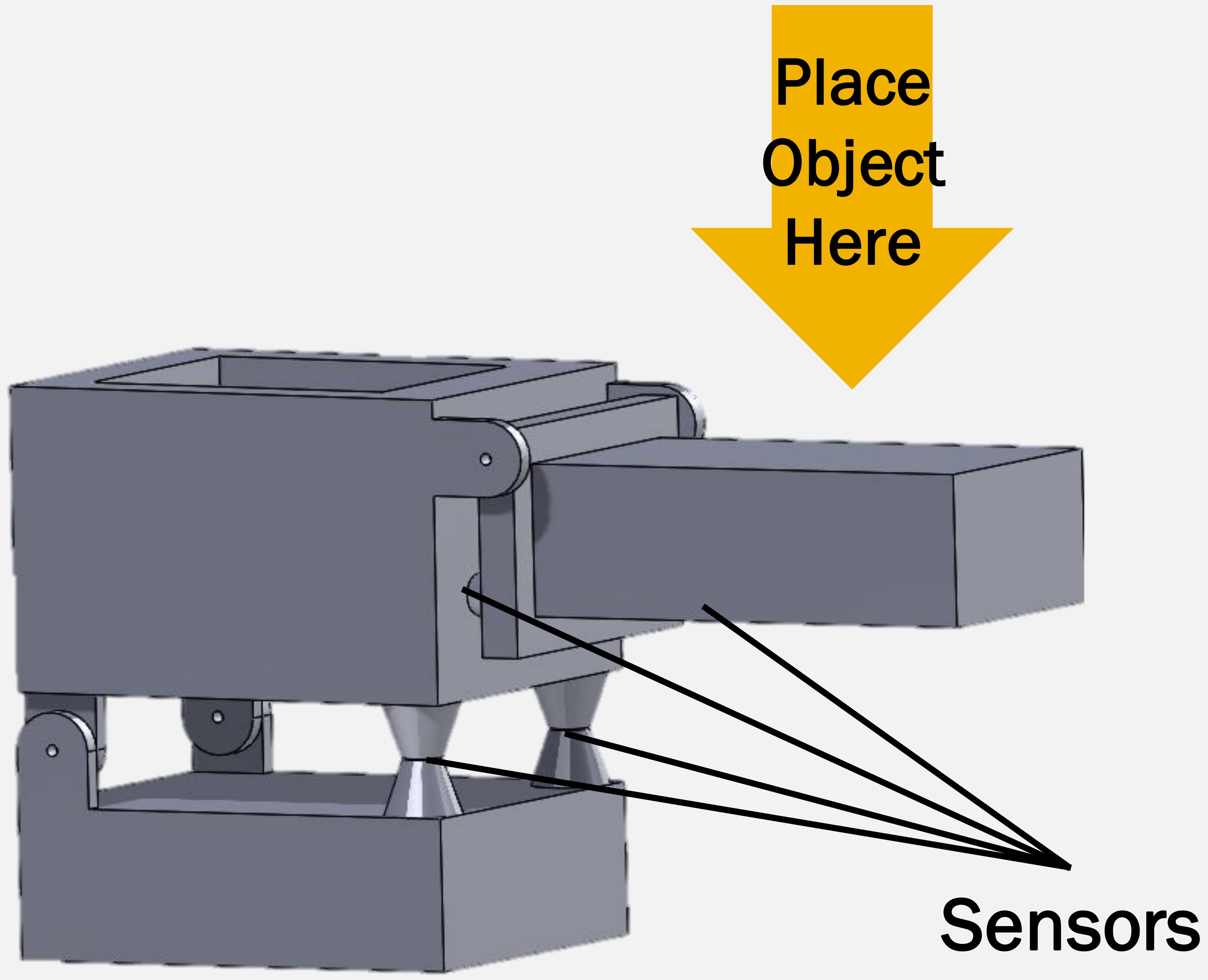
COST

- $1661

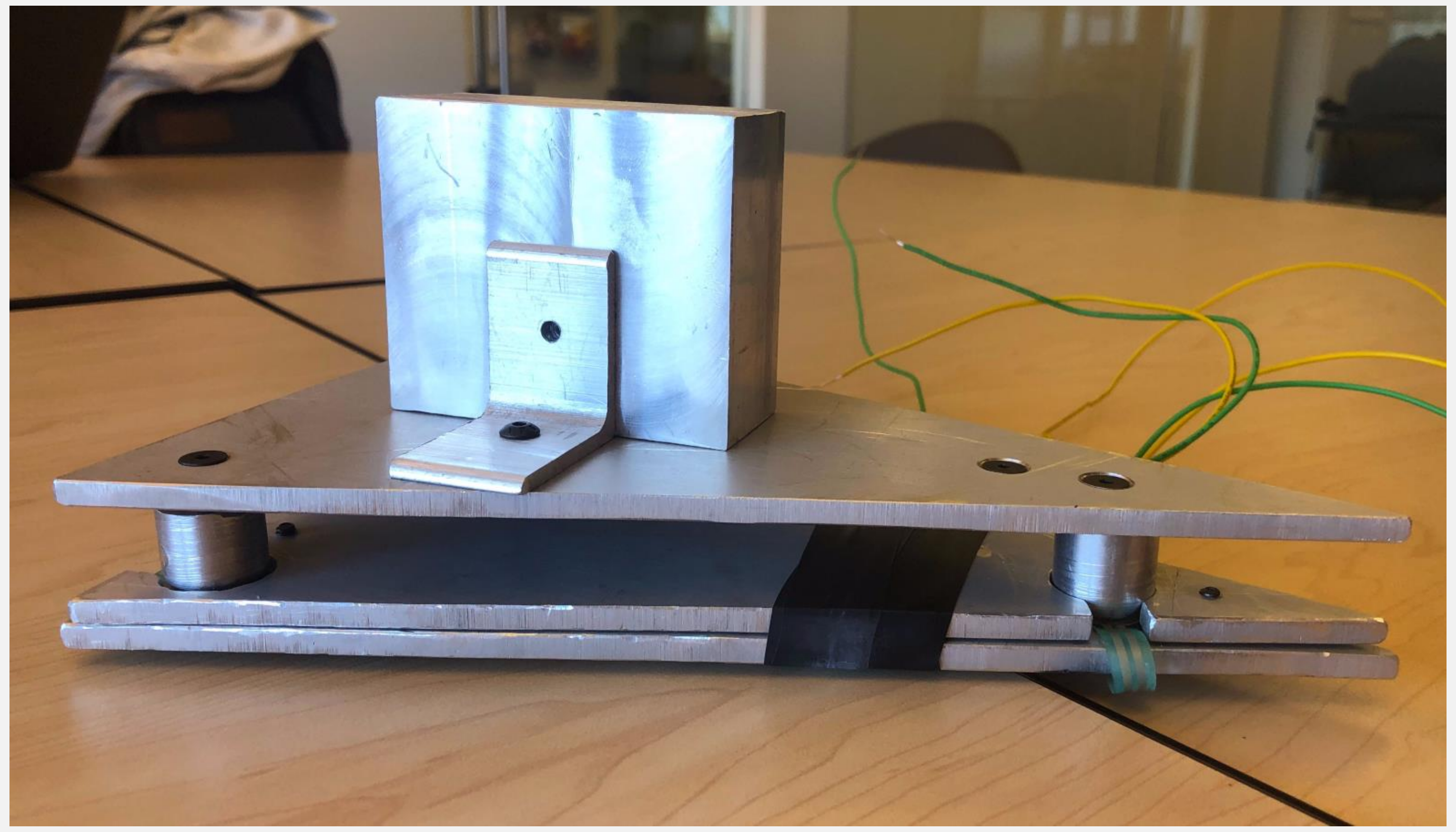
FIRST SEMESTER



September 2018

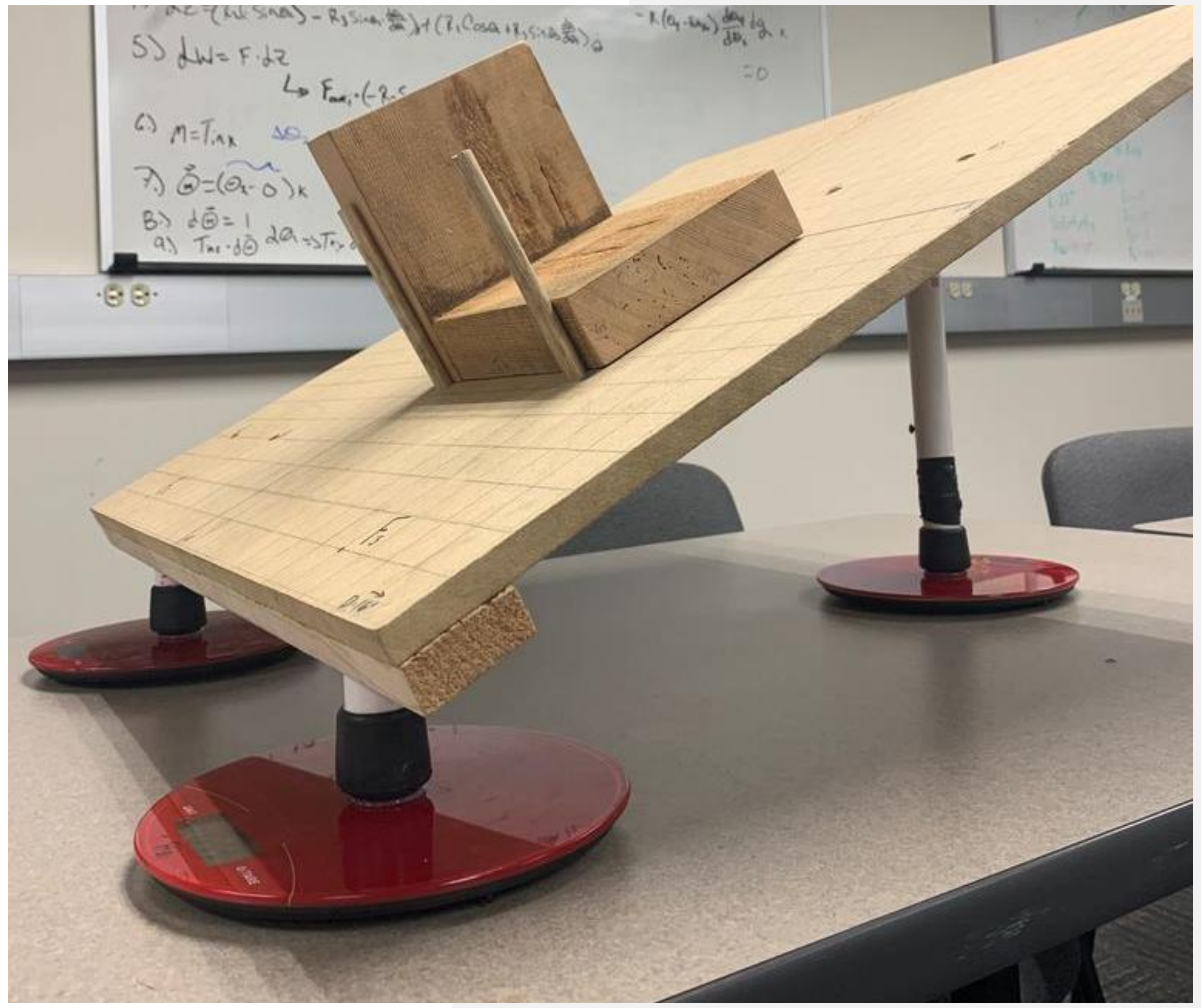


October 2018



November 2018

SECOND SEMESTER



January 2019

February 2019

April 2019

TESTING PROTOTYPE PROGRESSION

First Design Iteration

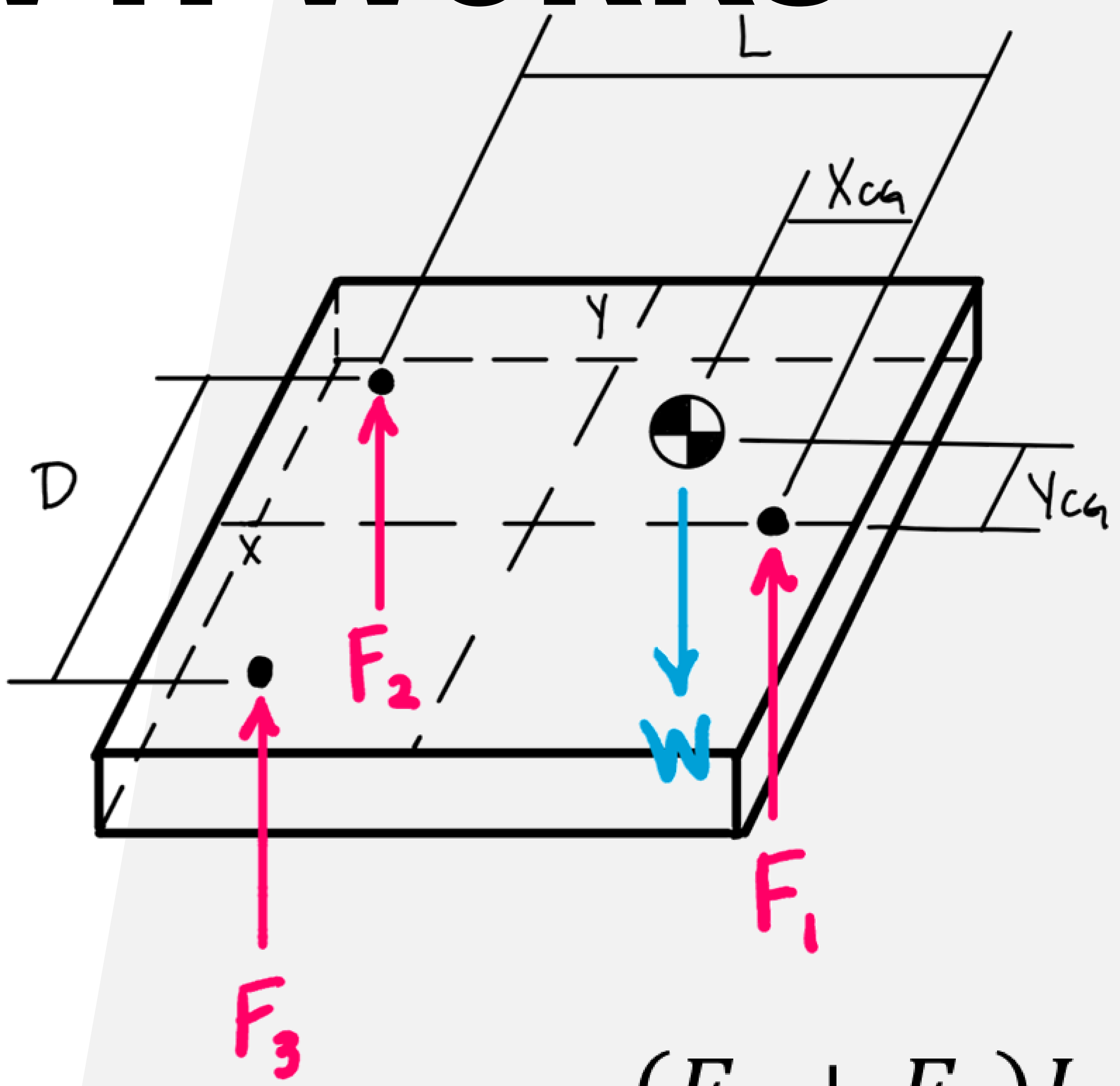
Second Design Iteration

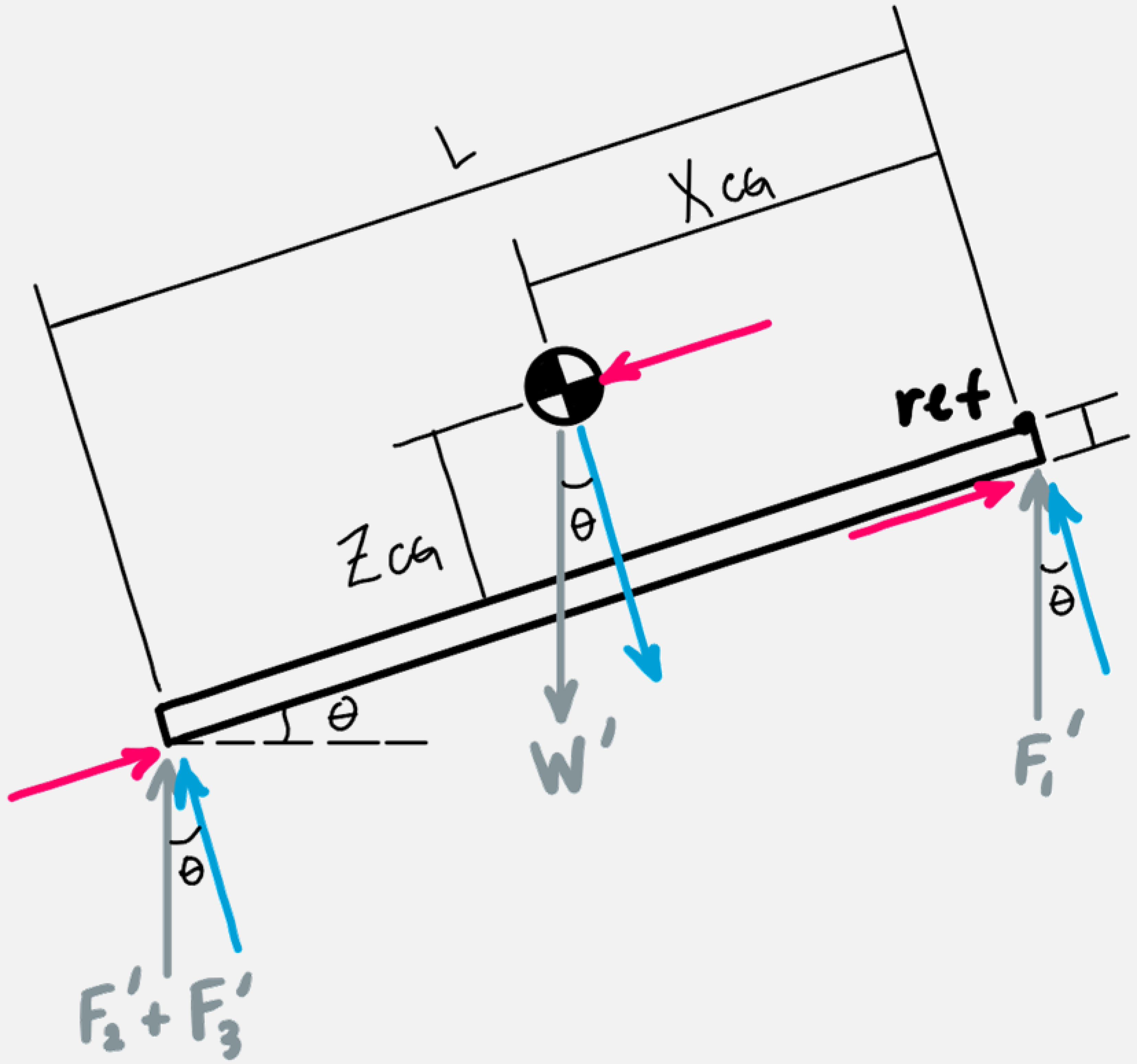
Final Design Iteration

CG TESTING DATA

	Measured	Actual	Percent Error
X	2.7"	2.75"	**1.85%**
Y	2.6"	2.56"	**1.54%**
Z	1.8"	1.9"	**5.56%**

HOW IT WORKS





$$X_{CG} = \frac{(F_2 + F_3)L}{W}$$

$$Y_{CG} = \frac{(F_2 + F_3)D}{2W}$$

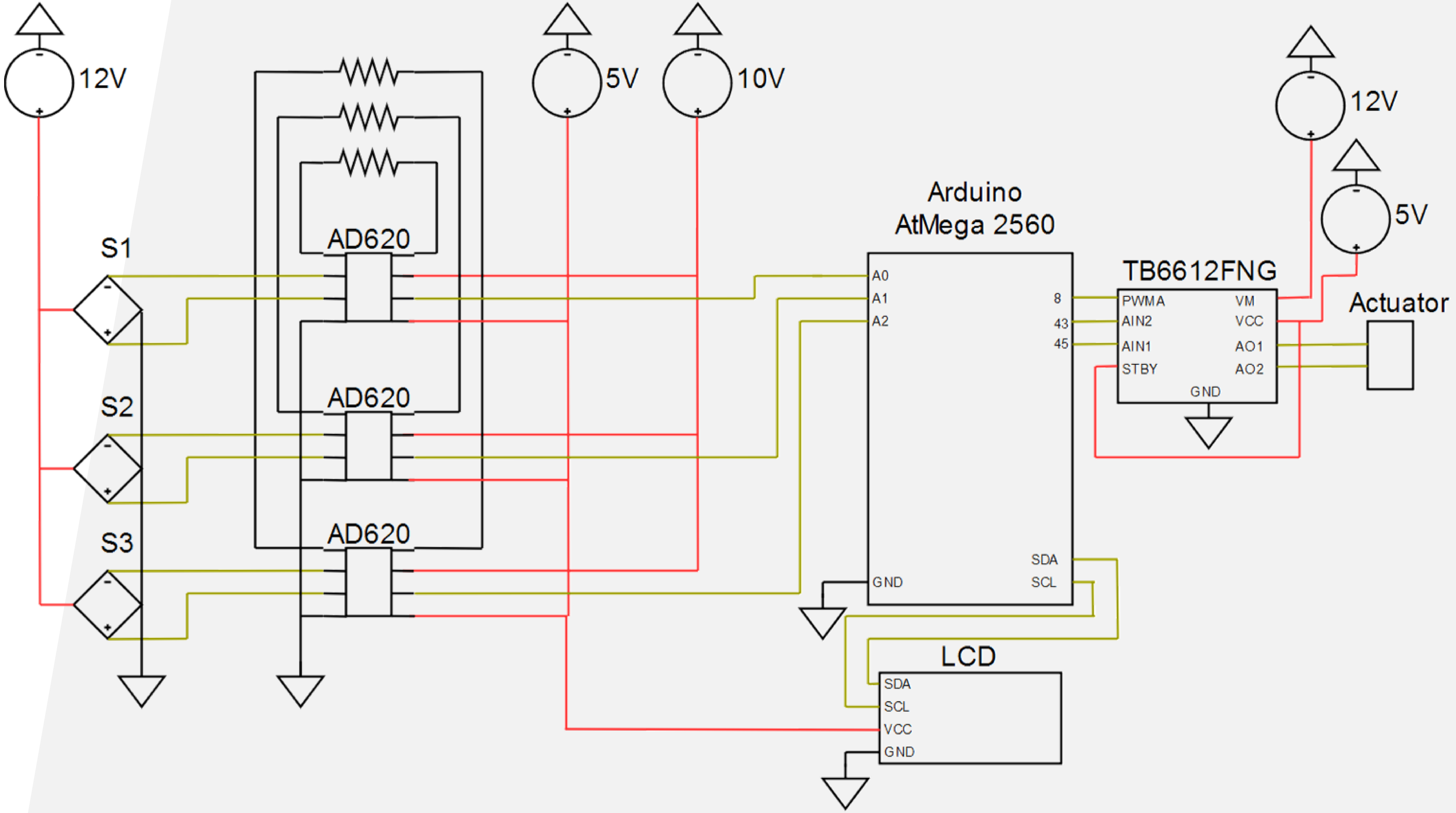
$$Z_{CG} = \frac{(F_2' + F_3')\cos\theta * L \; - W'\,(\sin\theta * t + \cos\theta * x_{cg})}{W'\sin\theta}$$

FINAL DESIGN

GENERAL SPECIFICATIONS

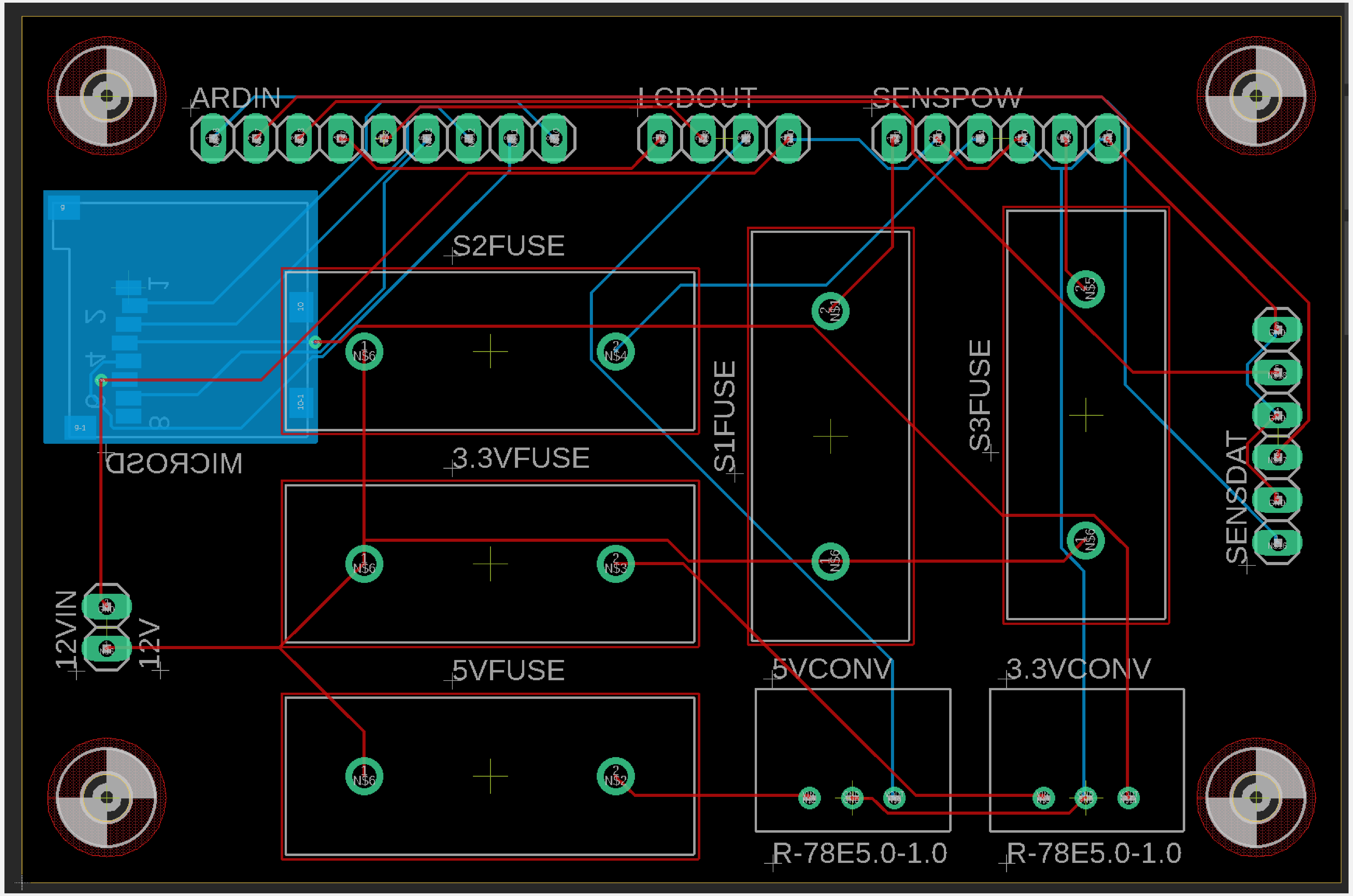
Weight	67.8 lbs
Size	24" x 24" x 33"
Maximum Angle	32°
Sensors	S-type Load Cell, 25 lb limit each
Actuator	150 lb ; 12 in stroke ; 0.37 in/sec Duty Cycle: 25% (5 min on/15 min off)

ELECTRICAL DESIGN

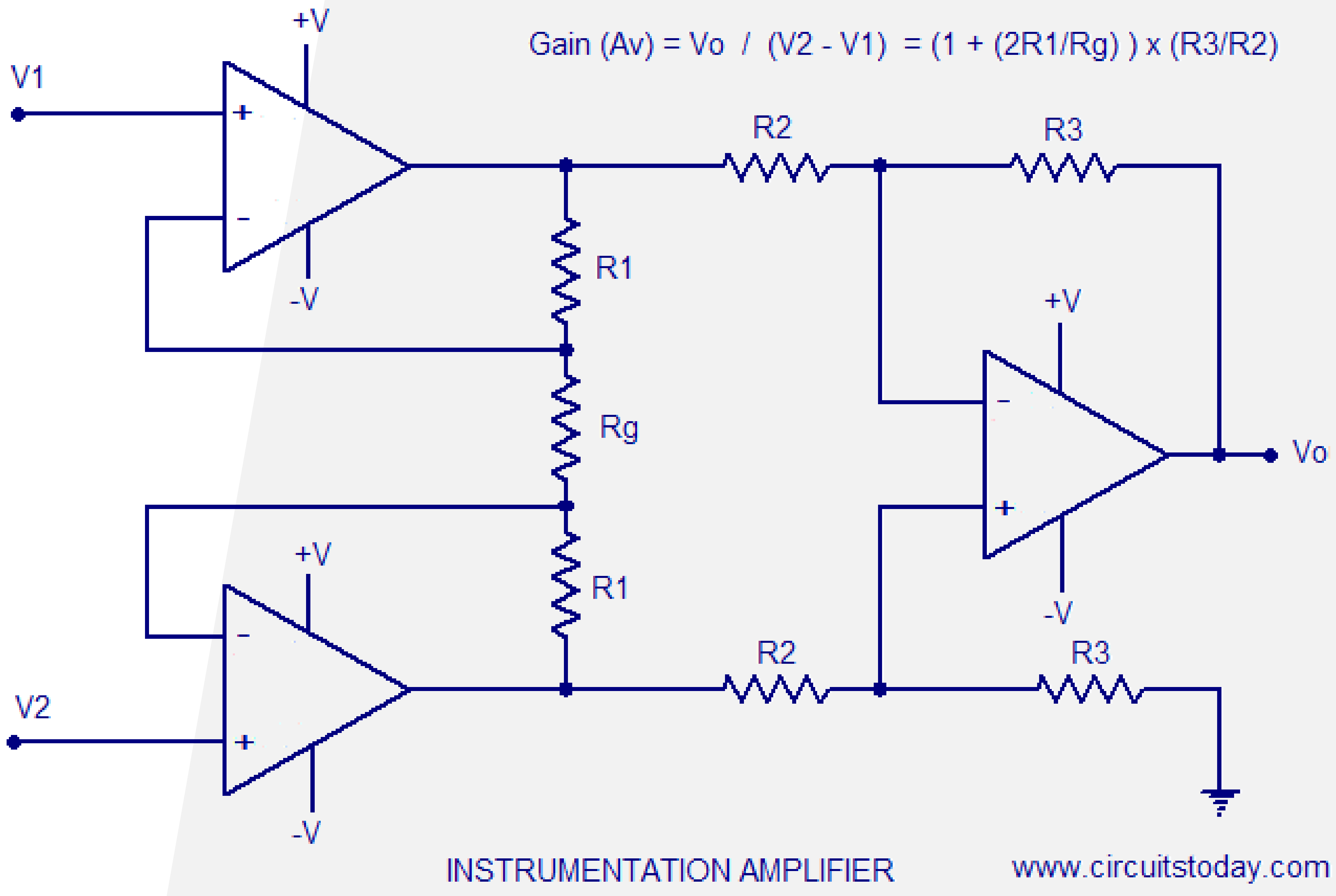


PROBLEMS

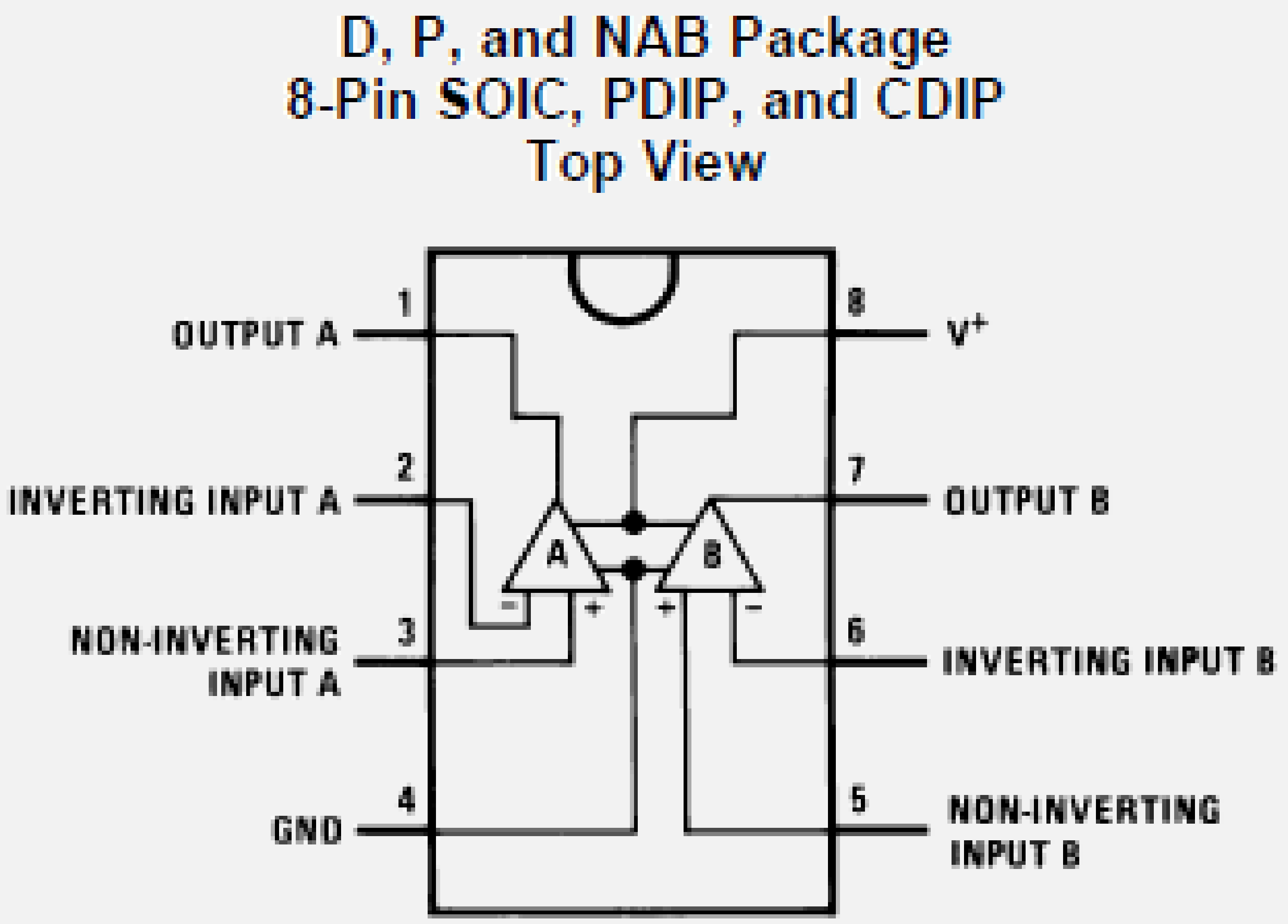
- PCB
- Shorting/Power
- LCD Display
- Amplification



AMPLIFICATION



LM358AN

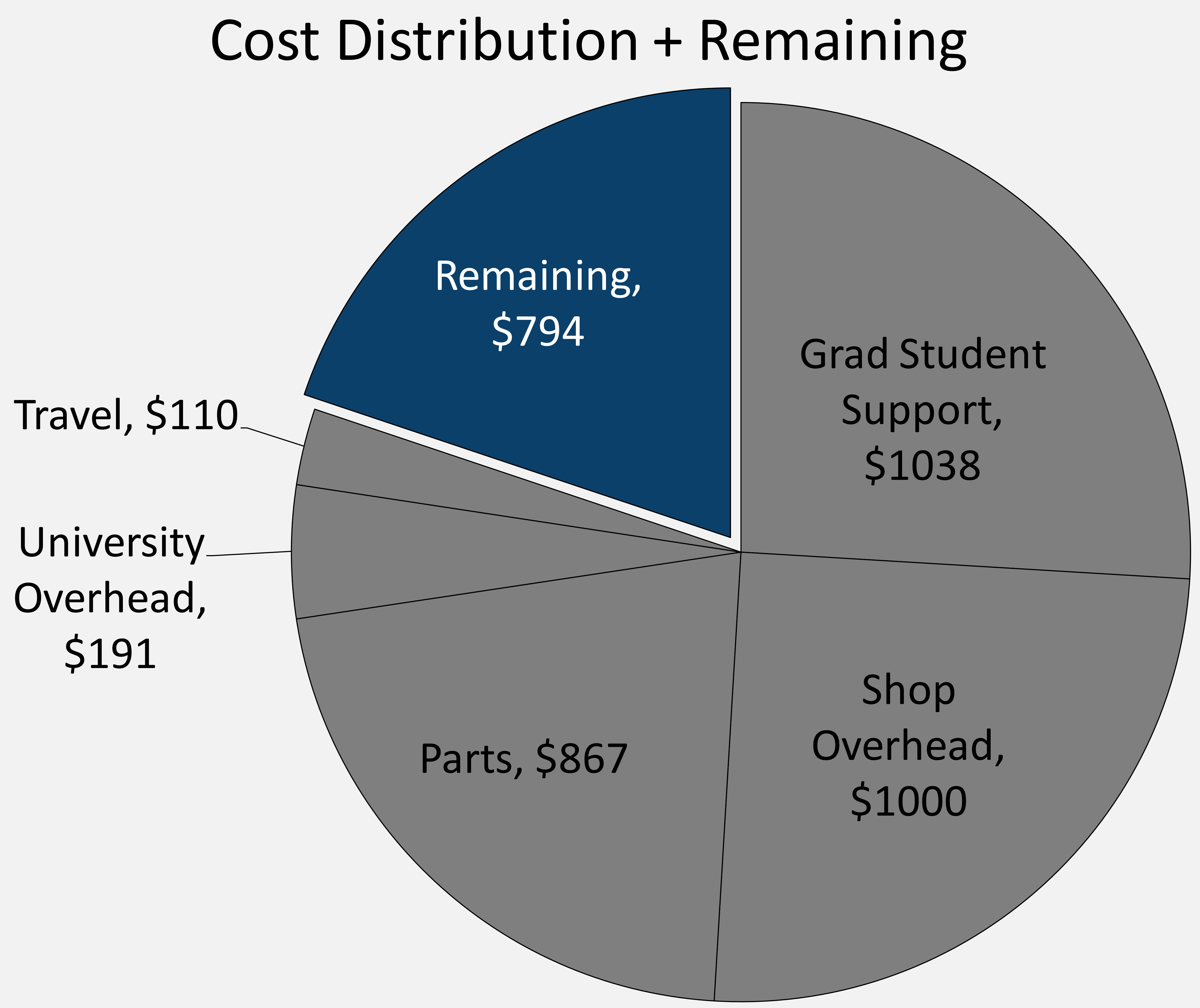


OPERATION INSTRUCTIONS

1. Turn on using red switch
2. Push button to start calibration
3. Relay is placed on top of device
4. Button is pushed again to start CG calculation
5. CG data is output to the LCD screen
6. Turn off the device

DEVELOPMENT COST

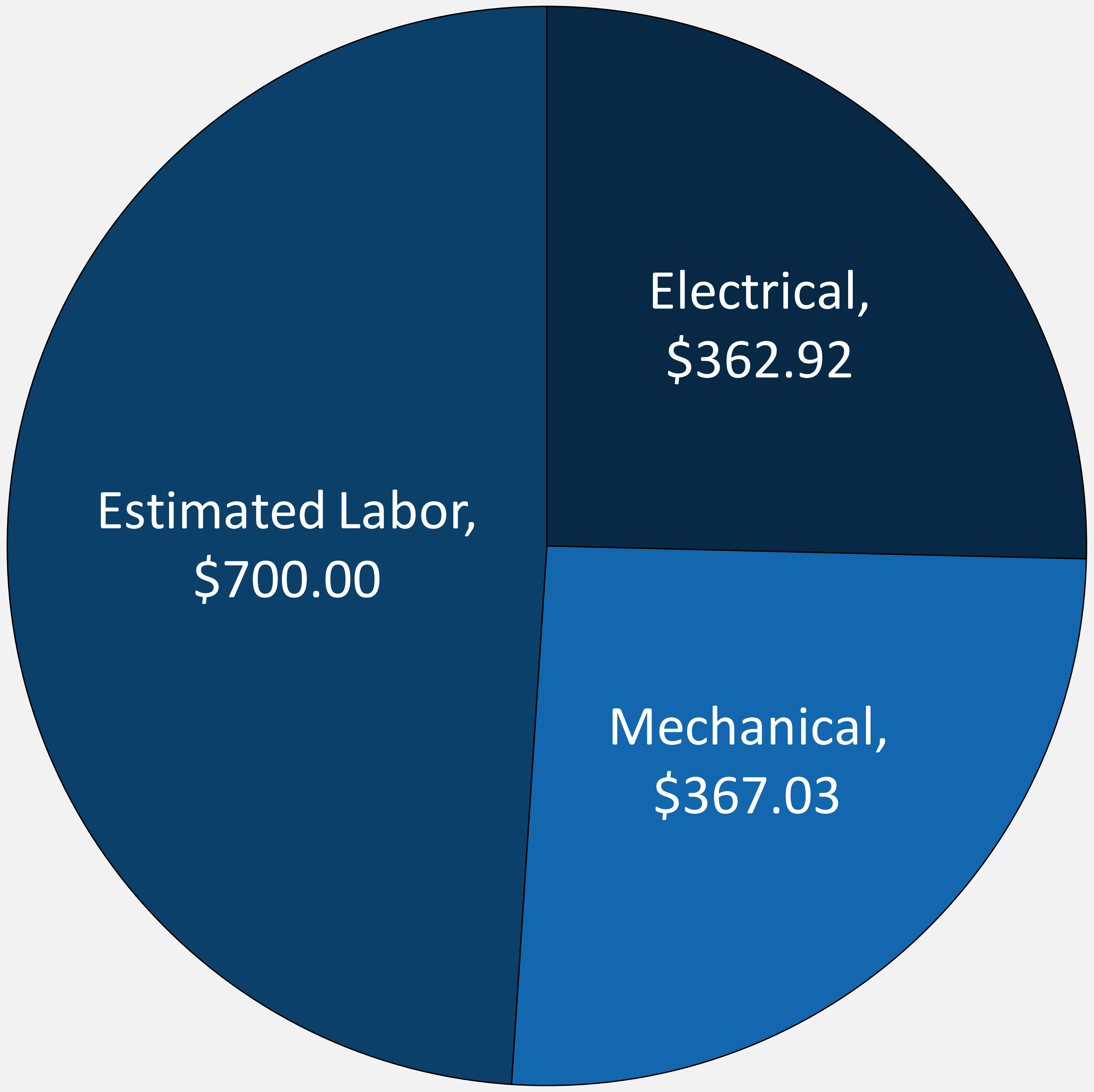
Budget Spending Distribution	
Grad Student Support	$ 1038
Shop Overhead	$ 1000
University Overhead	$ 191
Parts	$ 867
Travel	$ 110



ESTIMATED COST OF GOODS

Electrical	$362.92	Mechanical	$367.03	Other	$700.00
Arduino AtMega 2560	$13.99	LA Mounting Bracket	$16.84	Estimated Labor	$700.00
Arduino LCD	$12.99	Aluminum Stock	$241.42		
Breadboard Jumper Wires	$5.99	UHMW Plastic Bars	$17.34		
Linear Actuator	$116.86	Screws and Nuts	$4.18		
Microchip	$7.74	Other Fasteners	$62.24		
Op-amps	$65.91	Rubber Tubing	$25.00		
S-type Load Cells	$68.95				
PCB Samples	$18.67				
MIcroSD Card Port	$4.99				
MicroSD Card	$2.92				
DC Converters	$10.04				
Fuse Holder Blocks	$5.70				
Glass Fuses	$4.31				
Push Button	$5.89				
Power Supply	$10.99				
Power Socket	$6.99				

Parts/Service Type Cost Distribution



CHANGES FOR NEXT ITERATION

- Better sensors
- More accurate dimensioning during manufacturing
- Server rack mount rails instead of vertical bars
- Guard rails for sensor tracks

WHAT WE LEARNED

- Assembly can reveal more design issues
- Shop work takes longer than expected
- Getting sensors earlier
- Combine things one at a time
- Hope for the best, prepare for the worst

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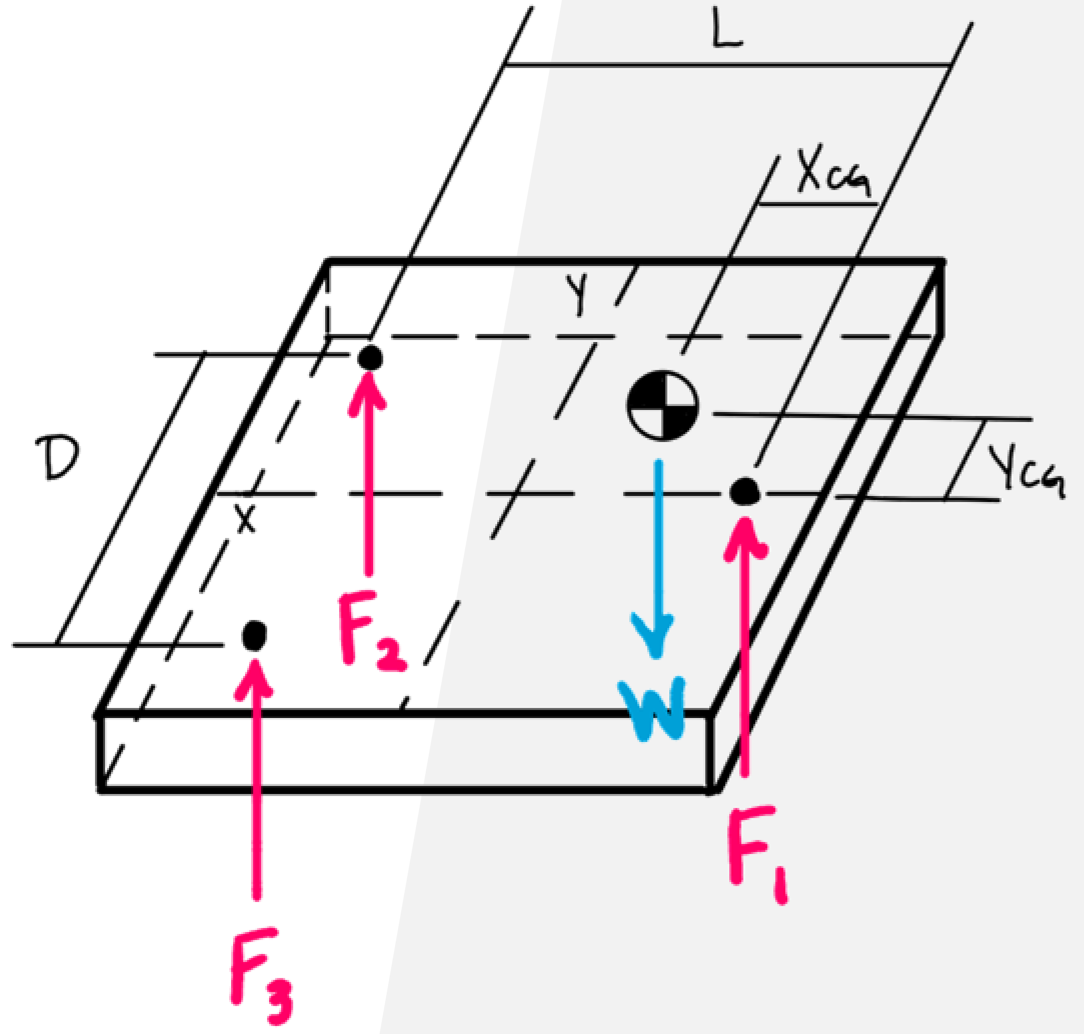
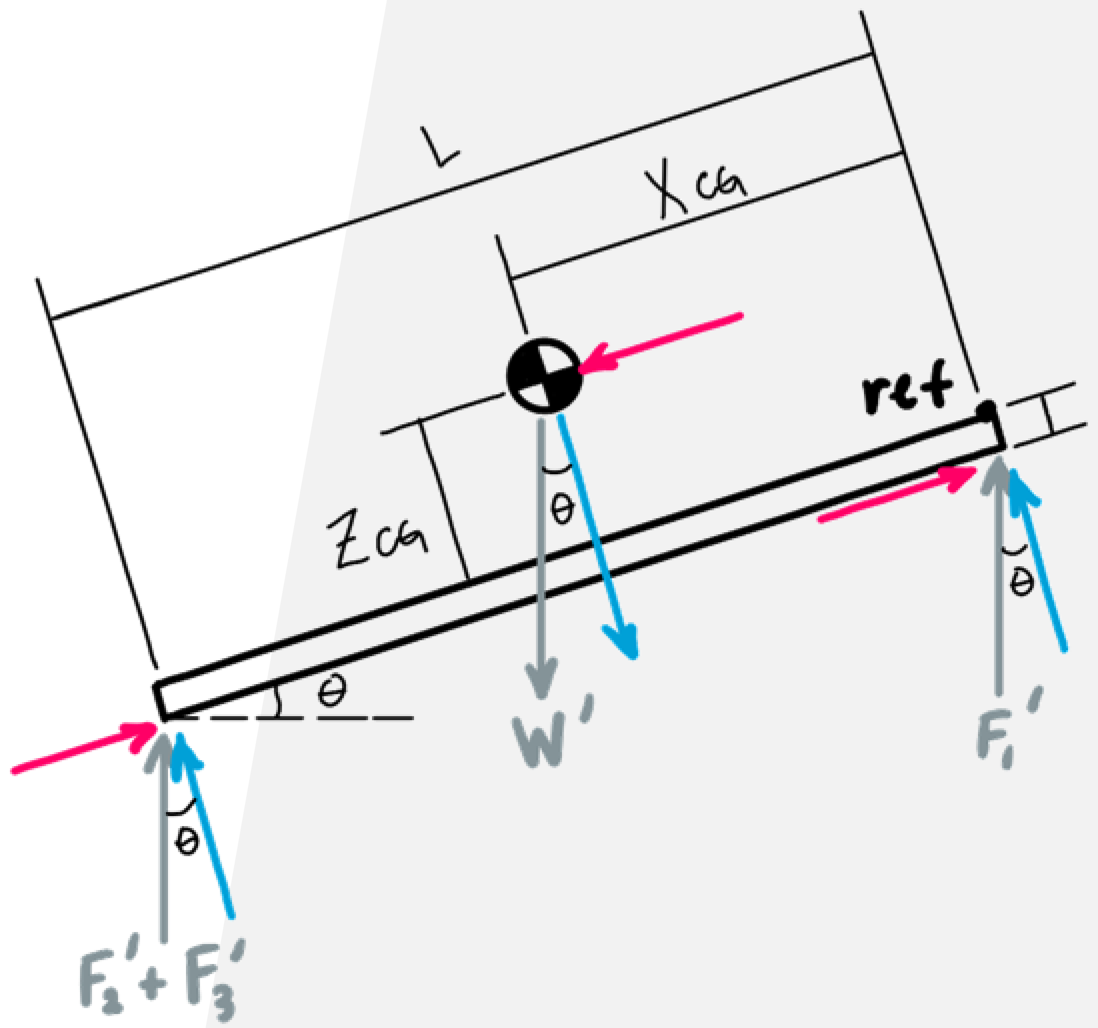
VARIABLE DEFINITIONS





$X_{CG} = Center\ of\ gravity\ x - coordinate$

$Y_{CG} = Center\ of\ gravity\ y - coordinate$

$Z_{CG} = Center\ of\ gravity\ z - coordinate$

$L = Distance\ between\ F_1\ and\ F_2\ in\ x\ direction$

$D = Distance\ between\ F_2\ and\ F_3\ in\ y\ direction$

$t = Top\ plate\ thickness$

$\theta = Angle\ of\ tilt$

$W = F_1 + F_2 + F_3 = Total\ object\ weight*$

$F_1 = Force\ exerted\ on\ sensor\ 1*$

$F_2 = Force\ exerted\ on\ sensor\ 2*$

$F_3 = Force\ exerted\ on\ sensor\ 3*$

**Prime superscript indicates tilted orientation*

MECHANICAL PARTS COST BREAKDOWN

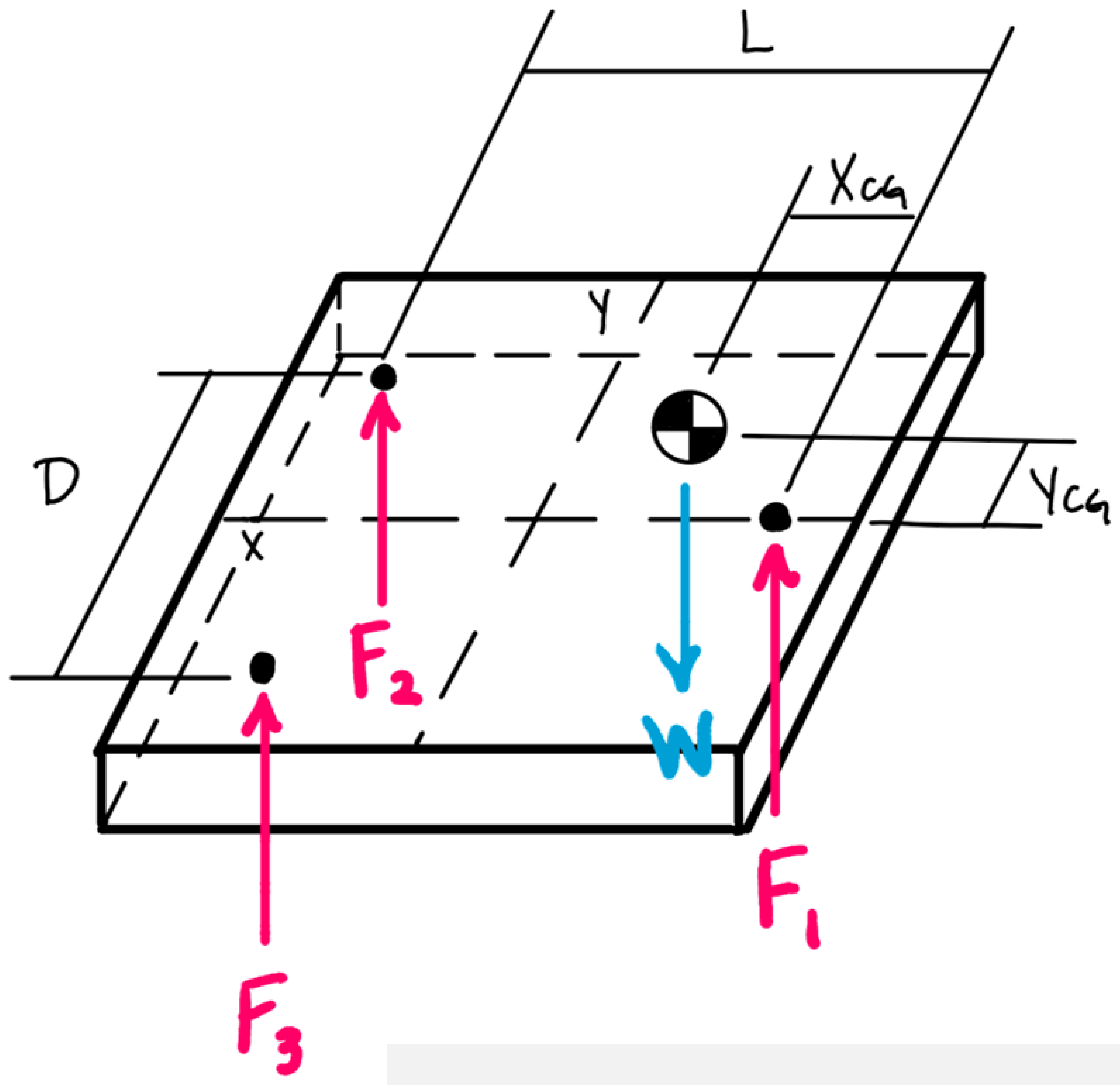
Aluminum Stock		Screws		Nuts		Other Fasteners	
1/4 x 24 x 24 Plate	47.72	1/4-20, 1.25" (7x)	1.53	1/4-28	0.05	Ball Joints	13.53
1/2 x 24 x 24 Plate	84.08	1/4-28, 1.5" (4x)	1.54	8-32 (4x)	0.30	Clevises	27.72
1/2 x 24 x 16 Plate	61.94	8-32, 0.5" (8x)	0.51	6-32	0.07	Brackets	2.50
1 x 2 x 2.5 Bar (2x)	17.02	6-32, 2.5"	0.20			Zip Ties	7.47
1/4 x 3/4 x 10 Bar (2x)	14.86					ZT Mounts	10.85
1.125D, 1.5L Rod	7.01					Cotter Pin	0.17
3/8 x 0.049, 2" Tubing	8.79						

BUDGET SPENDING ON PARTS

Expense Items	2018-2019							
	September	October	November	December	January	February	March	April
Mechanical Parts								
Particle Board						$ 7.50		
LA Mounting Bracket						$ 16.84		
Aluminum Plates						$ 230.89		
UHMW Plastic Bars							$ 17.34	
Ball Joints							$ 13.53	
Clevises							$ 27.72	
Zip Ties								$ 7.47
Zip Tie Adhesive Mounts								$ 10.85
Rubber Tubing								$ 25.00
Electrical Parts								
Arduino AtMega 2560		$ 20.94						$ 13.99
22lb Force Sensors		$ 45.87	$ 45.00					
Arduino LCD			$ 12.99					
Breadboard Jumper Wires			$ 5.99					
Linear Actuator						$ 116.86		

BUDGET SPENDING ON PARTS (CONT.)

Linear Actuator						$ 116.86		
Microchip						$ 7.74		
S-type Load Cells						$ 68.95		
PCB Samples							$ 18.67	
MIcroSD Card Port							$ 4.99	
MicroSD Card							$ 2.92	
DC Converters							$ 10.04	
Fuseholder Blocks							$ 5.70	
Glass Fuses							$ 4.31	
Push Button							$ 5.89	
Power Supply							$ 10.99	
Power Socket							$ 6.99	
Amplifiers								$ 65.91
Other								
3-D Printer Filament		$ 29.99						
Toy Balancing Eagle								$ 5.13



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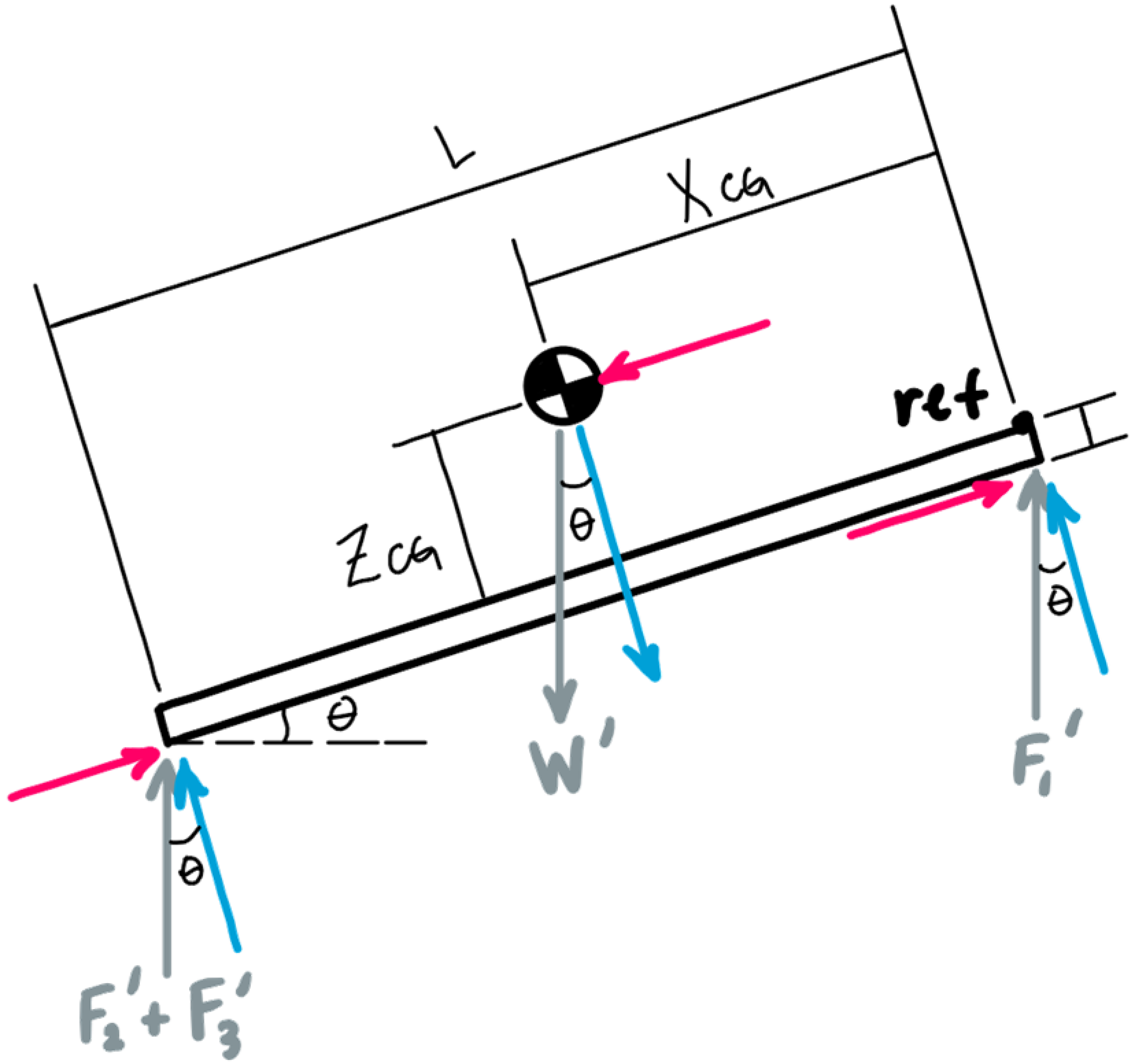

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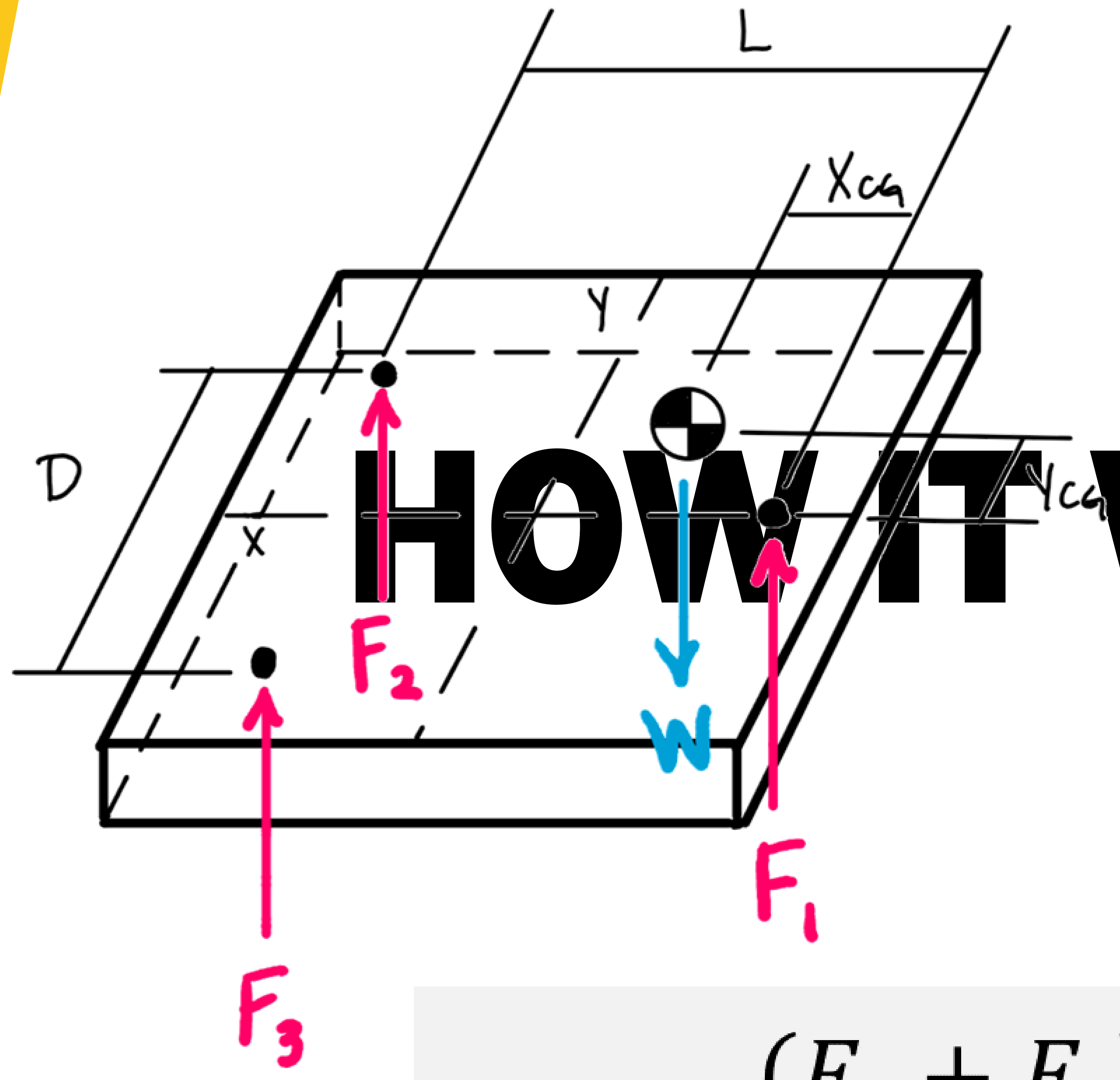
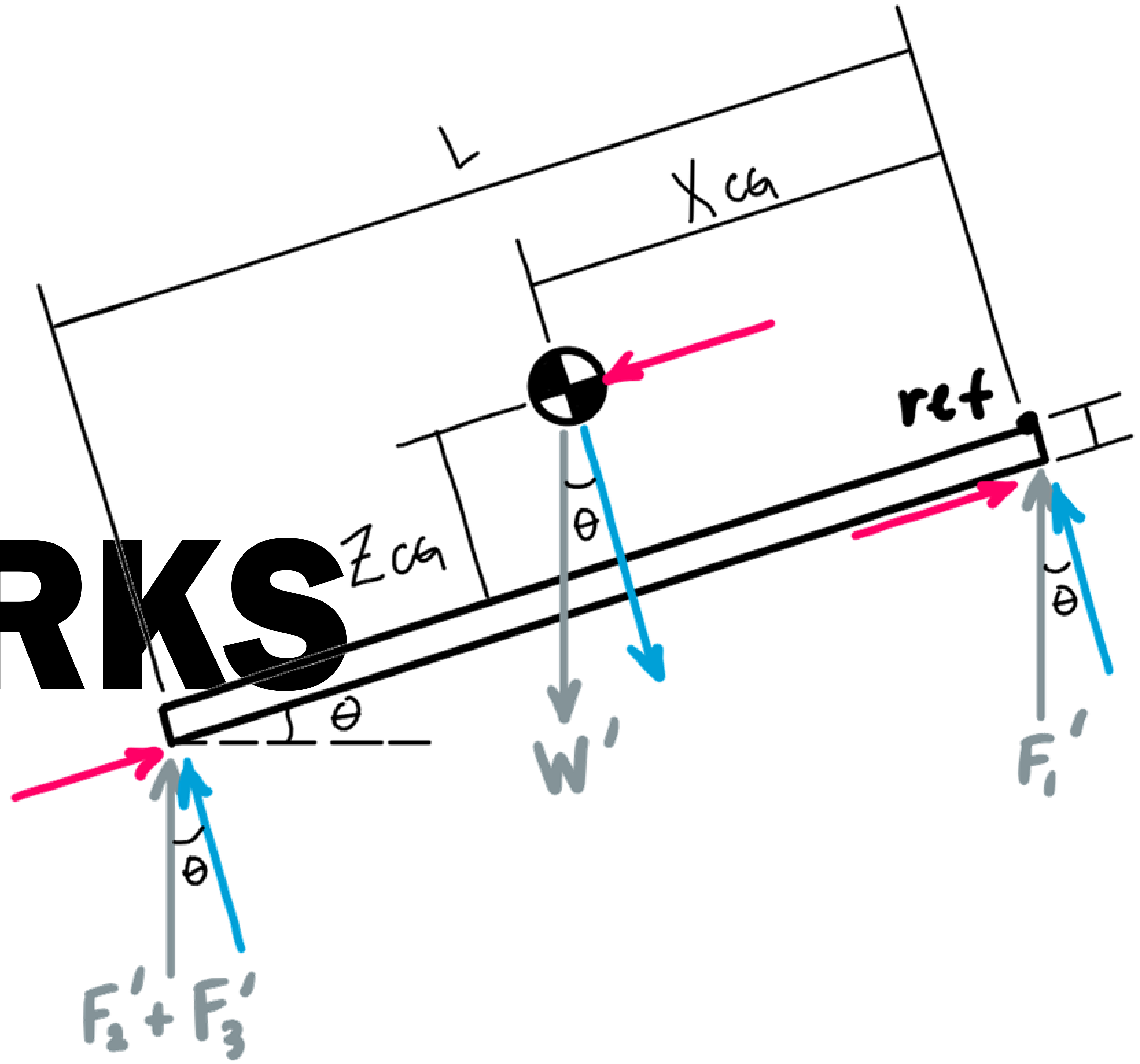
HOW IT WORKS





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