MTE 100
GRAPHING ROBOT

GROUP 8-14

Avery Chiu 20820648

Chuting Wang 20833432

Kerui Liu 20827426

NOVEMBER 4^{TH}, 2019

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

SUMMARY

The introduction describes what a function is and how creating a graphing robot is important for education. Functions are important for learning mathematics and a graphing robot helps students visualize how graphs appear and helps them learn about different parts of a function.

The scope describes how the robot operates. The graphing robot will take in user input on the computer and will generate a file of coordinates for the robot to interpret. The robot will start on one side of the page, interpret the coordinates, and draw a line or curve from one coordinate to the next. The robot stops as soon as it has finished plotting all the coordinates.

The criteria emphasized the importance of creating a lightweight robot that can graph functions quickly.

The constraints for the robot were that it cannot draw off the page and receive complex combined functions.

The requirements for the robot are that the function draw must clearly represent the function entered by the user and all the coordinates must come from the function entered by the user.

The design options featured 3 distinct design options. The first one displays the standard Lego EV3 robot on a platform with an arm that extends past the platform and under it. The paper itself is located under the platform. This robot moves around to draw the graph. The second option is similar, but instead the robot drives directly on the page and has an arm that draws the graph. The third option features a printer-like robot that rolls the page around and has an arm to draw on the graph.

Overall however, design 3 was chosen due to its ability to protect the page and keep it stable. Even though the design is bulky, it makes sure that the page does not move which will help draw a clear graph. Thus, design 3 was the best option.

INTRODUCTION

Functions are an integral part of mathematics are taught in high school and university. An example of a function y=x+2. A value of x is plugged into the equation which results in a y value. Since there are an infinite amount of x values that can exist, when all of them are plugged in and plotted on a cartesian (x,y) plane, it results in a graph of a function.

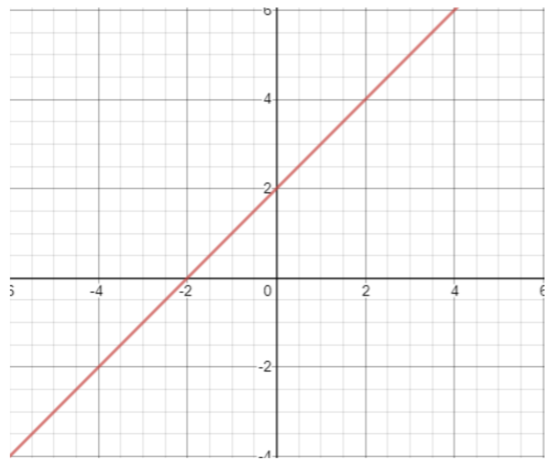


Figure 1: An example of a graph of the function y = x + 2 [1]

The Graphing Robot was created to help graph functions on a physical page and for educational purposes. Many students in high school and university struggle with concepts in calculus. A robot that creates visual copies of graphs helps them to visualize the functions they are seeing in the classroom. This is important for students since it can help them solve their calculus problems (e.g. curve sketching) in a fascinating way. In turn, this also helps attract more students into the STEM field as the robot will help strengthen their calculus skills while also showing them a great example of a mechatronic system.

SCOPE

Initial Start Up

During the initial start up, the robot will wait for file input from the computer. The user will enter a function from the console that they wanted to be graphed. This computer program creates a file for the robot. Once the robot gets the file, it displays that it has received the file and waits for a button press to start.

Regular Operation

During the regular operation of the robot, it will start from one side of the page/whiteboard and drag a pen across the page to graph the function that the user wanted. The robot will interpret the file which contains (x,y) coordinates. It will start at the bottom left corner, with the pen not on the page yet. The lifting and lowering of the pen will be controlled by a motor. It will use a motor to move the arm around, while using another motor to align the page so that it can draw. The robot will use the gyro sensor to angle itself so it can move to the next coordinate and it will use the encoder to make sure it travels the right distance to get to the point.

The Shutdown Procedure

The robot finishes as soon as all the points have been plotted and there are no more points to plot. The paper will slide off the robot. The computer and robot will tell the user that the program is complete. If for some reason a point cannot be plotted on the page, the robot will recognize that it is not in the domain or range of the page and stop.

Table 1: Specific details about the graphing robot

Specific Questions about the Robot	**How it is implemented**
What does the robot sense?	• The user enters a function on the computer which is interpreted and made into a file of coordinates • A file of coordinates is sent to the robot • The robot waits for a button press from the user before it starts moving • The robot will measure receive each coordinate from the file and measure the distance it must travel and draw to get to each coordinate • The robot will use a gyro sensor to calculate the angle it needs to travel • The robot will use a motor encoder to calculate the distance it needs to travel in between each point
How will the robot affect the environment and how will it use its motors?	• The robot will use a pen to draw a graph on a piece of paper • A motor will be used to control the arm for horizontal movement • A motor will be used to control the page for vertical movement • A motor will be used to control the movement of the arm up and down
How does the robot know when to stop?	• The robot will stop when all the tasks are complete, and all the plots have been pointed
How will the robot handle unexpected events?	• The computer has while loops to detect when the user enters improper input • The computer limits users for polynomial functions so they do not enter any polynomials with degrees

	greater than 10, which may cause extremely bizarre graphs • If the user enters something wrong, there will be certain points where the computer will check with the user to be sure they have entered the correct input • If there is a point that is off the page, the robot will not plot it and simply stop

Evaluating Success

This project will be successful if the robot can plot the points and trace a line between each of the points, creating a function that resembles the function the user entered. The points that the robot graphs out must be from the function that the user entered. It would be nice if the robot could draw smooth lines between each point, though this is difficult since both motors need to be powered exactly so that the curve between each point is smooth. The easier alternative is to just plot points and connect the dots with straight lines. It would also be nice if the robot could graph combined functions, however that may pose problems for the robot as certain combined functions behave very strangely.

CRITERIA

1. A robot that weighs less would be more favourable. This reduces the energy needed to operate the robot and simply makes it more user-friendly
2. The robot that can perform tasks and graph faster will be better. This allows for more efficiency and will please the user more. A long wait time may aggravate users who are impatient with the robot.

CONSTRAINTS

1. The movement of the robot should be restricted, within the page to prevent the robot from drawing off the page. The size of the page must be taken into account and at no point should the arm draw off the page.

2. The input of a function is being restricted to a single function, which implies that the system is unable to analyze and construct accurate representation of combined functions and is being restricted to application between functions (including addition, subtracting, multiplication, and division of two functions. For example, a function f(x) = x sin(x) is being entered, then the system can only read in f(x) = x, and recognize it as a polynomial function. The user will also be notified that no applications between functions is permitted at first. However, if user enters a function that is not processable

in the program, a 0 will be returned to the robot, which will disable the movement of the robot.

REQUIREMENTS

1. The robot should draw a clear graph. This requires the robot to draw a smooth connection between two points. Also, the robot arm should keep the pen up when the robot is not drawing points for the graph.
2. All the points plotted by the robot come from the function entered by the user. This requires the computer to check that the robot receives the correct output file with the right coordinates from the latest function user inputs.

DESIGN

DESIGN 1

This design will use the Tetrix Kit to build a box structure, with a hard-cardboard platform inside. The default EV3 Robot will drive on the platform and an arm will be attached to the bottom of the platform. A wire will be connected between the robot motor and the robot arm. There will be a continuous motor that will be used to control the movement of the arm. The paper will be placed on the bottom of the system. The general sketch of the robot is shown as the following figure 2.

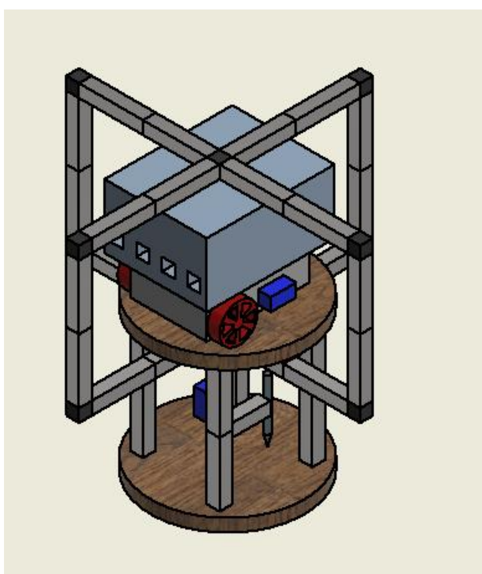


Figure 2: General shape of Graphing Robot design option 1

The benefits of this design are that the robot can reduce contact between the paper and the robot to prevent damage of graphs. This design uses the default EV3 robot, so it cuts down the complexity of construction of the robot.

The downside of using this design is that the paper is not fixed in a position which might lead to an inaccurate graph on the page. The size of the platform is closely related to the length of the wire given, which might be restricted to a certain size of the graph. In addition, the system is limited to a certain angle and range. The robot may fall off the platform if it goes past the boundary of the platform.

DESIGN 2

This design uses the default Lego EV3 Robot with an arm attached to it. The robot arm has two wheels that hold a pencil in between them. When the robot wants to lower the pencil, the motor will spin one of the wheels causing the pencil to lower itself onto the page. When the robot is not drawing, it will spin the wheel so that the pencil will shift back up. To maneuver, the robot will simply drive to each point while dragging the pencil. The general sketch of the robot is shown as the following figure 3.

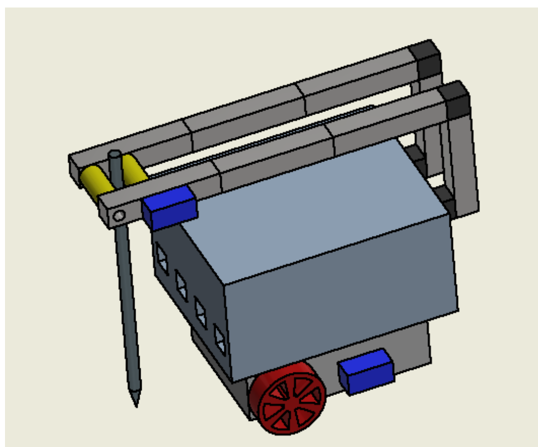


Figure 3: General shape of Graphing Robot design option 2

The benefits of using this design is that it is simple and easy to build mechanically. The robot can be kept in its current configuration and only an arm and motor need to be added. This is also more portable and easily configured since the robot only needs to be placed onto a page for it to draw. There is no complex setup.

The downside of using this design is that it is cumbersome for a plotter and more difficult to program to draw curves. The motor powers must be perfect, so that the robot can draw a smooth curve. Otherwise, the robot will simply connect the points on the graph with a straight line.

DESIGN 3

This design requires the use of the Tetrix Kit to build a stable platform for the base of the graphing robot. Two arc structure and a tie connecting the box holding the pen. Under the four columns, there are two wheels that help roll the paper horizontally so the robot can draw onto the full length of the piece of A size paper. The robot will hold the pencil with an arm which moves up and down. When the robot is required to lower the arm to draw or lift the arm to start on a new point, it uses the two wheels that hold the pencil in between them. The motor will spin one of the wheels when the pen needs to be adjusted. The general sketch of the robot is shown as the following figure 4.

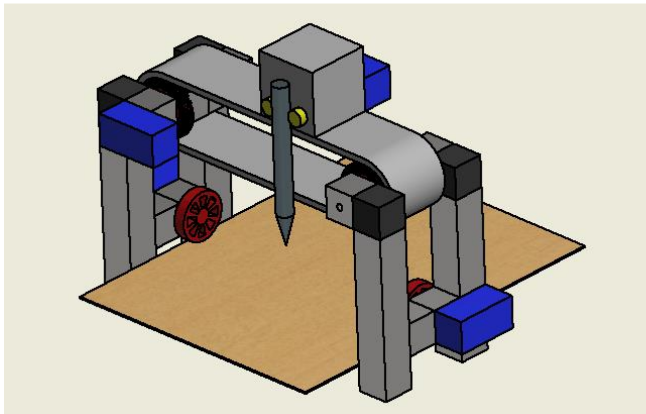


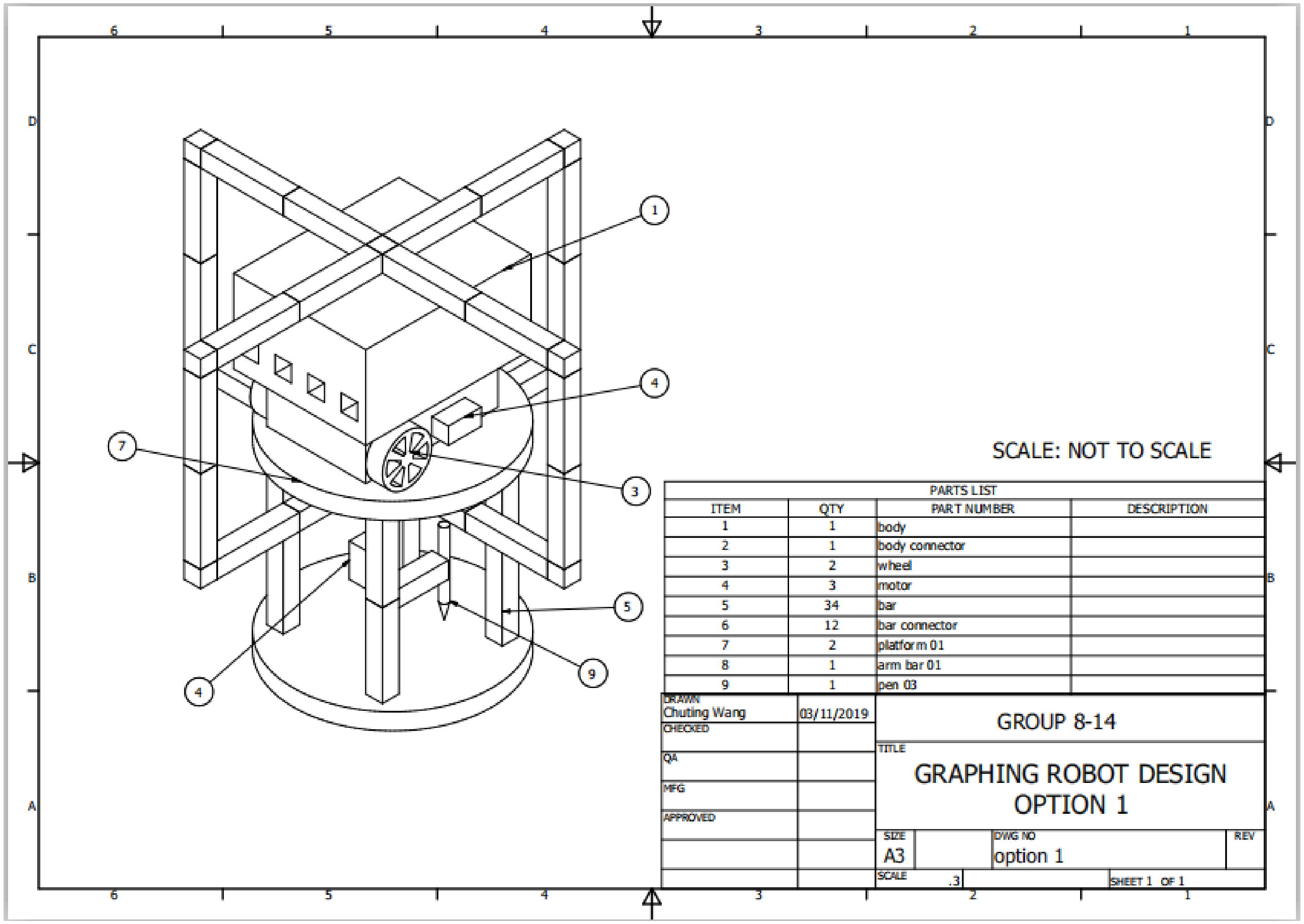
Figure 4: General shape of Graphing Robot design option 3

The benefit of using this design is that it is stable and only the pencil will be in contact with the paper. This helps avoid any interference between the wheel of the robot and the paper, which helps avoid erasing or damaging the graph. The design is also beneficial in a way that the robot is acting like a printer. The paper is rolling at the bottom, and the paper is being secured with the wheels under the columns, to avoid any movement of the paper. Moreover, this design will also help in drawing smooth and concise curves on the page, since the robot can move vertically while the wheels on the bottom helps to roll the paper horizontally.

The downside of using this design might be that the system will be relatively large and will be complex in constructing the parts. For example, when constructing the functions with curves, the arm and the paper must move at the same time with a precise motor speed, which can be extremely challenging to program.

Following are detailed drawings of Graphing Robot for each design option.

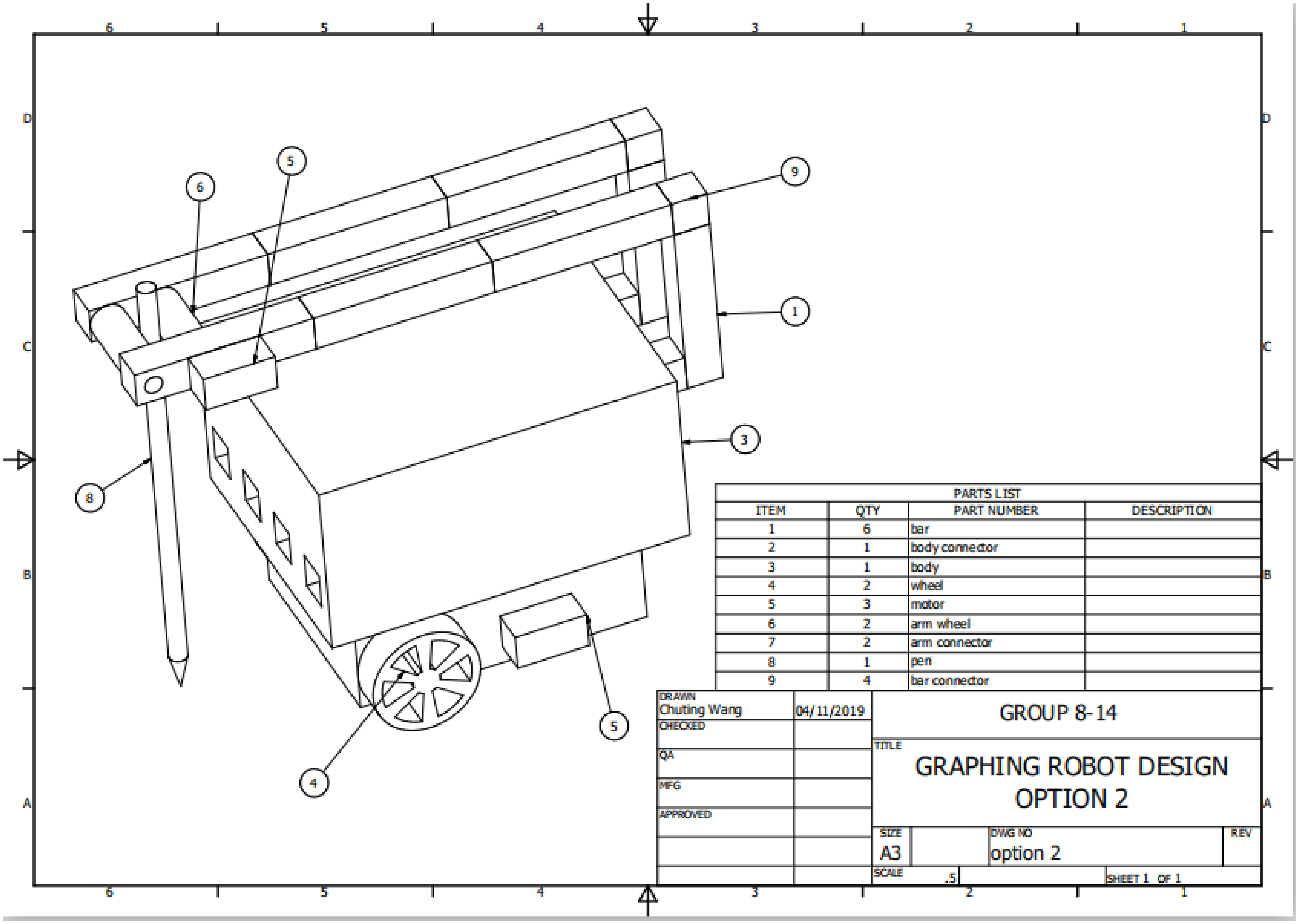
DESIGN 1 DETAILED DRAWING



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	body	
2	1	body connector	
3	2	wheel	
4	3	motor	
5	34	bar	
6	12	bar connector	
7	2	platform 01	
8	1	arm bar 01	
9	1	pen 03	

Figure 5: Detailed drawing of Graphing Robot design option 1

DESIGN 2 DETAILED DRAWING

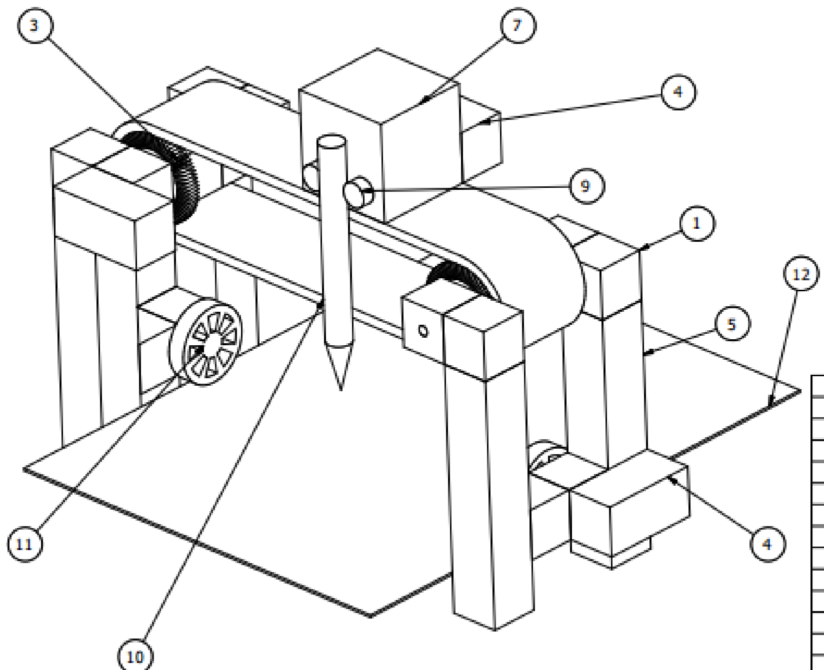


PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	6	bar	
2	1	body connector	
3	1	body	
4	2	wheel	
5	3	motor	
6	2	arm wheel	
7	2	arm connector	
8	1	pen	
9	4	bar connector	

Figure 6: Detailed drawing of Graphing Robot design option 2

DESIGN 3 DETAILED DRAWING



SCALE: NOT TO SCALE

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	4	bar connector	
2	10	bar with turning axis	
3	2	gear	
4	4	motor	
5	4	bar	
6	1	tie	
7	1	box holding the pen	
8	2	0.75 connector	
9	2	arm wheel 03	
10	1	pen 03	
11	2	small wheel	
12	1	clip board	

DRAWN Chuting Wang	03/11/2019	GROUP 8-14
CHECKED		TITLE GRAPHING ROBOT DESIGN OPTION 3
QA		
MFG		
APPROVED		SIZE A3 / DWG NO option 3 / REV
		SCALE .6 / SHEET 1 OF 1

Figure 7: Detailed drawing of Graphing Robot design option 3

PROJECT PLAN

Following is the detailed description of the individual task for each group member.

Table 2: Detailed Description of Project Plan

Member	Role
Avery Chiu	- Develop user interface for function including the polynomial function and trigonometric function. Create functions in C to drive the robot towards each point smoothly. - Build the platform for the robot. - Test graphing functions for the robot.
Kerui Liu	- Develop user interface for function including the Exponential function. - Create part of functions in C. - Build the platform/base for the robot and part of the robot arm. - Test graphing functions for the robot.
Chuting Wang	- Develop user interface for function including the rational function and logarithmic function. - Create part of functions in C. - Build part of the platform for the robot and the robot arm and add it to the robot. - Test graphing functions for the robot.

Gantt Chart For Final Project

Duration

The dates are not to scale

Sub Projects	Date Start	Date End	PERCENT COMPLETE	PERIODS					
				October 11, 2019 to October 25, 2019	October 26, 2019 to October 27, 2019	October 28, 2019 to October 31, 2019	November 1, 2019 to November 3, 2019	November 4, 2019 to November 7, 2019	November 8, 2019 to November 14, 2019
Develop user interface to receive functions and interpret the function they want	October 11, 2019	October 27, 2019	100%						
Testing code and file output	October 26, 2019	October 27, 2019	100%						
Write RobotC code to interpret file and output date	November 1, 2019	November 14, 2019	30%						
Create robot arm to draw	November 4, 2019	November 7, 2019	30%						
Create robot platform to drive on	November 4, 2019	November 7, 2019	30%						
Test graphing functions	November 4, 2019	November 7, 2019	0%						

Figure 8: Gantt Chart of Project Plan

CONCLUSION

In conclusion, the robot must be able to successfully plot the points from the function that the user enters and should trace each of the points. The finished product should resemble the function the user entered. Design option 3 was selected since it is the most stable design while providing customizable and possibly the largest scope for the robot to graph functions. Adding on to that, design option 3 can draw the graphs without the risk of causing damage to the product. For example, in design 2 the wheels might accidentally erase the graph. Overall, design 3 is the best option for this course project.

REFERENCES

[1] Desmos, "Desmos," Desmos, [Online]. Available: https://www.desmos.com/calculator. [Accessed 4 Novemeber 2019].