TECHNICAL FILE

PROJECT ELECTRICAL DRIVES

GROUP 6

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Table of Contents

Introduction

The following report is a descriptive outline of the work conducted by Group 6 for the Project Drives offered by the Department of Engineering of Hanze University of Applied Sciences for the BSc Mechanical Engineering. The contributing members of Group 6 for the project are Mihai Priscornita Tonea and MD Tahsinul Islam. This work has been possible thanks to the tutoring provided by Professor and customer interface Mr. Wiersma. The aim of this project is to:

Design a boatlift that is electrically driven and can hold a boat that weighs a maximum of 2 tons and has a width of 2 meters.

Throughout this paper the reader is provided with insight into the design process of the boatlift. The team adopted a systematic approach to decide on the best engineering design solution and has conducted a structural analysis of the model to only then translate the concept ideas and the statics calculations in a final prototype assembly on Solidworks. The design of the boatlift involves a very simple approach. The goal is to make it as easy to use as possible; involving simple items and mechanisms to make it work.

Product

The boatlift is an electrically operated machine designed to lift boats (including/not including passengers) that weigh a maximum of 2 tons and has a maximum width of 2 meters. It consists of simple everyday items such as chains/ropes for ease of replacement. The structure consists of two vertical bars on either side, a middle bar connecting the two vertical bars, an electric motor on the center of the middle bar, and retractable discs for the cables. A remote controller is used to activate and deactivate the lifting mechanism of the motor. Cables are used for pulling up and lowering the boat. A single electric motor is used for the whole operation. The motor can work in both vertical directions, i.e. pulling up and lowering down. The appropriate parameters of the motor are described later in the report with mathematical calculations. A gearbox is installed in the motor to deliver the appropriate torque needed for operation. The boatlift also is expected to operate at least 50,000 times and can carry up to 2 passengers in the boat while it is being lifted.

Systematic Engineering Design

Systematic design has been applied in order to design the optimal electric boatlift with the specific requirements of being able to securely hold a 2-ton boat which has a width of 2 meters. The group's approach consisted of an orientation, analyzing and decision stage with the outcome being a preliminary design concept which was later perfected thanks to statics calculations.

Orientation stage - Requirement list

The following list of requirements has been signed by the customer and it lists all the specifics the final product should respect:

FIXED REQUIREMENTS:

1) Maximum weight of boat (including or not including passengers) =2 tons

2) Width of the boat = 2 meters

3) Electrically powered

4) All constituent components must be water resistant

5) A locking system has to be present to lock the boat securely

VARIABLE REQUIREMENTS:

1) Boat might be loaded with 2 or more passengers (average weight of passenger is considered to be 80 kilograms)
2) Can be used at least 50,000 times
3) Usage of non-corrosive materials

WISHES:

1) Can be disassembled by user to protect from natural calamities (cyclone, hurricane, etc.)
2) Fire detector present for fire alarms

ENVIRONMENTAL:

1) Minimize CO_2 footprint as much as possible
2) Avoiding usage of non-degradable materials (plastics, polyethylene, etc.)

MANUFACTURING:

1) Manufacturing cost per unit is including and up to €3000

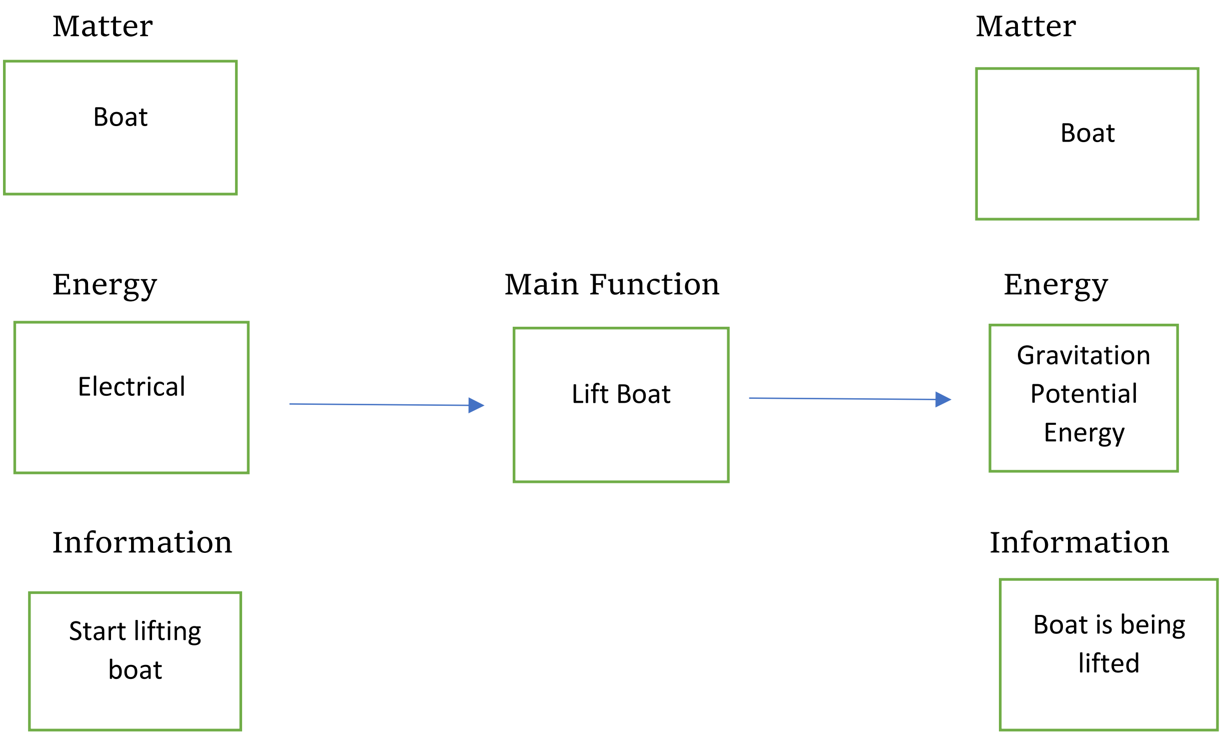
USER:

1) Intuitive to use according to 85% participants in a customer survey
2) Doesn't require heavy or complex machinery to assemble/disassemble
3) Constituent components include everyday items for easy replacements

All variable, user, manufacturing & environmental requirements have been adopted in the Kesselring diagram in order to evaluate the best concept among the proposed ones.

Orientation Stage- MEI Diagram

An MEI diagram has been created for the boatlift.



The matter that goes into and comes out of the system is simply the boat. The whole system is based centered around the boat. The input energy is of course electricity. The output energy is Gravitational Potential Energy. This is because the boat will be suspended at a certain height for a certain amount of time in the air will it is put in the water. At that time, a certain amount of Gravitational Potential Energy will be created. The information that goes in is the boat being on land and the output information is simply the boat successfully being placed into the water.

Furthermore, an MEI function diagram has also been prepared.

	Accumulate	Transform	Transport
Matter	Boat Empty platform		Lift & lower Boat
Energy	Electrical Gravitational Potential	Electric energy to Potential Energy	Transport Electricity to motor
Information	Boat present Boat aligned	Change position	Lift goes up/down

The matter that is accumulated are the boat itself and the empty platform of the boatlift that it will be placed into. The matter transportation that has to be done are lifting and lowering of the boat into the water.

For the accumulation of energy, Electrical and Gravitational Potential energy are accounted for. Electric energy converts into gravitational potential energy when the boat is lifted. Electricity has to be transported to the motor to provide it with electric energy.

Information that is gathered are the alignment and the availability of the boat. The boat must change its position to align with the machine properly. The transportation information is the boatlift lifting up/down.

Analyzing Stage – Function Decomposition

A complete function decomposition has been carried out to examine the functions of the boatlift in detail.

The matter flow begins with the proper alignment of the boat onto the machine. The boat is then locked into a position and the raising begins by a lifting mechanism. At a certain point, the lifting of the boat has to be ceased. After that, the boat has to be held up by a mechanism for a brief period of time. The boat then has to be lowered into the water and finally it has to be released from the holding mechanism of the boatlift.

The energy flow begins with mechanical energy when the boat is placed on the boatlift. Electrical energy is then converted into mechanical energy when the lift starts lifting the boat upwards. Furthermore, gravitational potential energy starts to develop from the mechanical energy as the boat is suspended in the air. Finally, gravitational potential energy converts to kinetic energy as the boat is lowered into the water and then completely released.

The first flow of information happens with the proper alignment of the boat onto the machine. The boat then has to be securely locked onto the machine. A signal has to be made to activate the electric motor to start lifting the boat. The boat then has to be lifted to a desired height and the motor needs to be deactivated. The boat then is suspended properly in the air for a short amount of time. Finally, the boat is lowered into the water and released completely.

Matter	Align boat with the machine	Lock boat into position	Start raising boat Lifting Mechanism	Stop raising boat	Hold the boat up	Lower the boat into water	Remove the boat from the shelf
Energy		Mechanical Energy Electrical energy for lights/sensors	Electrical to Mechanical Mechanical to Gravitational Potential	Stop the motor	Kinetic/Mechanical	Gravitational Potential to Kinetic	
Information	Boat is above the machine facing the proper direction	Boat is secured by the machine	Signal to turn the motor on in raising direction	Boat at the right height Turn motor off Signal the motor off	Boat stays up	Boat comes down	Boat is released from machine

Analysing stage - Morphological chart

A morphological chart was developed to consider different boatlift designs. The product includes eight different subfunctions:

-**Aligning boat with the machine**: This subfunction represents how the boat is to be aligned with the boatlift so it can be put onto the lift. The possible working principles are Boat drives on top of machine, Boat drives on tracks, and A sensor aligns the boat.

-**Hold boat in position**: This subfunction describes how the boat will be held in position on the boatlift once it has been aligned properly. The possible working principles are Tracks lock the boat, Obstacle (rope/chain), and Tracks collapse on themselves to lock the boat.

-**Start lifting boat**: This subfunction represents what will trigger the lifting of the boat. The possible working principles are Remote Control, Fixed button, Sensor at the front of the boat.

-**Lifting Mechanism**: This subfunction describes the mechanism that causes the lifting of the boat. The possible working principles are Cables pulling from top, Chains pulling from top, and Platform carrying boat moves up from below.

-**Stop lifting**: This subfunction represents how the lifting mechanism will be ceased once it has been lifted enough. The possible solutions are Pre-set height, Fixed Button, and Remote control.

-Hold the boat up: This subfunction represents how the boat will be kept held up after the lifting has been stopped. The possible solutions are Braking system, Constant pressure on platform from below, and Clamping.

-Lower Boat into water: This subfunction represents how the boat will be lowered into the water. The possible working principles are Motor in reverse, Gravity, and Gravity + Braking.

-Release Boat: This subfunction represents how the boat will be released from the holding mechanism after it has been lowered into the water. The possible solutions are Obstacle gets removed, Tracks open under the boat and unlocks it, and Tracks decollapse from themselves and unlock the boat.

This chart includes eight different subfunctions illustrated through different working principles. Each concept has its own unique coloured subfunctions.

Function		Method		
Serial	Description	1	2	3
A	Align boat with the machine	Boat drives on top of machine	Boat drives on tracks	A sensor puts boat in position
B	Hold boat in position	Tracks lock the boat	Obstacle (e.g. rope/chains)	Tracks collapse on themselves to lock boat
C	Start lifting boat	Remote control	Fixed button	Sensor at the front
D	Lifting Mechanism	Cables pulling from top	Chains pulling from the top	Platform carrying boat moves up from below

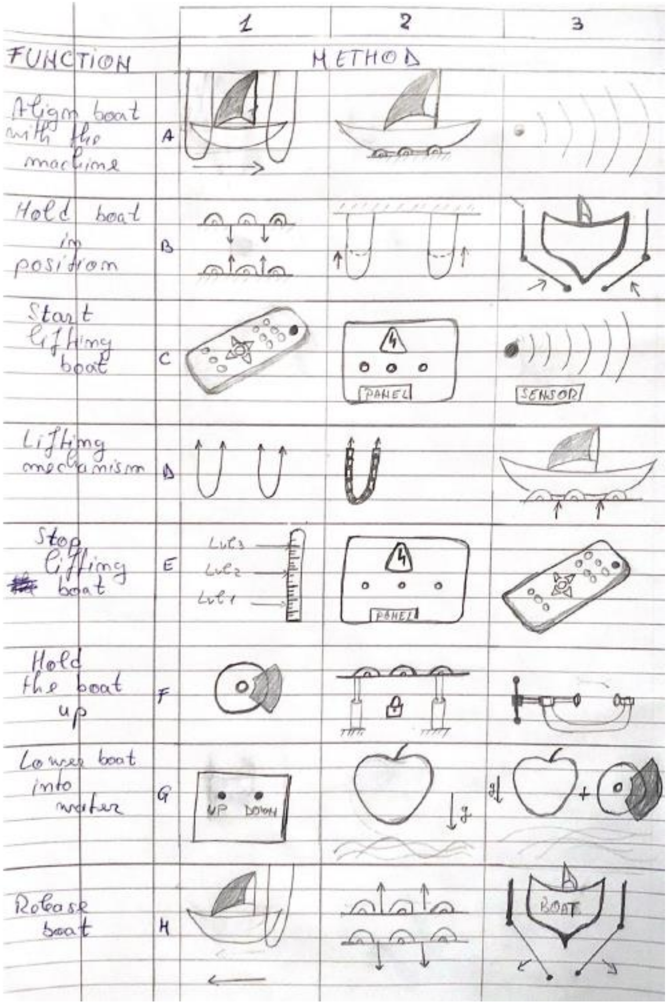
E	Stop lifting	Pre-set height	Fixed Button	Remote control
F	Hold the boat up	Braking system	Constant pressure on platform from below	Clamping
G	Lower boat into water	Motor in reverse	Gravity	Gravity + Braking
H	Release boat	Clamped cables released	Tracks open under the boat and unlocks it	Tracks unlock the boat

Concept 1 [X1] (Yellow): A1 – B2 – C1 – D1 - E3 - F3 – G1 – H1

Concept 2 [X2] (Green): A2 – B1- C2 – D2 – E2 – F1 – G2 – H3

Concept 3 [X3] (Blue): A3 – B3 – C3 – D3 – E1 – F2 – G3 – H2

Another Morphological Chart containing drawings of the subfunctions is provided below:



Analyzing stage - Concepts proposal

Three main broad concepts (X1, X2 and X3) have resulted from the Morphological Chart choices and they are reported below with their respective subfunctions and possible designs.

Concept 1(X1) stands as the easiest to use and operate arrangement as it involves simple subfunctions such as ropes, cables, and remote controls; things which people are familiar with in day to day life. This concept would be the least expensive and easiest to manufacture and use.

Concept 2(X2) uses slightly more complex subfunctions than X1 and is more casual as it doesn't involve a proper system to lower the boat. Instead, it relies on gravity. X2 also involves usage of tracks to get the boat onto the boatlift and to lock it in place.

Concept 3(X3) is by far the most complex and fanciest of the three. It involves usage of sensors for more than once and tracks that lock with each other to hold the boat in position. It would be the most expensive and complex system to manufacture and operate.

Decision stage - Kesselring Diagram

The following table is the Kesselring diagram used in the systematic design to decide which concept between X1, X2 and X3 is the best solution. The features against which the concepts were graded are listed in the left column under requirements. Those consist of the load of passengers (2 or more), number of usages (at least 50,000), manufacturing costs (€3000 per lift), user friendliness, ease of part replacement, minimum CO_2 footprint, avoid usage of non-degradable items, and ease of assembly and disassembly. Grades were attributed in the following way:

1 : Sufficient
2 : More than sufficient
3 : Good
4 : Very good

REQUIREMENTS	X1	X2	X3

Passenger carrying capability	2	3	4
At least 50,000 uses	4	3	2
€3000 per lift manufacturing cost	4	3	2
User friendliness	4	2	1
Ease of part replacement by user	3	2	1
Minimum CO_2 footprint	3	4	4
Avoid usage of non-degradable materials	3	2	4

Ease of assembly and disassembly	4	3	2
TOTAL (x/32)	27	22	20

Concept X1 scores the highest with 27/32 followed by X2 with 22/32 and X3 scoring 20/32. The three concepts X1, X2 and X3 have been evaluated with respect to certain requirements which are to be kept in mind.

Decision stage - Concept conclusion

Upon agreement, Concept 1(X1) was awarded the highest score by ranking higher in all sections of the Kesselring diagram. Concept X1 is less expensive to manufacture, is more sustainable and can potentially last longer. It is also far more intuitive to use than the other two concepts.

Through a systematic design approach, the group has decided to design the boatlift adopting all the requirements and wishes of the customer. This has led to calculations needed for supporting such a decision.

Mathematical Calculations - Motor parameters

Using the remote control, the boatlift can lift boats at different height levels. Two random heights are chosen to determine the power of the motor: Low (2 meters)

& Medium (4 meters) . Time taken to raise the boat to the respective heights are also considered: 30 seconds for 2 meters, 60 seconds for 4 meters, and 90 seconds for 6 meters. Taking these heights into consideration, appropriate calculations are done to determine the required power from the electrical motor**. The shaft length & diameter of the motor are taken as 0.5 meter & 0.05 meter respectively. The width of the winch is also taken as 0.05 meter.**

Height	2 meters	4 meters
Time	30 seconds	60 seconds

Low Height (2 meters at 30 seconds)

Velocity at which boat is lifted = Distance / Time = 2 meters/30 seconds = 0.066 m/s

Acceleration at which the boat is lifted = Velocity / Time = (0.066 m/s)/ 30 seconds = 0.0022 m/s^{-2}

Required force = Mass * Acceleration due to gravity = 2000 kg * 9.8 m/s^{-2} = 19600 N

Power needed = Force * Velocity = 19600 N * 0.066 m/s = 1294 W

Linear Work done = Force * Distance = 19600 N * 2 meters = 39200 J

Medium Height (4 meters at 60 seconds)

Velocity = Distance / Time = 4 meters/ 60 seconds = 0.066 m/s

Acceleration = Velocity / Time = (0.066 m/s) / 60 seconds = 0.0011 m/s^{-2}

Required force = Mass * Acceleration due to gravity = 2000 kg * 9.8 m/s^{-2} = 19600 N

Power needed = Force * Velocity = 19600 N * 0.066 m/s = 1294 W

Linear Work done = Force * Distance = 19600 * 4 = 78400 J

Acceleration at 2 meters	0.0022 m/s^{-2}
Acceleration at 4 meters	0.0011 m/s^{-2}

From the above calculations it is seen that the electric motor must have a power of at least 1294 W.

Angular velocity of the motor = Velocity / Radius of shaft = (0.066 m/s) / 0.025 m = 2.64 radians/second

Stall Torque produced by the motor = Power / Angular Velocity = 1294 W / (2.64 radians/second) = 490 Nm

Load Torque = Force * Width of winch = 19600 N * 0.05 meter = 980 Nm

It is seen that the stall torque isn't enough for the motor to be able to lift the boat. **To resolve this, a gearbox with a ratio 1:4 is installed.** As a result, the stall torque will reach the needed point to lift the boat.

The output power of the motor = Power * Angular Velocity = 1960 * 0.66 = 1293.6 W

Motor efficiency = (Power out / Power in) * 100 = (1293.6 / 1294) * 100 = 99.96 %

Current required for the motor = Power / (Voltage * Power factor) = 1294 W / (220 V * 0.8) = 7.35 Ampere *[Standard values of Voltage & Power Factor are taken]*

Mathematical Calculations – Operating Point

Motor characteristic is mathematically written as: T_M = 490 – (Angular velocity /5)

Load characteristic is mathematically written as: T_L = (Angular velocity)^2 / 1000

Since operating point lies on both characteristics, it can be written that,

$T_M = T_L$

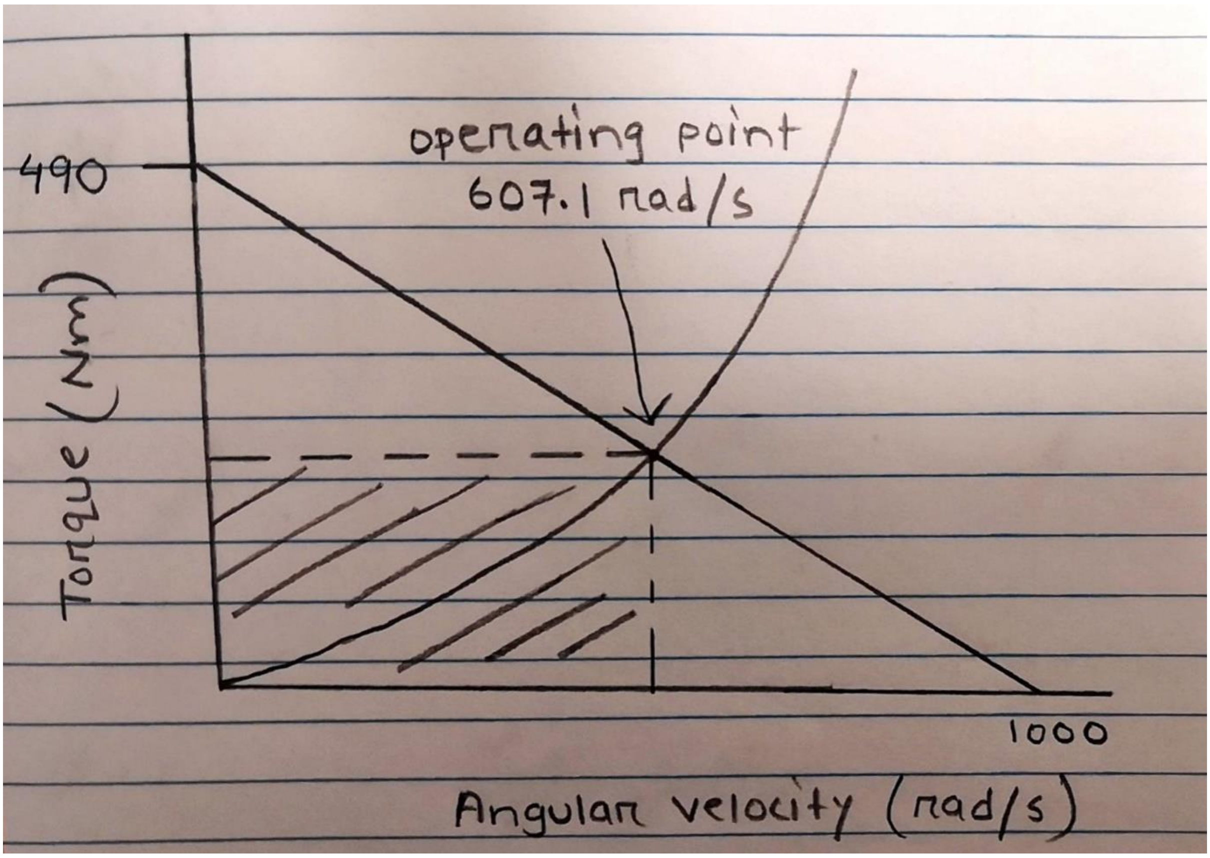
$\Longrightarrow$ 490 – (Angular Velocity/5) = $(\text{Angular Velocity})^2$ /1000

$\Longrightarrow$ ($(\text{Angular velocity})^2$ /1000) + ((Angular velocity /5)) – 490 = 0

Implementing the quadratic equation formula, a = 0.001, b = 0.2, and c = -490.

The two solutions that are obtained are: 607.1 & -807.1.

It is seen that the operating point of the motor is at 607.1 radians/second.



Mathematical Calculations – Calculating Maximum Power Point

Maximum Power is achieved at a certain angular velocity.

P = T * Angular velocity

⟹ P = 490 – (Angular velocity /5) * Angular velocity

⟹ P = (490 * Angular velocity) – ((Angular velocity)^2 /5)

The first derivative of the term is taken and is equaled to 0.

⟹ 490 – ((2 * Angular velocity) /5) = 0

⟹ Angular velocity = 1225 radians/second

At angular velocity 1225 radians/second, the power of the motor is maximum.

Required Input Power	1294 W
Angular Velocity	2.64 radians/second
Stall Torque	490 Nm

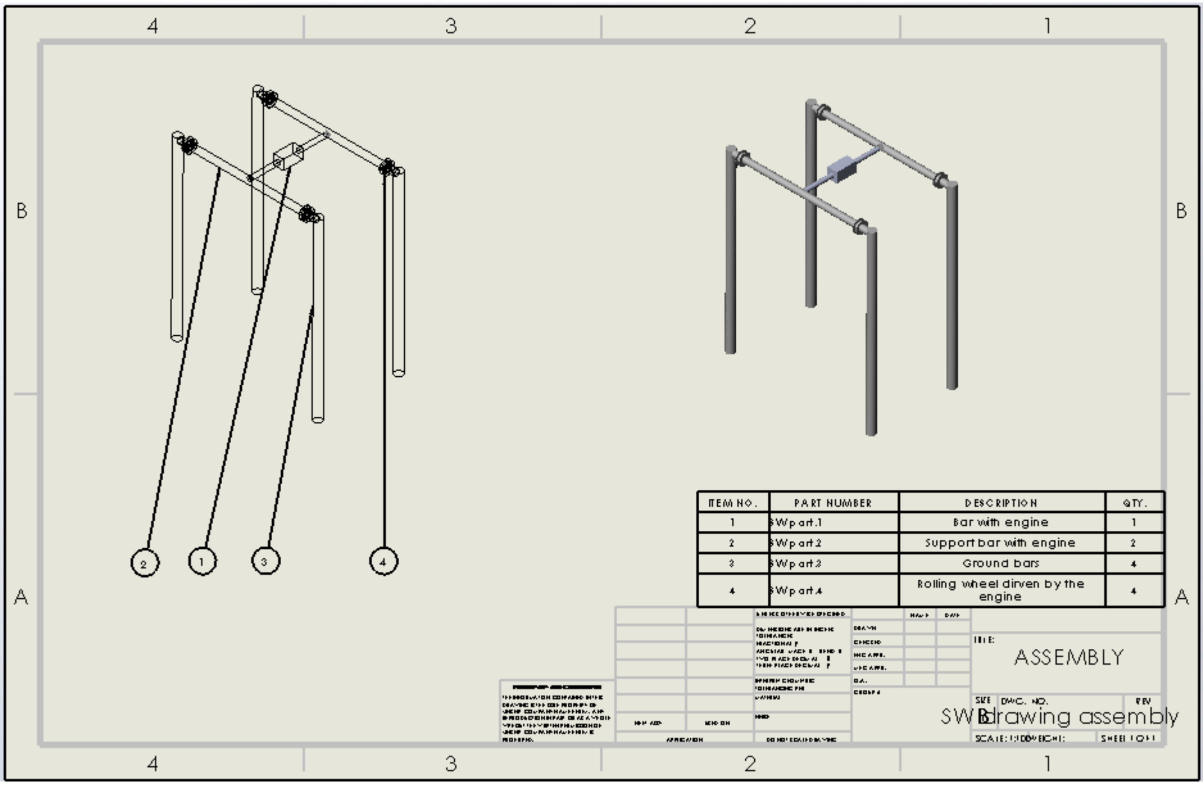
Motor Efficiency	99.96%
Required Current	7.35 Ampere
Gearbox Ratio	1:4
Operating Point	607.1 radians/second
Maximum Power Point	1225 radians/second

Concept Drawings & Part Dimensions

The drawings of the concept have been sketched multiple times to ensure a correctly working model to use in order to derive the right calculations. An assembly drawing and all parts drawings are provided below.

Assembly Drawing

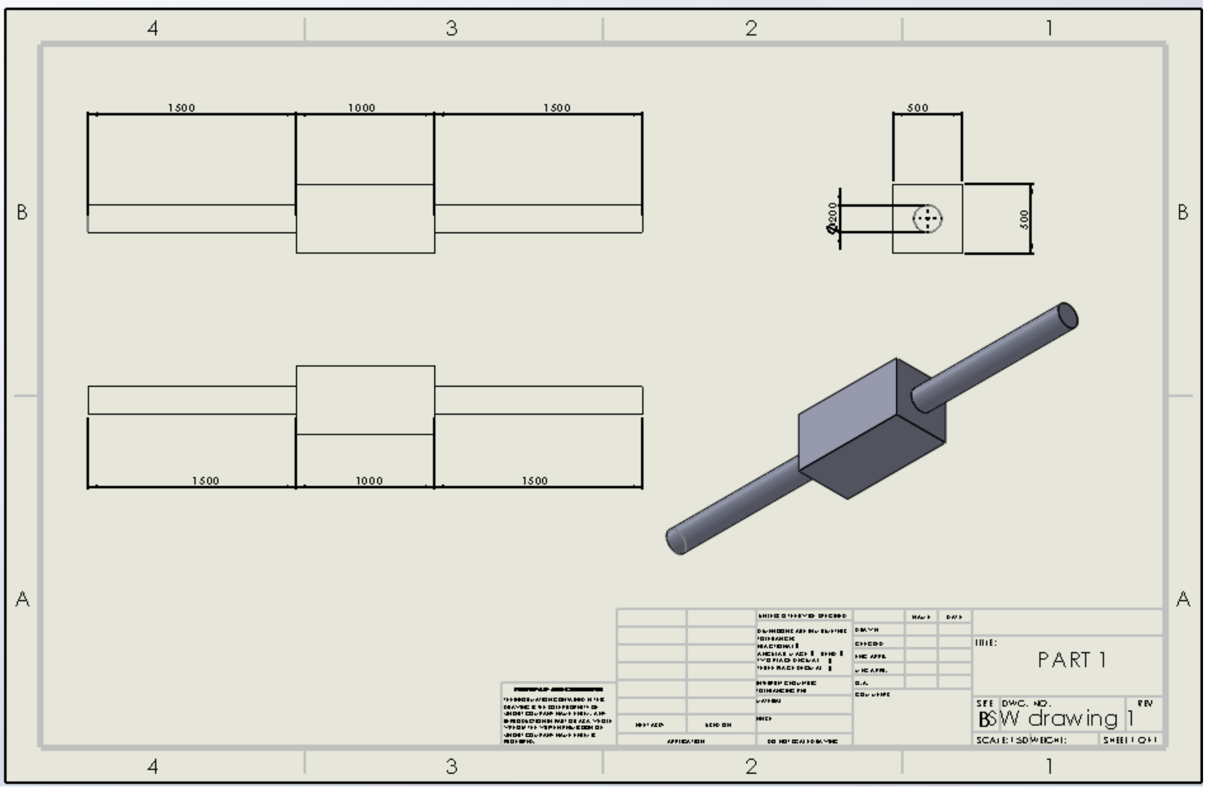
The whole unit consists of 1 middle bar which has the motor placed in its centre, 2 main bars which are connected to the middle bar at their mid points, 4 legs at both ends of each main bar, and 4 cable wheels.



Note: As some of the components of the boatlift cannot be made in SolidWorks (ropes, cables), they have been avoided in the drawings.

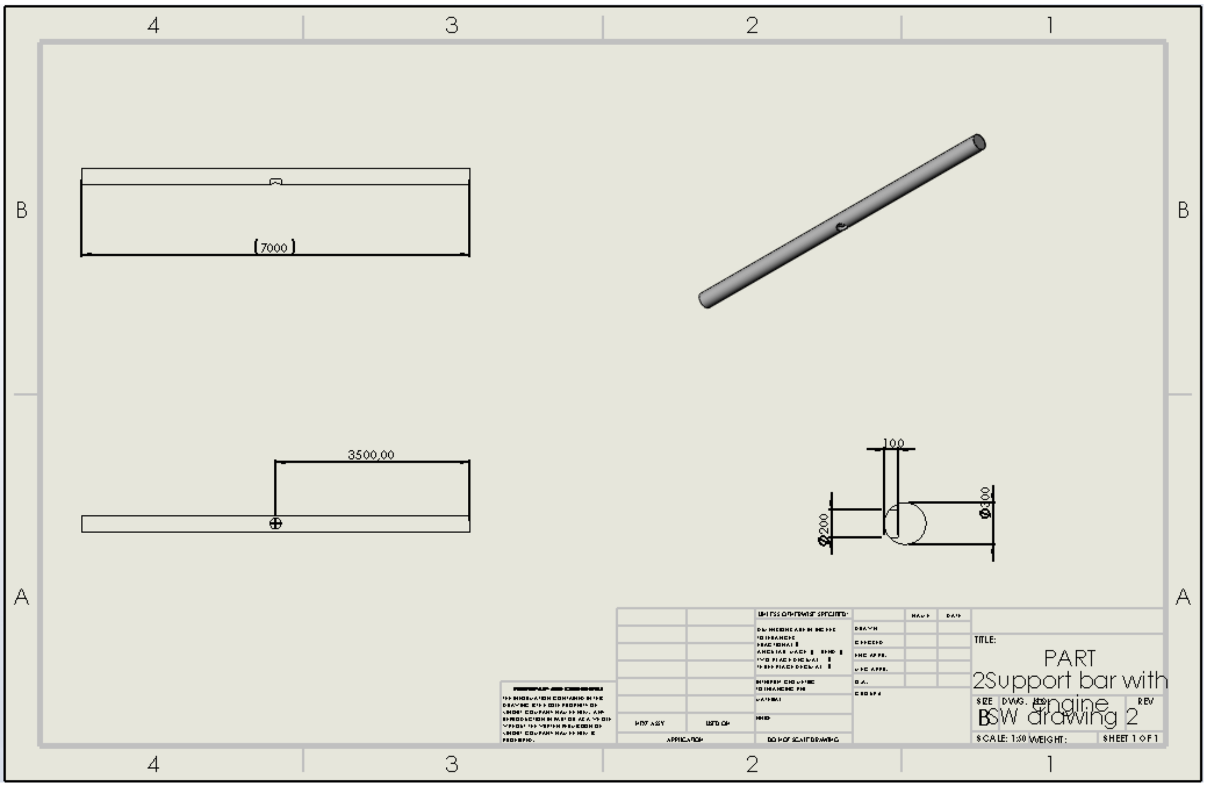
Middle Bar with Motor

The overall length of the middle bar is 4000 mm, or 4 meters and its diameter is 200 mm or 0.2 meter. A rectangular box houses the electric motor whose length is 1000 mm, or 1 meter and breadth is 500 mm or 0.5 meter. The length of the rectangular box is part of the overall total length of the Middle Bar.



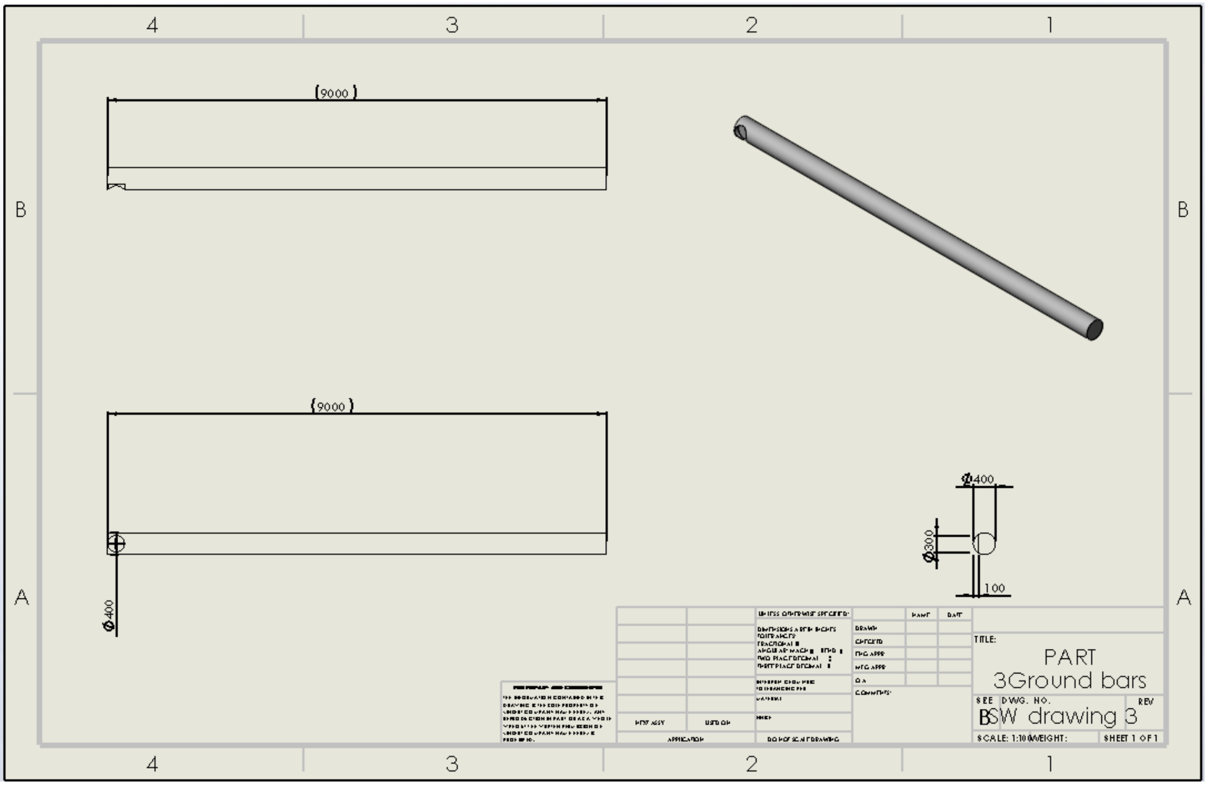
Main Bars

There are 2 main bars in the whole unit. They are both connected to the Middle Bar at their mid points. The overall length of the main bar is 7000 mm, or 7 meters and the diameter is 300 mm or 0.3 meter. There is a circular cut-out at the centre so that the Middle Bar can fit into it. The diameter of that cut-out is 200 mm or 0.2 m.



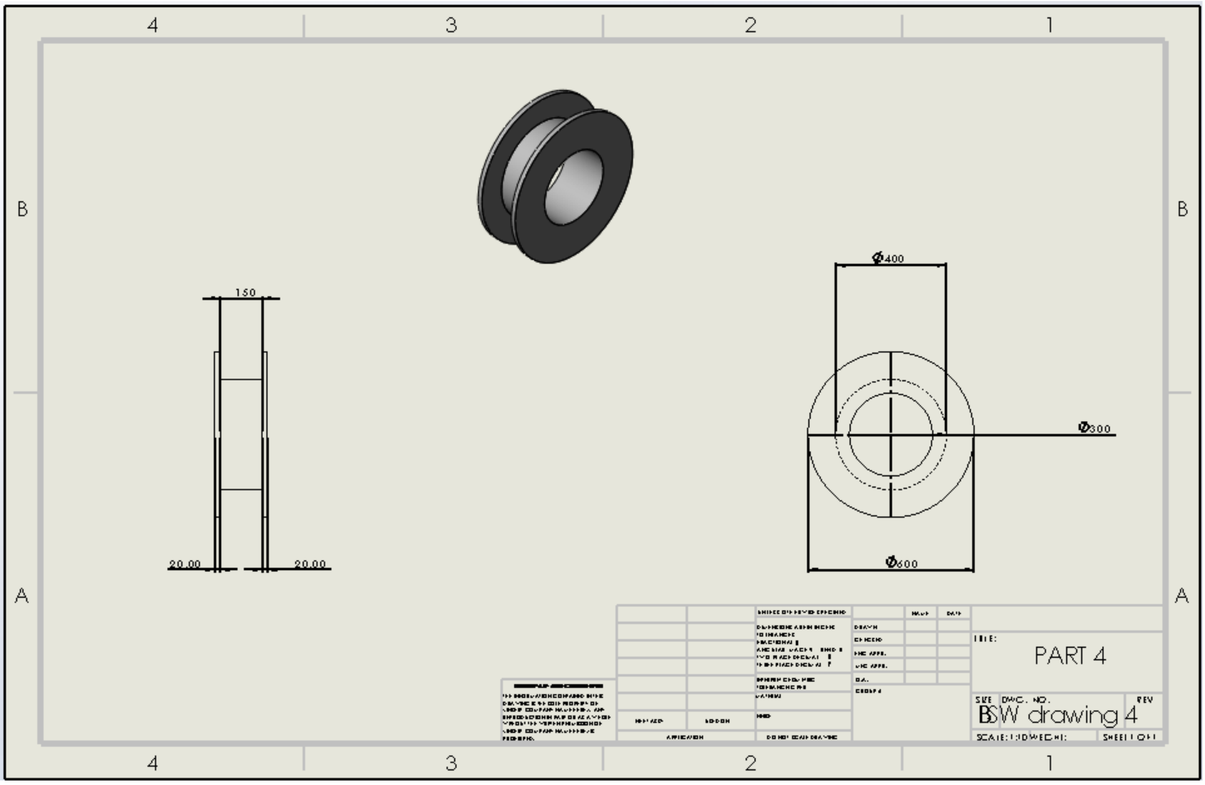
Legs

4 legs hold the entire unit in place. The legs are connected to both ends of the 2 Main Bars. The legs are 9000 mm or 9 meters in length and their diameter is 400 mm or 0.4 meter. There is a circular cut-out at one end of each leg so that the Main Bars can be fitted into them. The diameter of that circular cut-out is 300 mm or 0.3 meter.



Cable Wheels

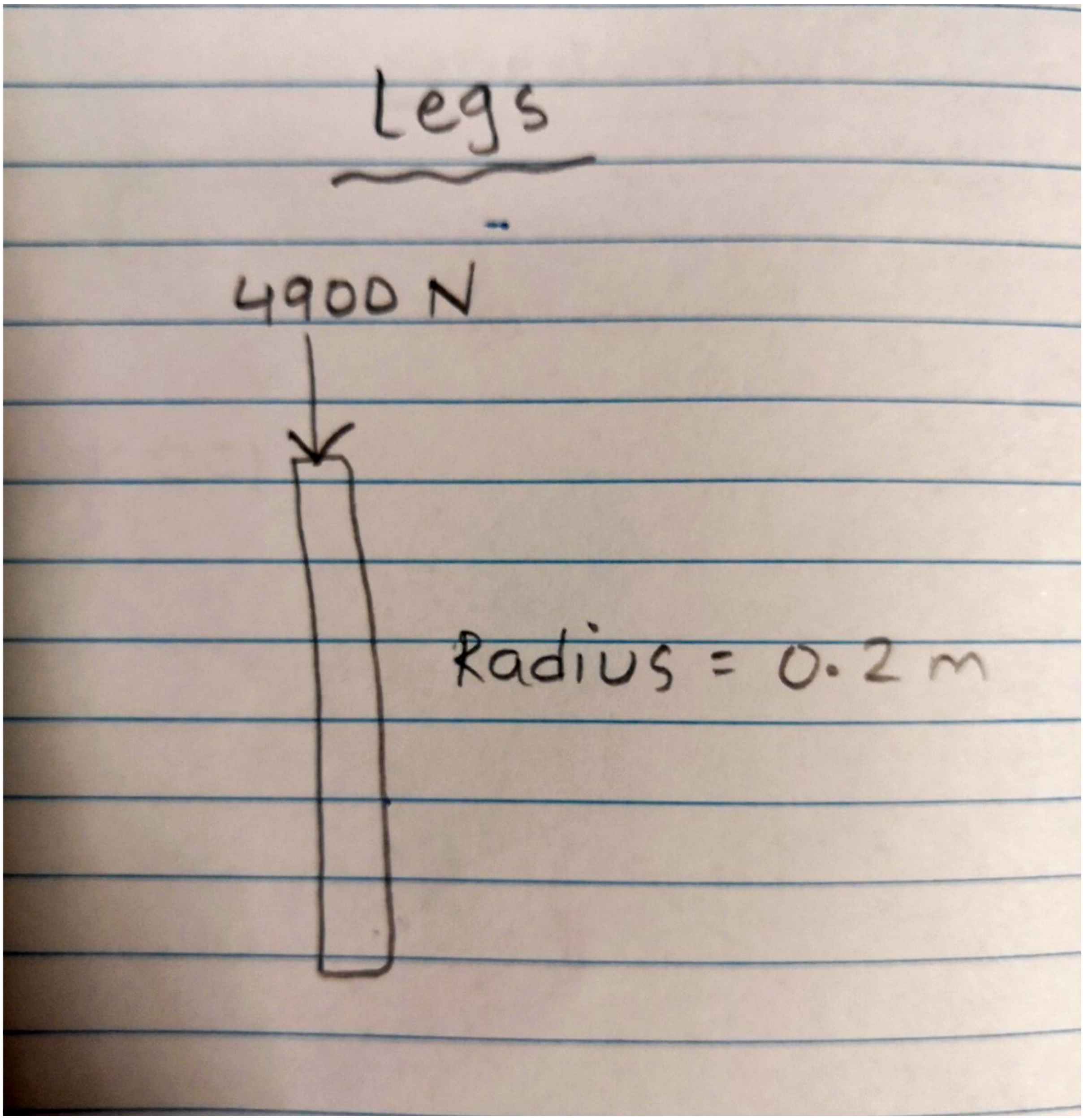
In total, there are 4 Cable Wheels on the unit. The cables either extract or retract using these wheels when lifting or lowering the boat. The outer diameter of the wheel is 600 mm or 0.6 meter and the inner diameter is 400 mm or 0.4 meter.



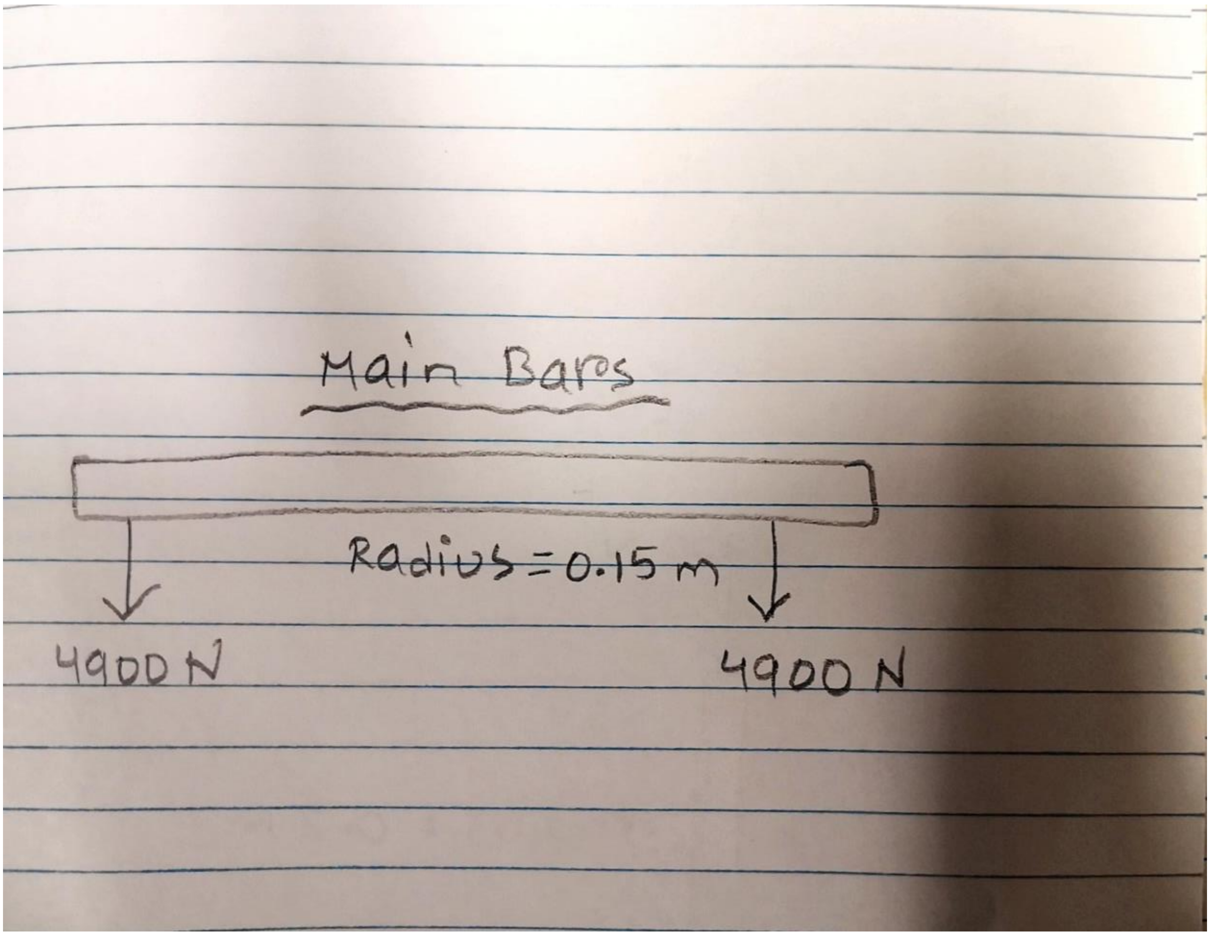
Mathematical Calculations – Strength Calculations of Parts

The 4 legs have to withstand a combined force of 19600 N. The combined force gets equally distributed among the 4 legs. So, each leg has to sustain (19600 /4) N = 4900 N force. This force acts along the axis of the leg. So, for the leg bars, this is a shear force.

The shear stress acting on the legs = Shear Force / Area = 4900 N / (3.1416 * $(0.2)^2$) m^2 = 37.69 kN



The exact same force acts as a normal force on the main bars. So, for the main bars, this is a normal force. This normal force acts on 2 points for the main bars whereas it acted only at one poinr for the legs.



The normal stress acting on the main bars = Normal Force / Area = 2 * 4900 N/ (3.1416 * $(0.15)^2$) m^2 = 140 kN