DESIGN REPORT - EGB111

Tutorial 5, Group ‘5G’; Thursday 9am

TEAM LEADER -

PROJECT MANAGER - Bouchra Senadji

TEAM MEMBERS	*Signature*
N10228144 - LIAM COONEY	- LC
N10535268 - JOSEPH HADDAD	- JH
N10491368 - JAMES ROGERS	- JR
N10262474 - DAN CHKHENKELI	- DC
N10279997 - JAN KODI	- JK

Author Declaration:

“In signing this cover sheet, each author attests that they have made a fair contribution to the conduct of the design project and the generation of this document. Each signed author also attests that they acknowledge the fair contribution of all other listed authors, and that if a team member is not included in the signed authorship list, the team has discussed this with the unit coordinator and this course of action is supported by the unit coordinator.”

This infers that if there is a team member whom is not making a fair contribution, they should not be listed in the team list and they should not be signing against the declaration. Should this be the case, you must reflect the matter in the peer review process and consult with the unit coordinator prior to submission so that the correct and appropriate action can be made. Ultimately, any team members omitted from the declaration, due to a team consensus of them not making a fair contribution, has the right of reply.

Statement of Contributions

Team Member	Report Sections Written	Technical Contributions	Percentage Contribution
Joseph Haddad	Conceptual design, Circuit design, Final Design. CAD Drawings Throughout. Mechanical design assistance. Proofreading. Referencing. List of Figures/ Tables.	Crane Base Construction & Electromechanical System.	25
Liam Cooney	Assorted structuring + formatting, Executive Summary Structural Design Mechanical Design Circuit Design assistance. Proofreading.	Structural design + concepts and design development.	25
James Rogers	Executive summary structural design	Truss construction + concepts	17
Dan Chkhenkeli	Introduction, design performance and evaluation, conclusion and recommendations Proofreading	Truss construction	17
Jan Kodi	Truss analysis (calculations)	Structural design Truss construction	15

Executive Summary

The given task is to design and construct a model lifting device, capable of moving a 0.5kg mass from one fixed location to another, without dropping the weight or breaking the device. This must be conducted under 1.5 minutes and the total mass of the device must not exceed 4kg. The peak running power of the electrical system must be less that 10W, with an input voltage of 24V and a current of 3A. An ideal device will have a factor of safety between 2 and 3.

The truss consists of two longitudinal beams(910mm) consisting of 12 section beams (82mm) and 11 (110mm) cross members. These beams were connected by a total of 26 cross members (79mm). The maximum tensile force on the truss was 53.96N and the maximum compressive force was 49.05N.

The base is constructed of HDF wood, bolted onto point C and extended the pivot point of the truss 450mm outwards to the middle of the board. The forces applied to the base are 34.662N (F_{BY}) and 29.757 (F_{AY}).

The mechanical design consists of two key components; two seperate gearhead motors for vertical and horizontal operations. The vertical component includes the usage of a 12VDC reversible gearhead motor, operating at an efficiency at 11.83%. This motor allows for a lifting speed of 0.089cm/s, drawing 0.031 amps of current and 0.372 watts of power. In conjunction to this, the YG2734 12VDC motor allows for horizontal pivoting while the truss sits on a modified lazy susan bearing. This model includes a higher gear ratio and torque, ensuring a slow, consistent rotation.

The motors have been wired in parallel with no resistors; decreasing current for each motor, while maintaining original voltage (6V). The motor resistance(6.38Ω & 7.89Ω respectively) is sufficient in allowing the system to lower the current below 1 Amp for each motor (0.94A & 0.76A respectively).

The final product comes to a weight of 1.45kg (excluding the electrical circuit), and draws a total power of 5.64W; sitting within the task regulations. The gearhead motors are located within the truss on top of the base, using space efficiently and minimising risk of tangeling components.

There were certain requirements that had to be met in order for this project to be considered a success. These were as follows; Lifting a 0.5kg mass 5cm off the pedestal, moving a 0.5kg mass from Pedestal A to B in under 45 seconds for an optimal result, having an optimum weight of 1.5kg, running at a peak power of less than 10 watts, and reaching a safety factor of 1 or 2 for the electrical mechanism, with a 2 or 3 for the mechanical components. Most of these goals were reached, bar the optimal weight for the system and the mechanical safety factor, which were failures.

Table of Contents

Author Declaration: ***1***

Executive Summary ***3***

Table of Contents **4**

List of Figures **5**

List of Tables **5**

1.1 Introduction **6**

2.1 Conceptual Design **7**

3.1 Detailed Design **11**

3.1.1 Structural Design 11

Truss Analysis 11

Material Testing and Selection 11

Balance/bolt force calculations 12

Truss Testing 13

Component selection 13

3.1.2 Mechanical Design 14

Lifting Mechanism 14

Pivoting Mechanism 14

Mechanical System Testing 15

3.1.3 Circuit Design 16

4.1 Final Design **17**

4.1.1 Detailed Description of the Design 17

5.1 Design Performance Evaluation **23**

6.1 Recommendations and Conclusions **24**

References **25**

Appendices **26**

List of Figures

2.1.1 Concept 2 Improvement 1 …………………………………………………………..…………… 9
2.1.2 Concept 2 Improvement 2 ……………………………………………………………………... 10
3.1.1.1 Action reaction forces of the base/ balance forces …………………..………………… 12
3.1.1.2 - Base design with motor positioning ………………………………………..………… 13
3.1.2.1 - Diagram of gear-head motor including dimensions in 'mm' ………...………… 14
3.1.2.2 - Diagram of YG-2734 gear-head motor ……………………………….……………. 14
3.1.3.1 - Circuit Diagram of Electrical System …………………………...…………. 16
4.1.1.1 - Isometric Drawing of Final Design ……………………………………...……… 17
4.1.1.2 - Motor and Drum ……………………………………………………………..…………. 19
4.1.1.3 - Horizontal Movement Component ……………………………….………………. 19

List of Tables

Concept Design Objectives …………………...………………………………………………………… 7
Concept 1 …………………………………………………………………………………………………… 7
Concept 2 …………………………………………………………………………………………………… 8
Concept 3 …………………………………………………………………………………………………… 8
Final Design Objectives ……………………………………………………………….………………… 20
Testing Results Compared to Calculations …………………………………………..………
20
Testing Results , How They Validate Performance & Process ………………………..….. 21
Cost Breakdown ……………………………………………………………………..………………… 22
Material Testing Data - (Compression Test) ………………………………………...……..
26
Truss Analysis - (Members) ……………………………………………………………...……. 32

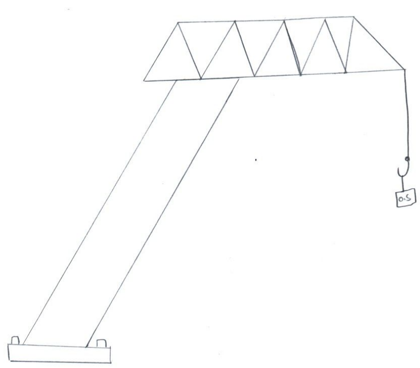
1.1 Introduction

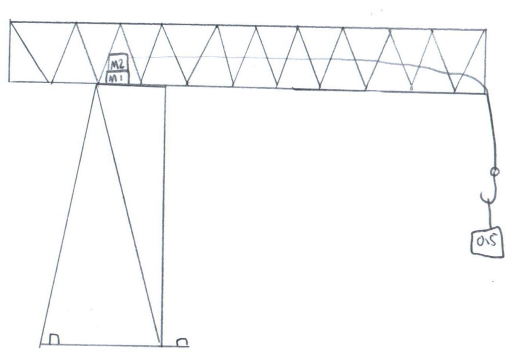
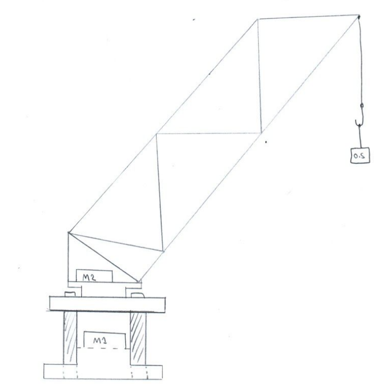
This report will detail the given task of the design and construction of a model lifting device, or crane, capable of moving a 0.5kg mass from one fixed location to the other, without dropping the weight or breaking the device. This must be completed in a time limit of 1.5 min, in which the total mass of the device must not exceed 4kg. Some more constraints include the peak running power, which must be valued at less than 10 watts, with an input voltage of 24V set at 3 amps. The following report will contain all major aspects of design, construction process and testing of the device, demonstration of design processes, which includes the final design and all previous iterations. Furthermore, it will contain a detailed analysis and tests of the structural, mechanical and electrical components. Finally, it will also demonstrate the design performance of the crane, with further design recommendations and improvements.

The purpose of this project is to follow a set of objectives which must be met to ensure a successful outcome. These objectives include, limiting the cost of excess materials and parts to not exceed $50, verify the overall weight of the device is less than 4kg, ensuring structural failures occur at the members, rather than the joints, making sure the device has a factor of safety between 2 and 3, and lastly, ensuring the electrical system is capable of lifting the mass at least 50mm (5cm) above the pedestal.

2.1 Conceptual Design

<u>Concept Design Objectives</u>
- Must meet weight regulations (weight ≤ 1.5kg)
- Project must be in contact with the testing board and be stable when bolted at ‘Point C’
- Components to be reasonably priced, meeting an appropriate budget
- Must be contextually appropriate in terms of construction; doable
- Truss must be inclusive of at least 5 ‘Truss bays’
- Project must meet the relocation requirements from point ‘A’ to point ‘B’, both horizontally and vertically.

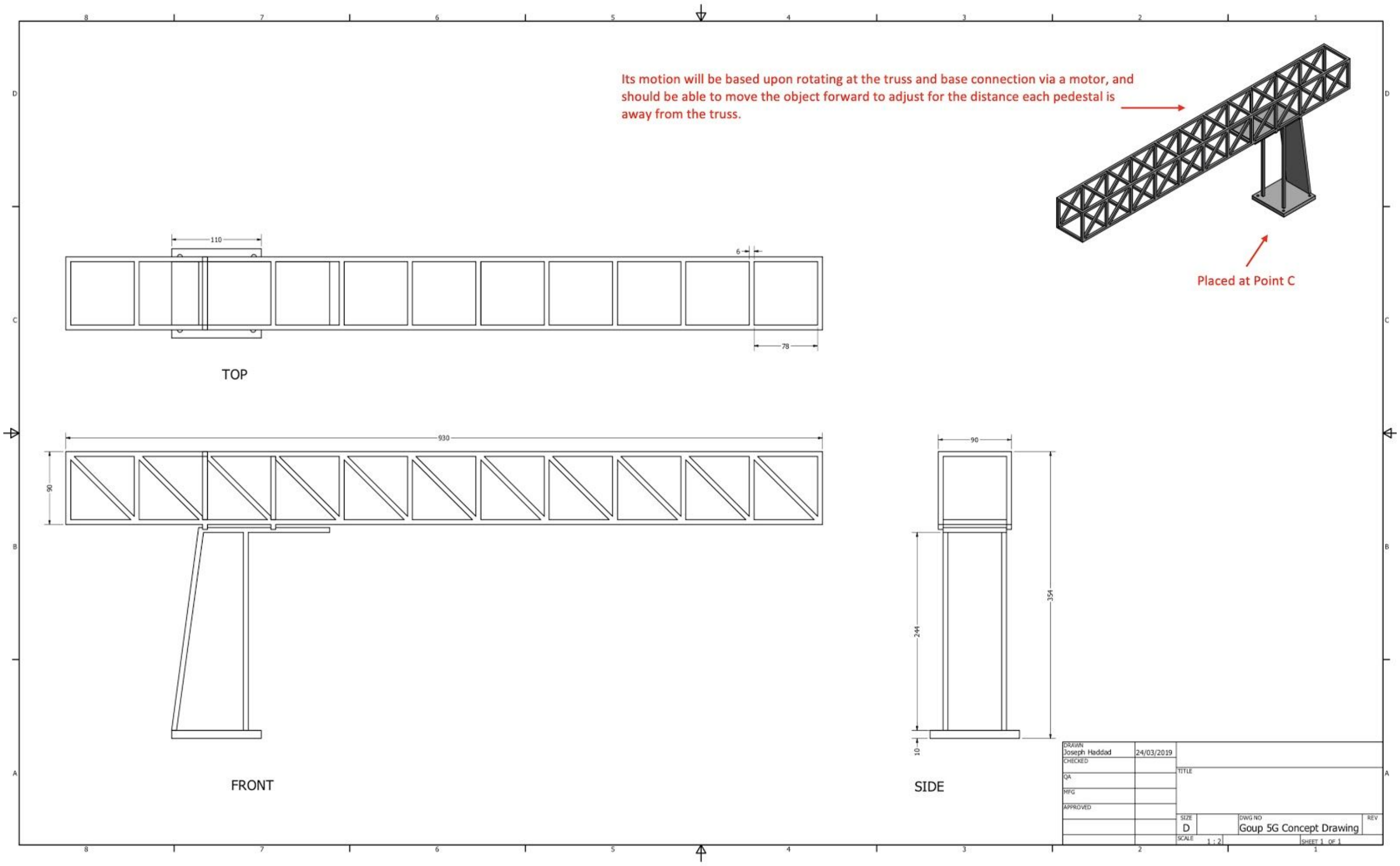
Concept 1	
	- Minimal material usage - Cylindrical PVC style base, may exceed weight regulations - Bolt-connections to testing board to ensure stability (bolted at point ‘C’) - Requires the use of two gear-motors for mechanical components; costly. - Horizontal mechanical component:; Lazy Susan bearing + gear motor - Vertical mechanical component: Drum and pulley system to lift the 0.5kg object - Meets requirements in terms of truss design; consisting of more than 5 truss ‘bays’ - Requires no rail-mechanism along the truss due the base design; truss is positioned centrally between point ‘A’ and point ‘B’, meaning object relocation only requires lifting and pivoting mechanical components

<table>
<tr><th colspan="2">Concept 2</th></tr>
<tr><td></td><td>- Minimal material usage; cost-effective and low mass design.
- Bolt-connections to the testing board at point ‘C’; ensuring stability
- Requires the use of two gear-motors for mechanical components
- Has more than 5 truss bays - truss regulations met
- Horizontal mechanical component:; Lazy Susan bearing + gear motor
- Vertical mechanical component: Drum and pulley system to lift the 0.5kg object.</td></tr>
<tr><th colspan="2">Concept 3</th></tr>
<tr><td></td><td>- Minimal material usage; both base and truss
- The truss does not feature 5 bays, more will need to be added.
- Requires the use of two gear-motors and assorted bearings for truss lifting and rotation.
- Bolt-connections to the testing board at point ‘C’; ensuring stability
- Low centre of gravity
- Complex construction for base component; may lead to electrical/mechanical system development difficulties.</td></tr>
</table>

Selection and Description of Initial Concept

Overall, the most appropriate design is ‘Concept 2’ due to its lower construction complexity in comparison to the other two concepts. Furthermore, its low material usage shows a higher potential to meet the weight regulation of 1.5kg without negatively affecting its structural integrity. The use of bolt-connections to the testing board at point ‘C’ eliminate the need for a counterweight and ensure any tensile force is stabilised. Concept 2’s potential stability also Creates the opportunity for the truss to be extended via the base placing it in a central position allowing movement of the statue from A to B.

Concept 2 Improvement 1

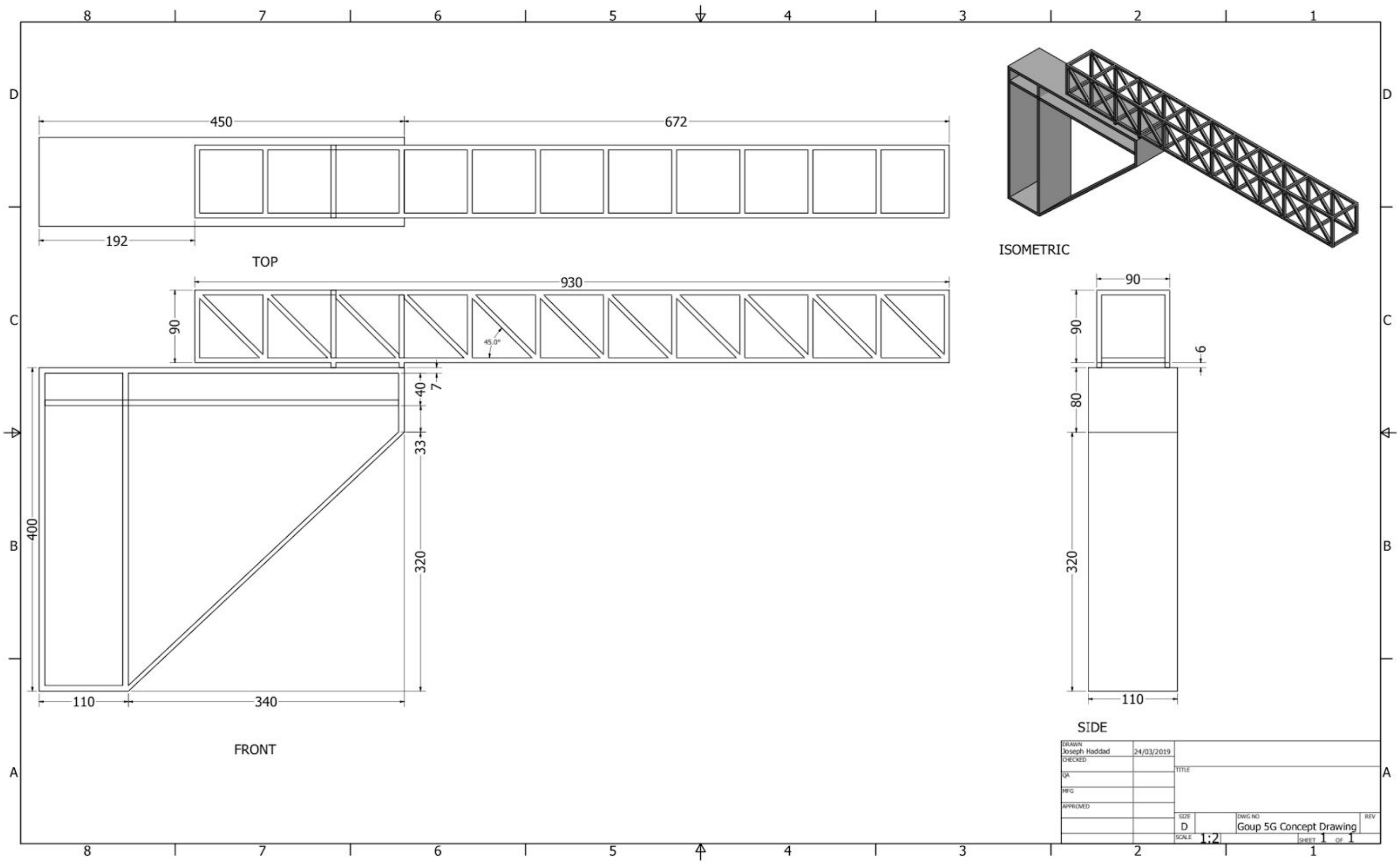


[*Figure 2.1.1 - Concept 2 Improvement 1]*

This initial improvement to the ‘Concept 2’ design includes an extension of base components in order to fit electro-mechanical components. The components will sit on top of the base inside the truss; eliminating the need for additional platforms that might exceed weight regulations. This however poses a risk to the strength of the base, as the additional extension and motor placements may not have enough support. Furthermore, the extension may collapse under load conditions, threatening the success of the relocation.

Additionally, an extension needs to be made to the lower section of the base as its cross sectional area (110x110mm) is not large enough to fit over the bolt holes, eliminating the ability for a fixed position. Furthermore improvements need to be made to this section to allow for bolt connections.

Concept 2 Improvement 2



[*Figure 2.1.2 - Concept 2 Improvement 2]*

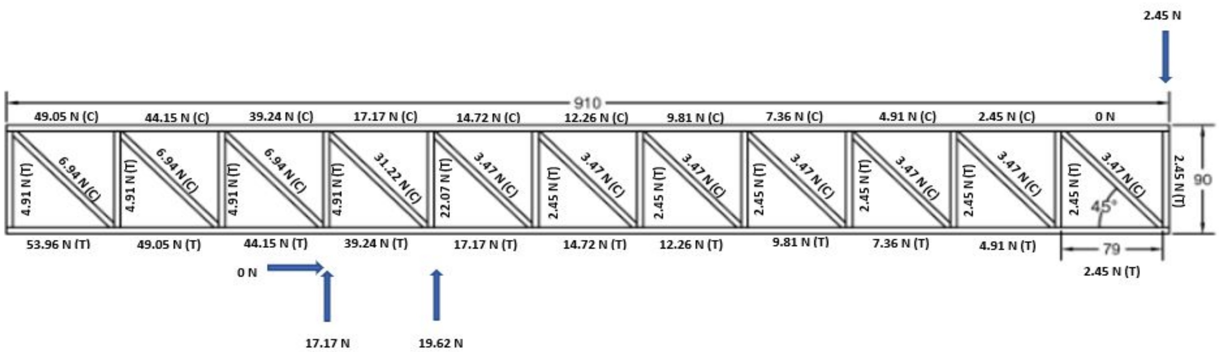
The third evolution of the design concept includes a longer base which is designed to extend out 450mm from the bolted point at C. Thus the truss is placeable at a fixed central point where it is able to horizontally turn from point A to B to pick up and drop off the weight. The base also features a platform where all electromechanical components can go. This feature however, adds weight to the device and can be eliminated via placing these components above with the truss. Additionally, they base has increased in size to 150mm to provide maximum contact with the ground and also allowing the 4 bolts to screw in at 110mm.

3.1 Detailed Design

3.1.1 Structural Design

Truss Analysis

The truss analysis was conducted to determine the critical compressive and tensile forces of each segment of the truss before construction. Initial calculations found that the truss was determinant; allowing for the method of joints process to be applied.



[*Figure 3.1.1 - Truss analysis diagram; see appendices for calculations*]

The method of joints process concluded that the critical compressive force to be 49.05N, while the critical tensile force is 53.96N. With this data, material testing can be undergone so that an appropriate material may be selected for truss construction; allowing relevant safety factors to be met.

Material Testing and Selection

Given the requirement to hold a factor of safety above 1.4, the critical compressive strength can be used to satisfy this factor, amounting to a force of 75.54N (53.96N). As our 'bays' are designed to be approximately 79mm in length, testing between 75mm-100mm lengths of balsa (with various cross-sectional areas) is needed. *(see appendices for testing data)*

Compression Test			
Balsa(5mm)	50mm	75mm	100mm
Average	439.7N	400.1N	386.8N

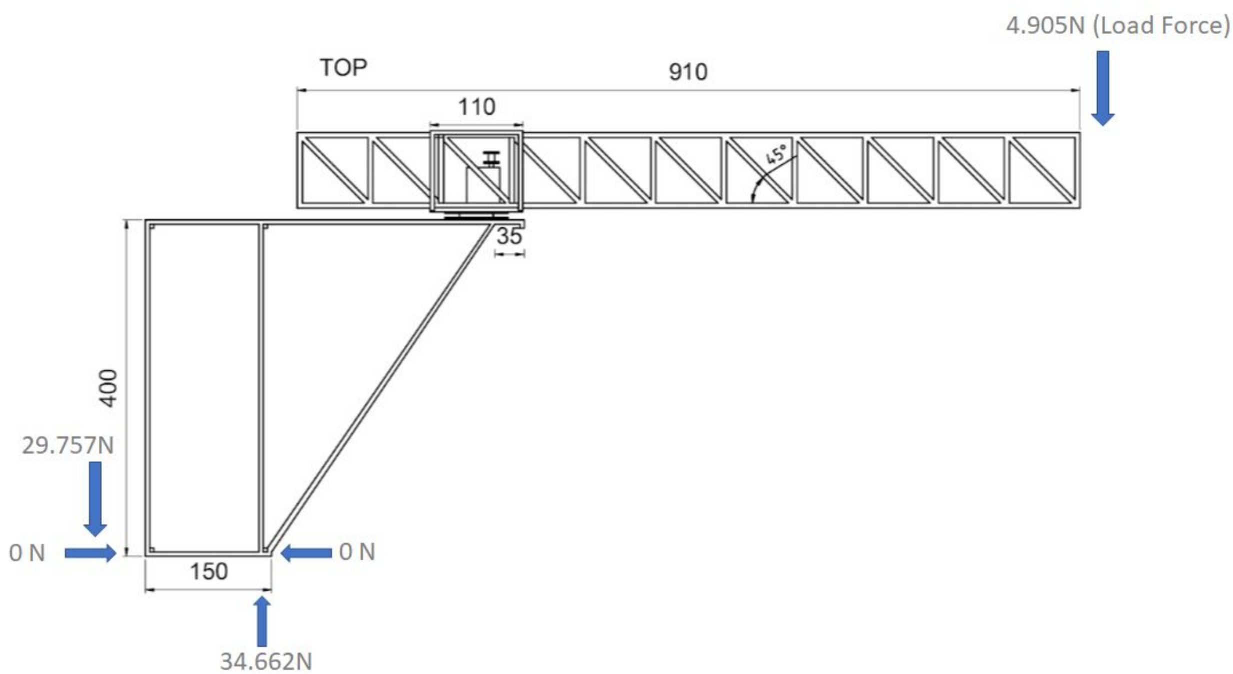
[Table - Data of 5x5mm balsa compression test]

Testing of 3x3mm balsa found to hold a critical compressive force ranging from 67N - 52.2N; demonstrating 79mm balsa is not strong enough for our design. This further supported the use of 5x5mm balsa, which ranged from 400.1N-386.8N respectively, to be used for our truss.

The critical forces for 5x5mm are above that of our safety value, showing that this selection can meet this regulation. However, this shows that member failure will not be possible under the conditions; joint failure must be investigated for our truss.
Given the weight regulations of 1.5kg for the project, the base had to be constructed with durable materials that didn't exceed said regulations. HDF-wood has been utilised for the base construction (with assorted support beams) due to its durability and mass. This will be further discussed in section 4.1; 'Final Design'.

Balance/bolt force calculations

Our design has eliminated the dependency on a counterweight for balance by utilising bolt supports to minimise inertia and ensure the balance of action-reaction forces. The inclusion of 4 bolt-holes on the base of the design is to be used respectively to the testing board; the balance forces can be seen in figure 3.1.1 below.

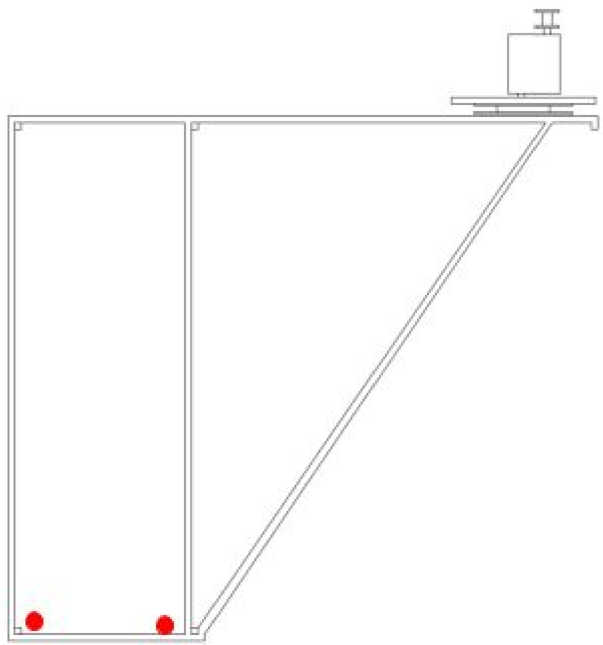


[Figure 3.1.1.1 - Action-Reaction forces of base / balance forces]
The concentric tensile force acting on the bolts is the sum of moments acting upon them; amounting to 34.662N. The concentric tensile force demands a reaction force of the same quantity to assure balance is kept. To combat this, the base is to be directly attached to the testing board via bolt connections. The connection is concentrically loaded through four bolt connections; where each bolt has identical cross sectional areas to one another. This means each bolt is experiencing 8.67N of tensile force. (see appendices for calculations).

Truss Testing

Truss testing on the completed design found the truss to be reliable to relocate the 5kg object. The initial force of lifting the object did not impede on the truss's structure or joints, allowing for a successful relocation.

Component selection

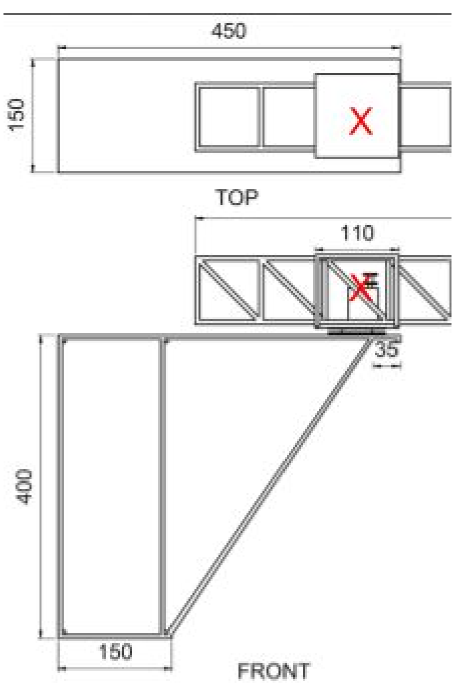


The objective of this base is to neutralize the need to extend or retract the horizontal length of the truss. As a result, it places the pivot point of the truss over the centre of the model area to ensure the same distance is kept between the pickup and drop off point.

The base was constructed of HDF wood**.** As it is light enough to be under the 4kg maximum weight, it also is structural strong enough to not break under the stress of lifting the mass.

The base is set to line up with the 4 bolt points on the testing board; these points are marked as red crosses in figure 3.1.2.

[*Figure 3.1.1.2 - Base design with motor positioning*]



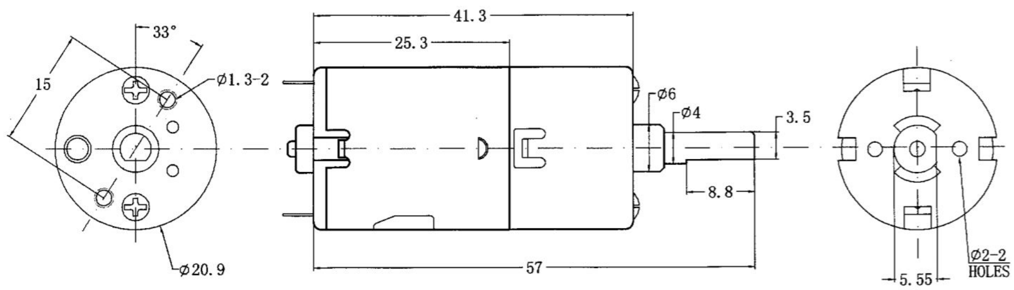
Truss + Motor positioning:
The motor will be placed at point X. The reason for this is because the 450mm extension allows the point of rotation to be in the centre of the board. The truss will also be places so that 310mm extends into the base, this means that the base extension from the motor is 600mm. This allows the truss to rotate and reach both pedestals.

The bearing is attached to a cage that rotates the truss, as it applies an equal force to all side of the truss, reduction torsion on the truss when in motion.
The joints consist of the HDF wood superglued to other members with gusset plates to reduce joint stress. The bearing and base are bolted onto each other as it is capable of withholding greater stress than glue.

3.1.2 Mechanical Design

Lifting Mechanism

Our lifting mechanism includes a 12VDC reversible gear-head motor purchased from 'Jaycar'; holding capabilities of 2100g·cm of torque at 70rpm, with a current draw of 390mA (JayCar, 2019).



[*Figure 3.1.2.1 - Diagram of gear-head motor including dimensions in 'mm'*]

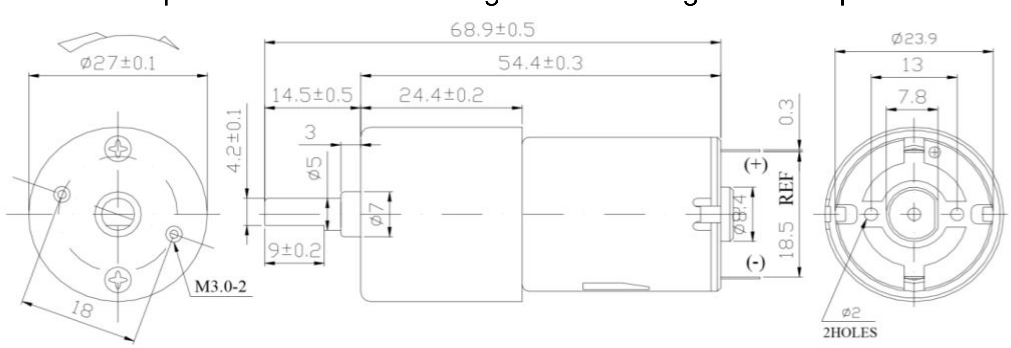
[*Sourced from JAYCAR,* /www.jaycar.com.au/medias/sys_master/images/9244423651358/YG2732-dataSheetMain.pdf]

With the specifications given, the electro-mechanical values including operating torque, lifting speed, required power, and operating efficiency are obtainable. Our operating torque sits at a modest 6.78g·cm, drastically below the stall torque of 2100g·cm demonstrating the motors ability to lift the 0.5kg object (see appendices for torque analysis). This will be done so at an approximate speed of 0.089cm/s as found through a speed analysis, using a drum of 1 cm in radius.

The lifting motion draws a total current of 0.031 Amps, with a total power of 0.372 watts drawn at a 12 volt input; allowing an operating efficiency of 1.18%.

Pivoting Mechanism

To rotate the truss for the relocation of the object, a 'lazy-susan' bearing is being used in conjunction with a YG-2734 12VDC gear-head motor; also sourced from JayCar. Providing specifications of a full-load current of 1.39 Amps at 12000 g·cm of torque, it is ensured that the truss can be pivoted without exceeding the current regulations in place.



[*Figure 3.1.2.2 - Diagram of YG-2734 gear-head motor (measurements in 'mm')*]

[*Sourced from JAYCAR*, /www.jaycar.com.au/medias/sys_master/images/9244423979038/YG2734-dataSheetMain.pdf]

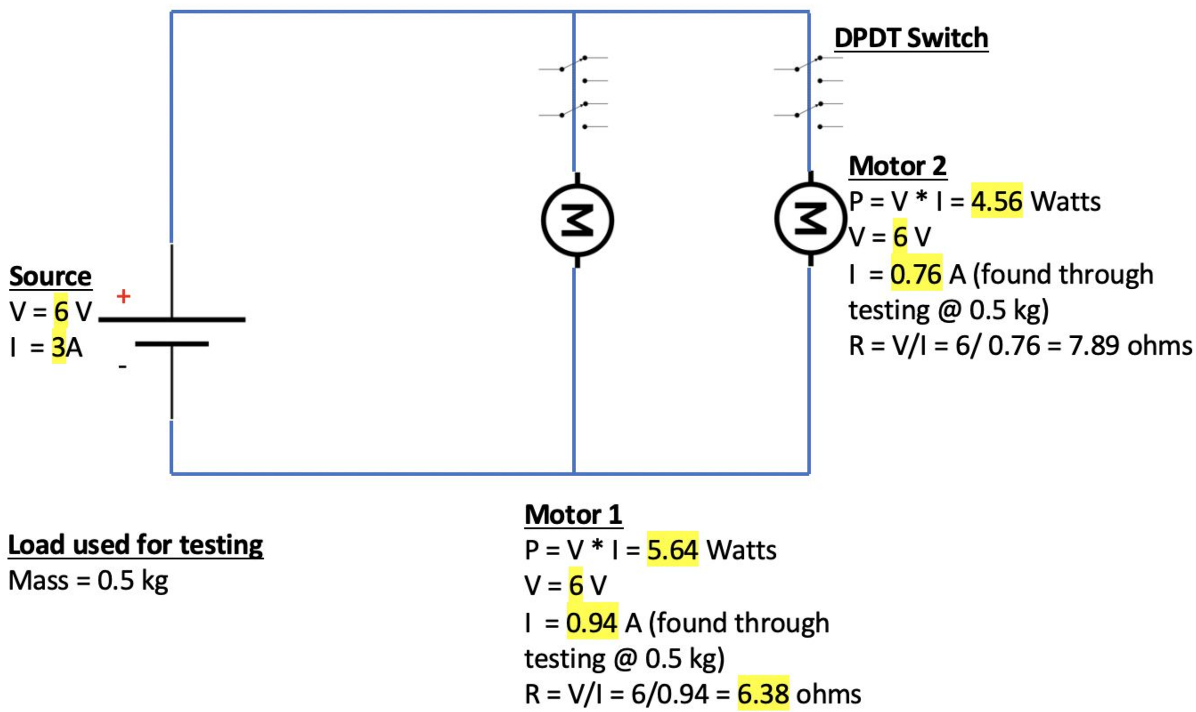
This motor was selected due to its high gear ratio of 244:1; allowing for a slow turning speed with a high level of torque. This is due to the dynamic forces acting upon the design (resultant of dynamic loading) that heighten the risk of damaging/breaking the system. The higher gear ratio ensures the rotation is consistent; mitigating possibilities of failure.

Overall, the motor is connected in horizontal with the truss; while the truss is attached onto the top of the ‘lazy-susan’ bearing. The rotation component of the motor pivots the truss at a consistent speed, smoothly on-top of the bearing.

Mechanical System Testing

The purpose of mechanical system testing was to ensure there was a system failure between a 1kg-1.5kg load to meet project regulations. As the system was running efficiently with both no-load and 0.5kg conditions, gradual weight was added to force a stall torque upon the lifting mechanism; as this is the weaker motor.
Connected to a 6V power supply, at the approximate half-way point on the lift, mechanical failure became evident. The motor stall occurred while lifting an object 1kg in mass, while drawing 0.1 amps of current. As the current drawn remained below project regulations and the object being heavier than 0.5kg, our mechanical system will pass the relevant safety test of not being ‘over-engineered’.

3.1.3 Circuit Design



[Figure 3.1.3.1 - Circuit Diagram of Electrical System]

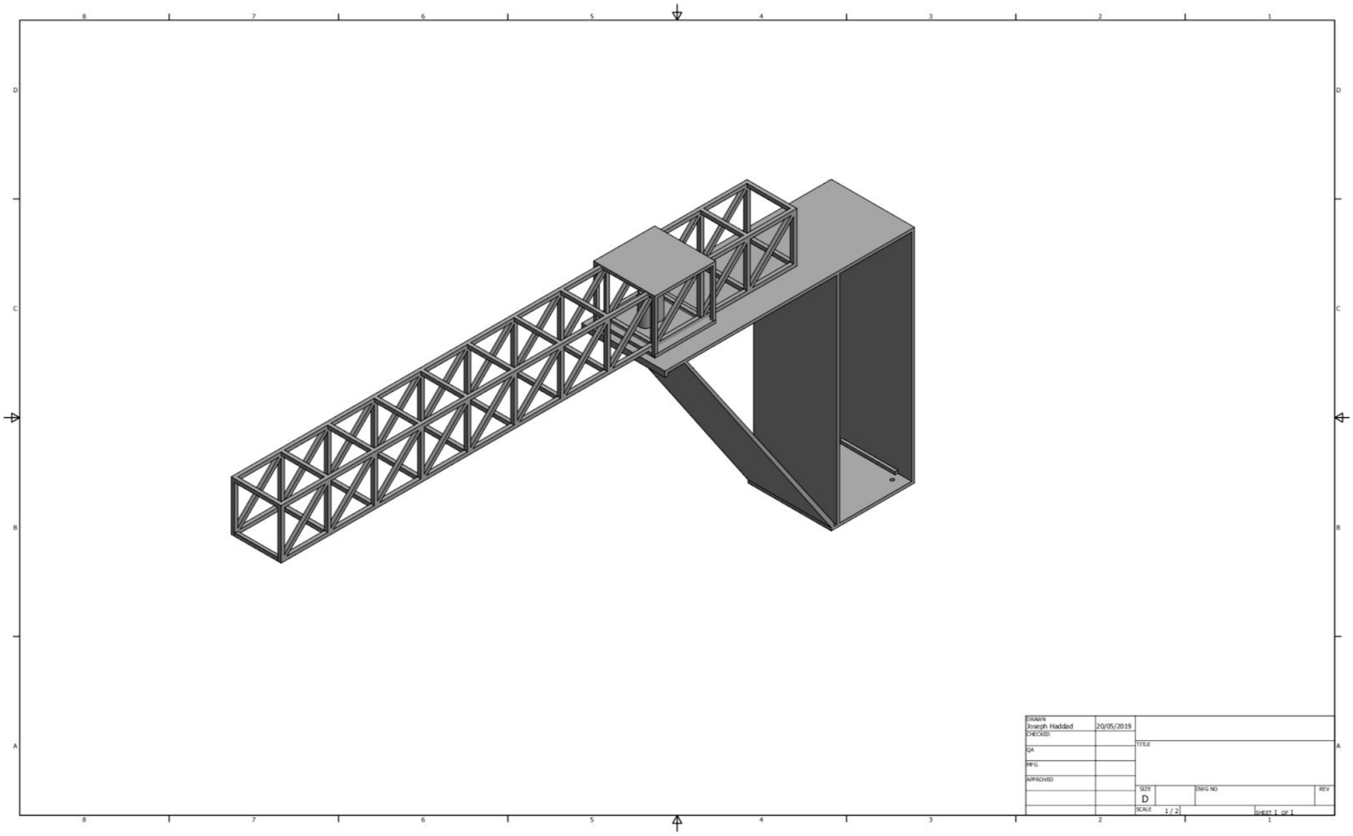
Given regulations of a 10 watt power limit, with a supply of 3 Amps and 6 Volts to relocate the 0.5kg load, the development of a circuit consistent of a variety of components is demanded. The use of preliminary testing results has allowed for the manipulation of the present circuit components to meet said regulations.

Current acts as a multiplier for power usage in this scenario as the formula which relates Power, Current and Voltage is "P = V*I". If the current is not reduced the system will draw 18W (6v*3A), drastically exceeding the power regulations outlined.

In order to assist the dropping of current, the circuit has been wired in parallel; allowing the current to split across each motor, provoking a decrease of current while the voltage is retained at its original value. Conveniently, the resistance of each motor eliminates the need for further implementation of resistors within the circuit; allowing the system to lower the current below 1 Amp for both motors.

4.1 Final Design

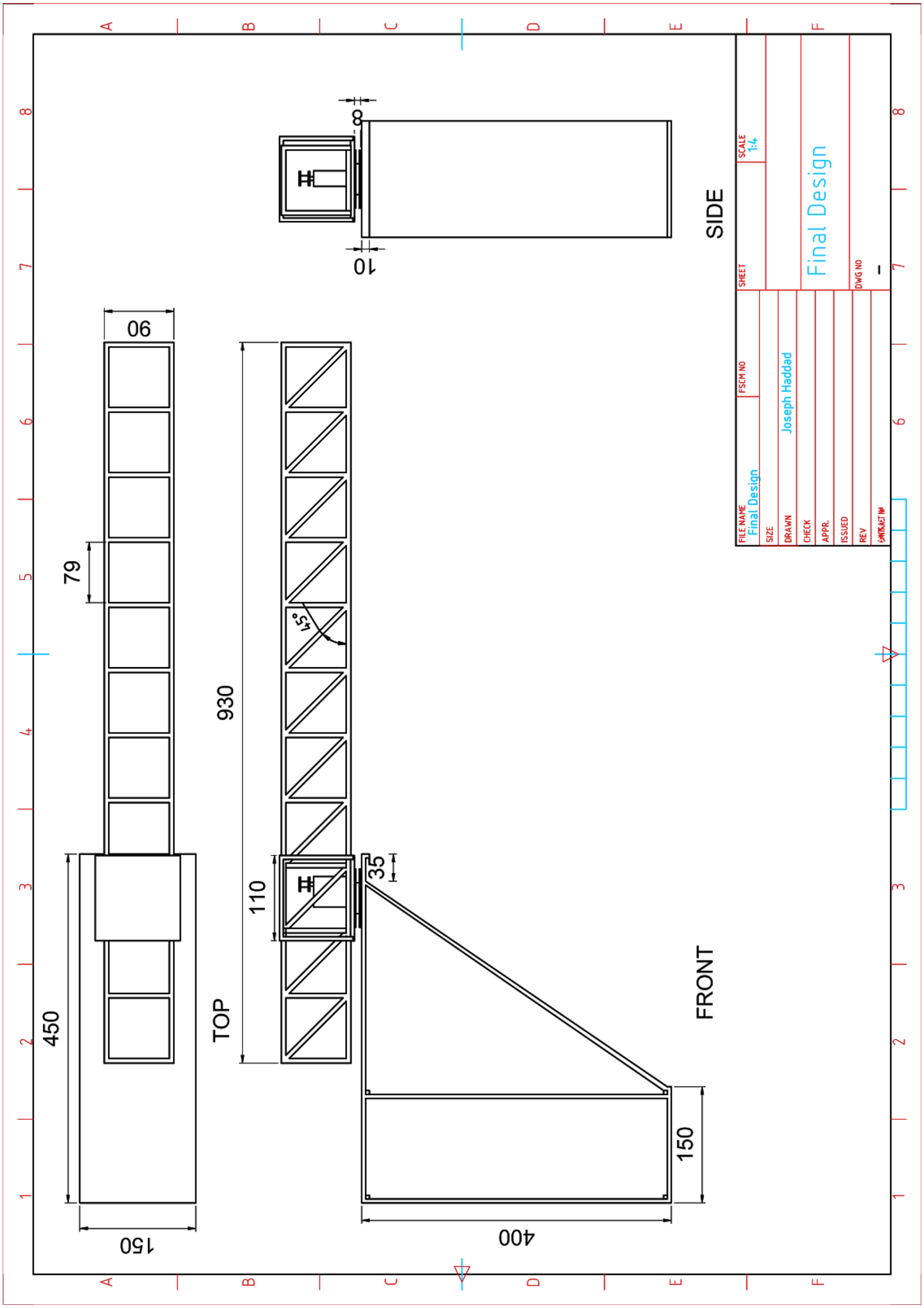
4.1.1 Detailed Description of the Design



[Figure 4.1.1.1 - Isometric Drawing of Final Design]

Shown above is the final iteration of the design, including the truss and base (A photo of the constructed truss is provided in appendix 5). The base, dimension wise, is very similar to the previous iteration, with a key difference being the removal of the components shelf. Instead, a wooden box has been built around the truss to allow it to be placed onto the bearing whilst having the motors placed inside it. Creating a central area for the mechanical system. As mentioned before, the truss is still located centrally between the mass relocation points and via a lazy susan bearing, allowing horizontal movement between them to be possible.

The materials used for the base construction are quite simple, only requiring HDF wood for the shell, and a hot glue gun to connect the joints. This will ensure the base can endure the required loads that will be placed on it. While the truss itself will be constructed of 5mm by 5mm balsa wood.


SIDE
TOP
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45°
450
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400
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FILE NAME
Final Design
SIZE
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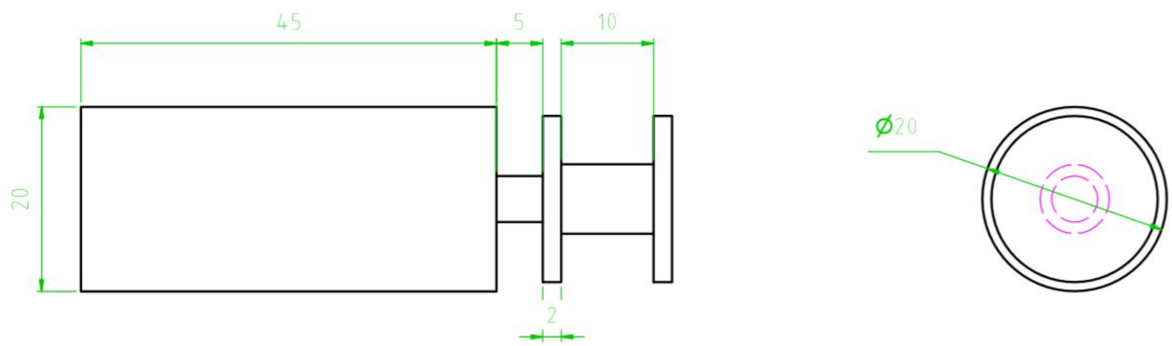
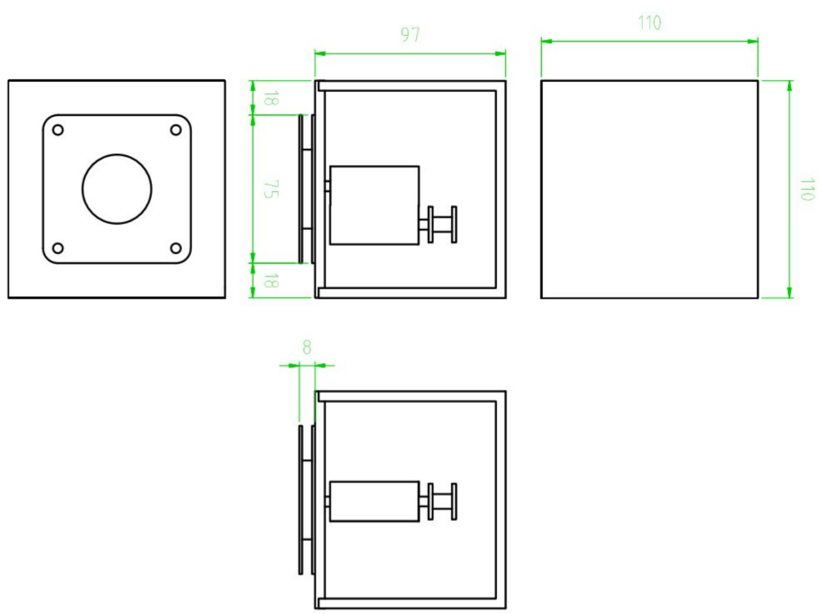


Motor and Drum - Detailed Dimensions
[Figure 4.1.1.2 - Motor and Drum]



Bearing and Truss Holder (Horizontal Movement Component) - Detailed Dimensions
[Figure 4.1.1.3 - Horizontal Movement Component]

4.1.2

Criteria Number	**FInal Design Objectives**
1	Successfully lift 0.5kg mass 50mm.
2	Relocate a 0.5 kg mass from Pedestal A to B in under 45 seconds in optimal scenario, or under 1.5 min as a worst case.
3	Total weight optimally under 1.5 kg and in the worst case is under 4kg.
4	Peak running power is less than 10 watts.
5	Electromechanical system is designed with a safety factor of between 1 and 2.
6	The main truss is designed with a safety factor of between 2 and 3.

Testing Results Compared to Calculations		
	Testing Results	**Calculations**
Truss Factor of Safety	Was unable to break at 1.5kg	Calculations show a critical compressive strength of 49.05N. Since the compressive strength of the 5x5 balsa is much greater than this it did not break.
Electromechanical system factor of safety.	Was able to lift 0.5 kg but stalled at 1kg.	By lowering the current the motors are provided with, the torque of the motor is decreased, as an increase / decrease in current at constant load is proportional with torque. The current was lowered through the circuit in parallel, as the current will split.
Ability to lift 0.5 kg mass	Can lift 0.5 kg load	Stall Torque = 2100g.cm The operating torque was calculated to be (6.78 g.cm), being below the stall torque, it's easily able to lift the 500g
10 Watt running power	Ran under 10 Watts	As shown in the circuit analysis, the power formula was used and was found that the peak running power was less than 10 watts.

Refer to appendix for worked calculations.

Criteria Number	**Testing Results, How They Validate Performance & Process**
1	Through testing, it was found that the completed crane system was able to lift the 0.5 kg mass without stalling, reaching a height 50mm successfully. Method of testing involved bolting the completed crane and connecting it to a power supply which supplies 6V and 3A. The mass was then lifted by the electromechanical system and the height was measured using a ruler.
2	Experimentation proved that the design was able to meet the optimal time requirements and beat the 45 second limit. The process of testing this involved a full trial experiment with a weight timer and completed crane. In an open area timed testing was performed moving a weight from A to B.
3	Even though the total weight of the device itself is 1.450 kg, it requires a 1kg counterweight in order to allow for horizontal movement, which reduces the performance of the crane from being optimal "<1.5 kg" to now just being under 4kg. The need for the counterweight was identified through testing as the motor was unable to grip onto the bearing and spin it without being stabilised by the weight.
4	The peak current draw at 6V is less than 1 amp meaning that the overall power draw of the system is less than 10 watts. This was tested through the use of a multimeter connected in series with the circuit. Results were taken from operational experiments under the loads it will face during testing.
5	Electromechanical systems design was able to stall within the set safety factor. Achieving this challenge was done through testing at the desired safety factor failure loads and determining whether resistance was needed to drop the current allowing for the system to stall / fail to lift or relocate the mass.
6	Due to use of the 5x5 mm balsa, testing this was unsuccessful. The compressive strength of the material. Allowed for 1.5 kg to be added to the truss without any damages structurally.

Cost Breakdown	
Time	**Money**

- Launch Pad
    - Material Testing = 2 hrs
    - Laser Cutting = 2 hrs
    - Truss Construction = 6 hrs
- Out of uni time
    - Electrical and mechanical systems construction = 6 hrs
    - Overall Assembly = 6 hrs
 	
Total Time = 24hrs
	- Gear Motor x2 = 14.95 + 23.45 = $38.4
	- Wire = $5.60
	- Lazy Susan Bearing = $3.90
	- Drum = $3
	
	Total Cost = $42.4

Equipment	
- Power Supply - Laser Cutter - Super Glue/ Hot Glue Gun - Balsa Wood 5x5 mm - HDF - Various Launchpad Tools	

5.1 Design Performance Evaluation

For this project, we had some clear final design objectives which had to be met in order to successfully complete this task. These objectives include lifting a 0.5kg mass 50mm high, moving a 0.5kg mass from pedestal A to pedestal B in under 45 seconds, or 90 seconds in the worst case scenario, mass of crane under 1.5 kg or 4 kg worst case scenario, peak running power of less than 10 watts, safety factor between 1 and 2 for the electromechanical systems and a safety factor of between 2 and 3 for the truss.

Most of the previously described objectives were successful, as the crane successfully lifted a mass of 0.5kg 5cm high, moved the mass from pedestal A to B in 19 seconds (26 seconds under the goal), ran at a peak power of 5.64 Watts (4.36 Watts under the goal), and reached the intended electrical safety factor of 1-2.

However, some of our goals were not reached, being the optimal weight and the safety factor of the truss itself. The optimal weight was not successful despite the crane only weighing 1.45kg, as a 1kg counterweight had to be added for the crane to be successfully operational, as the truss would slip when picking up the load to be transferred, so the counter-weight had to be added to allow rotation. The safety factor of the truss was also a failure, as to reach a safety factor of 2-3, the truss must be able to lift up to 1kg, and must have a structural failure, preferably at a member, at 1.5kg. Our truss successfully lifted 1kg, but did not have a structural failure at 1.5kg, making the overall mechanical safety factor above 3, not reaching our intended objective.

6.1 Recommendations and Conclusions

Some recommendations and changes can be made to the crane to improve the performance and reach our intended objectives. Firstly, to satisfy the weight requirement of the project, some aspects of the base can be adjusted, such as using a less dense material, such as balsa, instead of the dense HDF wood currently being used. This would dramatically reduce the weight of the overall design, allowing us (with minor adjustments to the horizontal motor connections), to use a counter-weight on the back of the truss to allow a horizontal rotation without reaching mechanical failure on the system. Another recommendation that we would incorporate with a next attempt would be the use of 3mm x 3mm balsa wood instead of the currently used 5mm x 5mm balsa. This would allow the system to reach an optimal safety rating of 2 or 3, as our current design did not break under the required 1.5kg load to reach that optimal safety rating.

To conclude this report, the design process and outcome of this project can be considered a success; as the majority of task regulations were satisfied. The object was relocated successfully within 45 second time frame, while drawing under the peak power requirement of 10 watts. Furthermore,the safety of the electromechanical system was met, giving an approximate safety rating of 1 and demonstrating motor failure under the 1.5kg load. However, some goals were not reached, as the design being too heavy, and did not fit the optimal weight of 1.5kg, narrowly missing the goal by approximately 1kg. The final objective was reaching a safety rating of 2 or 3 for the mechanism. This would have been achieved if the crane successfully lifted the 0.5kg and 1kg weights, while also breaking on the 1.5kg. Our design unfortunately did not reach this goal, and didn’t break when lifting the 1.5kg weight, due to the truss being over-engineered. This can be improved by using the previously stated recommendations, such as using 3x3 balsa wood to limit the member strength, allowing the truss to successfully experience member failure with the intended weights.

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Appendices

Appendix 1

Material Testing Data

Material – Balsa Wood

Cross Sectional Area = 5x5 = 25mm^2

Compression Test			
Balsa(5mm)	50mm	75mm	100mm
Test 1	422.9N	415.8N	454.7N
Test 2	519.3N	368.7N	379.8N
Test 3	377N	415.8N	326.1N
Average	439.7N	400.1N	386.8N

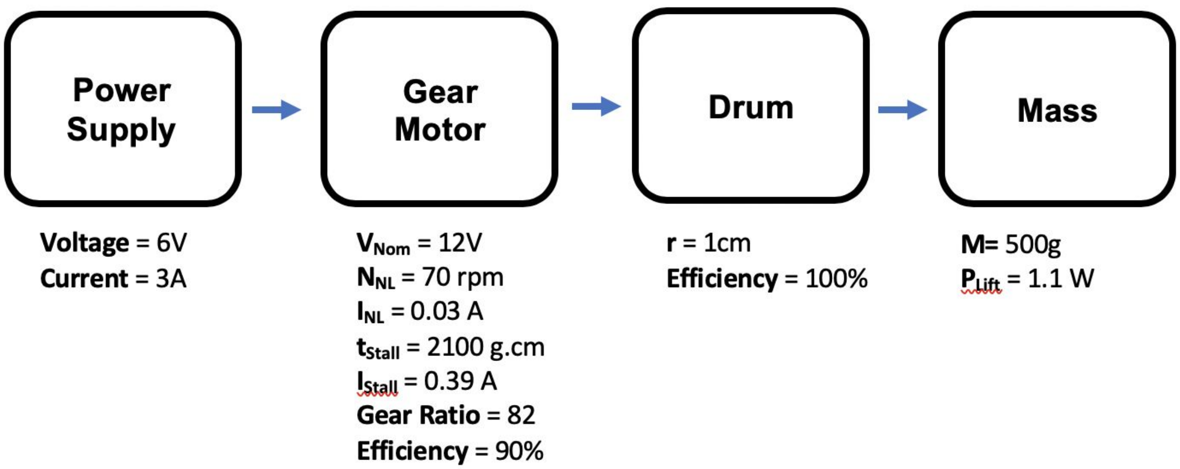
Material – Balsawood

Cross Sectional Area = 3x3 = 9mm^2

Compression Test			
Balsa(3mm)	50mm	75mm	100mm
Test 1	127.3N	46.9N	51N
Test 2	126.4N	80.1N	50.6N
Test 3	110.1N	74N	54.9N
Average	121.3	67	52.2

Appendix 2

Mechanical Calculations



<u>Torque Analysis</u>

T_{Drum} = Force * Radius

= 500g * 1cm

= 500g.cm

T_{Motor} = T_{Drum} / (Gear Ratio * Efficiency Gear)

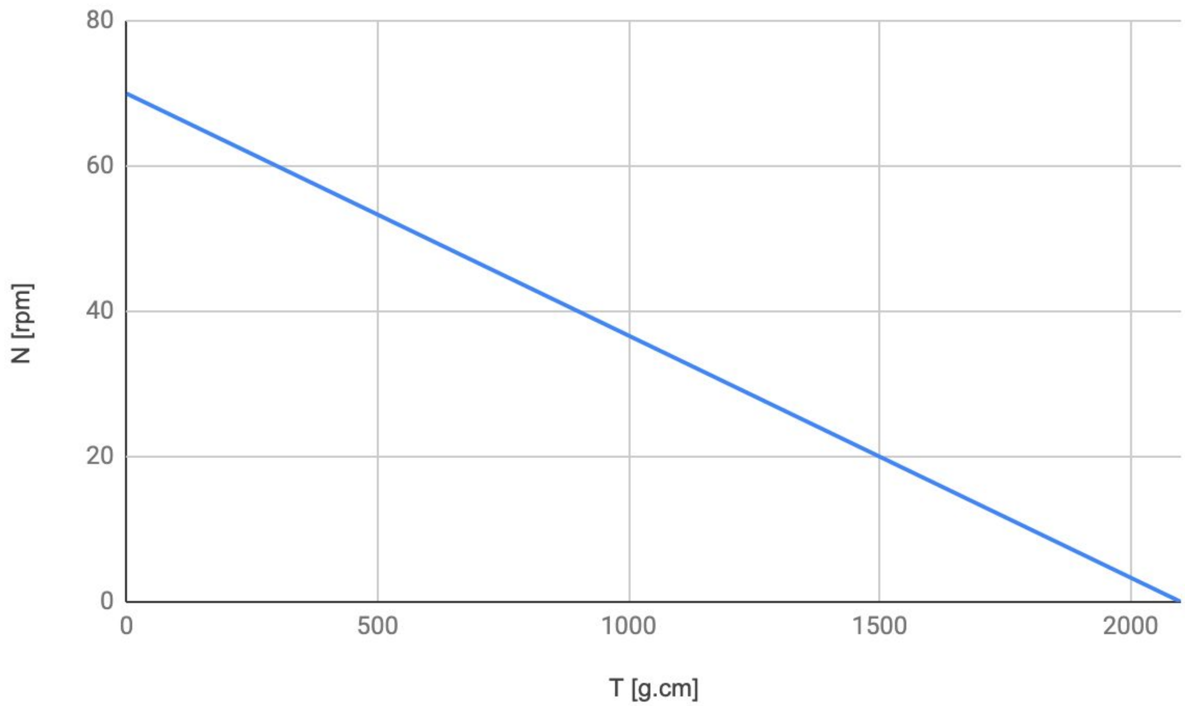
= 500 / (82 * 0.9)

= 6.78 g.cm = Operating Torque

Stall Torque = 2100g.cm

Therefore, the motor can lift the 500g mass since the operating torque (6.78 g.cm) is below the stall torque (2100 g.cm)

Speed Analysis



N [rpm] = (-70/2100) * T [g/cm] + 70

= (-70/2100) * 6.78 + 70

N_{Motor} = 69.774 rpm

N_{Drum} = N_{Motor} / Gear Ratio = 69.774 / 82 = 0.85 rpm

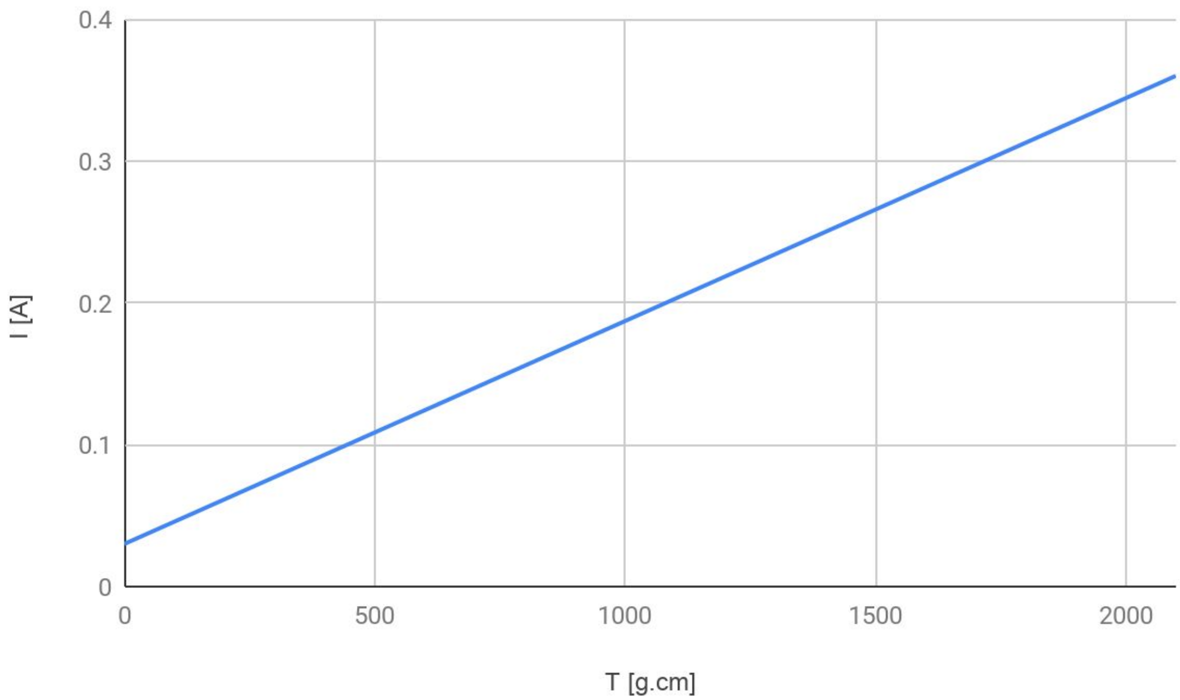
W_{Drum} = (2pi / 60) * N_{Drum}

= (2pi / 60) * 0.85

= 0.089 rad/s

Velocity = W_{Drum} * radius = 0.089 * 1 = 0.089cm/s

Power Analysis



I [A] = ((0.39 - 0.03) / 2100) * T [g.cm] + 0.03

= ((0.39 - 0.03) / 2100) * 6.78 + 0.03

= 0.031 Amps

This is below the supply limit of 3 Amps therefore, meets the power criteria.

Power Input -> P_{in} = V * I

= 12 * 0.031 = 0.372 Watts

Power Output -> P_{in} = F * V

= ((500/1000) * 9.81) * 0.00089

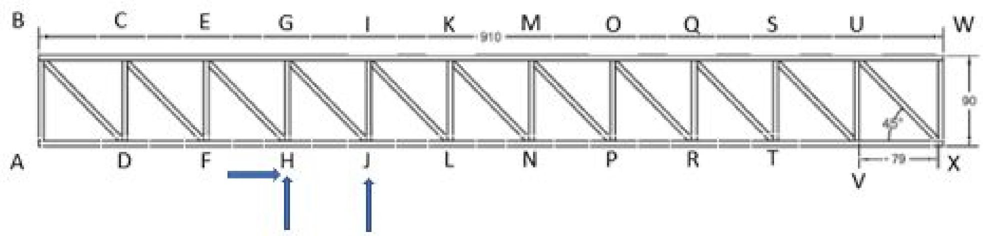
= 0.0044 Watts

Operating efficiency = (P_{in}/P_{out}) * 100

= (0.0044/0.372) * 100 = 1.2% efficiency

Truss Calculations

Appendix 3



Truss determinacy

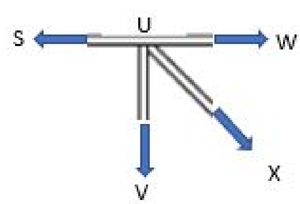
2J = M + R

2 × (24) = 45 + 3

∴ The truss design is determinant, therefore method of joints can be applied.

Method of Joints

Example of Calculations:



$\sum f_y = 0$

$= - f_{ux}\, sin(45) - f_{uv}$

$f_{uv} = - (- 3.47)\, sin(45)$

$f_{uv} = 2.45$ N (T)

$\sum f_x = 0$

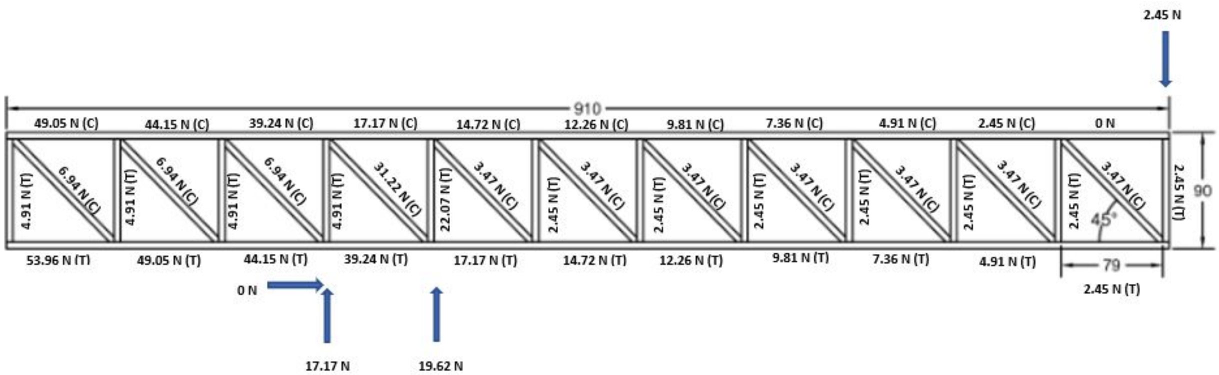
$= f_{ux}\, cos(45) + f_{uw} - f_{uv}$

$= (- 3.47)\, cos(45) + 0 - f_{uv}$

$f_{uv} = - 2.45$ N (C)

Table of Results:

Members				
AB = 4.905 N (T)	**ST** = 2.45 N (T)	**NP** = 12.26 N (T)	**IK** = 14.72 N (C)	**EH** = 6. 94 N (C)
CD = 4.905 N (T)	**UV** = 2.45 N (T)	**PR** = 9.81 N (T)	**KM** = 12.26 N (C)	**GJ** = 31.22 N (C)
EF = 4.905 N (T)	**WX** = 2.45 N (T)	**RT** = 7.36 N (T)	**MO** = 9.81 N (C)	**IL** = 3.47 N (C)
GH = 4.905 N (T)	**AD** = 53.96 N (T)	**TV** = 4.91 N (T)	**OQ** = 7.36 N (C)	**KN** = 3.47 N (C)
IG = 22.07 N (T)	**DF** = 49.05 N (T)	**VX** = 2.45 N (T)	**QS** = 4.91 N (C)	**MP** = 3.47 N (C)
KL = 2.45 N (T)	**FH** = 44.14 N (T)	**BC** = 49.05 N (C)	**SU** = 2.45 (C)	**OR** = 3.47 N (C)
MN = 2.45 N (T)	**HJ** = 39.24 N (T)	**CE** = 44.15 N (C)	**UW** = 0 N	**QT** = 3.47 N (C)
OP = 2.45 N (T)	**JL** = 17.17 N (T)	**EG** = 39.24 N (C)	**BD** = 6. 94 N (C)	**SV** = 3.47 N (C)
QR = 2.45 N (T)	**LN** = 14.72 N (T)	**GI** = 17.17 N (C)	**CF** = 6. 94 N (C)	**UX** = 3.47 N (C)



Truss Analysis Calculations

Reaction Force:

$\sum M_H = 0$

$= -2.45(661.81) + f_j(82.72)$

$f_j = 19.62$ N up

$\sum f_y = 0$

$= -2.45 + f_j + f_{Hy}$

$= 17.17 + f_{Hy}$

$f_{Hy} = 17.17$ N down

$\sum f_x = 0$

$f_{Hx} = 0$ N

Member forces:

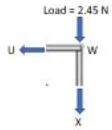
$\sum f_y = 0$

$= - f_{wx} - (-2.45)$

$f_{wx} = 2.45$ N (T)

$\sum f_x = 0$

$f_{wu} = 0$ N



$\sum f_y = 0$

$= f_{xu}\ sin(45) + f_{xw}$

$= f_{xu}\ sin(45) + 2.45$

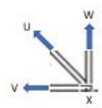
$f_{xu} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{xu}\ cos(45) - f_{xv}$

$= -(-3.47)\ cos(45) - f_{xv}$

$f_{xv} = 2.45$ N (T)



$\sum f_y = 0$

$= - f_{ux}\ sin(45) - f_{uv}$

$f_{uv} = -(-3.47)\ sin(45)$

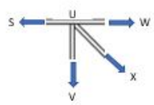
$f_{uv} = 2.45$ N (T)

$\sum f_x = 0$

$= f_{ux}\ cos(45) + f_{uw} - f_{us}$

$= (-3.47)\ cos(45) + 0 - f_{us}$

$f_{us} = -2.45$ N (C)



$\sum f_y = 0$

$= f_{vs}\ sin(45) + f_{vu}$

$= f_{vs}\ sin(45) + 2.45$

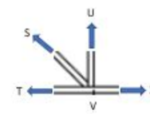
$f_{vs} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{vs}\ cos(45) - f_{vt} + f_{vx}$

$= -(-3.47)\ cos(45) - f_{vt} + 2.45$

$f_{vt} = 4.905$ (T)



$\sum f_y = 0$

$= - f_{sv}\ sin(45) - f_{st}$

$f_{st} = -(-3.47)\ sin(45)$

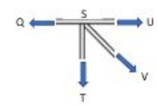
$f_{st} = 2.45$ N (T)

$\sum f_x = 0$

$= f_{sv}\ cos(45) + f_{su} - f_{sq}$

$= (-3.47)\ cos(45) - 2.45 - f_{sq}$

$f_{sq} = -4.905$ N (C)



$\sum f_y = 0$

$= f_{tq}\ sin(45) + f_{ts}$

$= f_{tq}\ sin(45) + 2.45$

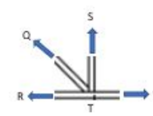
$f_{tq} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{tq}\ cos(45) - f_{tr} + f_{tv}$

$= -(-3.47)\ cos(45) - f_{tr} + 4.905$

$f_{tr} = 7.35$ (T)



$\sum f_y = 0$

$= - f_{qt}\ sin(45) - f_{qr}$

$f_{qr} = -(-3.47)\ sin(45)$

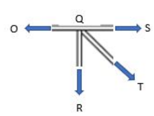
$f_{qr} = 2.45$ N (T)

$\sum f_x = 0$

$= f_{qt}\ cos(45) + f_{qs} - f_{qo}$

$= (-3.47)\ cos(45) - 4.905 - f_{qo}$

$f_{qo} = -7.35$ N (C)



$\sum f_y = 0$

$= f_{ro}\ sin(45) + f_{rq}$

$= f_{ro}\ sin(45) + 2.45$

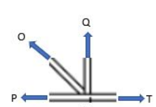
$f_{ro} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{ro}\ cos(45) - f_{rp} + f_{rt}$

$= -(-3.47)\ cos(45) - f_{rp} + 7.35$

$f_{rp} = 9.81$ (T)



$\sum f_y = 0$

$= - f_{or}\ sin(45) - f_{op}$

$f_{op} = -(-3.47)\ sin(45)$

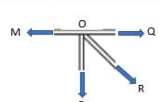
$f_{op} = 2.45$ N (T)

$\sum f_x = 0$

$= f_{or}\ cos(45) + f_{oq} - f_{om}$

$= (-3.47)\ cos(45) - 7.35 - f_{om}$

$f_{om} = -9.81$ N (C)



$\sum f_y = 0$

$= f_{pm}\ sin(45) + f_{po}$

$= f_{pm}\ sin(45) + 2.45$

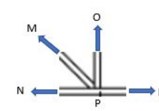
$f_{pm} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{pm}\ cos(45) - f_{pn} + f_{pt}$

$= -(-3.47)\ cos(45) - f_{pn} + 7.35$

$f_{pn} = 12.26$ N (T)



$\sum f_y = 0$

$= - f_{mp}\ sin(45) - f_{mn}$

$f_{mn} = -(-3.47)\ sin(45)$

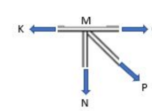
$f_{mn} = 2.45$ N (T)

$\sum f_x = 0$

$= f_{mp}\ cos(45) + f_{mo} - f_{mk}$

$= (-3.47)\ cos(45) - 7.35 - f_{mk}$

$f_{mk} = -12.26$ N (C)



$\sum f_y = 0$

$= f_{nk}\ sin(45) + f_{nm}$

$= f_{nk}\ sin(45) + 2.45$

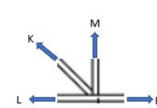
$f_{nk} = -3.47$ N (C)

$\sum f_x = 0$

$= - f_{nk}\ cos(45) - f_{nl} + f_{np}$

$= -(-3.47)\ cos(45) - f_{nl} + 12.26$

$f_{nl} = 14.72$ N (T)

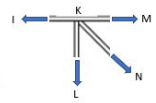


$\Sigma f_y = 0$

$= -f_{kn}\,sin(45) - f_{kl}$

$f_{kl} = -(-3.47)\,sin(45)$

$f_{kl} = 2.45$ N (T)



$\Sigma f_x = 0$

$= f_{kn}\,cos(45) + f_{km} - f_{ki}$

$= (-3.47)\,cos(45) - 12.26 - f_{ki}$

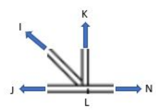
$f_{ki} = -14.72$ N (C)

$\Sigma f_y = 0$

$= f_{li}\,sin(45) + f_{lk}$

$= f_{li}\,sin(45) + 2.45$

$f_{li} = -3.47$ N (C)



$\Sigma f_x = 0$

$= -f_{li}\,cos(45) - f_{lj} + f_{ln}$

$= -(-3.47)\,cos(45) - f_{lj} + 14.72$

$f_{lj} = 17.17$ N (T)

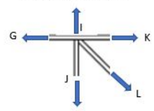
$\Sigma f_y = 0$

$= -f_{il}\,sin(45) - f_{ij} + f_j$

$f_{ij} = -(-3.47)\,sin(45) + 19.62$

$f_{ij} = 22.07$ N (T)

Reaction force = 19.62 N



$\Sigma f_x = 0$

$= f_{il}\,cos(45) + f_{ik} - f_{ig}$

$= (-3.47)\,cos(45) - 14.72 - f_{ig}$

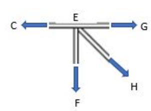
$f_{ig} = -17.17$ N (C)

$\Sigma f_y = 0$

$= -f_{eh}\,sin(45) - f_{ef}$

$f_{ef} = -(-6.94)\,sin(45)$

$f_{ef} = 4.905$ N (T)



$\Sigma f_x = 0$

$= f_{eh}\,cos(45) + f_{eg} - f_{ec}$

$= (-6.94)\,cos(45) - 39.24 - f_{ec}$

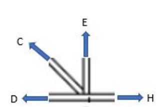
$f_{ec} = -44.145$ N (C)

$\Sigma f_y = 0$

$= f_{fc}\,sin(45) + f_{fe}$

$= f_{fc}\,sin(45) + 4.905$

$f_{fc} = -6.94$ N (C)



$\Sigma f_x = 0$

$= -f_{fc}\,cos(45) - f_{fd} + f_{fh}$

$= -(-6.94)\,cos(45) - f_{fd} + 44.145$

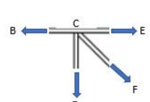
$f_{fd} = 49.05$ N (T)

$\Sigma f_y = 0$

$= -f_{cf}\,sin(45) - f_{cd}$

$f_{cd} = -(-6.94)\,sin(45)$

$f_{cd} = 4.905$ N (T)



$\Sigma f_x = 0$

$= f_{cf}\,cos(45) + f_{ce} - f_{cb}$

$= (-6.94)\,cos(45) - 44.145 - f_{cb}$

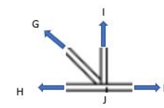
$f_{cb} = -49.05$ N (C)

$\Sigma f_y = 0$

$= f_{jg}\,sin(45) + f_{ji}$

$= f_{jg}\,sin(45) + 22.07$

$f_{jg} = -31.22$ N (C)



$\Sigma f_x = 0$

$= -f_{jg}\,cos(45) - f_{jh} + f_{jl}$

$= -(-31.22)\,cos(45) - f_{jh} + 17.17$

$f_{jh} = 39.24$ N (T)

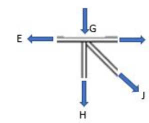
$\Sigma f_y = 0$

$= -f_{gj}\,sin(45) - f_{gh} - 17.17$

$f_{gh} = -(-31.22)\,sin(45) - 17.17$

$f_{gh} = 4.905$ N (T)

Reaction force = 17.17 N



$\Sigma f_x = 0$

$= f_{gj}\,cos(45) + f_{gi} - f_{ge}$

$= (-31.22)\,cos(45) - 17.17 - f_{ge}$

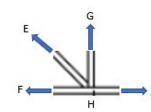
$f_{ge} = -39.24$ N (C)

$\Sigma f_y = 0$

$= f_{he}\,sin(45) + f_{hg}$

$= f_{he}\,sin(45) + 4.905$

$f_{he} = -6.94$ N (C)



$\Sigma f_x = 0$

$= -f_{he}\,cos(45) - f_{hf} + f_{hj}$

$= -(-6.94)\,cos(45) - f_{hf} + 39.24$

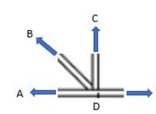
$f_{hf} = 44.145$ N (T)

$\Sigma f_y = 0$

$= f_{db}\,sin(45) + f_{dc}$

$= f_{db}\,sin(45) + 4.905$

$f_{db} = -6.94$ N (C)



$\Sigma f_x = 0$

$= -f_{db}\,cos(45) - f_{da} + f_{df}$

$= -(-6.94)\,cos(45) - f_{da} + 49.05$

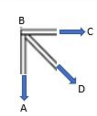
$f_{da} = 53.955$ N (T)

$\Sigma f_y = 0$

$= -f_{bd}\,sin(45) - f_{ba}$

$f_{ba} = -(-6.94)\,sin(45)$

$f_{ba} = 4.905$ N (T)



Appendix 4

Reaction Forces - Balance Forces

$\Sigma M_A = 0$

$0 = (F_{LOAD} * 1.06) + (F_{BY} * 0.15)$

$0 = -4.905 * 1.06 + F_{BY} * 0.15$

$5.1993 = F_{BY} * 0.15$

$F_{BY} = 34.662N$

$\Sigma F_y = 0$

$0 = -4.905 + F_{BY} + F_{AY}$

$F_{AY} = -4.905 + F_{BY} + F_{AY}$

$F_{AY} = 4.905 - 34.662$

$F_{AY} = -29.757N$

$\Sigma F_X = 0$
$0 = F_{BX} - F_{AX}$
Because there are no forces in the x coordinates F_{BX} *and* F_{AX} *are* $0N$.

Reaction Forces - Concentric Tensile Force on Bolts

$F_{CTF} = F_{BY}/4$
$F_{CTF} = 34.662/4$
$F_{CTF} = 8.6655N$

Appendix 5

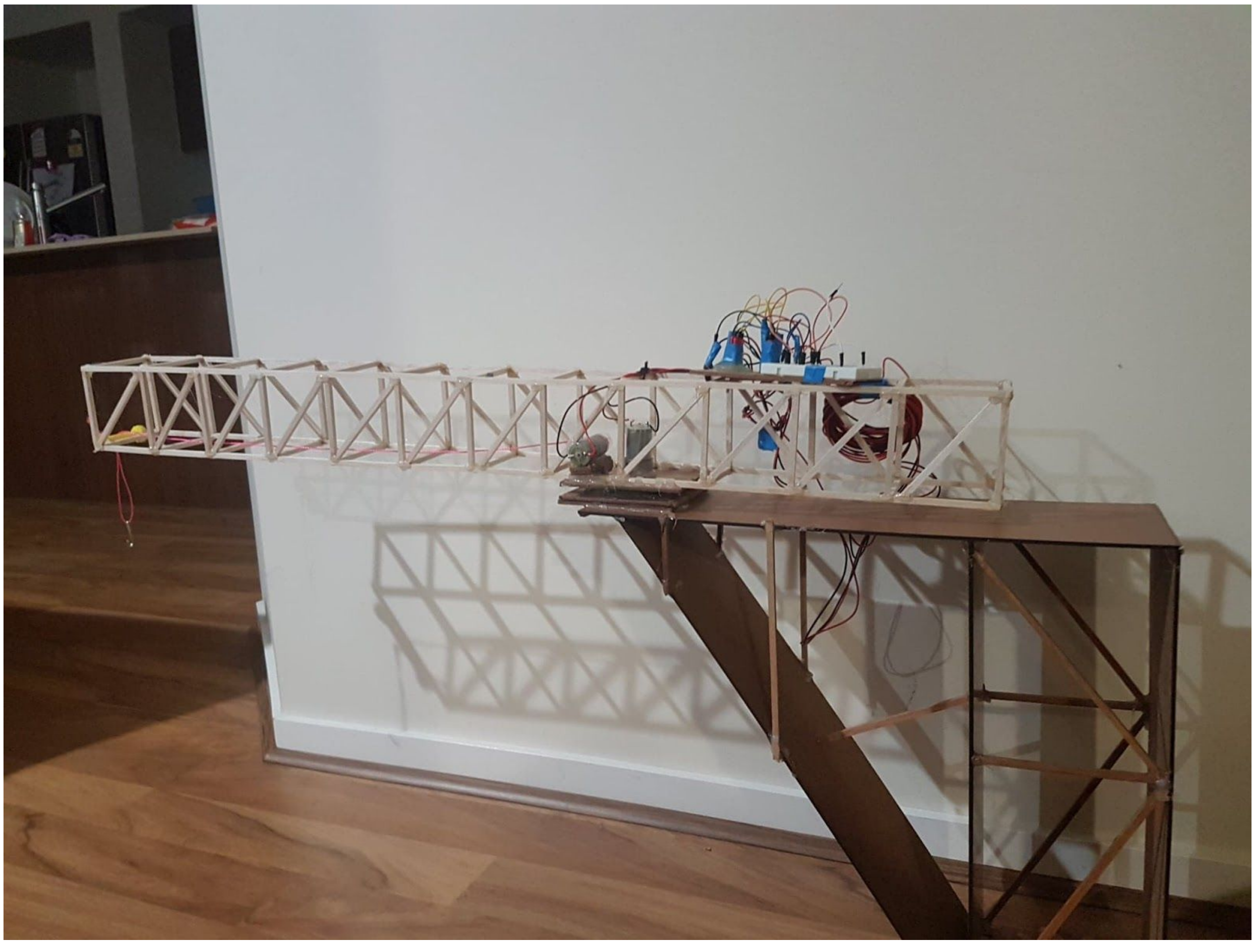


Image of the final completed design. Here the base features added supporting beams in order to allow it to be more stable when holding the load. As without them the base is unable to evenly distribute the load therefore, will fracture easily.
Should be good enough
Yeah just add and intext to their sections