

CWC-Scale Generator

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Project Description

- Collegiate Wind Competition: Teams compete to make small scale wind turbine
- CWC fosters innovation in the wind energy industry
- Wind energy is an important and growing field
 - Wind Energy in US[1]: 2023 - 10% VS 2014 - 4%
- Previous generators used were modified drone motors (performed poorly)
- Goal: Create a generator to be modified by CWC Team
- Sponsored by Professor David Willy, +20 years in industry
- Solves multiple problems
 - Design around commercially available vs custom parts
 - Availability and lead times of commercial products
 - Modularity to match aerodynamic requirements

Dynamometer QFD

Minimize or Maximize												
House Of Quality			Technical Specifications (How)							Competitive Assessment		
			Dimensions of the electrical box	Current sensor with low error margin	Display screen size	high-precision Torque sensor	Voltage sensor with low error margin	Operating Temperature	Load capacity			
	Customer Requirements (What)	Importance	1	2	3	4	5	6	7	1	2	3
1	Torque measurement	21	3	1	1	9	1	3	3	9	9	9
2	Voltage measurement	21	3	1	1	1	9	3	3	9	9	9
3	Safe	31	9	1	1	1	1	9	9	3	3	3
4	RPM measurement	13	3	1	1	1	1	3	3	9	3	3
5	Current measurement	21	3	9	1	1	1	3	3	9	9	9
6	Transportability	17	9	1	3	1	1	1	1	9	9	9
7	User friendly	29	9	3	9	3	3	1	1	1	1	1
			Target	11 in^3	0.50%	4x20	0.50%	0.50%	-10 - 50 C	0-48V		
Importance			39	17	17	17	17	23	23			

Generator QFD

Minimize or Maximize																	
House Of Quality			Technical Specifications (How)												Competitive Assessment		
			Maximum 48 Volts	45 cm Roter Diameter of Turbine	Low Total Resistant Torque (Nm)	Low Kv Rating	Magnetic Flux (Tesla)	Turbine Power(W)	Generator Power(W)	Number of Coils	Tip Speed Ratio	Diameter of coil(mm)	Cut Out Speed(m/s)	Cut In Speed(m/s)			
	Customer Requirements (What)	Importance	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1	Low Voltage	96	9	3	9	9	9	9	9	9	3	9	9	9	1	9	3
2	Small Size	60	3	9	3	1	3	9	3	9	9	9	1	1	1	9	1
3	High Power Generation	100	9	1	9	9	9	9	9	9	9	9	9	9	9	3	1
4	Under Budget	28	1	3	1	1	1	3	3	3	3	3	3	3	1	3	9
5	Ability to change easy	60	1	3	3	9	3	3	9	9	9	9	1	1	3	3	1
6	Up to design standards for CWC	102	9	9	9	9	9	9	9	3	9	9	9	9	9	9	3
7	3 phase AC	34	3	3	3	3	3	1	3	9	1	3	1	1	3	9	9
Target			48 V	45 cm	2 Nm	20-100 watt	1-3 T	100 kW	0.5-10 kW	6 coils	7 to 8	0.321-0.644 mm	25 m/s	3 m/s			
Importance			35	31	37	41	37	43	45	51	43	51	33	33			

Dynamometer Final Arduino Circuit

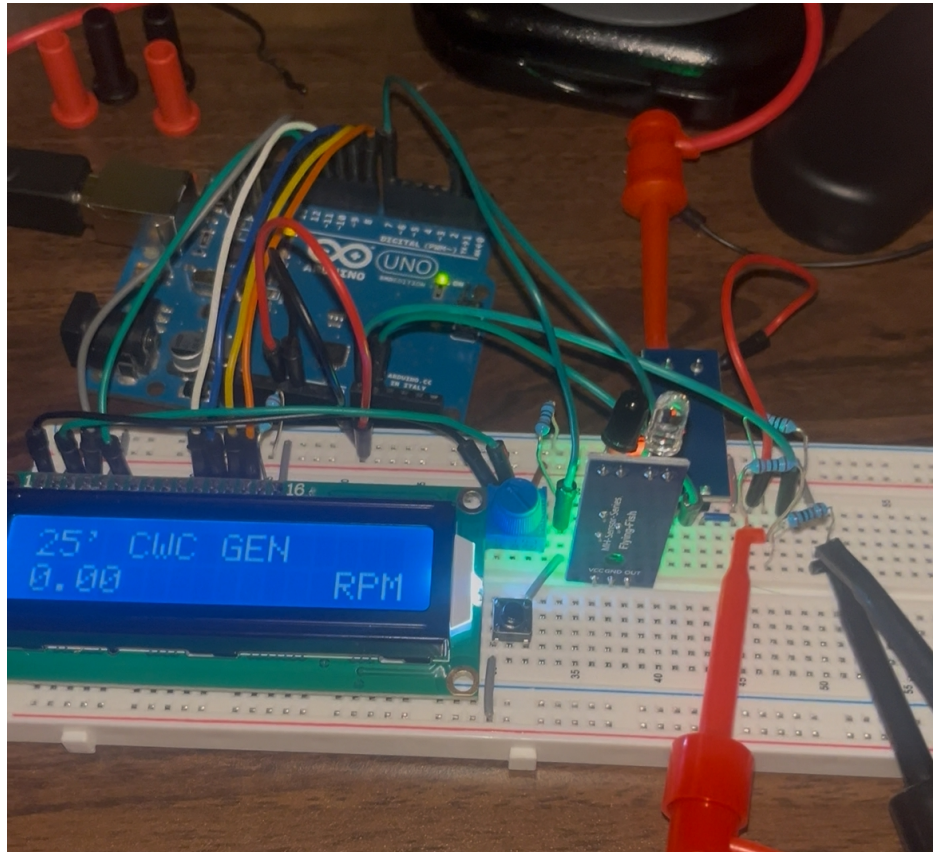


Figure 1: Arduino Circuit with Breadboard

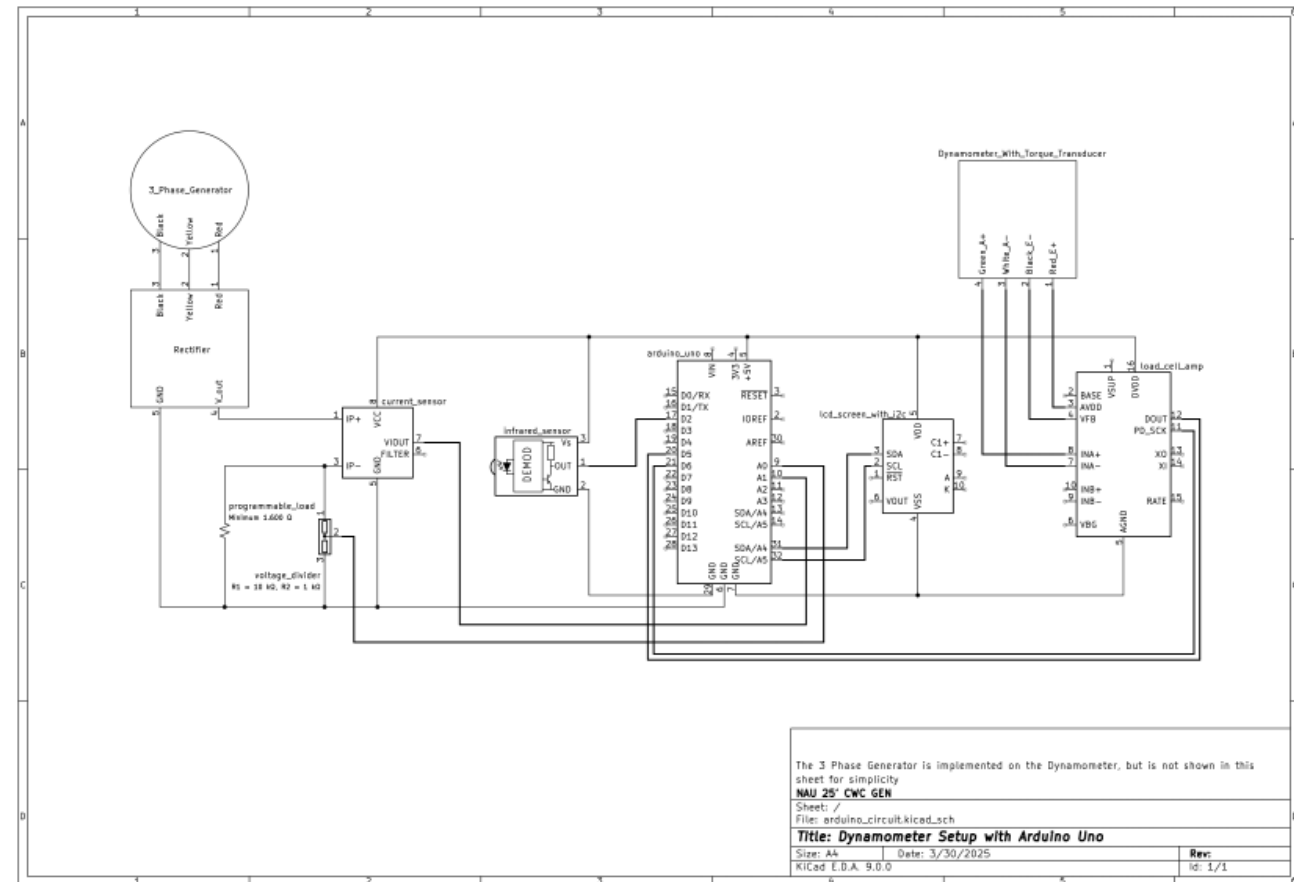


Figure 2: Schematic of Arduino Circuit Implementation for Dyno

Dynamometer Permanent Circuit



Figure 3: Electrical Box

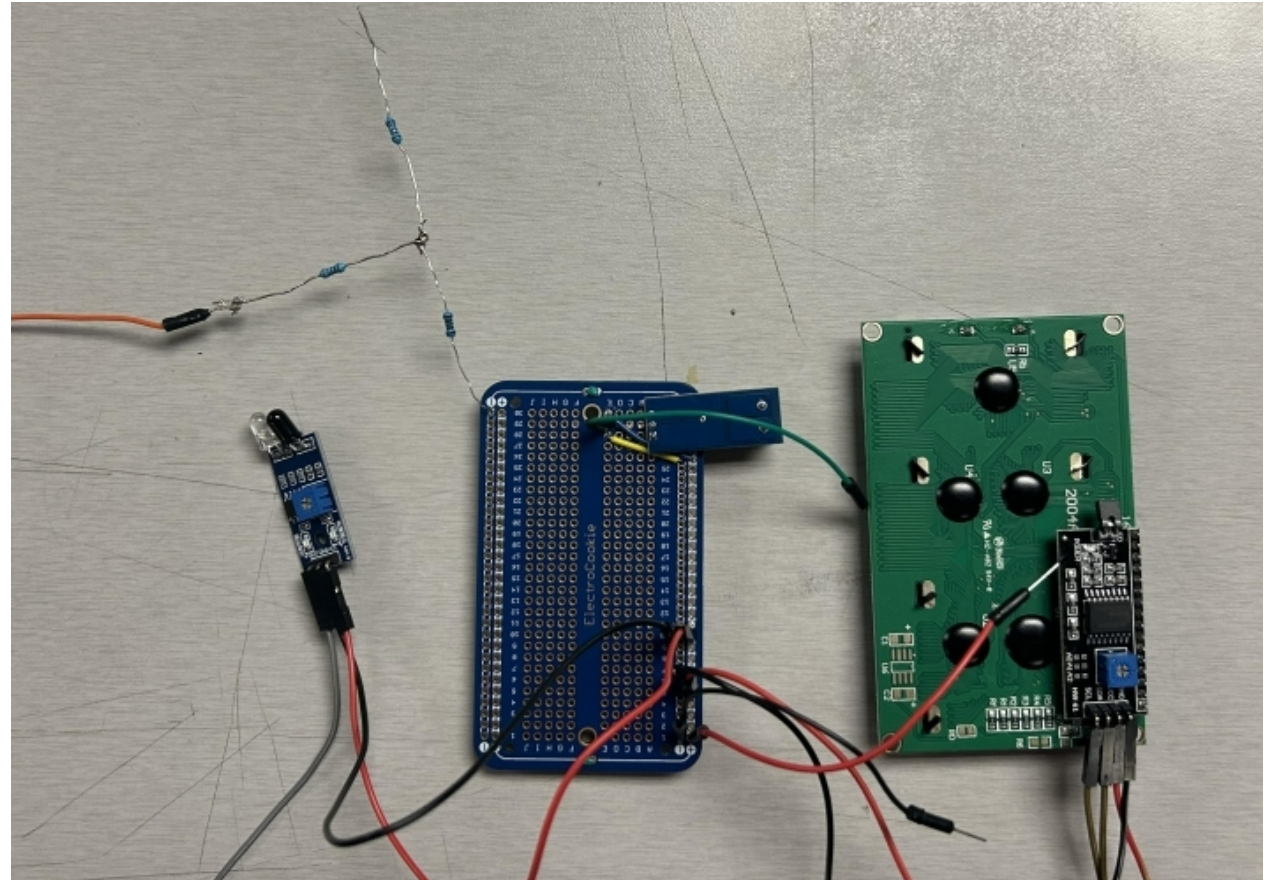


Figure 4: Permanent Circuit using an ElectroCookie

Three Phase Generator

- Three different segments of copper
- 120 degrees offset, evenly in phase with each other
- Safer than (lower amps) and produces more power than single phase motors

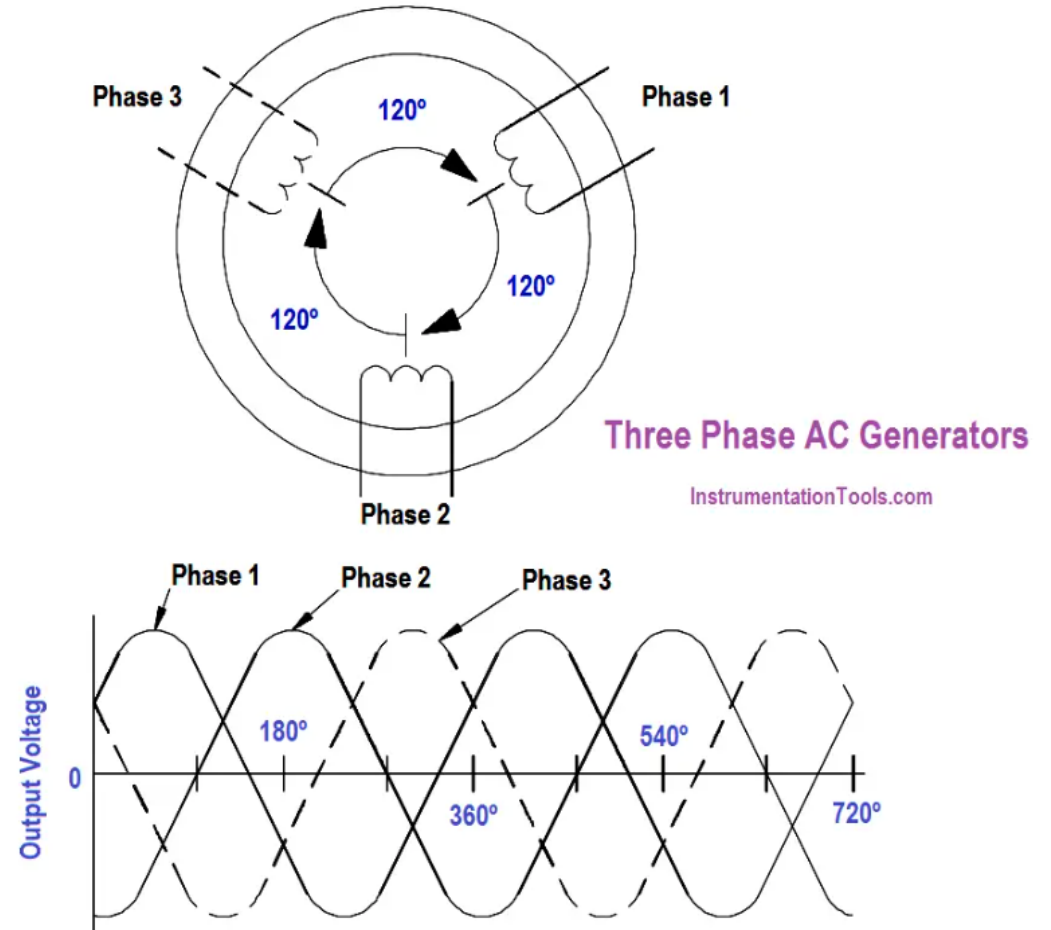


Figure 5: Three Phase Generator

Outer vs Inner Rotor

Outer Roter

- High torque
- Lower speed
- Larger amount of magnetic poles

Inner Roter

- Higher acceleration
- Better heat dissipation

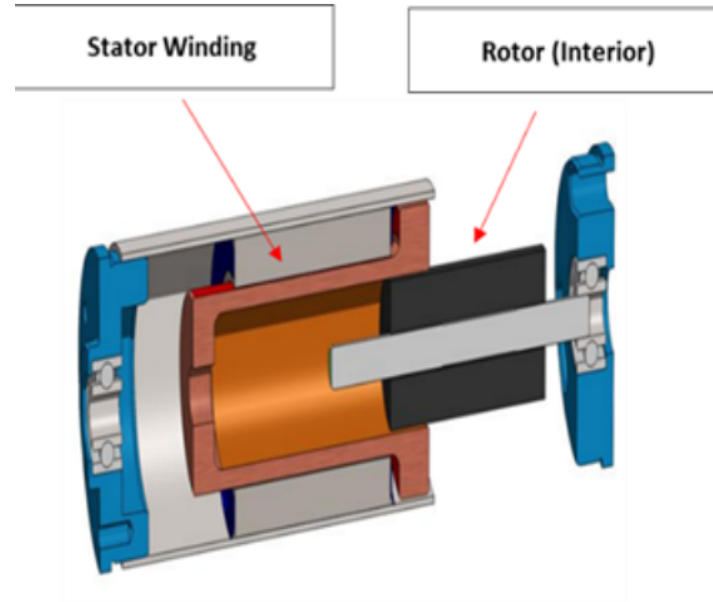


Figure 6: Inner Rotor Example

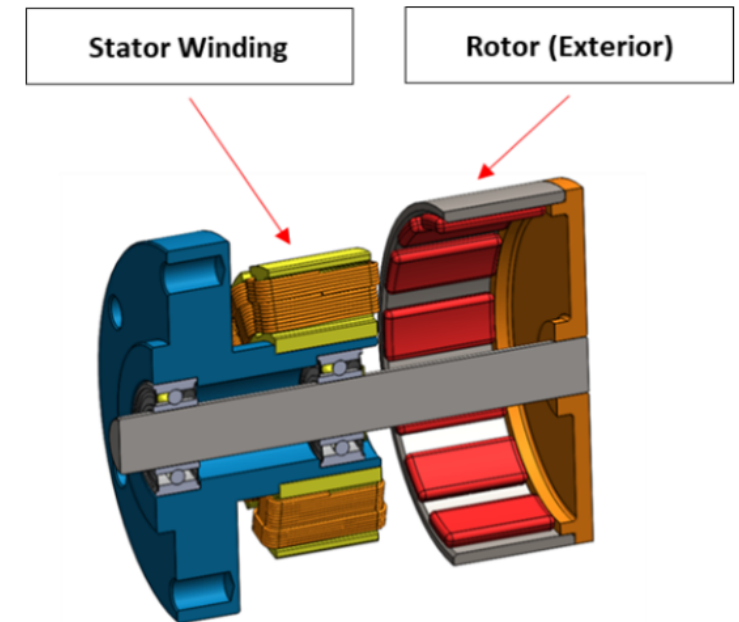


Figure 7: Outer Rotor Example

Wire Gauge Equations

Step 1: Electrical Considerations

$$J = \frac{I}{A}$$

J == Current Density

I == Current running through wire

A == cross-sectional area of wire

Step 3: Wire Resistance

$$R = \rho \frac{L}{A}$$

R == Resistance of Wire

ρ == Resistivity of Copper

L == total length of wire

A == cross sectional area of wire

Step 2: Find Diameter

$$d = \sqrt{\frac{4A}{\pi}}$$

d == diameter of wire

A == cross sectional area of wire

Step 4: Power Loss

$$P_{copper} = I^2 R$$

P_{copper} == Copper Losses

I == current

R == Resistance of winding

Wire Gauge Calculations

Step 1: Electrical Considerations

$$J = \frac{I}{A}$$

$$A = \frac{I}{J}$$

$$A = \frac{21[A]}{5 \left[\frac{A}{mm^2} \right]}$$

$$A = 4.2 [mm^2]$$

Step 3: Wire Resistance

$$R = \rho \frac{L}{A}$$

$$R = (1.68 \times 10^{-8} [\Omega m]) \frac{5[m]}{4.2 \times 10^{-6} [m^2]}$$

$$R = 0.02 [\Omega]$$

Step 2: Find Diameter

$$d = \sqrt{\frac{4A}{\pi}}$$

$$d = \sqrt{\frac{4(4.2 [mm^2])}{\pi}}$$

$$d = 2.31 [mm]$$

Step 4: Power Loss

$$P_{copper} = I^2 R$$

$$P_{copper} = (21[A])^2 (0.02 [\Omega])$$

$$P_{copper} = 8.82 [W]$$

Magnetic Flux Equations

Total Magnetic Flux

$$\Phi = \int \vec{B} \cdot d\vec{A}$$

Magnetomotive force

$$F = MMF = Ni$$

Total Flux

$$\Phi = \frac{F}{R_{gap}}$$

Reluctance of air gap

$$R_{gap} = \frac{l}{\mu A}$$

Magnetic Flux Density

$$B = \frac{\Phi}{A}$$

Φ == Total Flux

B == Magnetic Flux Density

A == Cross – sectional Area

R_{gap} == Reluctance of air gap

μ == permeability of air

l == length of length

F == Magnetomotive force

N == Number of turns

i == Current

Magnetic Flux Equations

Total Magnetic Flux

$$\Phi = \int \vec{B} \cdot d\vec{A}$$

Magnetomotive force

$$F = 20 \times 5A$$

$$F = 100A$$

Total Flux

$$\Phi = \frac{100[A]}{5.05 \times 10^{-3}[\text{wb}]}$$

$$\Phi = 1.98 \times 10^{-6}[\text{wb}]$$

Reluctance of air gap

$$R_{\text{gap}} = \frac{0.5 \times 10^{-3}[\text{m}]}{4\pi \times 10^{-7}[\text{H/m}] \times 7.875 \times 10^{-6}[\text{m}]}$$

$$R_{\text{gap}} = 5.05 \times 10^{-3}[\text{wb}]$$

Magnetic Flux Density

$$B = \frac{1.98 \times 10^{-6}[\text{wb}]}{7.875 \times 10^{-6}[\text{m}]}$$

$$B = 0.25 \text{ T}$$

Goal for the motor is to keep the range of magnetic Flux density to a range of 1.0 – 2.3T, Our goal is to keep it around 1.5 T with the given parameters

Number of Coils Per Phase

$$N_{cph} = \frac{\text{number of slots}}{3} = \frac{12}{3} = 4$$

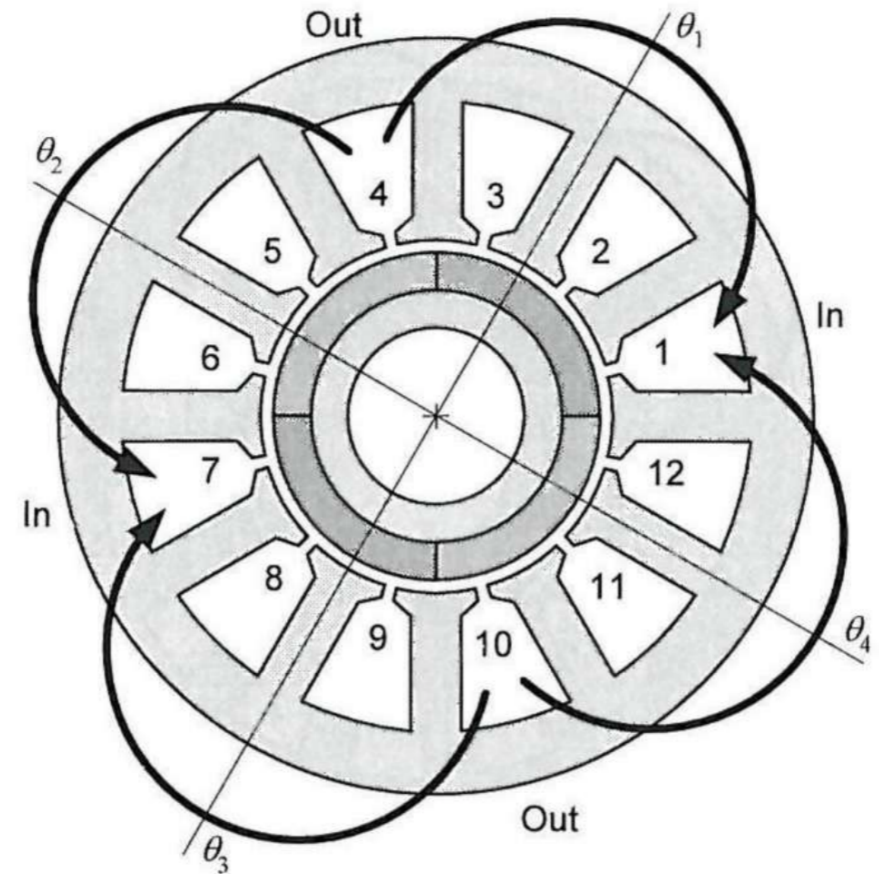


Figure 8: Coil Winding Example

Introducing the Generators



Figure 9: MAD JENNY



Figure 10: Melon Motor

Maxwell CAD - MADJENNY

- Magnets in silver
- Stator in green
- 3 Phase coils in red, blue, and yellow
- As geometrically close to MADJENNY as possible

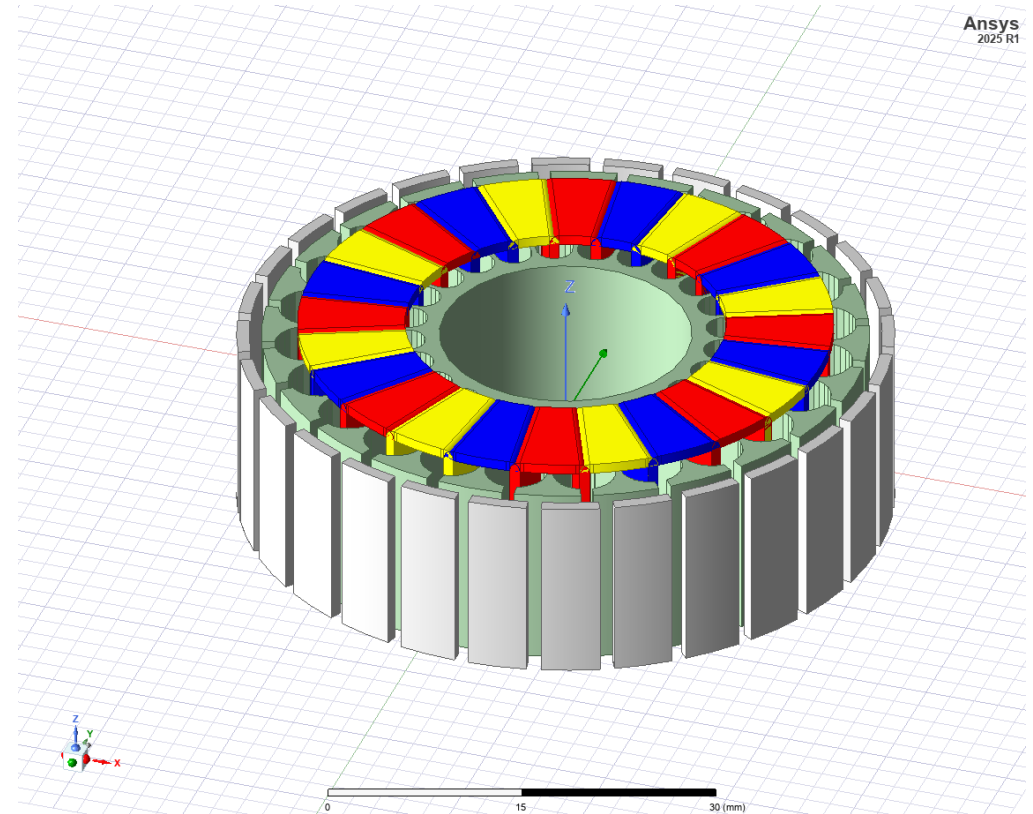


Figure 11: MAD JENNY Simulation

Maxwell Simulations - MADJENNY

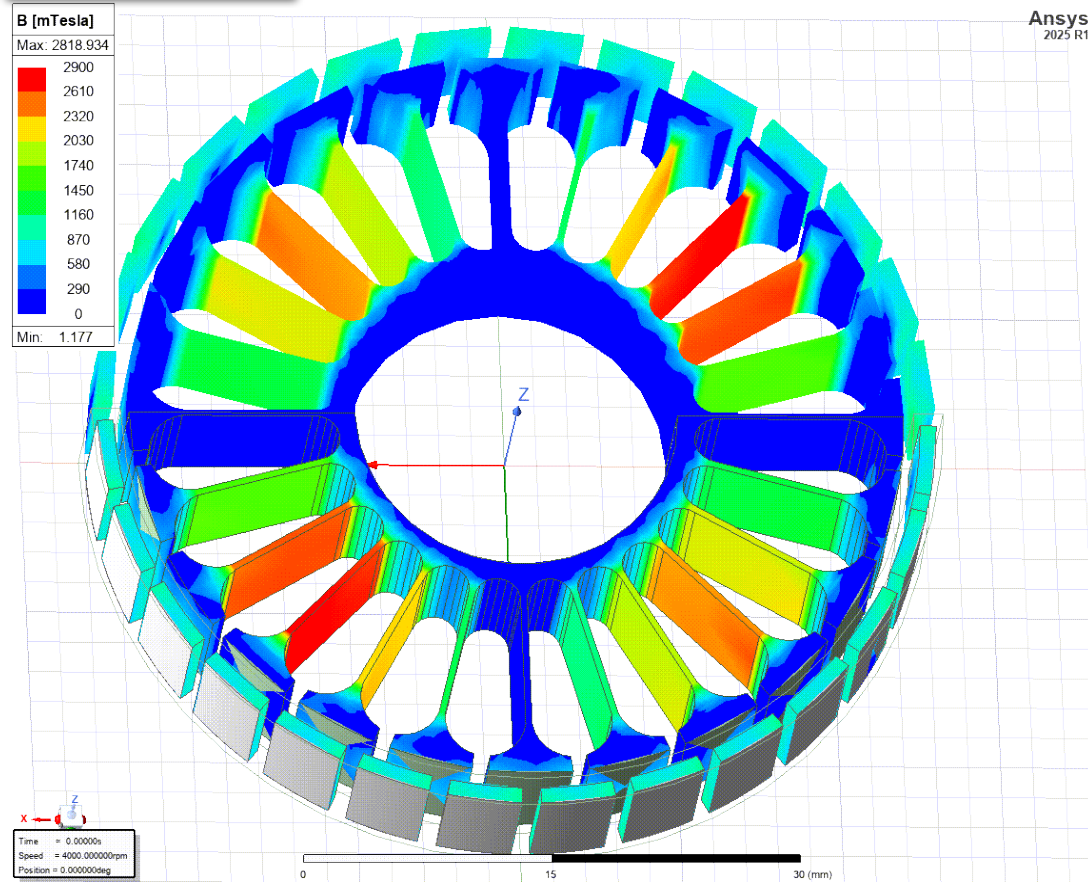


Figure 12: Surface Simulation of MAD JENNY

Max:
2.8 T

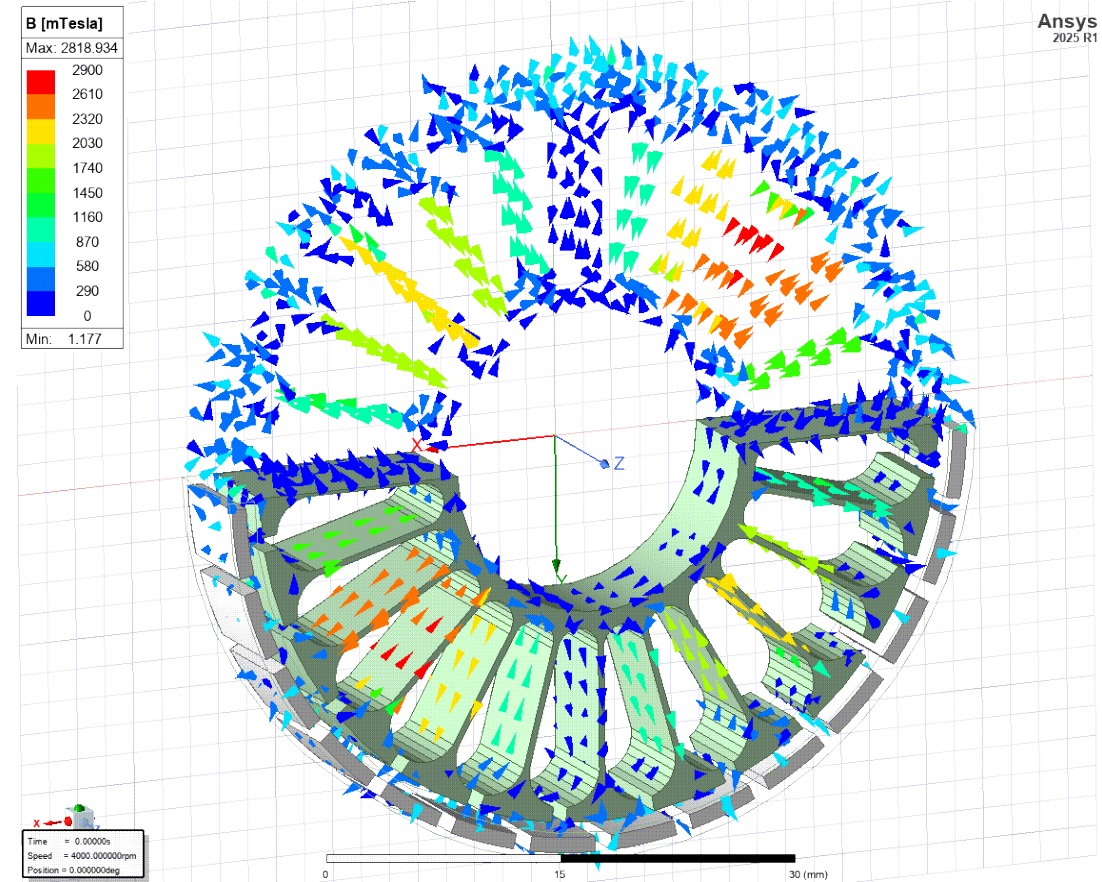


Figure 13: Vector Simulation of MAD JENNY

MotorCAD Simulation- Motor Melon

- Delta circuit, produces higher torque
- 14 magnet poles
- 12 slots

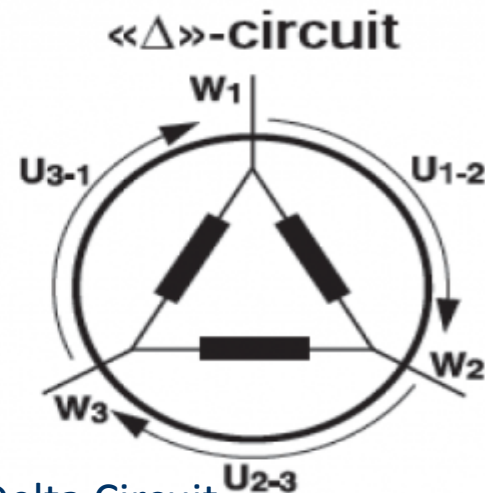
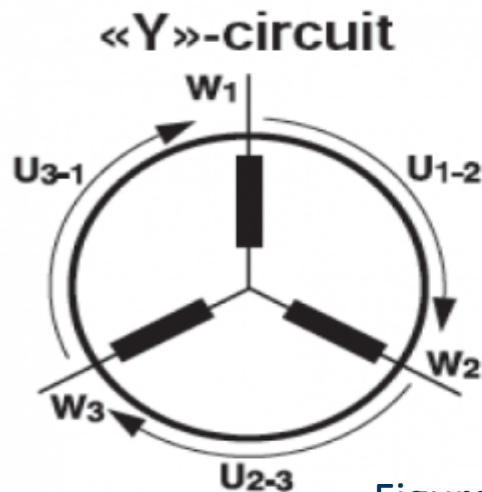


Figure 14: Y vs Delta Circuit

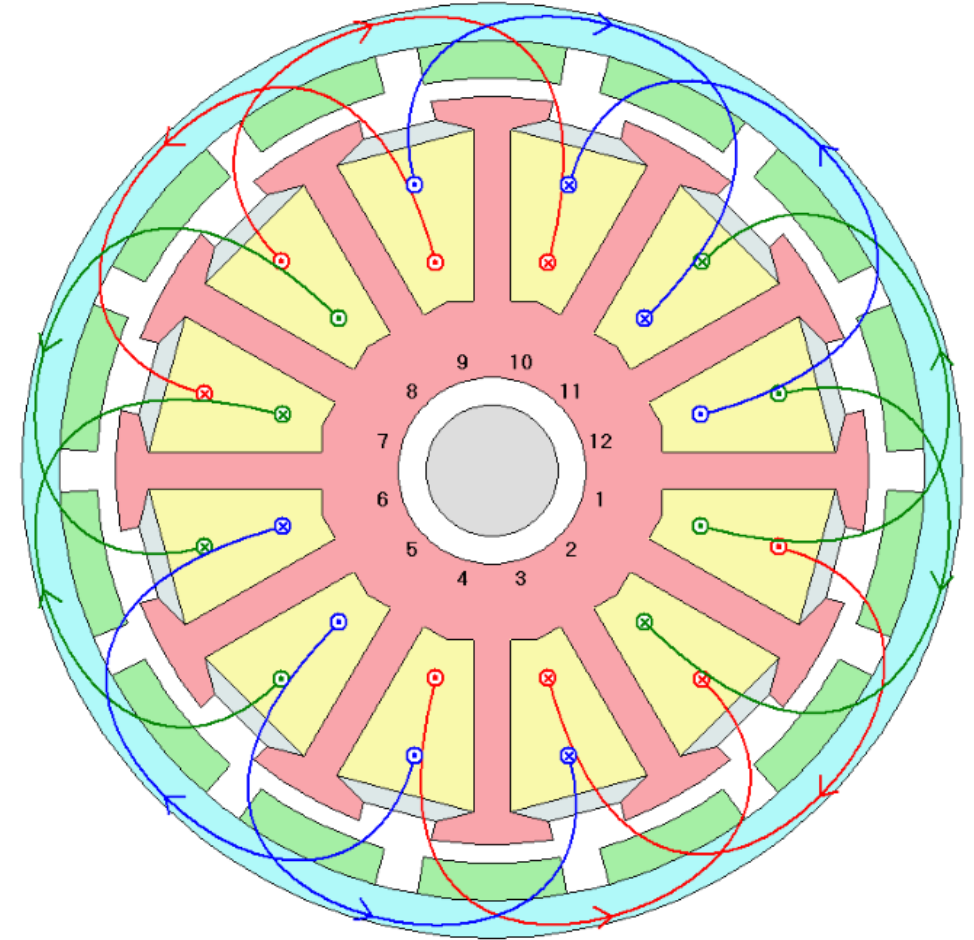


Figure 15: Melon Motor Simulation

MotorCAD Simulations of Coils

50 Turns

- 17.1 Volts
- 5 Amps
- .42 Nm of torque

25 Turns

- 5.04 Volts
- 5 Amps
- .222 Nm of torque

12 Turns

- 1.54 Volts
- 5 Amps
- .106 Nm of torque

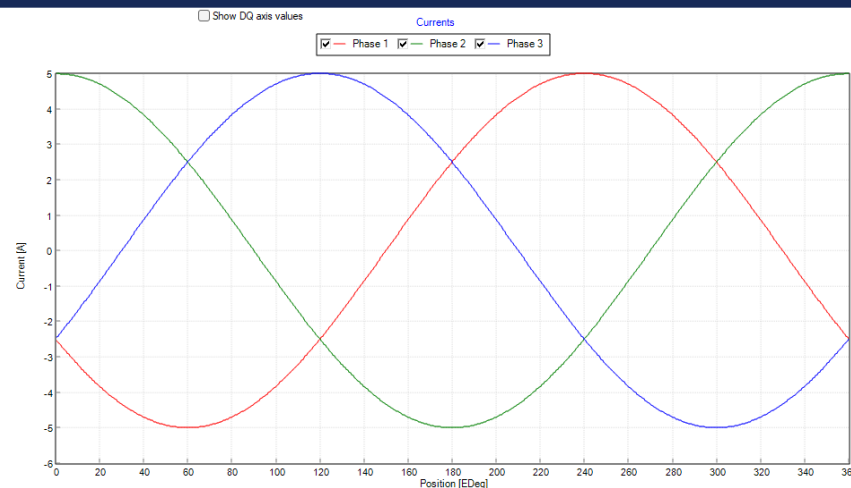


Figure 16: 50 Turn,
Current

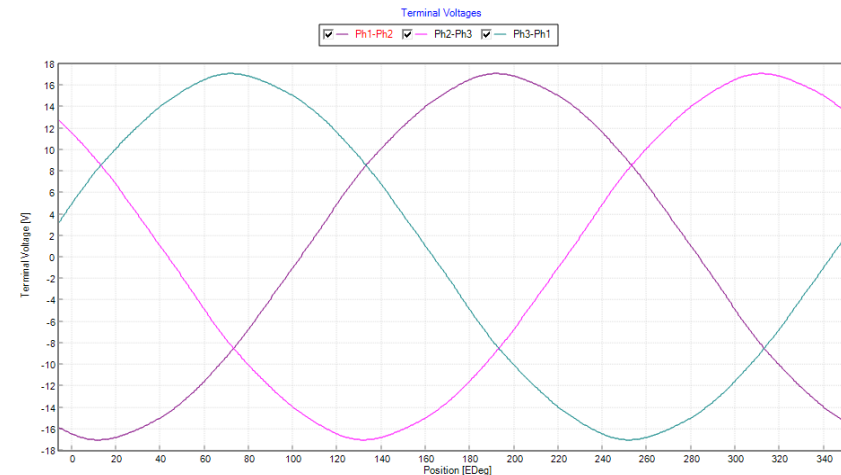


Figure 17: 50 Turn,
Voltage

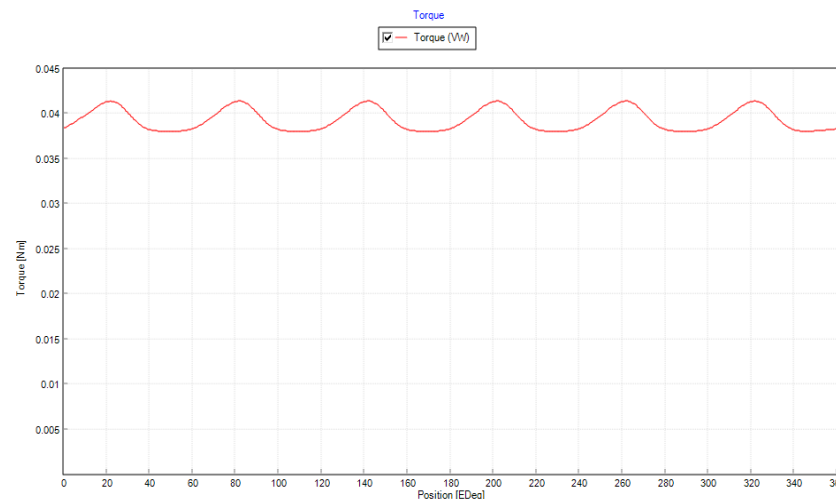


Figure 18: 50 Turn, Torque

MotorCAD Simulation – Melon Motor

Cross-sectional area of Melon Motor

Outer Rotor

Top half = magnet & rotor

Bottom half = Stator & winding of copper

Maximum

- 1.98 Tesla

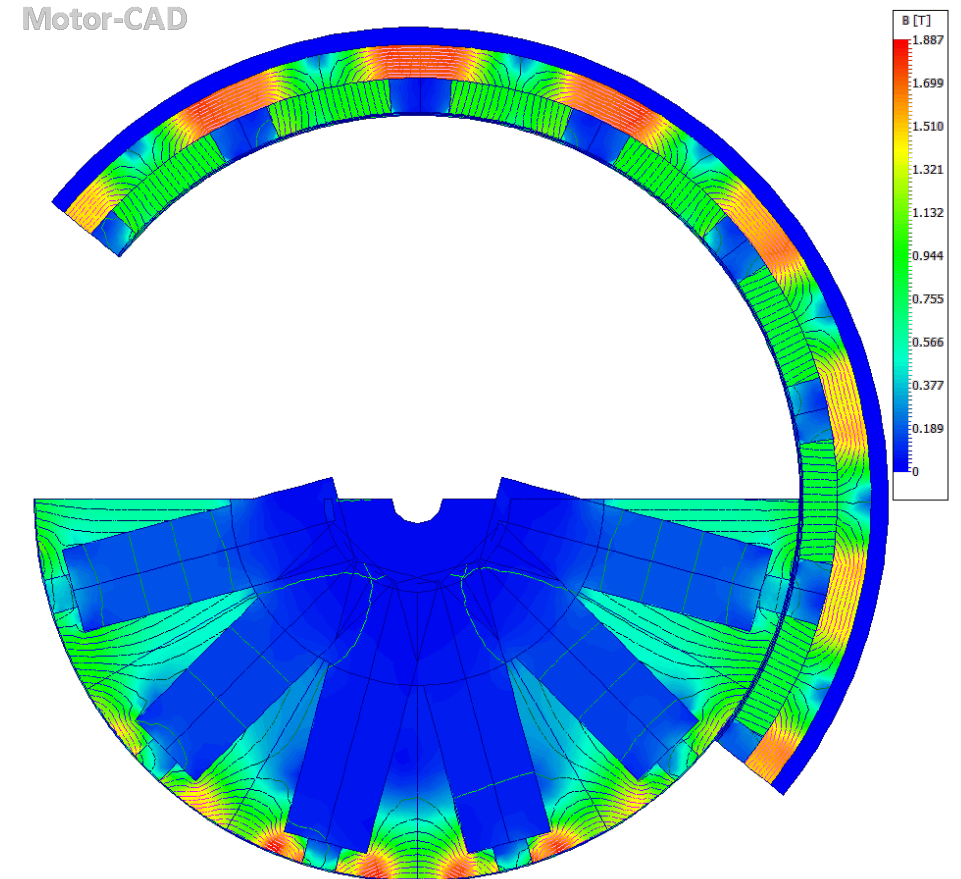


Figure 19: Melon Motor Magnetic Flux Simulation

This Semester's Schedule

- On schedule for more research, simulations, and concepts on generators

Initiation					Planning and design				
Define goals	Everyone	100%	1/23/25	1/24/25	Create schedule	Naomi Echo	100%	2/5/25	2/9/25
Develop team charter	Everyone	100%	1/24/25	1/26/25	Identify deliverables	Naomi Echo	100%	2/7/25	2/12/25
Do tutorials on SolidWorks	Everyone	100%	1/24/25	1/26/25	Develop budget	Javan Jake	100%	2/12/25	2/15/25
Meet with Dr. Willy	Everyone	100%	1/27/25	1/31/25	Finish dyno	Alonso, Naomi	95%	2/12/25	3/15/25
Initialize website	Alonso Garcia	100%	1/29/25	2/3/25	Solder dyno	Naomi Echo	95%	2/14/25	3/7/25
Meet with Kevin Bruns	Everyone	100%	1/31/25	2/4/25	Replace Dyno Screen	N.E.	100%	2/19/25	2/21/25
Research cogging torque	Alonso Garcia	100%	1/31/25	2/10/25	Electrical box for dyno	Naomi and Alonso	100%	2/14/25	3/10/25
Research Kv	Javan Jake	100%	1/31/25	2/10/25	4 mm Adaptor to test gen.	Kaitlyn Redman	100%	2/14/25	2/24/25
Research tip speed ratio	Naomi Echo	100%	1/31/25	2/10/25	Tachometer Sensor	Naomi Echo	100%	2/21/25	2/25/25
Research shaft & bearings	Kaitlyn Redman	100%	1/31/25	2/10/25	Voltage Sensor	Javan Jake	100%	2/21/25	2/25/25
Research air gap size	Christian Brown	100%	1/31/25	2/10/25	Current Sensor	Kaitlyn Redman	100%	2/21/25	2/25/25
Complete/rehearse presentation	Everyone	100%	1/31/25	2/10/25	Torque Sensor	Christian Brown	100%	2/21/25	2/25/25
Take apart generator and alternator	Everyone	100%	2/4/25	2/13/25	Arduino Code	Alonso Garcia	100%	2/21/25	3/8/25
					Make Arduino Schematic	Everyone	100%	2/24/25	3/1/25
					Build Arduino Board	Naomi, Alonso	100%	3/10/25	3/14/25
					Ch. 1,6,10	Naomi Echo	100%	2/17/25	3/1/25
					Ch. 1,2,7,10	Christian Brown	100%	2/17/25	3/1/25
					Ch. 1,8,10	Alonso Garcia	50%	2/17/25	4/4/25
					Ch. 1,3,9,10	Javan Jake	100%	2/17/25	3/1/25
					Ch. 1,5,10	Kaitlyn Redman	100%	2/17/25	3/1/25
					Modify generator	Everyone	10%	3/8/25	4/5/25
					Design new generator	Everyone	0%	4/1/25	4/15/25

This Semester's Schedule cont.

Testing					Evaluation/Deliverables				
Learn ANSYS	C.B./K.R.	100%	2/22/25	3/6/25	Compare current generators	Everyone	20%	3/12/25	4/5/25
Learn MotorCAD	A.G./N.E.	100%	2/22/25	3/6/25	Modified vs New gen.	Everyone	0%	4/23/25	5/5/25
Build generator in ANSYS	Cristian Brown	100%	3/7/25	3/29/25	Report 1	Everyone	100%	2/12/25	3/3/25
Build generator in ANSYS	Kaitlyn Redman	20%	3/7/25	3/29/25	Report 2	Everyone	0%	3/30/25	4/14/25
Build generator in MotorCAD	Naomi Echo	100%	3/17/25	3/29/25	Presentation 1	Everyone	100%	1/31/25	2/9/25
Build generator in MotorCAD	Javan Jake	100%	3/17/25	3/29/25	Presentation 2	Everyone	100%	3/10/25	3/14/25
Test exsiting generator	Everyone	50%	3/10/25	4/4/25	Presentation 3	Everyone	100%	3/24/25	3/30/25
Test Modify generator	Everyone	0%	4/4/25	4/11/25	Website Check 1	Alonso Garcia	100%	3/3/25	3/9/25
Test new generator	Everyone	0%	4/18/25	4/22/25	Website Check 2	Alonso Garcia	20%	3/18/25	5/5/25

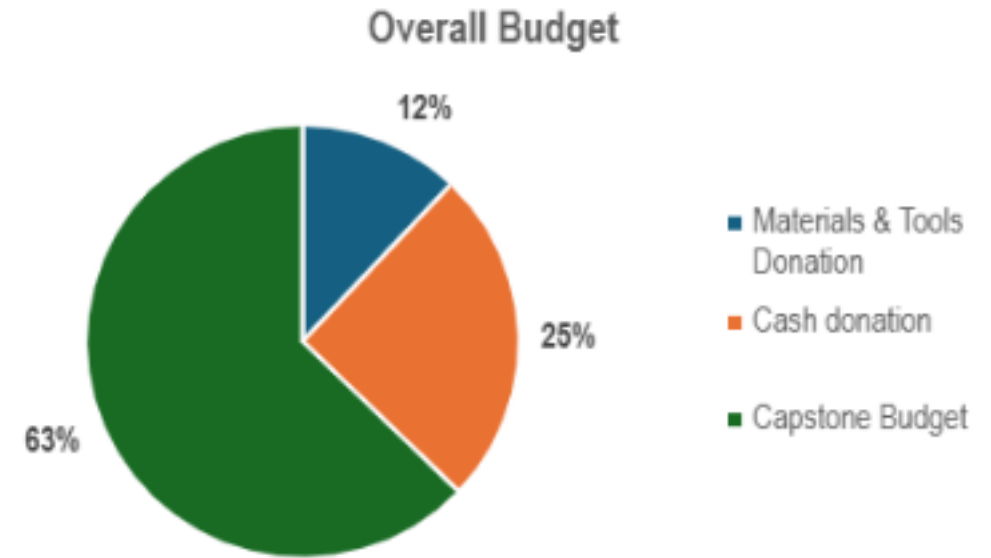
Next Semester's Schedule

Initiation					Testing		
Update Dr. Willy on any progress during the summer	Everyone	0%	8/25/25	8/29/25	Test all built generators	Everyone	0%
Modify existing generators	Everyone	0%	8/25/25	9/22/25	TBA	TBA	
UGRADS Registration	Everyone	0%	10/20/25	10/26/25	Evaluation/Deliverables		
TBA	TBA				HW 00	Everyone (Individual)	0%
Planning and design					Project Management	Everyone	0%
Build our own generators	Everyone	0%	9/22/25	10/27/25	Engineering Calculations	Everyone	0%
33+% Build	Everyone	0%	8/25/25	9/22/25	Self-Learning or Individual Analysis	Everyone (Individual)	0%
67+% Build	Everyone	0%	9/23/25	10/13/25	Peer Evaluations 1	Everyone (Individual)	0%
Draft of Poster	Everyone	0%	10/27/25	11/2/25	Website Check #1	AG	0%
100+% Build	Everyone	0%	10/14/25	11/3/25	Testing Plan	Everyone	0%
Final Poster	Everyone	0%	11/10/25	11/30/25	Peer Evaluations 2	Everyone (Individual)	0%
Initial Testing Results Video	Everyone	0%	11/4/25	11/17/25	Peer Evaluations 3	Everyone (Individual)	0%
Product Demo	Everyone	0%	11/18/25	11/24/25	Final CAD Packet	Everyone	0%
Final Testing Results Video	Everyone	0%	11/18/25	11/24/25	Final Report	Everyone	0%
Practice Presentation	Everyone	0%	12/1/25	12/7/25	Final Website Check	AG	0%
TBA	TBA	0%			Peer Evaluations 4	Everyone (Individual)	0%
					Client Handoff	Everyone	0%
					TBA	TBA	

Budget & Fundraising

Budget & Fundraising

Find No.	Company:	Description:	Amount:
1	Gofundme	Online donation for capstone team. Can be shared through friends, family, and social media.	\$120.00
2	Cash gifts	Cash donations from families/friends	\$80.00
3	Materials & tools	Tools and Materials that were donations throughout the course	\$95.95
4	Northern Arizona University	Capstone budget	\$500.00
		Total:	\$795.95



Total Cash: \$200

Total Donation: \$96

Total Capstone Budget: \$500

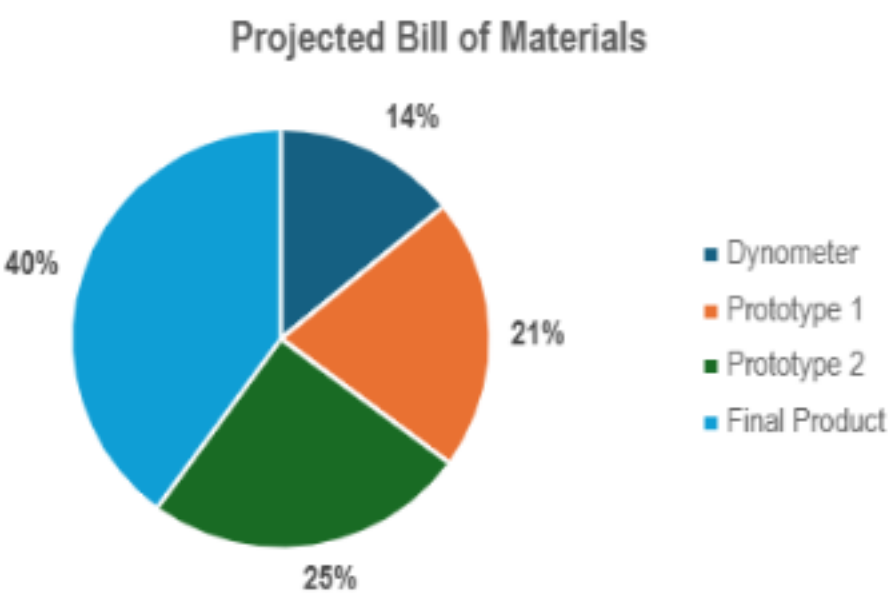
Total: \$796

Bill of Material

Bill of Material: Dynamometer

Find No.	Company:	Description:	Cost	Purchase/Not Purchase
1	Amazon	IR Infrared Obstacle Avoidance Sensor IR transmitting Arduino	\$9.99	Purchase
2	Amazon	5pcs 30A range current Sensor Module Arduino	\$11.99	Purchase
3	Amazon	Electric Motor	\$9.99	Purchase
4	Amazon	LCD Screen Display Module Blue Backlight X 2	\$39.96	Purchase
5	Amazon	ElectroCookie Solderable Breadboard	\$8.49	Purchase
6	Amazon	LeMotech Electrical Box 5.9"x3.9"x2.8"	\$15.99	Purchase
7	The Home Depot	10 Ga Copper Wire	\$2.64	Purchase

Total: \$99



Moving Forward

- Concept Generation of Generator
 - Number of Slots
 - Outer or Inner Rotor
 - Casing
- Modify Generators (MAD JENNY & Melon Motor)
- Create our own generator
 - Analyze in ANSYS
 - Create CAD

Thank you

Any Questions?

References

[1] Climate Central, “A Decade of Growth in Solar and Wind Power: Trends Across the U.S. | Climate Central,” [www.climatecentral.org](https://www.climatecentral.org/report/solar-and-wind-power-2024), Apr. 03, 2024.
<https://www.climatecentral.org/report/solar-and-wind-power-2024>