Spring 2020

Fire Fighter Robot

Sultan Alhajrri
Central Washington University, alhajrisul@cwu.edu

FIRE FIGHTER ROBOT

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ALHAJRI'S TEAM

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1. Introduction:

a. Description

Fires are a threat to both human life and property. According to the national fire administration 39% of all fires are structural fires. These type of fires result in significant loss of lives, injuries and destruction of property worth millions of dollars. The state has put in measures to curb the devastating destruction of fires through policies and agencies dedicated to respond to fires like the fire departments.

b. Motivation:

Fire fighter try their best to respond quickly to cases of fires and even put their lives at risk as they endeavor to save human life and protect property from fires.

Some attempts have been made to automate fire fighting for the navy (Shipboard Autonomous Firefighting Robot, n.d.), (firefighting robot, n.d.)

c. Functional statement

Even though the men and women working in the fire department are well equipped and trained, more often than not, due to the unpredictable environment created by fires, the fire fighters end up being injured or even die in course of performing their duties.

This is undesired in this current technological space. Fire fighters should have better working conditions to make their work safe and efficient.

d. <u>Requirements:</u>

To design and manufacture a firefighting robot

Specific objectives:

1. To design and implement a test environment
2. To design and implement an alarm system
3. To design and implement a fire detection system
4. To design and fabricate the frame of the robot
5. To design and implement a water dispensation system
6. To design and implement the drive system
7. To design and implement the control system

Constrains:

I. The robot cannot climb stairs
II. High skills required to implement some sections.
III. Some parts like the rubber wheels will melt at high temperature

e. <u>Engineering Merit:</u>

The desired features include:

To have a robot that can be remotely navigated by an operator hence removing the human element from the harsh conditions of a burning area.

To have a camera providing adequate vision of the burning building/ structure to aid in directing the robot to put out fire in the appropriate location.

To have a well calibrated sensors and accuracy and sensitivity to detect fires with precision

To have a robust robot body that protects the circuitry from the high temperatures

To have an efficient water dispensation mechanism with the capability of putting out the fires from a close or from the desired distance.

f. **Scope of Effort:**

The 2solution is to build a robot with considerations of the power capability to power the entire electronic circuit, motor drivers and the water pump. The robot has to have fire resistant materials that are also easy to manipulate during the frame and body fabrication in its construction. The material should also offer some weight advantage in that it should not be heavy. An example of such a material is carbon steel A36, it has high tensile strength to withstand impact from falling materials. (ASTM A36 Steel Plate, 2015).

The robot drive mechanism has to have enough torque and power to enable it carry its entire payload without being cumbersome. Also, the robot will have a speed controller to aid in navigation and steering.

The control of the robot should be facilitated with a good signal strength to enable adequate range of use by the operator.

g. **<u>Success Criteria:</u>**

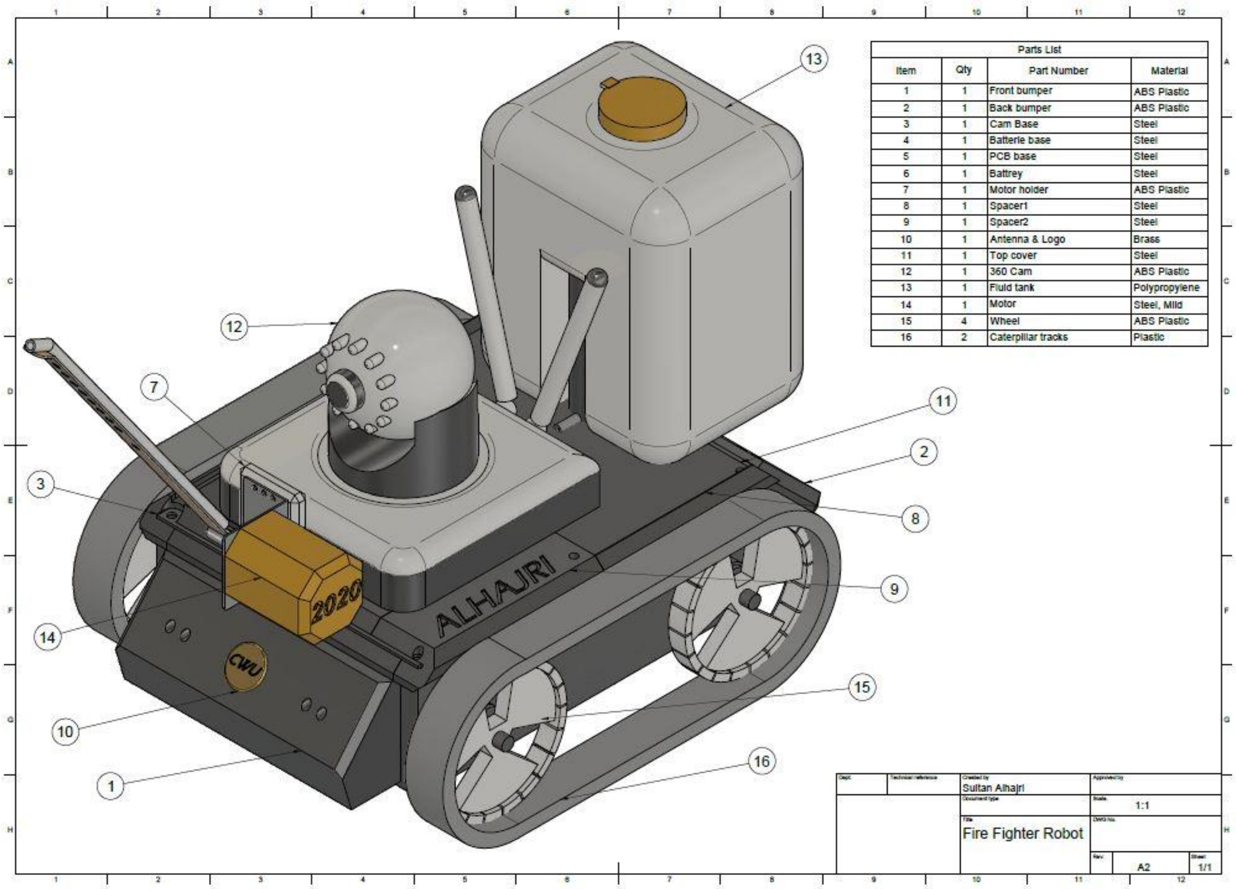
The ROBO Team has planned on how to implement this project. Each member has been assigned a task while doing continuous research to ensure the success of this projects. With the right amount of funds, this project can be further pursued and improved.

2. Design and Analysis:

a. ***Approach: Proposed***

The design as well as the analysis part is given in the appendix A. Analysis of the movement of the cart is done. On the basis of the correct dimensions of the cart the maximum required speed will be achieved.

b. ***Design Description:***



Parts List			
Item	Qty	Part Number	Material
1	1	Front bumper	ABS Plastic
2	1	Back bumper	ABS Plastic
3	1	Cam Base	Steel
4	1	Batterie base	Steel
5	1	PCB base	Steel
6	1	Battrey	Steel
7	1	Motor holder	ABS Plastic
8	1	Spacer1	Steel
9	1	Spacer2	Steel
10	1	Antenna & Logo	Brass
11	1	Top cover	Steel
12	1	360 Cam	ABS Plastic
13	1	Fluid tank	Polypropylene
14	1	Motor	Steel, Mild
15	4	Wheel	ABS Plastic
16	2	Caterpillar tracks	Plastic

Figure 1: Bottom Part

The team is going to design the chained wheel fire fighter robot which has the metallic platform. There will be wheel connections and wheel on which the whole cart will run. The chain will be attached with the cart and the wheels will run over it. The team will be handling only the mechanical part of the project.

c. ***Benchmark***

The movement of the cart depends on the proper programing in the software portion. The cart must be used for small level fire.

d. ***Performance Predictions:***

- It will be able to work successfully in the heat of 50 to 70 degrees Celsius
- Due to the aerodynamic body shape the cart will move smoothly.

e. ***Description of Analyses:***

Analysis is given in the Appendix B1 and B2.

f. ***Scope of Testing and Evaluation:***

The bottom platform of the whole project will be checked mechanically, and the working of wheels will be checked.

g. ***Analyses:***

Cart velocity = Distance /time

= 2m/1s = 2 m/s

Size of the wheels=d = 4 inches

Circumference = 2*pi*2 = 4*pi inches

Distance traveled in 1 rotation = 12.56 inches

Friction force will be calculated with

$$f = us * N$$

$$f = us * mg$$

$$f = 0.4 * 80 * 9.81 = 313.92N$$

h.

The parts of this project will be fluid valve, fire extinguisher, robotic arm, chained wheel, cart and battery. Shape of the cart will be flat from the top and curved from the sides. Bottom plate will be smaller than the top one.

i.

Wheels, water tank, chain, fire extinguisher and camera will be present in the final assembly. All will be joined at the particular positions as this is shown in the SOLIDWORK design.

j.

The tolerance value for all the connections in assembly will be under 5%. Highest accuracy will be tried to achieve so that the project can function according to the objective.

k.

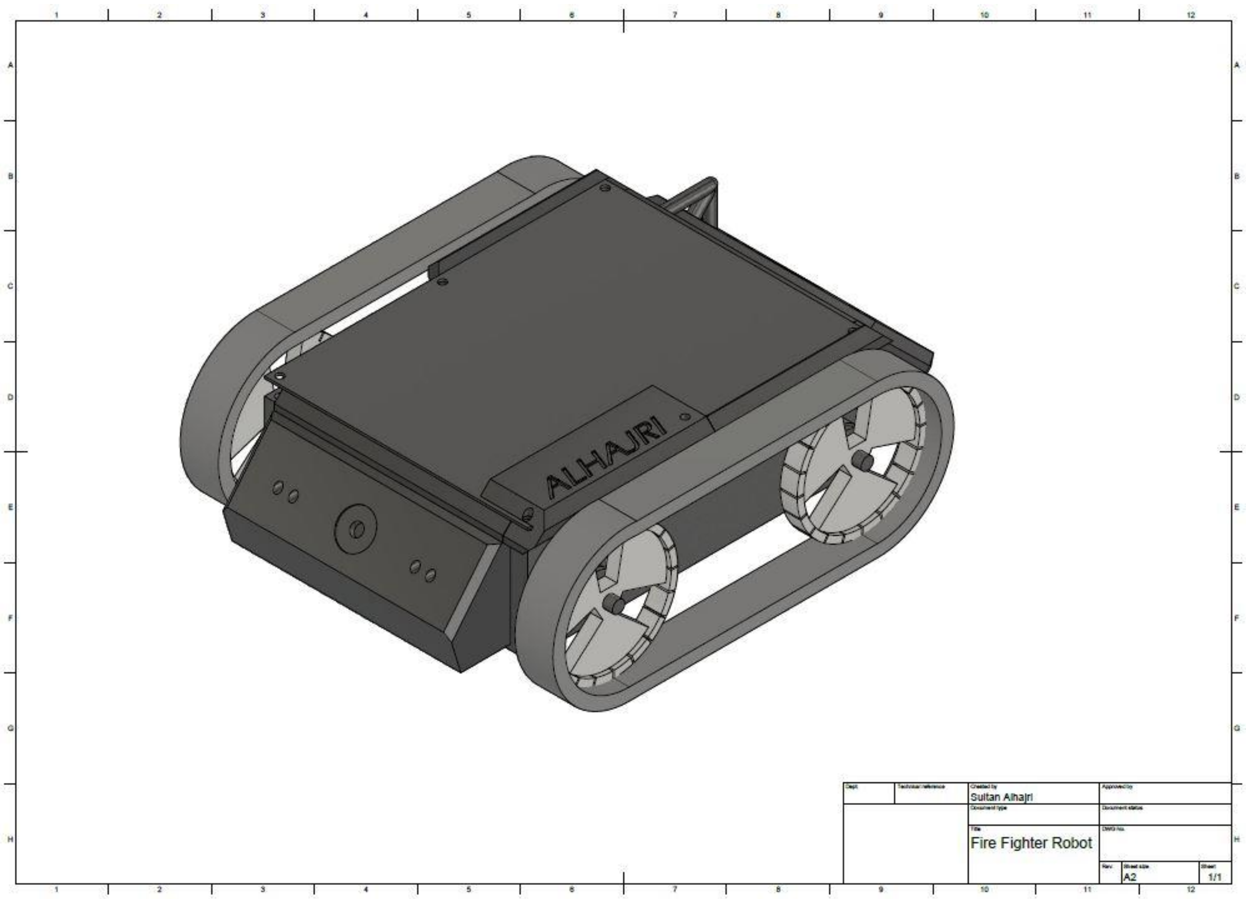
- Can stop working in damp conditions.
- Schedule risk
- Cost Risk
- Analysis method maturity
- Equipment and material availability
- Materials uncertainty.
- Funding constraints

3. Methods & Construction

a. Methods

- 3D modeling all bottom parts with drawings.
- Buying all the necessary parts such as a battery, wires, switches, chassis with wheels, and more from online stores such as Amazon.
- 3D printing all the other bottom parts such as the front and back bumpers, PCB base and battery base.
- CNC milling and lathe machining the front logo of the robot that will also perform as an antenna for the receiver.
- Testing the geometry and durability of the parts before assembly.

Full construction of the bottom part is given below



The bottom consist of chain and wheel. The wheels will be moving on the chain. The shape of the bottom will be such that the upper part will be more in length as compare to the lower part of the platform. Machining and drilling will be done in this part to connect the wheels through screws. There will be electrical part and the mechanical part. This team will be doing the mechanical part in which proper dimensions of the wheel, chain, shaping of the whole cart and the placement and movement mechanism will be done.

b. Construction

The whole project will be constructed with the high grade aluminum so it can sustain in the higher level temperatures.

Part	Made by	Description
Chassis & wheels	Online store	The main and largest part of the robot that will carry all other parts from inside and out.
Motors	Online store	They will drive the wheels in the chassis for more than 50 RPM.
Battery	Online store	The power source of the robot. It’s a rechargeable 12V 8Ah.
Front bumper	3D Printer	To protect the front of the chassis, robotic arm and gives the robot better and tougher look with the white LEDs and Logo/Antenna.
Back bumper	3D Printer	To protect the back of the chassis and it has on it the main power switch, voltmeter, charging plug and red LEDs
Logo/Antenna	CNC Mill/Lathe	The Front vehicle golden logo also will be attached by wire to the radio receiver antenna input.

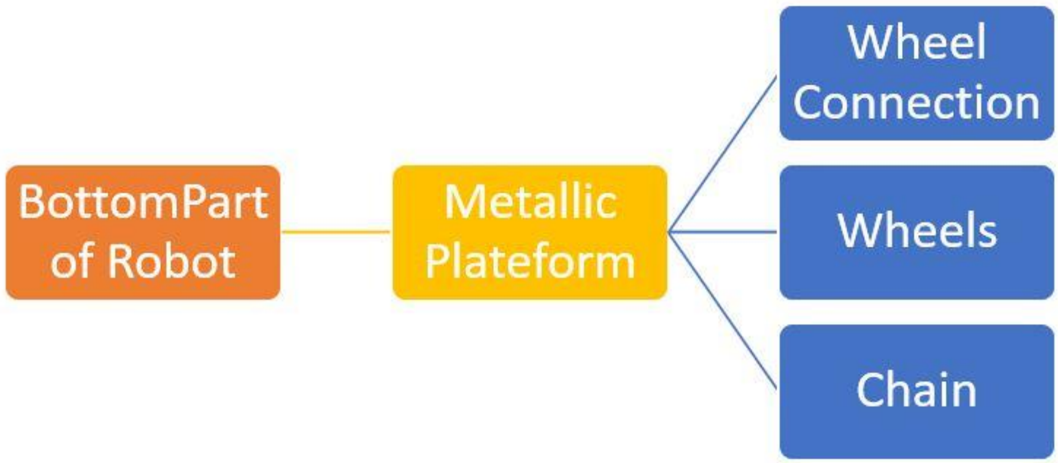
i. Description:

There will be four wheels and the couple of chains in the mechanical part. The chain will also be made up of aluminum. There will be upper plate and lower plate of the bottom part of cart.

ii. Manufacturing Issues:

- Improper cutting of the cart
- Wrong wheel selection
- Poor drilling technique

iii. Drawing Tree, Drawing ID’s:



Tree2

iv. Parts Lists and Labels

i. Metallic Platform

ii. Wheels

iii. Chain

v. Discussion of assembly.

The holes will be created in the cart. The rods will be placed inside it on which the wheels will be kept. Then the wheels will be wrapped with chain.

- Construction and Manufacturing issues/modifications:

- The bottom section of the Fire Fighter Robot has three main parts other than the chassis which are the main PCB with the microcontroller and drivers, the 12V 8Ah lithium acid battery, and the front and rear bumpers. All these parts will be placed inside of the robot chassis by custom design fixtures/widgets which are made from plastic by a 3D printer. The main fixture/widget on the bottom section of the robot is the 3D printed front and rear bumpers. The rear bumper is more important than the front as it holds the fluid tank in place from the bottom and has the main power switch with the charger plug of the robot. However, the 3D printed bumpers must be made with intolerance with flat, parallel and perpendicular surfaces/faces according to the drawing datum. At the first time of printing the rear bumper widget, it came out of the printer with bent surfaces which cannot be used as it won't fit on the chassis. To solve the tolerance and flatness issue, the 3D printer timing belts for the X and Y axis were tightened, the Z offset was lowered by 0.01mm than it was and more glue stick was added to the printer table, then the result came perfectly.

- The Fire Fighter Robot was being tested multiple times as the top section, and the bottom section was of the robot was treated spritely and both by the remote. The bottom section has three main parts, the wheels and their motors, the battery, and the PCB. All the bottom section parts were fully functional during and after the test without any technical issues. The wheels were able to run the robot at a constant speed of 1mile per hour, even though it's not an ideal speed, but it has enough torque to make the robot clime at 45 degree's ramp. The battery was able to continually run the robot for around 3 hours in one charge, and able to be fully recharged in around 45 minutes of charging. The PCB was able to be wirelessly connected with the remote and then power and control all the electronics in the robot without any technical issues. The robot was fully functional with a wireless connection range was more than what was expected. The main issue that might reduce the connection range by 50% or even to 100% if the robot was controlled from behind isolating walls such as thick concrete and masonry walls. Overall, the Fire Fighter Robot was and still fully functional as it was intended.

- The bottom section of the Fire Fighter Robot was successfully functional as it was expected, but there is still a large room for improvement. All the bottom section parts can be upgraded, but the total price of the robot might increase to %100 or even more if high-quality parts were used. One of the main components that can be upgraded in the bottom section is the battery. The current battery is 12V 8Ah sealed-lead-acid. The current battery was bought for less than $15, and it was able to operate the robot for 3 hours and get fully charged in 45 minutes. This type of battery is not efficient because it cannot be discharged for lower than 10V because it will decrease its life span. There are other types of cells, such as lithium-ion batteries that are more efficient than the sealed-lead-acid but way more expensive as it for more than $100 for 12V 8Ah. If the current battery was replaced, the whole robot will reduce 1 kg from its total weight and get a bigger room for an extra battery. The current battery and the bottom section parts were functional and were doing their job correctly at the lowest affordable price.

4. Testing Method

a. Introduction:

Velocity test will be conducted in which the time will measured in seconds and the distance will be measured in meters. In the case of an issue the wheels will be welded again.

b. Method/Approach:

Simple calculus techniques and physics formulas will be used. After finding the values of the required variables they will be placed in the equation and the results will be used to make the improvement in the project.

c. Test Procedure description:

Introduction:

The bottom section of the Fire Fighter Robot has three main parts which the main PCB and wheels motors and the battery. All the bottom parts will be tested at the same time with the top section parts as they all controlled by a remote with a smartphone in it. The main PCB should be able to power and control the wheel's motors. The robot should be able to run for at least at a speed of 1 mile/hour. The robot should be able to turn left, right, forward and backward when the button is pressed. a measuring tape will be used to measure the remote connection range. A stopwatch will be used to see how long it takes for the battery to charge and discharge.

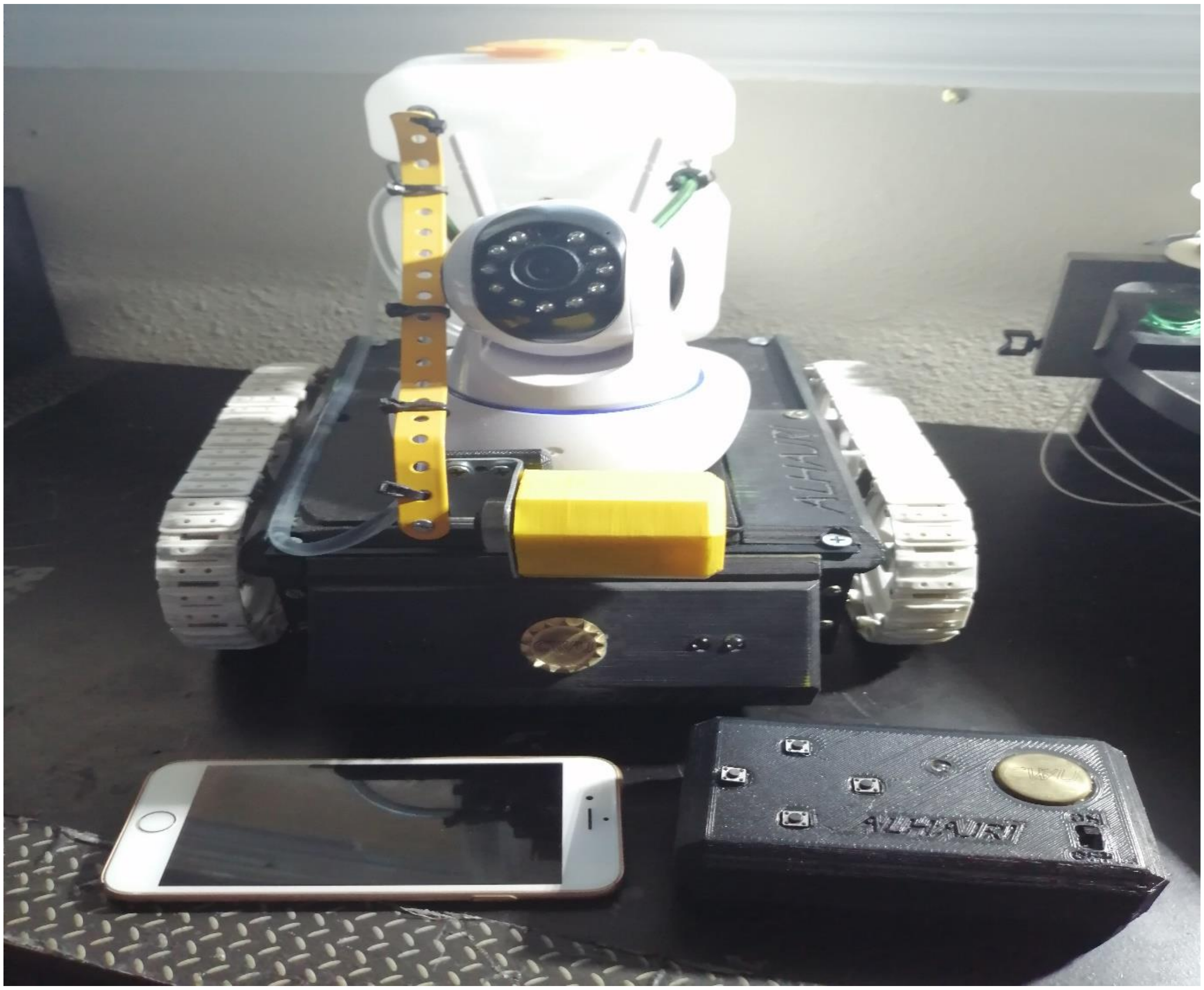
Method/Approach:

The wireless remote with the smartphone in it, is the most important part to complete the test. if the remote fails, nothing on the robot can be operated or tested as everting in the robot is connected to one main PCB with a microcontroller that controlled wirelessly by the remote. Nassar Alhaddad is an experienced engineer specializing in the electronics filed. He can easily troubleshoot and locate the issue in the remote or the main PCB as it hard to locate the familiar, whether from the remote or the main PCB

Test Procedure:

- Three main parts to complete the test:

The Robot – The Remote – A Smarphone



- The test should take less than two hours to test the whole robot.
- Place: Office.
- **Test Steps:**

  1- Place the smartphone in the remote tope slot as shown below.

2- Turn on the Remote from the switch.

3- Turn on the Fire Fighter Robot.

4- Turn on the smartphone and login into the V380s app.

5- Slide/touch on the smartphone screen to rotate the camera.

6- Press the left and right buttons for two second to switch from rover mode to robotic arm and spray mode. See image below. (to check)

7- Switch back to rover mode by pressing the left and right button at the same time for two second.
8- Press the top button to move forward.
9- Press the bottom button to move backward.
10- Press left or right button to rotate the robot.
11- Keep the robot moving forward until it run out of power, and time it.
12- After the robot ran out of power:
13- Turn off the Robot from the switch in the back of the robot.
14- Turn off the wireless remote.
15- Plug the charger into the robot plug in the back next to the power switch.
16- Start a stop watch while the battery is charging to see how long it takes for one full charge.
17- Stop the stopwatch after the LED on the charger turns from red to green.

- The progress of testing the functionality of the robot went very well as it was expected with no rick involved.

Deliverables:

the main PCB was able to power and control the whole robot and was able to connect with wireless remote after switching on the robot and the remote with no delays. The whole robot was able to run for 1 Mile/h and able to rotate in its position without lagging. The battery can run the robot for around 1 hour and 45 minutes before the voltage drops from 13V to 11.5V and can be fully charged to 13.1Vin less than an hour. Overall, the test was passed and the robot is completely functional without any issues.

e. Full performance test after assembly:

- The Fire Fighter Robot was successfully assembled for the first time without any issues from the 3D printed and retailed parts. After the robot was assembled, it was tested in performance by running it for around two weeks. The bottom section parts of the robot which are the battery, the main PCB and wheels geared motors were running without any issue as it was controlled by the radio remote. The 12V 8ah sealed lead acid battery was powerful enough to provide power the whole robot for more than 2 hours of continuous running. The main PCB was capable to control and run all the electronics in the robot and with a strong connection signal between the main PCB's receiver and the remote's transmitter from a long distance. After using the robot for 2 hours continually, the connection signal between the remote and main PCB was getting low. The voltage regulator on the main PCB was getting overheated witch also cause the decoder onboard to overheat too, which makes the signal seems weaker. To solve the overheating issue, a 12V mini cooling fan will be added inside the chassis to cool down the whole main PCB. After all, the Fire Fighter Robot was running as it was expected before it was assembled and there are rooms for future improvements in the whole project but that all rely on the budget.

- After the Fire Fighter Robot was fully assembled and used for around two months, it was still functioning as it was before with no newer issues. Also, there is room for more improvement in the design and parts. The test has successfully met the requirement for the Fire Fighter Robot to function as it should be. Three main parts were tested for the bottom section of the Fire Fighter Robot. The main parts that were tested were: the robot’s wheels, the wireless remote, and the battery of the robot. All the parts were tested by using the wireless remote of the Fire Fighter Robot. If the wireless remote failed to operate correctly, the test would fail for all the three parts of the bottom section of the robot. Luckily, the remote was correctly working. After turning on the remote and placing the smartphone in the remote slot, the 360 camera app got connected successfully to the camera on the robot with only two seconds delay. The maximum connection range of the wireless remote was around 90 meters. When the forward button was pressed, the robot was going forward at a constant speed of 1 mile/hour without any issues. When the bottom button was pressed, the robot moved backward at the same speed as going forward without any issues. When the left button was pressed, the robot rotated counterclockwise at a speed of 40 RPM as both wheels were rotating in reverse directions. When the right button was pressed by the operator, the robot rotated clockwise at the same speed of the other direction without any issues. The robot 12V battery ran out of power as the voltage reached to 10V after 3 hours of continuous use. The battery charger was able to charge the battery to 13V in around 45 minutes fully. Overall, the whole test met the requirement, and the robot was fully functional as it was expected.

5. Budget:

i. *Discuss part suppliers, substantive costs and sequence or buying issues*

The parts as well as the estimated cost is given below

PART IDENT	PART DESCRIPTION	SOURCE	COST APPROX. (USD)

Fluid valve	DN15-DN80 OD. 20 mm L= 5 mm	Amazon	$15
360 degrees Camera	WiFi connection	Amazon	$40
3 Motors	12V 50 RPM	Amazon	$160
Chained Wheel	52 Chain links L = 13 cm	Amazon	$25
Chassis	Weight = 33 lb Max Load = 10 kg L = 8 cm W = 6 cm H = 3 cm	Amazon	$110
Battery	Exide 12V 65AH EP65-12	Amazon	$25

ii. labor or outsourcing rates & estimate costs

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

iii. Labor

Team members itself will be the labor for this project.

iv. Estimate total project cost

Estimated total project cost of this project will be 375 USD. This will be the cost of making the purchases for the parts of the project.

v. Funding source(s)

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.

vi. Actual Cost and Cost Change:

- The bottom section of the Fire Fighter Robot costs had an initial budget of $160 for its parts. The total money spent from the budget to this point is $168 which is %105. The total money left from the budget is $0 and it’s minus $8. To this point, all the bottom section parts were bought and manufactured for the robot and ready for assembly. After the robot being assembled, helpfully it will function well after the test to avoid spending more money on modifications or parts failure. The main parts for the bottom section with their price including tax and shipping were the chassis for $80, battery for $25 and the chained wheels for $25. During this Winter season, the chassis with the chained wheels became cheaper than before as they were for $110 instead of $80. All parts were bought in the first week of the Winter quarter 2020 as it is shown below in the budget history table. In the second week, $20 was spent on the 3D printer filament for the front and rear bumpers and both of them were not printed with the correct diminutions/size scale. As there was enough filament, they were edited and reprinted without extra expenses. $18 were spent on black spray paint and a blank PCB and that was the last purchase for the project.
- Budget history:

PSR#	Date	Money Spent
01	01/05/2020 – 01/12/2020	$130
02	01/12/2020 – 01/19/2020	$20
03	01/19/2020 – 01/26/2020	$8
04	01/26/2020 – 02/02/2020	$10
05	02/02/2020 – 02/09/2020	$0
	Total money spent so far =	$168

- After the bottom section of the Fire Fighter Robot was fully assembled and tested, the budget was not affected as much. While testing the durability of the whole assembly of the Fire Fighter Robot, the electrical components on the main PCB were getting overheated from the voltage regulator. The overheating issue caused the encoder to fail which made the robot loos the wireless connection with the remote. During (02/23/2020 – 03/02/2020) period, a $5 cooling fan was added to the chaises. Also another $5 was spent to replace the encoder/decoder from the main PCB, because they were burnt out from the heat of the voltage regulator. After the fan was installed, the overheating issue never appeared again as the fan was blasting enough air to cool down the whole PCB. Other than the $10, there weren't any other issues or the need for the bottom section to spend money on. The starting budget was $160 and the current budget is minus $18.
- Budget history:

PSR#	Date	Money Spent
01	01/05/2020 – 01/12/2020	$130
02	01/12/2020 – 01/19/2020	$20
03	01/19/2020 – 01/26/2020	$8
04	01/26/2020 – 02/02/2020	$10
05	02/02/2020 – 02/09/2020	$0
06	02/09/2020 – 02/16/2020	$0
07	02/16/2020 – 02/23/2020	$0
08	02/23/2020 – 03/02/2020	$10
09	03/02/2020 – 03/08/2020	$0
10	03/08/2020 – 03/16/2020	$0
11	04/01/2020 – 04/13/2020	$0
12	04/03/2020 – 04/19/2020	$0
13	04/19/2020 – 04/26/2020	$0
14	04/26/2020 – 05/04/2020	$0
15	05/04/2020 – 05/11/2020	$0
16	05/11/2020 – 05/18/2020	$0
	Total money spent so far =	$178

6. Schedule

i. ***High level Gantt Chart.***

Gantt Chart is present in Appendix E.

ii. ***Define specific tasks, identify them, and assign times***

Specific tasks in this chart is

- Number of hours required for finishing each task like
- Proposal
- Analysis
- Documentation
- Proposal Mods
- Part Construction

The due date of proposal is given as 6th of December.

iii. *Allocate task dates, sequence and estimate duration (use arrows, highlights)*

The task of submitting the proposal will be completed by the 6th of December. Second task will be working and building the project of Fire Fighter Robot which will be started on 20th of January.

iv. *Specify deliverables, milestones*

- Submission of the proposal is the first deliverable.
- Submission of the analysis section with 12 green sheets is second deliverable.
- Manufacturing and construction of project is the third deliverable which will be started in the mid of January
- The completion of the whole project is forth deliverable which will be completed within two and half months.

v. *Estimate total project time*

Estimated total project time will be 190 hours.

vii. *Gantt Chart*

This is attached in Appendix E.

viii. *Manufacturing schedule issues/changes:*

The schedule of the bottom section of the Fire Fighter Robot which is the Gantt chart attached in Appendix E was designed in the fall quarter. During the analysis of the project bottom section parts, few elements were added to the schedule as well as the actual duration hours got typed in for most tasks. The first task for the proposal from 1a to 1i and the second task for the analysis from 2a to 2e were done on time, but the actual duration hours were more than what was estimated by ten hours more for each of the first and second tasks as it is shown in the chart. The third task for the documentation which includes the parts drawings mostly was done ahead of time and took fewer hours than the estimated by ten hours less. Also, few new drawings that also was done on time were added to the third task such as the battery, front and rear bumpers, and antenna. The fourth task for the proposal mods and seventh for the part construction were also done ahead of time and took fewer duration hours by twenty hours less than the estimated duration time. That provides enough time to do the next tasks without hesitating to fail on assembling and running the robot on time.

All the tasks in the schedule for the bottom section of the Fire Fighter Robot project are almost done as it was scheduled. The 9th task was for the device construction and assembly of the bottom section of the robot, was done on time with the same estimated time. The 9f job took 3 hours fewer than the estimated hours for the website update. The 10th task section was for the devise evolution and testing of the robot, which was done in 51 hours, which was 24 hours less than what has been estimated. Also, the 10th task was successfully done ahead of its time, and it saved time for the team to fix issues if there was any. The 10g job took three hours more than what was estimated because, at that time, the robot had some wireless connection issues, as it wasn't responding to the wireless remote. Thankfully, the team mentor Nassar Alhaddad was able to fix the problem by replacing the radio receiver module on the main PCB and the remote transmitter module to a newer one, after he troubleshoots both of them. The old receiver and transmitter modules failed because of the overheat from the voltage regulator, as it was very close to it. The overheat issues were solved by adding a 12V high rpm fan to the inside the robot's chassis, to cool down the whole PCB/the robot's brain. The 11th task for the 495 deliverables was 50% done on time without any issues, as shown in the Gantt Chart in Appendix E. The only jobs left from the 10th task section are making the CD for the project and updating the website for the last time. Shofar, there was not any significant schedule changes or spent more actual hours than what was estimated.

7. Project Management

i.

Mohammad Alhajri the student of the Mechanical Engineering will take care the top part of the project. Sultan Alhajri will be the partner who will take care the bottom part of the project. Electronic engineering tech. department at CWU will help doing the electrical part.

ii.

- Drilling Machine
- Metal cutter
- Saw
- Holding Clamp
- Spanner
- Nuts
- Hammer

Some of the processes are

- Cutting
- Sawing

- Drilling
- Machining

iii. Soft Resources: Software, Web support, etc.

  - SOLIDWORKS
  - YOUTUBE videos

iv. Financial Resources: Sponsors, Grants, Donations

Only team members of project will pay the whole cost of the project.

8. Discussion

i. Design Evolution / Performance Creep

During the starting part of the project the team will design and fabricate the frame of the whole robot. After cutting the parts they will be joined according to the design which has been made in Fusion360 / SOLIDWORK. After drilling the holes for wheels and placing the small rods in the bottom frame the chain will be placed on it.

ii. Project Risk analysis:

The top risk in this project will be receiving an injury during the machining part of the project. The second highest risk will be receiving the cut in fingers while sawing the aluminum metal. Proper training for the machining and sawing will be required or the risk of receiving injury will increase.

iii. Successful

The project will be said as the successful one if the chain is properly attached on the four wheels. If the project parts will be cut according to the required dimensions and if it will be assembled correctly, then the project will be understood as the successful.

v. Project Documentation:

The documentation of the project will include the lower part plate design, the chain design, wheel design and the bottom plate design.

vi. Next phase:

Next phase of the project is manufacturing the whole project according to the design and the dimensions. The whole construction process will be done in next phase.

vii. Design Manufacturing issues / Modifications:

Inside the chassis/body of the Fire Fighter Robot, there are two main parts, which are the 12V battery and the printed circuit board. Both of these parts need to be secured in position inside the body of the robot. The chassis is made from metal sheets which are very conducive to electricity. It was very risky to install the PCB directly on the chassis which makes a short-circuit that will lead to a failure in the robot control microcontroller and the battery will be drained over its limits. A 0.16" thick with 0.1" deep pocket widget that will work as a PCB Base, was 3D designed and printed in PLA plastic for isolation. The widget was placed in between the chassis and the PCB to protect the bottom soldering of the PCB from short-circuit as well as it will hold the PCB in place by its pocket. The battery terminal was also very close to the chassis, so a 0.16" thick and flat widget was 3D designed and printed to place it in between the battery and the chassis.

After the Fire Fighter Robot was assembled completely, it has been used for around 14 days to make a full performance and construction durability test. there was an issue that caused other issues in the bottom section of the robot during the test. The issue was the connection between the main PCB of the robot and the remote controller as the decoder used to fail to decode the Forward and Right move request. After replacing the decoder with a new, it started to function again but after like an hour of use it failed. The over-heat inside the chassis from the voltage regulators on the board is very close to the decoder which made it overheat and fail. A 12V cooling fan was added inside the chassis on the side to blow air directly on the 5V voltage regulators.

9. Conclusion

i.

The design title of this project is “Fire Fighter Robot”. As the team is doing the mechanical part for this project so the final product will be moveable on floor. The whole connections of the parts will be assembled with the correct dimensions. The chain and wheels will be attached with the tank. The water tank will be attached on the top part.

ii.

The important analysis of this project will be the free body diagram which will help to understand the forces and stresses on the frame. Second important analysis will be maximum moment analysis for the whole robot. The final important analysis will be the dimension and reaction force analysis due to the load. This will help to improve the speed of the robot.

iii.

- It will be able to work successfully in the heat of 50 to 70 degrees Celsius
- Due to the aerodynamic body shape the cart will move smoothly.

Acknowledgement

This is acknowledged to all people who assisted during the completion of this proposal.

The faculty members of the department of mechanical engineering and especially the instructor who provided the guidance throughout the process of completing the proposal. Thanks to all for the support.

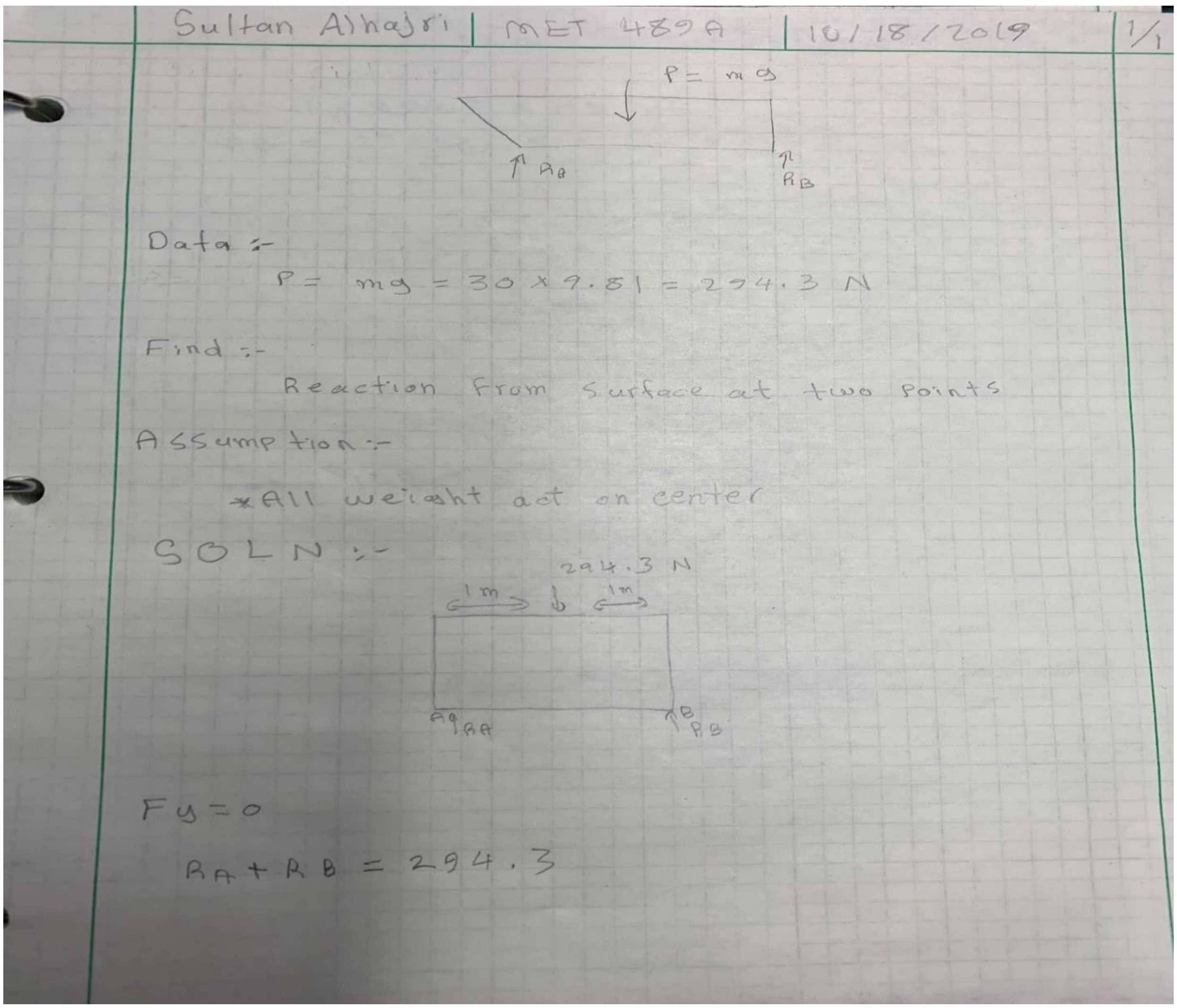
References

Arduino based Fire Fighting Robot using flame sensor. (n.d.). Retrieved December 5, 2019, from https://create.arduino.cc/projecthub/130797/arduino-based-fire-fighting-robot-using-falme-sensor-4e0556?ref=user&ref_id=447872&offset=0.

Han, A. (2019, April 17). Meet the Robot Firefighter That Battled the Notre Dame Blaze. Retrieved December 5, 2019, from https://www.popularmechanics.com/technology/robots/a27183452/robot-firefighter-notre-dame-colossus/.

Appendix A Analysis

Appendix A1: Free body diagram of bottom part of the robot.


Sultan Alhajri | MET 489A | 10/18/2019 | 1/1

$P = mg$

R_A R_B

Data :-

$P = mg = 30 \times 9.81 = 294.3$ N

Find :-

Reaction from surface at two points

Assumption :-

*All weight act on center

SOLN :-

294.3 N

1m 1m

R_A R_B

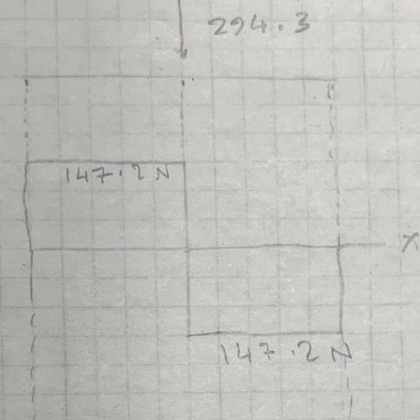
$F_y = 0$

$R_A + R_B = 294.3$

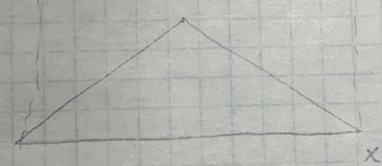
Appendix A2: Page shear force and max moment.

$A = 1 \times 294.3 = R_B \times 2$

$R_B = \frac{294.3}{2}$ N-m $= 147.2$ N

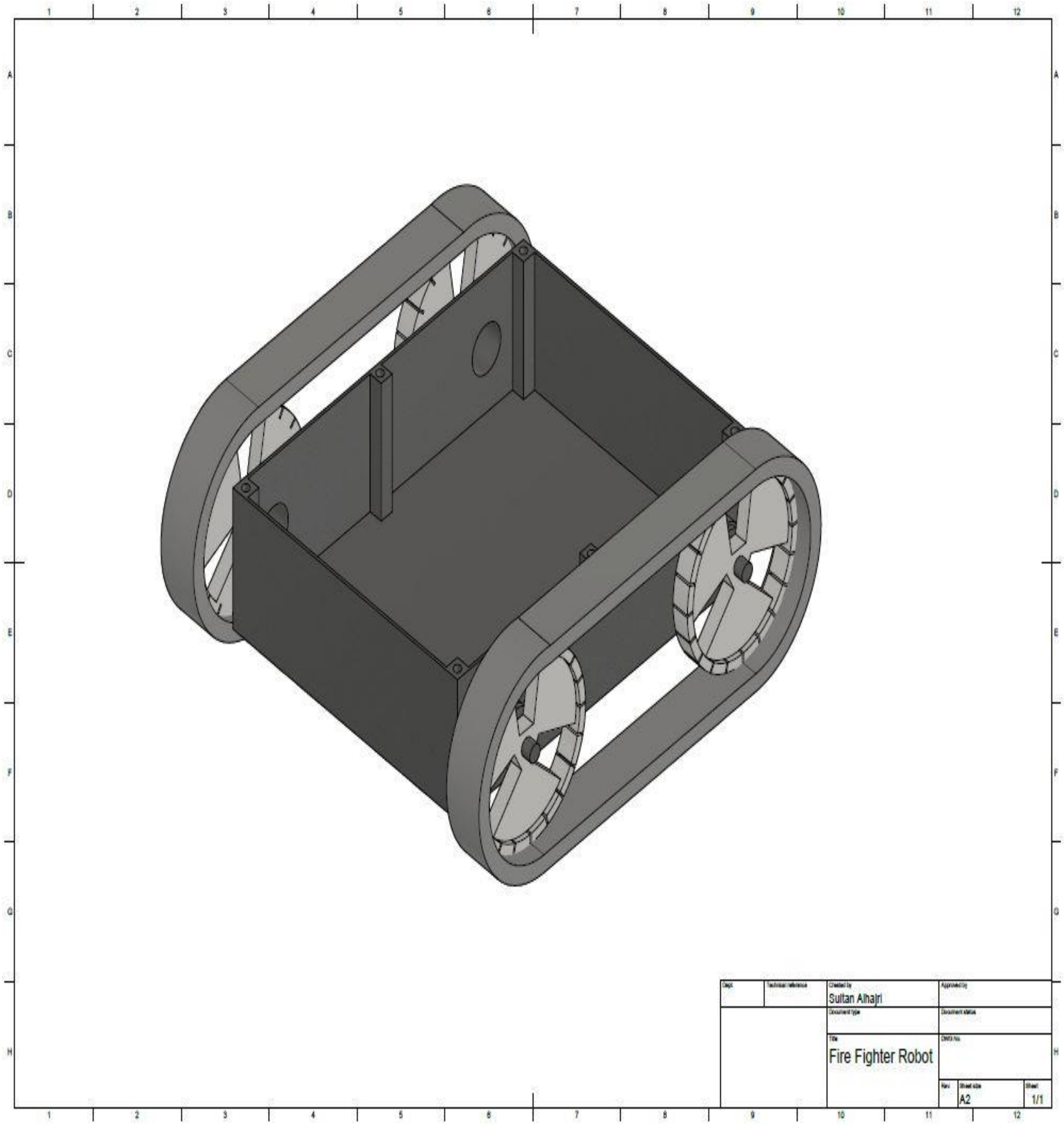


$M_{max} = 147.2 \times 1 = 147.2$ N-m

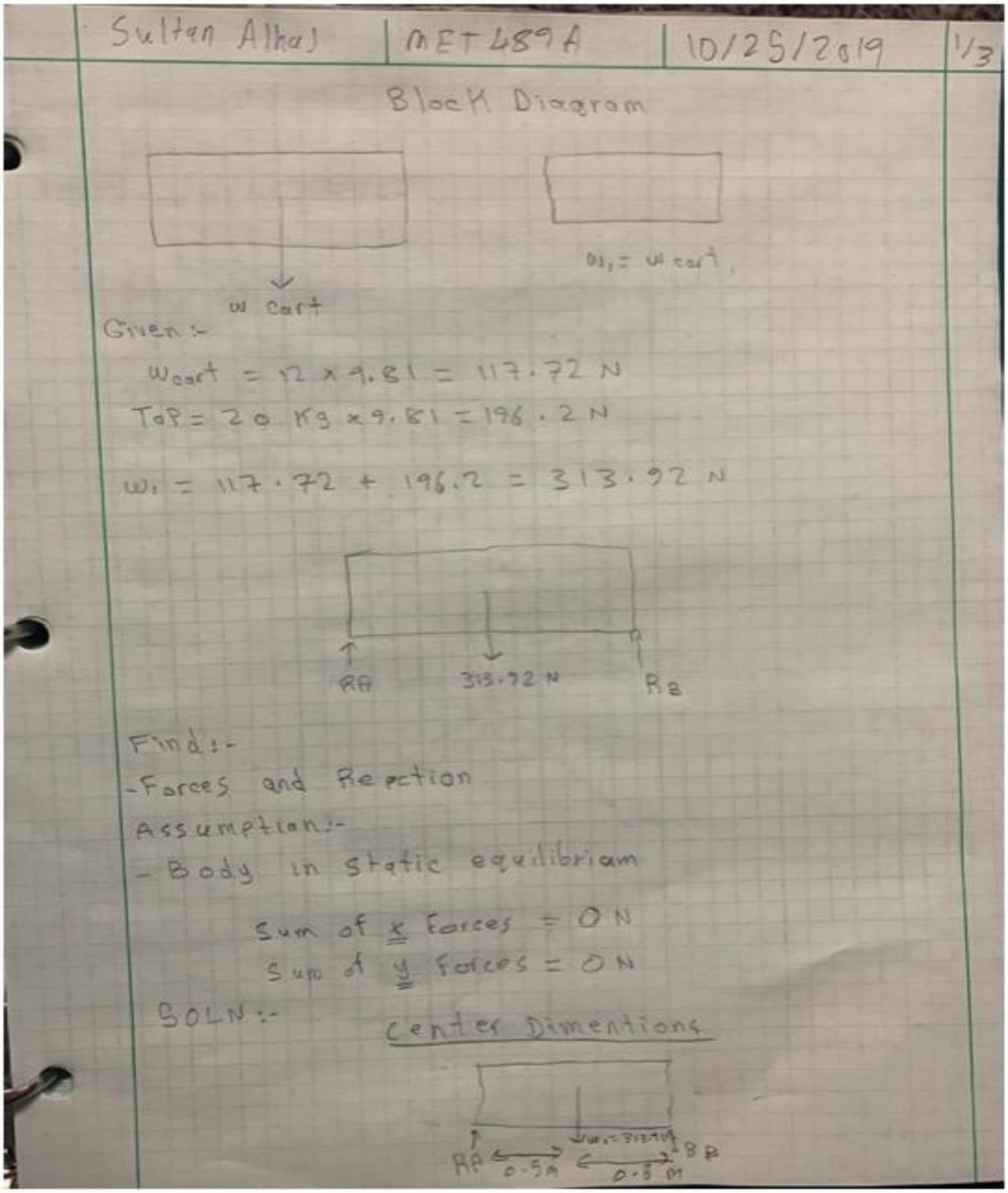


$R_A = 294.3 - 147.2 = 147.2$ N

Appendix A3: Sketching the chained wheel and the cart.



Appendix A4: Reaction Force Calculation.



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Block Diagram

$w_1 = w_{cart}$

w cart

Given:-

$W_{cart} = 12 \times 9.81 = 117.72$ N

$T_oP = 20$ Kg $\times 9.81 = 196.2$ N

$w_1 = 117.72 + 196.2 = 313.92$ N

RA 313.92 N RB

Find:-

- Forces and Reaction

Assumption:-

- Body in static equilibriam

Sum of x Forces = 0 N

Sum of y Forces = 0 N

SOLN:-

Center Dimentions

$w_1 = 313.92$ N

RA 0.5 m 0.5 m RB

Appendix A5: Force Diagram and Moment.

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$\Sigma F_y = 0$

$R_A + R_B = W_1$

$R_A + R_B = 313.92\ N$

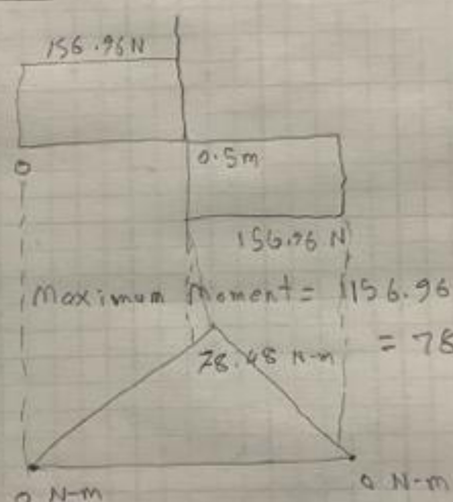
$M_A = M_B$

Because surface is same throughout

$M_A = 2R_B$

$2R_B = 313.92$

$R_B = \frac{313.92}{2} = 156.96\ N$



Maximum Moment = 156.96 × 0.5

= 78.48 N-m

Also $R_A = W_1 - R_B$

$= 313.92 - 156.96$

$= 156.96\ N$

Appendix A6: Frame Characteristic.

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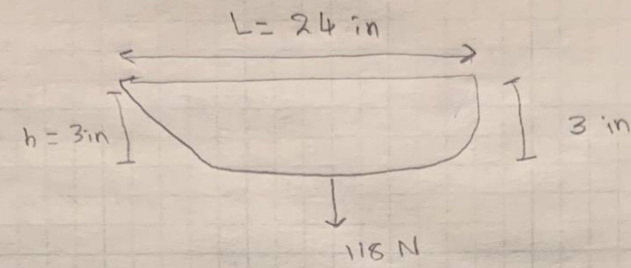

① Wheight of Platform = 118 N

② Parts for wheel = 4

③ chain Points = 16

④ Drilling Points = 35

⑤ Height of Platform = 3 in

⑥ Length of the Platform = 24 in

⑦ Curved Area = 3/4 inch.

⑧ Heat bearing Capacity = 110°c

Appendix A7: Weight and stress.

(9) Weight of the cylinders on it
= 9.6 lb × 2 = 162 lb

(10) Arm force = 4 lb

(11) Total weight = 314 N

(12) Shear force = 137 N

(13) Maximum Moment = 80 N-m

(14) Torsion = 5 radians

(15) Shear stress = 99 MPa

(16) Shear strain = 55

Appendix A8: Chained Wheel.

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Chained wheel

wheel circumference = $2\pi r$

Radius of the wheel = 6 inches

Length of (chain) = 1 feet

Diameter of wheel = 12 inches

Connecting Rods = 2

Rod Length = 5 inches

innerdia = $\frac{1}{2}$ inches

Angular velocity = 3 $\frac{rad}{s}$

Acceleration = 1.5 $\frac{rad}{s^2}$

Hieght of base = 3 inches

Curve Hieght = 2.1 inches

Appendix A9: Chained Wheel.

Linear velocity = 3.9 $\frac{ft}{s}$

Break = 2 - spring

Base weight = 24 lb

Track Length = 7 inches

Sustainablilaty factor = 3

Race factor = 3.9

Lower length = 8 inches

upper length = 3.5 inches

Appendix A10: Friction Calculation.

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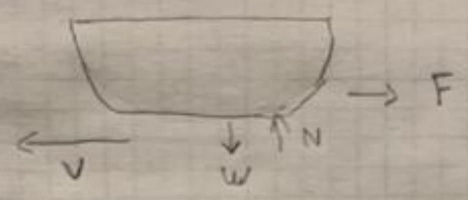

$W = mg$

$N = mg$

$m = 40$ Kg

$g = 9.81\ m/s^2$

$W = 9.81\ m/s^2$

$W = 9.81 \times 40 = 392.4$ N

$N = W = 392.4$ N

We know that

$F_k = \mu_k N$ (At motion)

$F_s = \mu_s N$ (At Rest)

During Rest $\mu_s = 0.5$

During motion $\mu_k = 0.4$

$F_K = 0.4 \times 392.4$

$= 156.96$ N

f_k Approx $= 137$ N

Appendix A11: Friction and velocity max.

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$f_s = \mu_s N$

$= 0.5 \times 392.4$

$= 196.2\ N$

Wasted Force = 196.2 ≈ 197 N

$V_{initial} = 0\ m/s$

$V_{final} = 10\ m/s$

Time Consumed = 2 s

$acceleration = \frac{10 - 0}{2}$

$= 5\ m/s^2$

Max speed = 10 m/s

Appendix A12: Tire and Speed Relation.

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Tyre and Speed Relation
with Radius Calculation

Number of Rotation = N

Angular velocity = ω

Linear velocity = V

Relation with them = r

R = Radius of the tire

D = Diameter of tires

Keeping Diameter = 3 inches

Radius = 3/2 inch = 1.5 inch

Keeping Rotation = 20

N = 20

$360^\circ = 2\pi$ Radians

$1^\circ = \frac{2\pi}{360}$ radians

$1^\circ = \frac{\pi}{180}$ rad

$\omega = 2\pi f$

$f = 1/T$

For 5 sec motion

Appendix A13: Radius Calculation.

Radius Calculation

$f = 1/5$ Hz

$$\omega = \frac{2\pi N}{60}$$

for 10 Rotation

$$\omega = \frac{2\pi \times 10}{60}$$

$$= \frac{2\pi}{6} = \frac{\pi}{3} \text{ rad/s}$$

Required Angular velocity

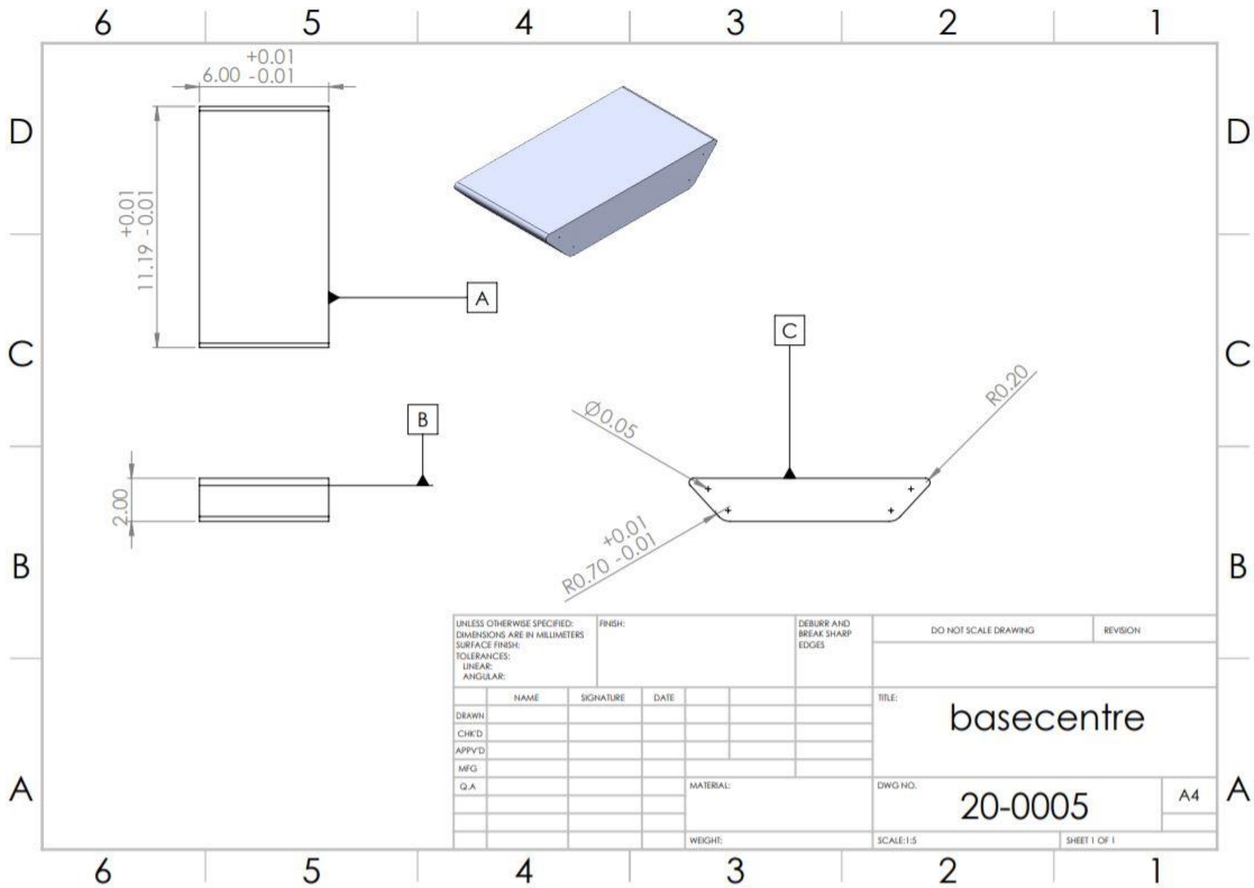
$= 1.046$ rad/s

(move Right)

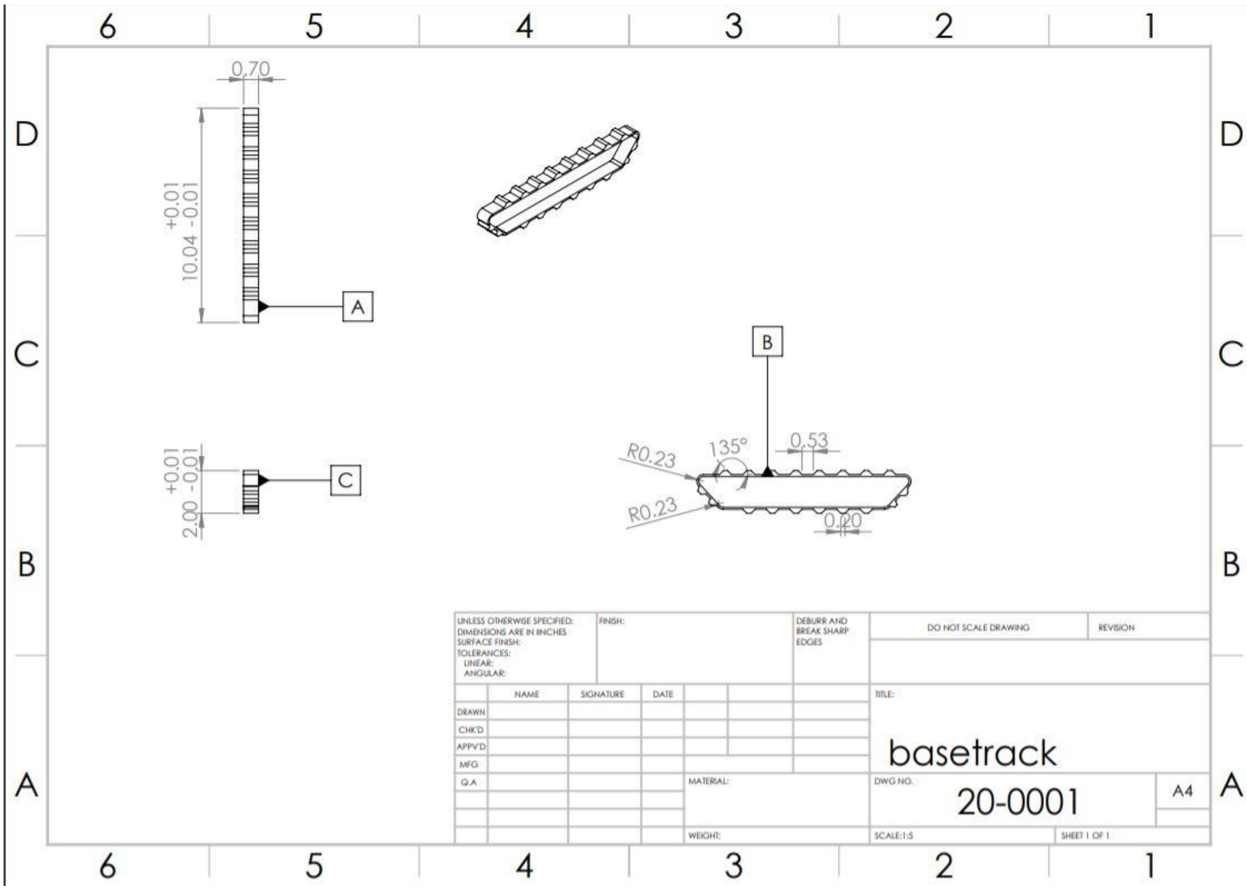
$$\text{Radius} = \frac{L}{\theta}$$

Appendix B_ Drawing

B1

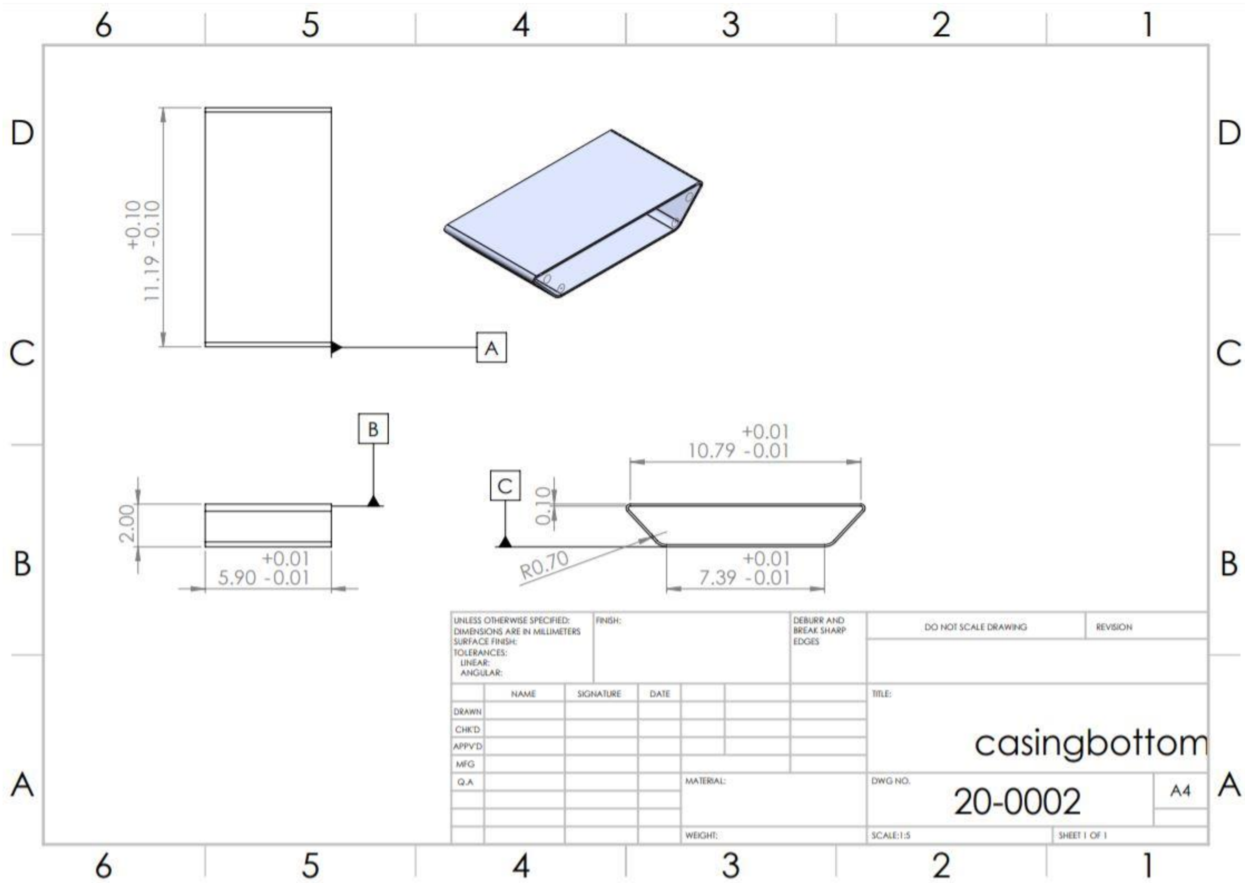


B2



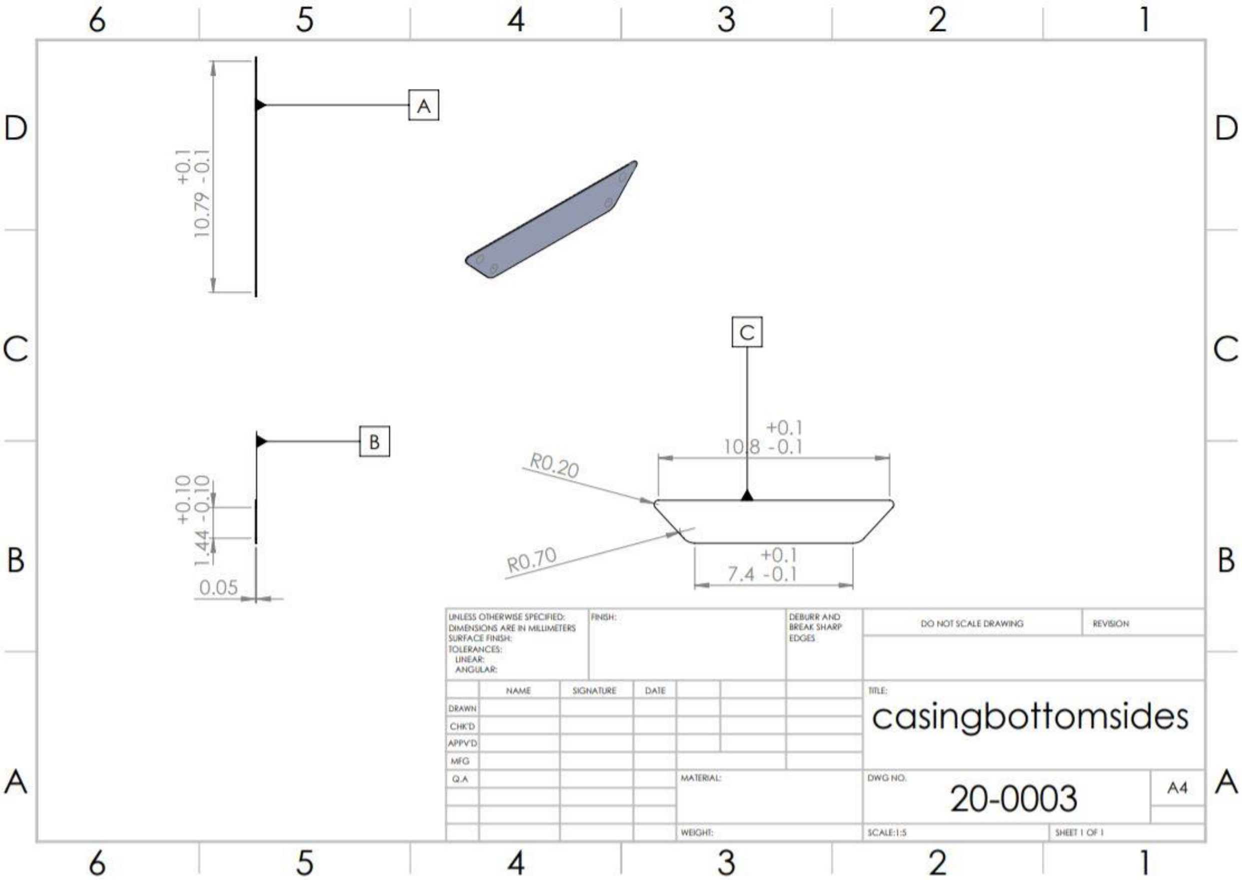
0.70
10.04 +0.01 -0.01
A
2.00 +0.01 -0.01
C
B
R0.23
135°
0.53
R0.23
0.20
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
basetrack
DWG NO.
20-0001
A4
SCALE:1:5
SHEET 1 OF 1

B3



A
B
C
11.19 +0.10 -0.10
2.00
5.90 +0.01 -0.01
10.79 +0.01 -0.01
0.10
R0.70
7.39 +0.01 -0.01
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
casingbottom
DWG NO.
20-0002
A4
SCALE:1:5
SHEET 1 OF 1

B4



A
+0.1
10.79 -0.1
B
+0.10
1.44 -0.10
0.05
C
+0.1
10.8 -0.1
R0.20
R0.70
+0.1
7.4 -0.1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
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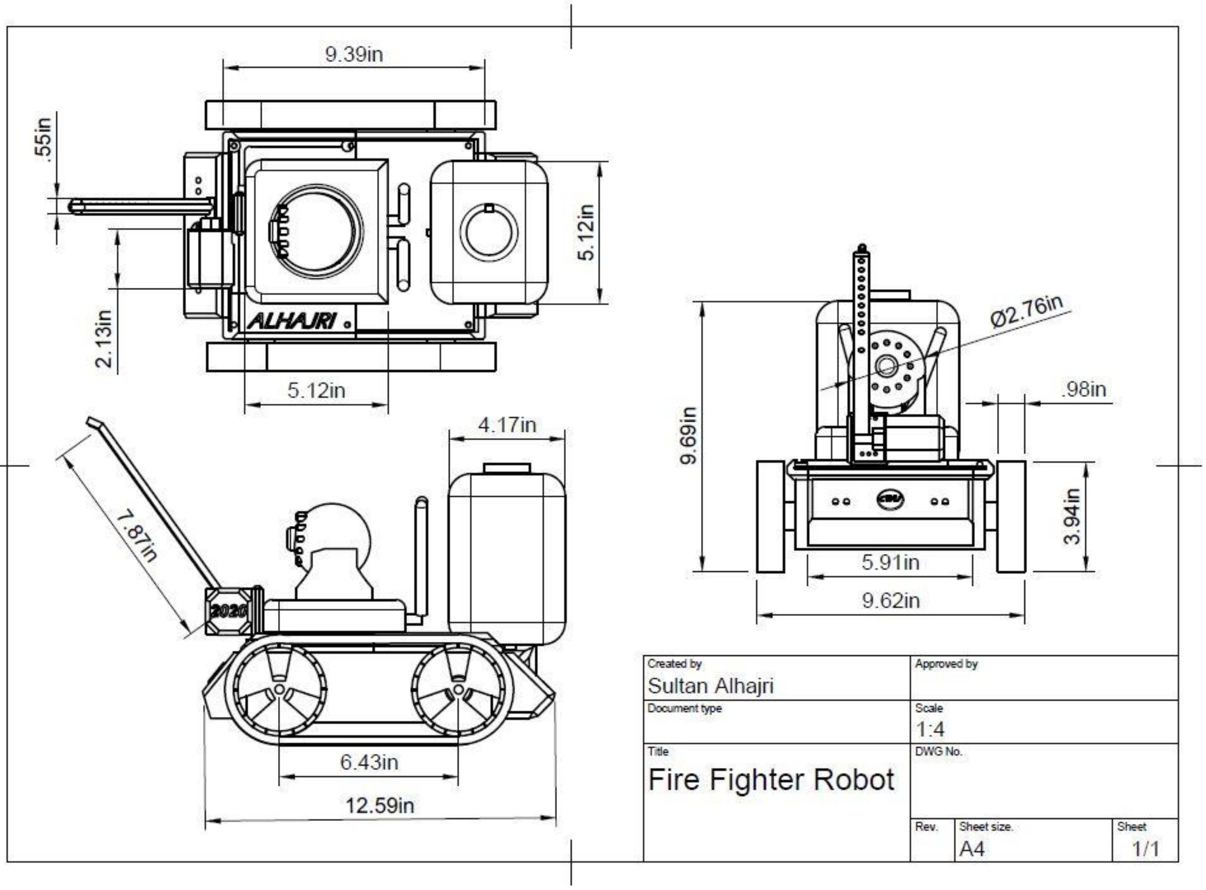
20-0003
A4
WEIGHT:
SCALE:1:5
SHEET 1 OF 1

B5



9.39in
.55in
2.13in
5.12in
5.12in
ALHAJRI
4.17in
7.87in
2020
6.43in
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9.69in
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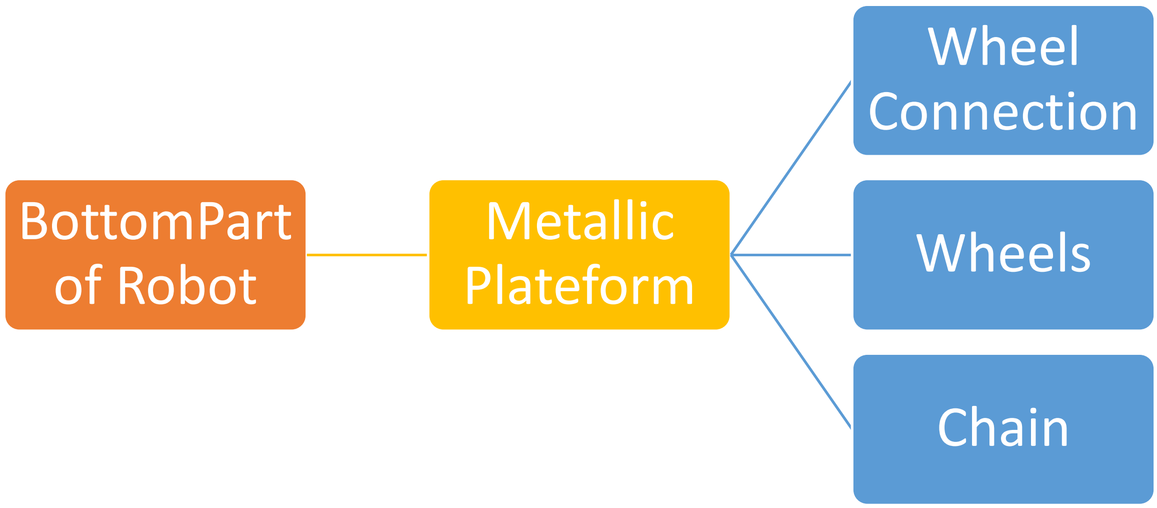
3.94in
5.91in
9.62in
Created by
Sultan Alhajri
Approved by
Document type
Scale
1:4
Title
Fire Fighter Robot
DWG No.
Rev.
Sheet size.
A4
Sheet
1/1

Appendix C_ Part List

C1-Bottom Part Tree Diagram



Appendix D_ Budget

D1

PART IDENT	PART DESCRIPTION	SOURCE	COST APPROX. (USD)
Fluid valve	DN15-DN80 OD. 20 mm L= 5 mm	Amazon	$15
360 degrees Camera	WiFi connection	Amazon	$40
3 Motors	12V 50 RPM	Amazon	$160
Chained Wheel	52 Chain links L = 13 cm	Amazon	$25
Cart	Weight = 33 lb. Max Load = 10 kg L = 8 cm W = 6 cm H = 3 cm	Amazon	$110
Battery	Exide 12V 65AH EP65-12	Amazon	$25

Appendix D:

D2

I	**Description**	**Cost**
1	Chained Wheel	$25
2	Cart	$110
3	Battery	$25
Total		**$160**

The cost of the bottom section parts in this project is approximately 160$. It will be a total of 375$ with the top section parts of the project.

Appendix E-Gantt Chart

DEFINE HOW THE STUDENTS SHOULD INDICATE STARTING EARLY/LATE AND FINISHING EARLY/LATE
X to indicate work

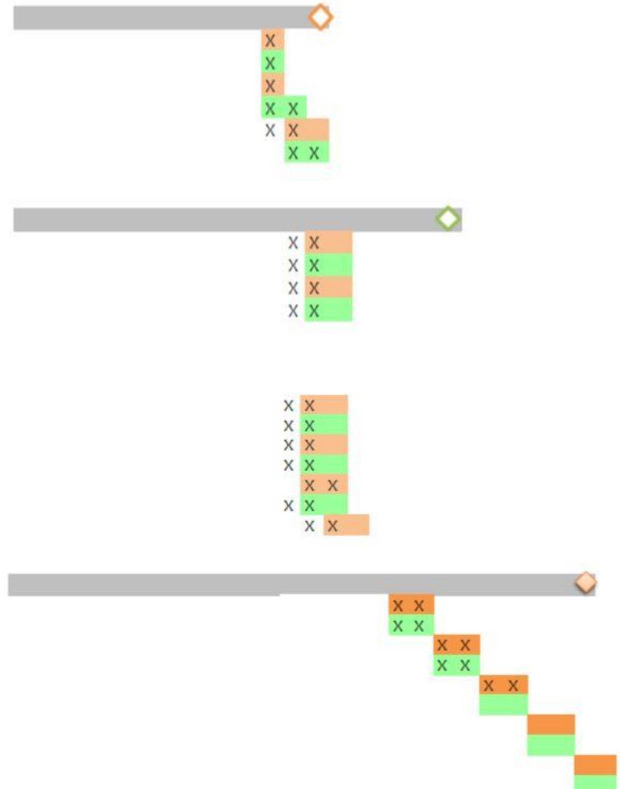
EXAMPLE SCHEDULE FOR SENIOR PROJECT:
NOTE: STUDENTS MUST MAKE THEIR OWN SCHEDULE!!!!!!!!!!!!!
PROJECT TITLE: Fire Fighter Robot
Principal Investigator.: Sultan Alhajri

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

Months: S | October | November | Dec | January | February | March | April | May | June

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	%Con	Work
1	Proposal*				
1a	Outline	1	2		X
1b	Intro	3	4		X X
1c	Methods	1	3		X X
1d	Analysis	1	3		X X
1e	Discussion	1	4		X X X
1f	Parts and Budget	1	1		X X X X
1g	Drawings	4	5		X X X X
1h	Schedule	4	6		X X X X
1i	Summary & Appx	4	5		X X X X
	subtotal:	20	33		
2	Analyses				
2a	Battery=>Geo	2	4		X X X X
2b	Bumper Anal=>Geo	4	6		X X X X
2c	Antenna=>Geo	3	6		X X X X
2d	Kinematic => Geo	2	3		X X X X
2e	Tolerance => Geo	3	2		X X X X
	subtotal:	14	21		
3	Documentation				
3a	Part 1 Chassis drawing	3	2		X X
3b	Part 2 F_Bumper drawing	3	2		X X
3c	Part 3 R_Bumper drawing	3	3		X X X
3d	Part 4 PCB_Base drawings	3	4		X X X
3e	Part 5 Battery_Base drawin	4	2		X X X
3f	Part 6 Antenna drawings	8	7		X X X
3g	Part 7 Battery drawing	2	1		X X X
3h	Part 8 Top_Cover drawing	2	2		X X
3i	Subassembly side	3	2		X X
3j	Device robot drawing	4	3		X X X
3k	Kinematic Check	3	2		X X X
3l	ANSIY14.5 Compl	3	3		X X X
3m	Make Object Files	2	2		X
	subtotal:	43	35		
4	Proposal Mods				
4a	Project Robot Schedule	2	1		X X
4b	Project Robot Part Inv.	2	1		X X
4c	Crit Des Review*	3	2		X X
	subtotal:	7	4		
7	Part Construction				
7a	Buy Part Chassis	1	1		X
7b	Buy Part Mototrs	1	1		X
7c	Buy Part 12V Battery	1	1		X
7d	Make Part Front Bumper	15	10		X X
7e	Make Part Back Bumper	15	12		X X
7f	Make Part PCB Base	5	2		X X
7g	Make Part Battery Base	5	2		X X
7h	Make Part Logo/Antenna	4	2		X
7i	Wiring Part Front Bumper	1	1		X X
7j	Wiring Part Back Bumper	2	2		X X
7k	Paint Parts 3D printed	8	5		X X
7l	Make Part PCB Processor	8	6		X X
7m	Take Part Pictures	2	2		X
7n	Update Website	8	6		X X
7o	Manufacture Plan*	4			
	subtotal:	80	53		

9	Device Construct		
9a	Assemble Pumbers	3	2
9b	Assemble Main PCB	3	2
9c	Assemble Battery	2	1
9d	Assemble Top Cover	1	1
9e	Take Dev Pictures	2	2
9f	Update Website	6	3
	subtotal:	17	11
10	Device Evaluation		
10a	Test Robot full assembeled body	3	2
10b	Test Wheels Motors	2	1
10c	Test Battery	24	8
10d	Test Battery Charger	24	24
10e	Test Main PCB	2	1
10f	Test Robot speed	1	1
10g	Perform FULL Evaluation	2	5
10h	Make upgrade plane	2	1
10i	Make parts upgraded	8	4
10j	Take Testing Pics	2	2
10k	Update Website	5	2
	subtotal:	75	51
11	495 Deliverables		
11a	Get Report Guide	5	3
11b	Make Rep Outline	5	4
11c	Write Report	8	6
11d	Make Slide Outline	3	7
11e	Create Presentation	5	4
11f	Make CD Deliv. List	5	
11g	Write 495 CD parts	5	
11h	Update Website	4	
11i	Project CD*	2	
	subtotal:	42	24
	Total Est. Hours=	298	234
Labor$	100	29800	



=Total Actual Hrs

Appendix F

Expertise and Resources

Only the team members will be required for completing this project. Basic software knowledge will be required. The knowledge Engineering design process will be enough to complete this project.

Appendix G-Testing

Sultan Alhajri | MET 489A

Testing of Fire Fighter Cart

cost	Power	water throw (ft)
1	1 w	1 ft
2	1.5 w	2 ft
3	2 w	2.5 ft
4	3 w	3.5 ft
5	4 w	5 ft
6	4.5 N	5.8 ft
7	5.5 w	7 ft

Appendix H

S/A

SULTAN ALHAJRI

Hajri.sdr@gmail.com | 509-859-4460 | 1917 West Peakview Drive , Ellensburg , Washington 98926-2314

Summary

I am a dedicated trainee Engineer who is always willing to explore new options and ready to work under minimal supervision. I am currently 20 years old, self-motivated and goal-oriented young Engineer whose happiness is bringing change in the field of mechanical engineering. I am also able to communicate in Arabic and English. I am currently a student at Central Washington University. So, I had an experience about the security personnel in ARAMCO.

Skills

* Time management
* Problem solving
* Decision making
*Team work
* Bilingual

Experience

Trainer at Aramco 01/2015 - 01/2016
Security | BUQAIQ, Saudi Arabia
I worked as a trainer in the department of accounting in Aramco. Also, I have been a great help for them by making their work fast, and organize the work between the employers.

Education and Training

Associate of Science 2017
Southern University at Shreveport | Shreveport, LA

Mechanical Engineering Technology : currently student 2020
Central Washington University | Ellensburg, WA

Conference

Occupational Safety and Health Management (OSHA) - 2018

Appendix J:

JOB HAZARD ANALYSIS
{Manufacturing Fire Fighter Robot Parts}

Prepared by: Sultan Alhajri	Reviewed by: Approved by:

Location of Task:	Central Washington University
Required Equipment / Training for Task:	Milling machine operations, Operation of the drill press, Operation of belt sander, 3D printing operations and First aid.
Reference Materials as appropriate:	SDS for the spray paint https://www.krylon.com/document/SDS/en/US/724504016014

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
☒	☒	☒	☒	☒	☒	☐
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

TASK	TASK DISCRIPTION	HAZARDS	CONTROLS
CNC MILLING	Set up of 3D mill	Injury to hands from milling blades.	Never disconnect safety shields from milling blades.
		Hearing damage from noise of machine operation.	Wear hearing protection, such as ear plugs, if operating machine for periods extending more than 10 minutes.
	During milling	Possible eye injury from wire stitches thrown out by milling blade.	Wear safety glasses during operation.
		Crushing finger hazard from book clamp.	Do not hold book at spine when activating book clamp. Hold book at the

			face.
PRESS DRILLING	Clean the table.	Eye injury from metal debris.	Wear eye protection. Do not use compressed air.
	Load the vise.	Foot injury if the vise falls	Secure the vise on the table with T-pins.
		Finger pinching while sliding the vise	Don't let fingers get under the vise unless lifting it from the table.
	Lock the table in place.	Back strain	Don't lean over the table to twist the lock handle.
	Load the bit.	Hand injury from the bit	Wear gloves. Don't hold on the end of the bit.
	Feed the drill with the feed.	Injury caused by breaking the bit	Feed with the appropriate pressure. Use the appropriate bit for the type of metal. Wear eye protection.
		Eye or skin damage from cutting oil	Use the lowest RPM. Wear eye protection. Wear a long sleeved shirt.
		Hand injury from the exposed pulley near the feed handle	Make sure a pulley guard is in place. Don't push the feed handle toward the pulley.
	Unload the vise.	Foot injury if the vise falls	Leave the vise secure on the pins.
BELT SANDING	Check condition of belt.	Abrasion of fingers and hands	Avoid contact with belt edge or surface.
	Start sander.	Flying sawdust	Wear safety glasses or face shield.
	Align materials flat on table.	Pinching fingers or hand	Keep fingers and hands away from pinch points.
	Contact material with belt sander.	Cutting fingers or hand	Avoid contact with belt edge or surface.
		Flying sawdust	Wear safety glasses or face shield.

3D PRINTING	During printing	Injury due to touching of nozzle tip temperature	Attend the UP! 3D Printer tutorial qualification training. Wear leather gloves and stay away from the nozzle head as the printer prints.
	Removal of printed part	Injury due to poor removal of part from platform bed Cut or eye damage due to sharp/rough edges and small plastic pieces while removing support material on part. Injury due to platform bed temperature	Wear leather gloves. Use proper tooling for removal of part following the tutorial training. Wear leather gloves, safety glasses, and avoid handing rough edges. Wear leather gloves.
SPRAY PAINTING	Spray paint parts	Toxic fumes	Wear safety glasses and a dust mask.