Summer 2020

Footsteps Power Generator

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Mechanical Footsteps Power Generator

(Springs - Gear - Rack)

By:

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Partner:

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Table of Content

1. Introduction

a. Motivation:

This project was motivated by the need for a device that would generate electricity from human motion, especially footsteps. Electricity is a very important resource in our daily life. There are numerous sources from which we are able to generate electrical energy. The major sources of energy include but are not limited to coal, natural gas, petroleum, and nuclear energy. Most of these sources have adverse effects on the environmental inclusion such as air pollution; for example, from coal energy generation plants which then cumulatively leads to effects such as increase in rates of global warming.

This project seeks to establish an environmentally friendly way of generating electric power from human motion. Such a system could be highly effective for installation in places that expect frequent mobility of a large population such as in educational institutions like universities and subway station entrances and platforms.

b. Function Statement:

A device is needed to generate electrical power when a human is walking over it, by transmitting the vertical motion of a human into rotary motion for a generator.

c. Requirements:

1) It must generate 2 Volts for each step.
2) The top plate must move down 5 inches and returns to its initial position.
3) It must support the weight of 180 pounds
4) The device must be less than 20 pounds

d. Success Criteria:

1) The project must meet all the requisite safety criteria.

2) The device developed should also be relatively small and lightweight without compromising its functionality.

3) The device should be manufacturable with ease.

4) Its construction materials need to be easily accessible and inexpensive so as to minimize the cost of production per unit.

e. Scope of Effort:

This project will include rack, gear and springs.

f. Benchmark:

Pavegen technology is similar project that generate power from footsteps. Pavegen's tiles are electro-magnetic. As people step on the tiles, their weight causes electric-magnetic induction generators to vertically displace, which results in a rotatory motion that generates off-grid electricity.

(https://smartcityhub.com/energy/pavegen-energy-through-the-power-of-footsteps/)

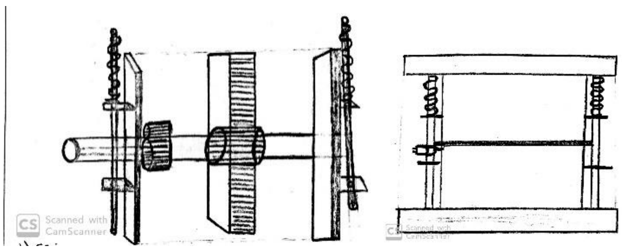
g. The Success of The Project:

The project would be considered a success if it is able to generate electricity from an extremely minimal amount of human motion with zero negative impact on the environment.

2. Design and Analyses

<u>Design description:</u>

The device is designed to generate 0.98 Watts for each step. By stepping on the top plate of the device the force will be reduced by springs and going vertically through rack installed at the bottom of the plate. The pinon will convert the vertical motion applied on the top plate to rotational motion and deliver it to the AC motor.



a) Benchmark:

Pavegen technology is similar project that generate power from footsteps. Pavegen's tiles are electro-magnetic. As people step on the tiles, their weight causes electric-magnetic induction generators to vertically displace, which results in a rotatory motion that generates off-grid electricity.

b) Performance prediction:

The device is needed to generate electrical power when a human is walking over it, by transmitting the vertical motion of a human into rotary motion for a generator.

c) Description of Analysis:

- A1: The calculation of the spring constant for the force selected.
- A2: The calculation of pinion design.
- A3: The calculation of the maximum stress possible on the pinion.
- A4: finding the power based on the calculation of the torque>
- A5: finding the pinion minimum diameter.
- A6: The calculation of linear velocity of the rack.
- A7: calculation of the gear.
- A8: calculation of the volts generated based on the power applied.
- A9: calculation of the gear ratio.
- A10: calculation of the gear speed.
- A11: calculation of the contact stress of the pinion.
- A12: calculation of the bending of the pinion.

3. Methods and Construction

i. Method:

This project requires drilling, cutting, bending and welding. The Supporting plate is the main part of the device that holds all parts together. Welding was chosen as it provides strong hold and doesn't add to the overall weight of the device. The welding must hold the right plate perpendicular to the supporting plate. Otherwise, the amount of power generated will be reduced, and the shaft will be damaged. Using clamps and angle iron is the best way for welding right angle. When cutting the steel plates to make parts, the cut was slightly angled. That could cause the device to be unbalanced. One way to make straight cut, is to draw a line on the part before proceeding.

The device has a top plate that moves down five inches when applying 180 pounds on it, and it must go back to its initial place when removing the force. In order for this process to happen, two springs were added to the design. The springs must be placed under the top plate and must hold its position. To keep the springs in place, two holes were drilled on the top plate and two holes on the supporters. The design was edited to have two springs placed in the shafts, and the shaft must be screwed on the top plate and go through the holes on the supporters. That will help keeping the springs in its place and improve the outcome of the device.

The device was tested for carrying 165 pounds and generating 2 volts per step. The device passed the first test of carrying the weight and keeping function. The second test was to generate an average of 2 volts. The first few trials went well, and the results were positive. However, while testing the device the generator stopped giving any results. After inspecting the DC motor, the problem was identified as the system failed to deliver power to the generator because a small gear that connect the system to DC motor fell off during testing. The gear must hold its position on the shaft to keep the energy going through the system. J-B weld is quick and effective solution to hold the gear on the shaft.

ii. Welding

The device will be built in 4 sections. Some parts will be measured and cut in the machining room. The second section of the process is to drill holes on the steel plates. Third section is bending. Last section is testing the parts. The welding must hold the right plate perpendicular to the supporting plate. Otherwise, the amount of power will be reduced, and the shaft will be damaged. Using clamps and angle iron is the best way for welding right angle.

4. Testing method:

Each part of the device will be tested for safety and performance by applying different amount of force on the top plate and observe and record the results.

- The top plate will be tested for bending force and it must support the weight selected.

- The springs should allow the top plate to move down five inches and moves it back to its initial position.
- The rack will be tested for transmitting the power to the pinion.
- The pinion mesh with gears to transmit the power to the ac motor

The purpose of the device is to generate electricity from human motion. Therefore, the device will be tested on carrying a maximum load of 180 pounds. The process to test the device is to have a person weight as the source of load by stepping on the top plate. Electricity generated will be measured using voltmeter. The device will also be tested for some safety factors, such as the electricity insulation to make sure there is no electricity leak that could cause electric shock. The device must be safe for human use. Therefor, the device must maintain balance. Moreover, the performance of each part of the device will be tested separately.

The first testing for the project is to determine if the device meet the requirement of carrying 180 pounds. The process for testing this section is based on using human weight to apply force on the top plate. The device was tested on 165 pounds and successfully passed the test. The second testing is determining if the device would generate 2 volts for each step when applying a force of 165. The testing results were successful until something wrong happened to the generator causing failure to deliver energy. The source of the problem was determined by tracking the movements starting from the top plate to the rack and transforming the motion to pinion until getting to the DC motor where it stops delivering the energy. After inspecting the DC motor, small gear failed to hold its position on the shaft that connect the system to the DC motor. This issue caused a delay in the project since the device failed to pass the testing and meet requirement. To solve this problem cold weld was used to hold the gear on the shaft. After letting it dry for appropriate time the testing resumed and successfully gefarnates an average of 2 volts per step.

5. **Budget**

a. labor or outsourcing rates & estimate costs

Labor for making this project will be the team members of this project.

b. Labor

Team members itself will be the labor for this project.

ii. Estimated cost of this part of project will be 135 USD. This will be the cost of making the purchases for the parts of the project.

iv. The team of this project will make the contribution in purchasing all the items of this project. So funding source will be the members of the project team.

Price list:

Part	**Price**
1. Rack	$35
2. Pinion	$50
3. spring	$20
4. MD steel	$30

The budget for this project was estimated to be $135. The percentage used from the budget until today is %97. The budget was calculated to cover all raw materials, and all the parts that need to be ordered online. However, A few aspects were not considered when calculating the budget, such as tax, delivery charge and more important the amount of material needed. First issue was noticed that would affect the budget is the delivery charge and tax, for each order around $4 to $6 was added to the total price to cover tax and delivery. To keep the budget in track, tax and delivery price was not paid from the budget. Second issue was noticed is the amount of steel material for one order was not enough, so more steel sheets were ordered online using money that was determined to buy DC motor. In order to keep the project going with all unexpected issues, more money was added to the budget to make it a total of $300.

Testing:

The budget estimated for buying the parts and manufacturing only. The testing was done at home and no extra parts or devices needed to complete the testing. A problem happened during testing caused delay in the project. The DC motor stopped delivering power, so immediate fix needed to be done to it. J-B weld was bought using the budget estimated for the parts and manufacturing. The budget estimated for the project is $300. J-B weld was bought for $7 and that fixed the problem. Testing resumed after making sure the J-B weld had enough time to dry and was tested before installed on the device.

6. Schedule

a. Fall:

- First the outline for the project is created on the first week of the fall quarter.
- Second week start working on design and analysis and complete twelve green sheets design analysis by the end of the fall quarter.
- Solidwork drawings and assembly should be created for each part of the device.
- Determine the test methods and where the device will be tested.
- Determine construction method and where the device will be built.

b. Winter:

- During the winter term the project will be built.

c. Spring:

- During the spring term the device will be tested.

The estimated time for manufacturing parts was slightly less than the actual time needed to make the parts due to several reasons. For the welding parts, the right process for welding was not indicated in the drawing. The welding must hold the right plate perpendicular to the supporting plate, that was indicated in the drawing, but the method for welding a part on specific angle was not known. The problem was indicated few minutes before working on the part. Due to the unexpected issue, the process was put in hold until the research is completed. A few solutions were found online for the same problem. The method was determined best for the project is to weld two pieces of angle iron and make the angle between them 90 degrees and use clamps to hold the parts on the angle iron. After setting it up that way the process was resumed, and the welding was completed as planned.

April-May: The project process was mostly done on time. However, few issues caused a delay during manufacturing and testing. The first issue with manufacturing the project was during the welding process. In order for the welding to be done on the project, other parts had to be made to help with welding the right and left plates 90 degrees on the supporters. The other issue was during testing when the DC motor stopped generating electricity because one gear inside the DC motor falls off and needed to be weld on the shaft. JB weld used to solve the issue and the DC motor generated electricity to resume testing.

Testing: The last process is testing the project.

7. Project Management

a. Human resources

The professors and staff in mechanical engineering technology department are available to help in building this project.

b. Physical resource

Machining book is one helpful source for operation. The notes from Mechanical design class helped with designing the parts.

c. Soft resources

Information from the internet could be used for some research during this project. Smellier projects outline.

d. financial resource

The project doesn’t have sponsored, the cost of the project will be sheared between the group members.

8. Discussion

a. Design evaluation

Spring, rack and pinion connections will be made with the gears in the project. The combination of shaft, gears, spring and rack system will allow the whole setup to move linearly in one direction and then the other in a linear way. The dimensions will be kept same as already described in the SOLIDWORKS. With the use of nuts and bolts the connection of the whole setup will be made. Whole parts including generator, gear, spring, rack and pinion will be assembled at the end. The project has two shafts on each side to keep springs in its place while using the device. After designing the appropriate shat to the project, L-bracket with hole on top was designed to hold the shaft by allowing it to go throw the hole. Although, that helps to keep the springs in its place, the shaft and the top plate were not stable, because the shaft was holed by one side. A second L-bracket was made to hold the bottom of the shaft. The design was successful for holding the top plate, springs and shafts. However, because the shafts are hold by two different locations, the friction significantly increased causing loud noise and reduction of the outcome of the device. L-bracket will be redesigned to have rubber around the holes. The testing shows that the device successfully meets all the safety requirements. The results of the testing are very good, and the device is generating about 0.55 volts more than expected due to the efficiency of the device by not wasting a lot of the energy when it is been translating throw through the system. One of the requirements is to have the device placed one foot under the ground and test it under this condition. The device was not tested under that condition which leaves one of the requirements not tested. However, the performance of the device is very good and generates more than 2 volts per step.

b. Project risk analysis

Electrical contact hazards, injury during machining and cutting parts, and getting cuts while using the inappropriate way of installation will be the project risks.

c. Success

The project will be said as the successful if the all the connections are made according to the design. Proper connection of gear, with the rack and pinion will guarantee the success of the project. Success of the project will be determined by detecting the output power after applying the force on the top plate of the whole assembly.

d. Project documentation

A proper document of the project justification will be provided through which the necessity of this project will be explained. The other documents will be the proper schedule for the completion of project, estimated cost, required material and work breakdown structure which will be attached with the whole project report.

e. Next phase

Project assembling process will be done in the next phase, in which order of gear, rack and pinion system will be placed. After that drilling machining and fastening process will take place. Whole project will be made in next phase.

9. Conclusion

This project seeks to establish an environmentally friendly way of generating electric power from human motion. Such a system could be highly effective for installation in places that expect frequent mobility of a large population such as in educational institutions like universities and subway station entrances and platforms.

The device is designed to generate 0.98 Watts for each step. By stepping on the top plate of the device the force will be reduced by springs and going vertically through rack installed at the bottom of the plate. The pinon will convert the vertical motion applied on the top plate to rotational motion and deliver it to the AC motor to generate the power.

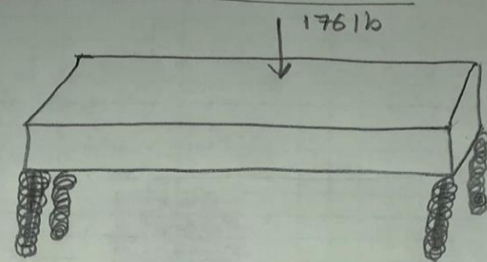
Appendix A-1. Springs

Force on springs

Given:

$F = 176$ lb

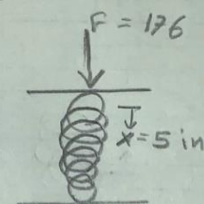
$x = 5$ in



Find:

spring constant

Method: 1) $F = -Kx$ ← how far compressed



solution:

$$K = \frac{176\text{ lb}}{5\text{ in}} = \boxed{35\text{ lb/in}}$$

Appendix A-2. Pinion design

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Pinion

σ_{max} = maximum contact compressive stress N/m^2

$E1, E2$ = yougs modulus

M_t = torque N-m

$E1 = E2 = 1.1 \times 10^6\ N/m^2$

$$\sigma_{max} = H_B \times C_B \times K_{cl}$$

H_B = Brinell hardness

C_B = cofficient depends on hardness

K_{cl} = life factor.

life factor:

$$K_{cl} = \left(\frac{1 \times 10^7}{N}\right)^{1/6}$$

$$N = 60 \times n \times T$$

n = rpm

N = life in no. of cycles

T = life in hours

Appendix A-3. Pinion maximum stress

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Maximum stress

T = life in hours

= 5000 hours

from [PSG]

$C_B = 20$

$H_B = 200$

substituting the value of N, n, T in (

$N = 60 \times n \times T$

$K_{cl} = 1.139$

substituting the values in σ_{max} equation

$\sigma_{max} = 20 \times 200 \times 1.1309 = 4520 \times 10^5 \ N/m^2$

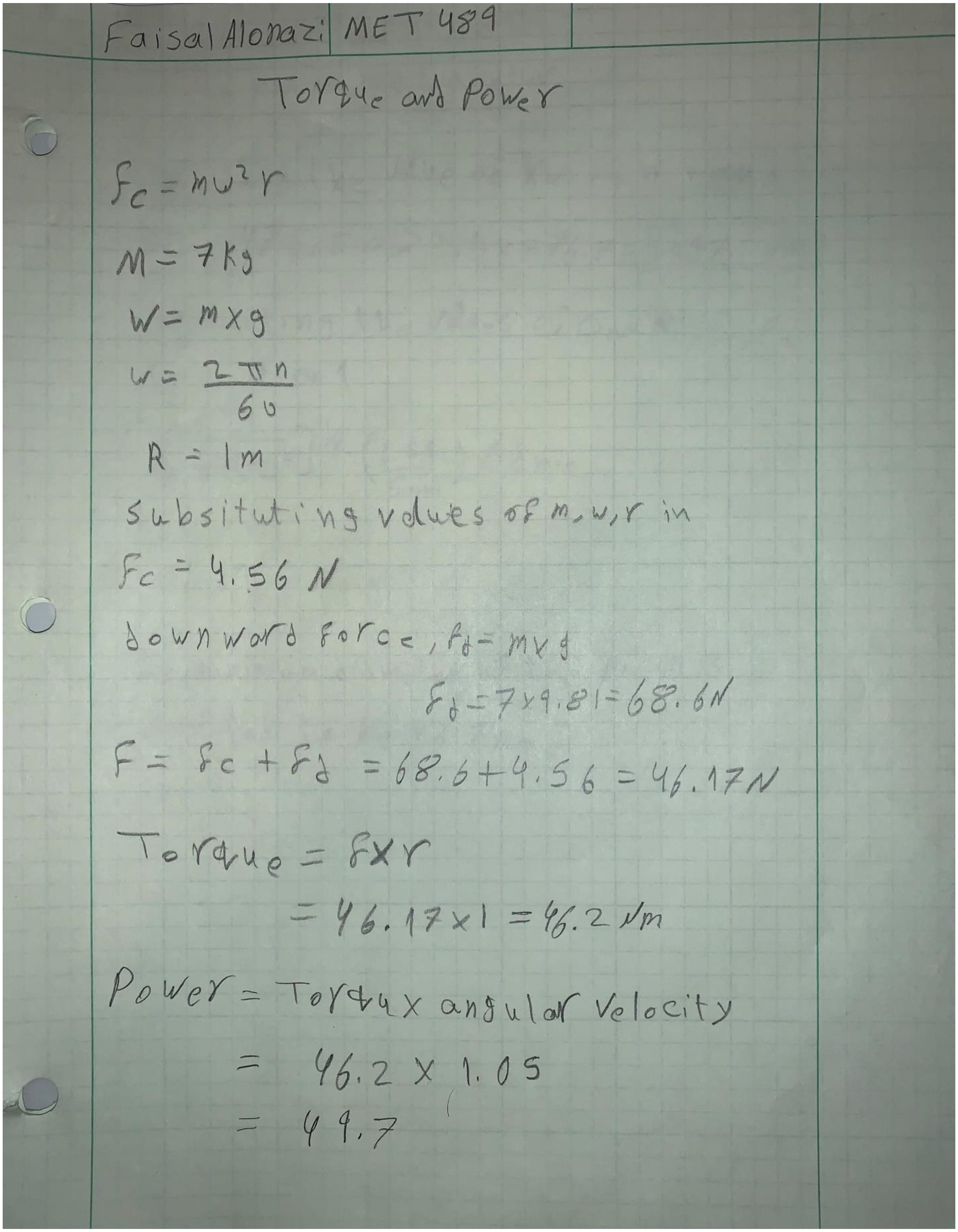
calculation of Mt:

$Mt = 97420 \times (Kw/n)$

for power:

$F_c = m\omega^2 r$

Appendix A-4. Pinion, torque and power



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Torque and Power

$f_c = mw^2 r$

$M = 7\,kg$

$W = m \times g$

$w = \frac{2\pi n}{60}$

$R = 1m$

subsituting values of m, w, r in

$f_c = 4.56\ N$

downward force, $f_d = m \times g$

$f_d = 7 \times 9.81 = 68.6N$

$F = f_c + f_d = 68.6 + 4.56 = 46.17N$

$Torque = f \times r$

$= 46.17 \times 1 = 46.2\ Nm$

Power = Torqu x angular Velocity

$= 46.2 \times 1.05$

$= 49.7$

Appendix A-5. Pinion minimum diameter

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Pinion min diameter

Substiuting the value of Kw and n in eqn 3

$Mt = 476.7 \Rightarrow 1.4 \times 776.7 = \boxed{1087.1\ Nm}$

Substituting the values of σ_{max} Mt, E_1, E_2 in equation 1

$$\left[\frac{Mt}{\left(\frac{1}{E1}\right)+\left(\frac{1}{E2}\right)^2}\right]^{1/3}\left(\frac{0.59}{\sigma_{max}}\right) < d_{min}$$

the minimum diameter of the pinion is calculated to be 43.7 mm

Appendix A-6. Rack

Rack Analyses

$n = 300$ rpm

$P_d = 6$

$N_p = 24$

$L = 8$ in

distance from the pitch line to the back of the rack: $B = 1.333$ [table 8-10, Machine elements in Mechanical Design].

linear velocity of the rack $= V_{rack} = \left(\frac{D_p}{2}\right)(n_p)$

$V_{rack} = (1.5)(300)\left(\frac{2\pi \text{ rad}}{\text{rev}}\right) = 28[illegible]$ in/min

$t = \frac{s}{V} = \frac{8 \text{ in}}{282 \text{ in/min}} \cdot \frac{60 \text{ sec}}{\text{min}} = 1.70$ sec.

$\theta_p = \frac{8 \text{ in}}{.75} = 10.66 \text{ rad} \cdot \frac{1 \text{ rev}}{2\pi \text{ rad}} = 16.75 \text{ rev}$

Appendix A-7. Gear

Gears Analyses

teeth #: 24

Pitch diameter: 1.5

$D_p = \frac{36}{24} = 1.5$

circular pitch $= \frac{\pi D_p}{N} = \frac{\pi(1.5)}{21} = .196$

$P_d = \frac{N}{D} = \frac{24}{1.6} = 15 \Rightarrow \boxed{16}$

outside diameter $= \frac{26}{16} = \boxed{1.625 \text{ in}}$

Addendum (a) $= \frac{1}{16} = \boxed{.0625}$

Dedendum (b) $= \frac{1.25}{16} = \boxed{.0781}$

tooth thikness $= \frac{\pi}{(16 \times 2)} = \boxed{.09817}$

Depth (ht) $= \frac{2.25}{16} = \boxed{.1406}$

Root radius $= \left(\frac{1.625}{2}\right) - .0781 = \boxed{0.7344}$

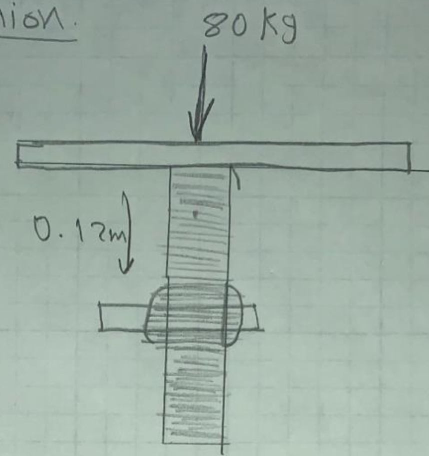
Appendix A-8. Power generated

rack and pinion.

Given:

$F = 80\ kg$

$X = .12\ m$



solution:

$F = 80\ kg \times 9.81 = 784.8\ N$

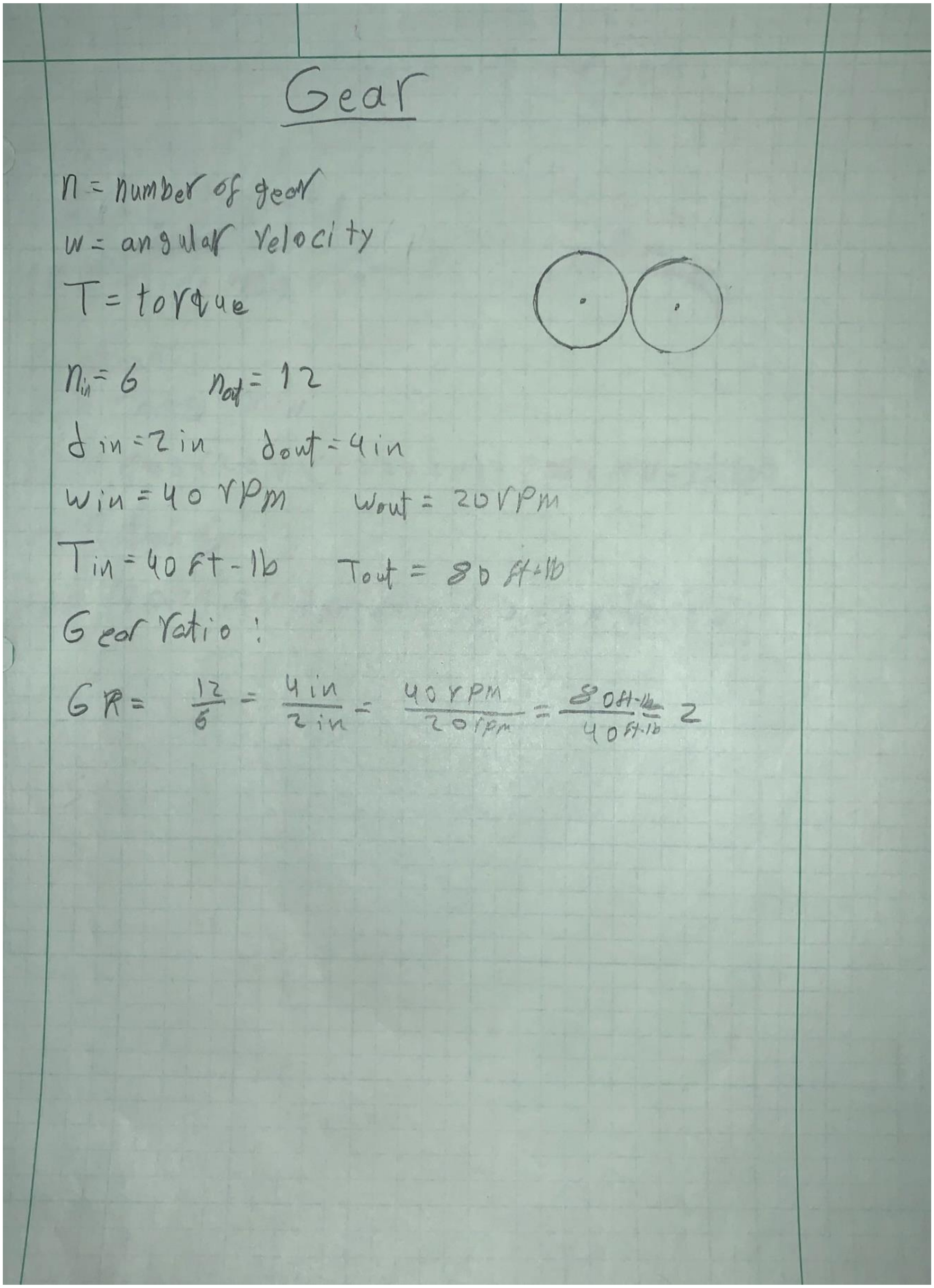
Power:

$(784.8 \times 0.12)/60 = 1.56\ W$

$V = 1.56/0.25 = 2.08$ Volts

$P_T = 12v \times 0.25A = 6\ W$ @ 300 rpm.

Appendix A-9. Gear



Gear

n = number of gear

w = angular velocity

T = torque

$n_{in} = 6$ $n_{out} = 12$

$d_{in} = 2\text{ in}$ $d_{out} = 4\text{ in}$

$w_{in} = 40\text{ rpm}$ $w_{out} = 20\text{ rpm}$

$T_{in} = 40\text{ ft-lb}$ $T_{out} = 80\text{ ft-lb}$

Gear ratio:

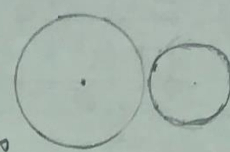
$$GR = \frac{12}{6} = \frac{4\text{ in}}{2\text{ in}} = \frac{40\text{ rpm}}{20\text{ rpm}} = \frac{80\text{ ft-lb}}{40\text{ ft-lb}} = 2$$

Appendix A-10. Gear

Speed of Gear

Speed of diven gear =

$$\frac{\text{number of teeth (driver)}}{\text{number of teth (driven)}} \times 100$$



$$S = \frac{28}{10} \times 100 = 280 \text{ rev/min.}$$

Appendix A-11. Contact stress

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contact stress

$N_p = 24$ $\quad F = 2.00$

$N_G = 36$ $\quad p = 0.323\ hp$

$D_p = 1.5$ $\quad P_d = 16$

$$V_t = \frac{D_p}{2} \cdot \omega_p = \frac{1.5\ in}{2} \cdot \frac{300\ rev}{min} \cdot \frac{2\pi\ rad}{1\ rev} \cdot \frac{1\ ft}{12\ in} = 117.81$$

$$W_t = 33000 \frac{(0.323\ hp)}{117.81} = 90.47\ lb$$

$$m_G = \frac{36}{24} = 1.5$$

$$I = 0.108$$

$$C_p = 2300$$

$$S_c = C_p \sqrt{\frac{W_t K_o K_s K_m K_v}{F D_p I}}$$

$$S_c = 2300 \sqrt{\frac{90.471 \times 1.5 \times 1.00 \times 1.21 \times 1.41}{2.00 \times 1.5 \times .108}} = 61483\ psi$$

Appendix A-12. Bending stress

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Bending stress

$N_p = 24$ $\quad F = 2.00$ $\quad P_d = 16$ $\quad D_p = 1.5$

$N_G = 36$ $\quad S_{tp} = 61483\,Psi$

$n_p = 300\,rpm$ $\quad S_{tG} = 49988\,Psi$

$n_G = 200\,rpm$

$S_{at} = 95000\,psi$

$N_{LP} = (60)(24000)(300)(1) = 4.32\times10^8$ cycles

$N_{cG} = (60)(36000)(200)(1) = 4.32\times10^8$ cycles

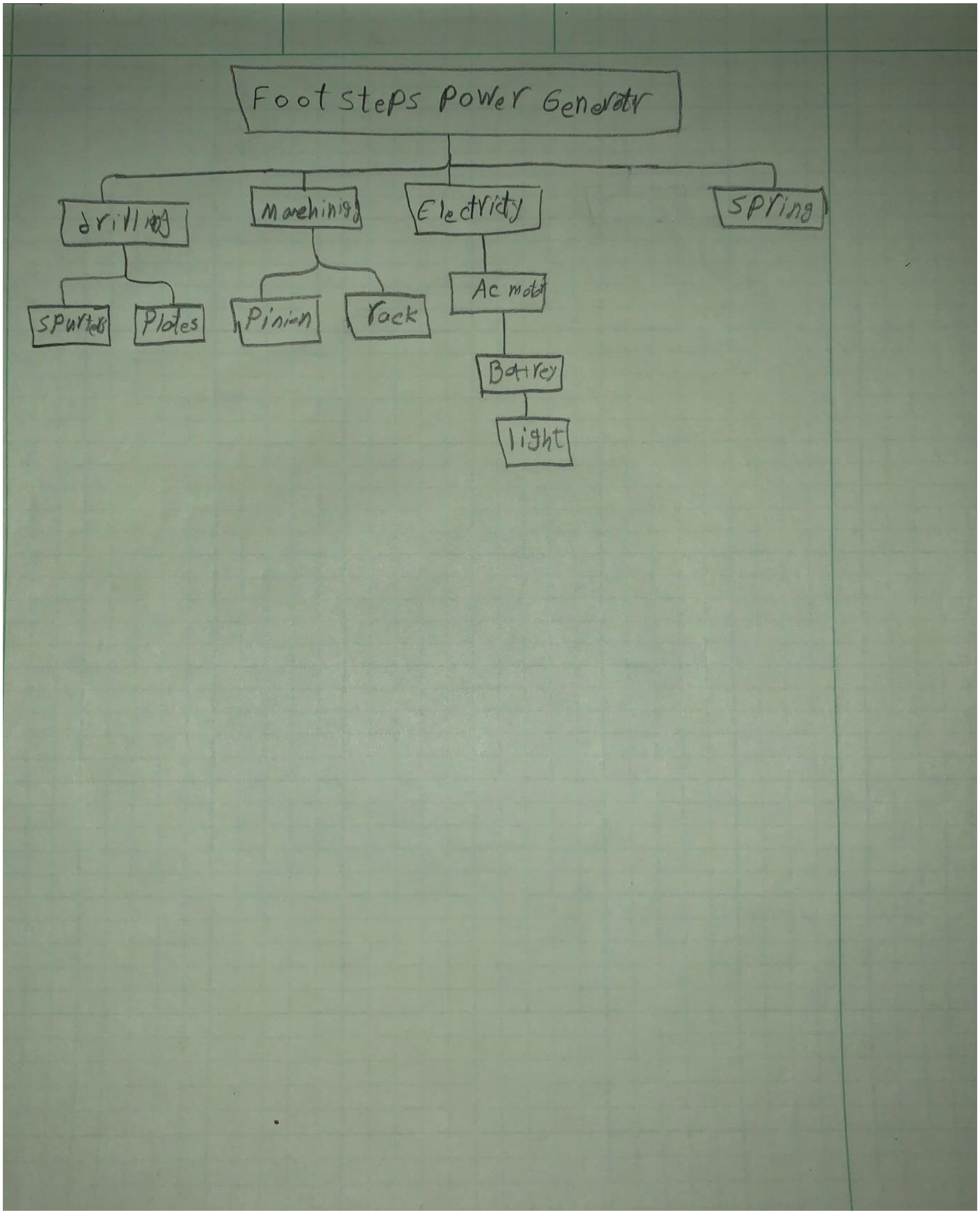
$Y_{Np} = 0.89$

$Y_{NG} = 0.89$

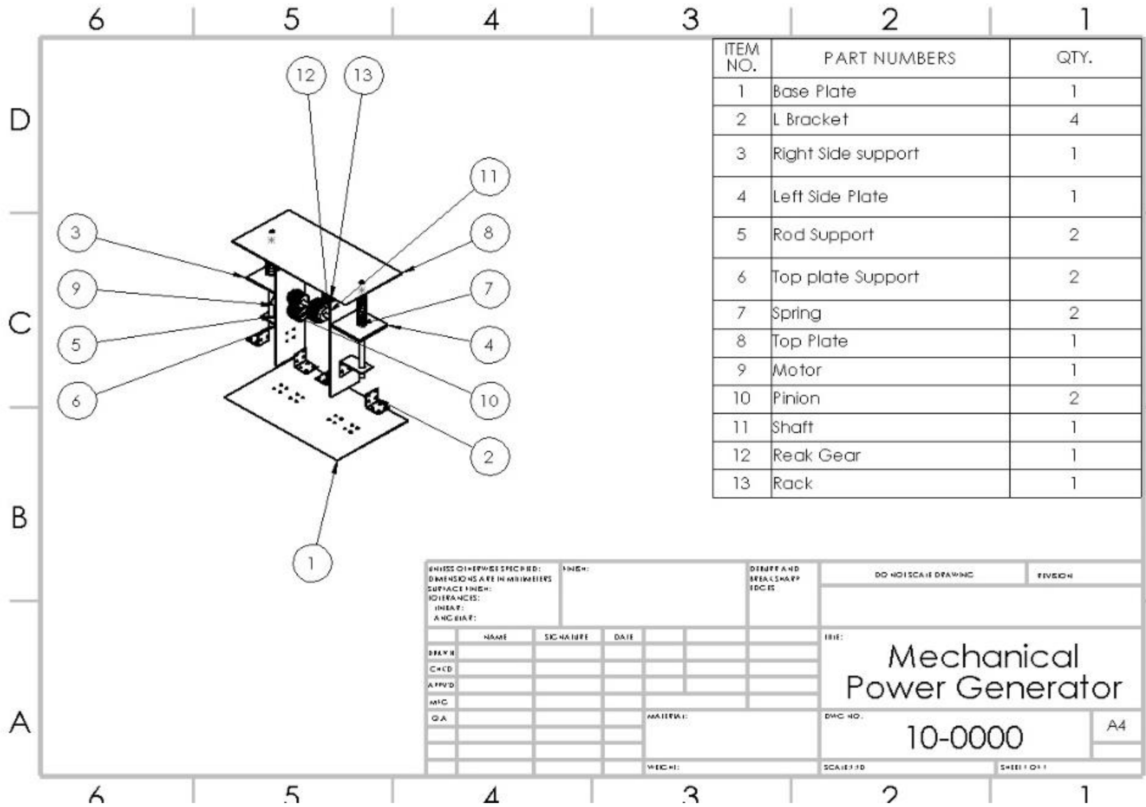
$$Sf = \frac{95000\,Psi}{61483\,Psi} \cdot \frac{.89}{1.25} = 1.100$$

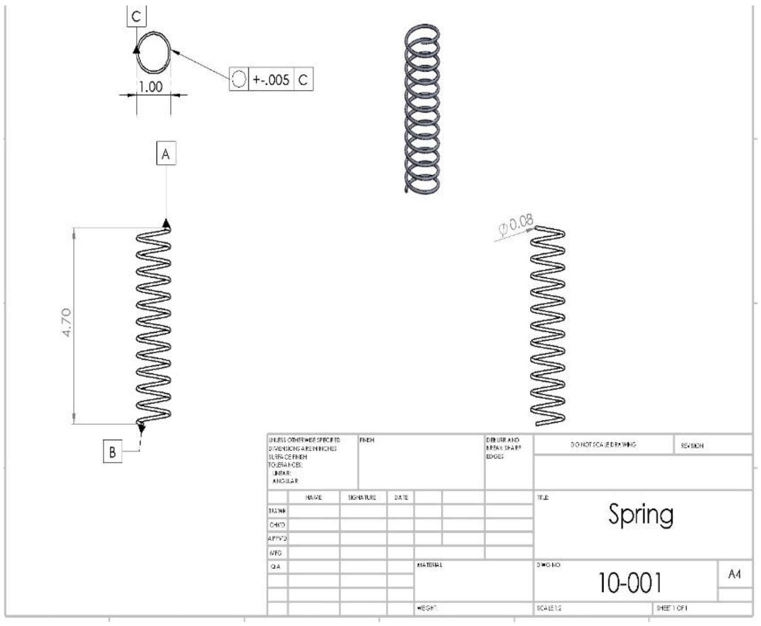
$$SF = \frac{95000\,Psi}{49988\,Psi} \cdot \frac{.89}{1.25} = 1.127$$

10. Appendix B-Drawing

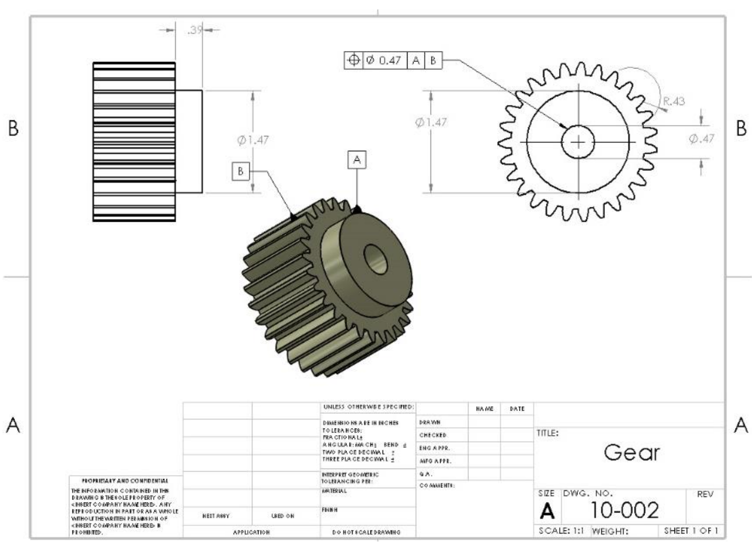


11. Appendix B

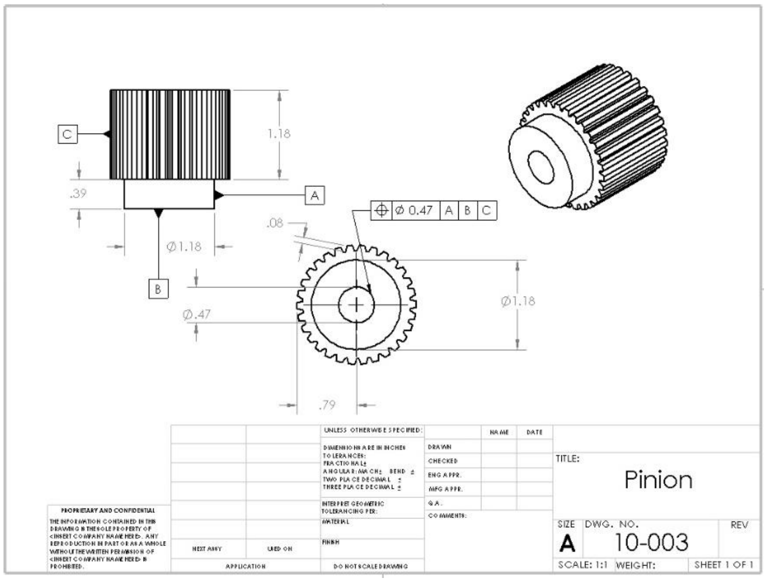




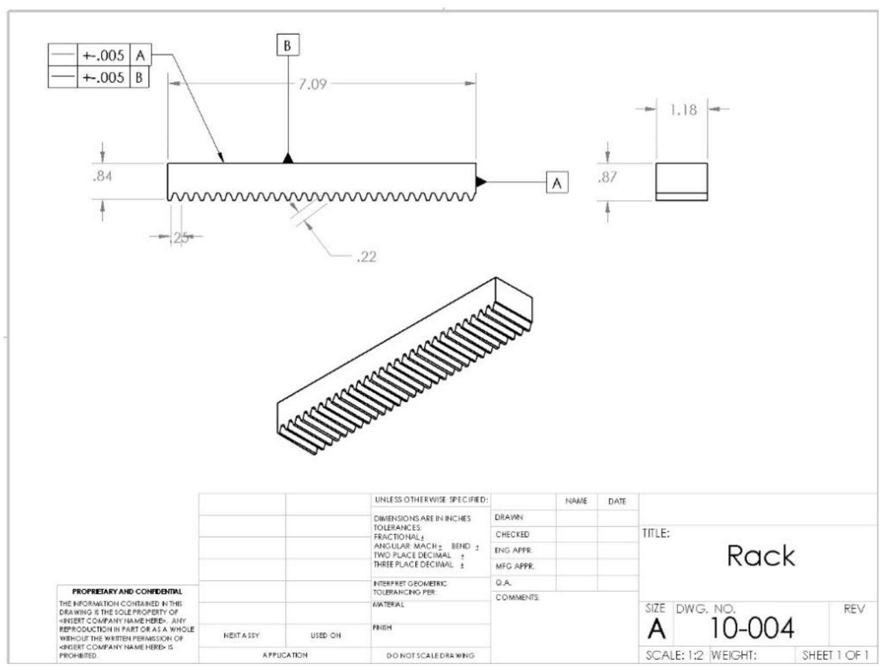
Appendix B-1. Spring drawing



Appendix B-2. Pinion drawing.



Appendix B-3. Gear drawing



Appendix B-3. Rack drawing.

12. Appendix C:

Part Ident	*Part Description*	*Source*	*Cost*	*Disposition*
MD Steel	*A569/ASTM A1011*	*Onlinemetals.com*	*$30.00*	*Order*
Rack	*FAAC Galvanized Steel Rack*	*Allsecurityequipmint.com*	*$35.00*	*order*
AC Motor	*Shaded pole open motor*	*Globalindustrial.com*	*$55.00*	*order*
		Cost Total:	*$120.00*	

13. Appendix E:

	A	B	C	D	E	Sep	October	November	Dec	January	February	March	April	May	June	Notes
1	**DEFINE HOW THE STUDENTS SHOULD INDICATE STARTING EARLY/LATE AND FINISHING EARLY/LATE**															
2	**X to indicate work**															
3																
4	**EXAMPLE** SCHEDULE FOR SENIOR PROJECT:															Note: March x Finals
5	**NOTE: STUDENTS MUST MAKE THEIR OWN SCHEDULE!!!!!!!!!!!!!**															Note: June x Presentation
6	PROJECT TITLE: Footsteps power generator															Note: June y-z Spr Finals
7	Principal Investigator.: Faisal Alonazi															
8			Duration													
9	TASK:	Description	Est.	Actua	%Com	S	October	November	Dec	January	February	March	April	May	June	
10	ID		(hrs)	(hrs)												
11																
12	1	Proposal*														
13	1a	Outline	2	2		X	X									
14	1b	Intro	2	2		X	X									
15	1c	Methods	4	4			X X X									
16	1d	Analysis	8	10			X X X	X x								
17	1e	Discussion	2	3			X X X									
18	1f	Parts and Budget	5	6				X X X								
19	1g	Drawings	6	10			x x x	x x x x			X	X X X X				Started on time ended late
20	1h	Schedule	1	2							X	X X				Started on time ended on time
21	1i	Summary & Appx	3	3								X X X				Started late ended late
22		subtotal:	33	42							X X	X				Started early ended early
23																
24	2	Analyses														
25	2a	Stress Anal=>Geo	3	4			x x									
26	2b	Power Anal=>Geo	3	4			x									
27	2c	Kinematic => Geo	2	3				x								
28		subtotal:	8	11												
29																
30	3	Documentation														
31	3a	Part 1 spring drawing	1	1			X									
32	3b	Part 2 gear drawing	4	5			X X x									
33	3c	Subassembly spring	1	1			X									
34	3d	Part 3 rack drawing	2	3				X								
35	3e	Part 4 Pinion	2	3				X								
36	3f	Subassembly rack and pinon	1	1				X								
37	3j	Device drawing	2	3				x								
38	3l	ANSIY14.5 Compl	4	4												
39	3m	Make Object Files														
40		subtotal:	17	21												

14. Appendix H- Resume

Faisal Alonazi

Mechanical Engineering Tch

EDUCATION

- Bachelor's in Mechanical Engineering Technology

  Central Washington University

  09/2018-06/2020

- Associate of Science Diploma

  Lane Community College

  09/2015-06/2017

- ESL Pro.

  Lane Community College

  06/2014-07/2015

SKILLS

- Teamwork
- Presentation and Public Speaking
- Problem Solving
- Project Management

LANGUAGES

- Arabic
- English

15. Appendix J:

JOB HAZARD ANALYSIS

Prepared by: Faisal Alonazi	Reviewed by: Approved by:

16.

Location of Task:	Hogue
Required Equipment / Training for Task:	Hand Tool
Reference Materials as appropriate:	https://ehs.berkeley.edu/sites/default/files/jsa-library/fsdrillpress43.pdf https://ehs.berkeley.edu/job-safety-analysis-jsas-listed-topic

17.

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
X	☐	X	☐	☐	☐	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

18.

TASK DESCRIPTION	HAZARDS	CONTROLS
Clean the table.	**Eye injury from metal debris**	**Wear eye protection. Do not use compressed air.**
Put material in vise or clamp, apply lubricant while drilling and drill	**Fall, Pinch points, Posture**	**Ensure PPE is worn.** **Ensure area is clear of all tripping hazards. Be aware of hand and finger location at all times Rotate job tasks when possible.**
Unload the vise.	**Foot injury if the vise falls**	**Leave the vise secure on the table with T-pins until it is unloaded.**
Start the threader/ cutter.	**Injuries due to catching the clothing**	**Don't wear loose clothing while operating the threader/cutter. Wear eye protection.** **Wear long-sleeved shirt, gloves, and face shield**