# MACE Design 1 - DMT

## Group D9

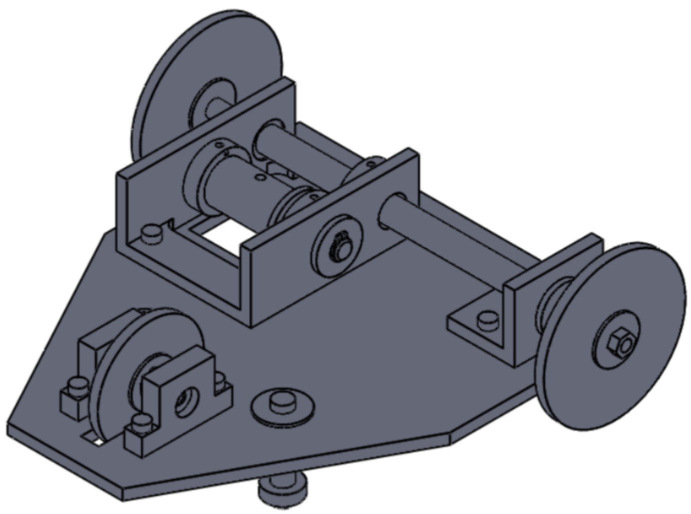

*Figure 1: Final Car Design*

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## Project Overview



### 1 - INTRODUCTION:

#### 1.1. Aims and objectives

The aim for this task is to design and manufacture a vehicle that is suitable to travel the full length of a 5m track (angled at 5.74 degrees) in the shortest time possible. In order to ensure it is a stable vehicle, it must be able to; stand upright before it begins to move, run the course of the race track twice, and it must be able to complete its journey without any damage to the vehicle and the track itself (both times).

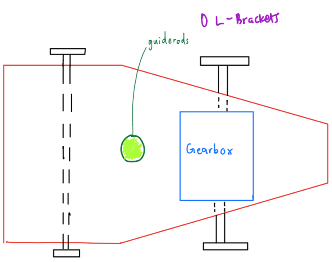
#### 1.2. Explanation of constraint

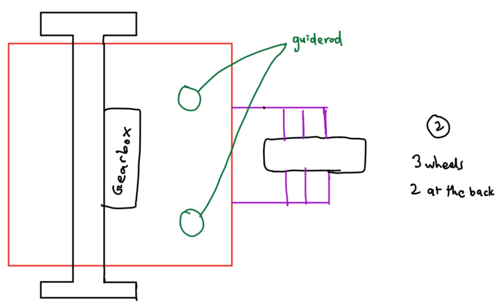
The constraints for this particular design task are mainly in regards to the design and assembly of the vehicle itself as opposed to the race. The vehicle cannot be assembled with any glue and cannot include any ‘bought-in components’ (Heinemann, 2018). All components of the vehicle must be chosen from ‘a list of pre-fabricated components’ and the cost related to each component shall be used when evaluating the overall performance of the vehicle. The dimensions of the chassis are also constrained, as only a 450 x 195 x 6mm sheet of plywood is supplied and additionally, the vehicle must have a gear box to contain the “engine” of the vehicle, which must be taken into consideration when designing the chassis itself. Out of the constraints detailed above, our group took the cost of components and dimensions of our chassis into special consideration, as the latter could greatly affect performance of the vehicle in the race as well as contribute negatively to the weight of the car. We were aware that both constraints would influence our ‘Performance Indicator (PI)’ mark which determines how well our vehicle was designed and built. The factors affecting the PI mark awarded to each vehicle are: best race time, cost of parts, manufacturing time and weight of the car, from greatest weighting to least therefore we held these factors to high importance.

## 2 - PRESENTATION OF DESIGNS:

### 2.1. Initial Sketches

The first thing we considered during the design process was on the number and the placement of the wheels. We were contemplating between 3 and 4 wheels. Both of the options had its pros and cons. For 3 wheels (see figure 2.2 and 2.3), we would have reduced the amount of weight of the car, while for 4 wheels (see figure 2.1), we would have had a more stable car. In the end, we decided to go with 3 wheels for several reasons. Firstly the car would have been perfectly stable with 3 wheels due to the guide rods ensuring no lateral movement furthermore if we chose 4 wheels then we would have had to use a wider chassis which would have resulted in a greater weight of the chassis. This has many negative outcomes because having a greater weight would mean the car would be slower and the friction between the track will be greater as F=μR and R is greater with a greater weight of the car, furthermore the shape of the chassis would have been bad aerodynamically because the chassis would have been wider from the front end. We chose to have 1 wheel placed at the front instead of the back because the majority of the weight of the parts was at the back so the back required more stability hence the use of the 2 back wheels.



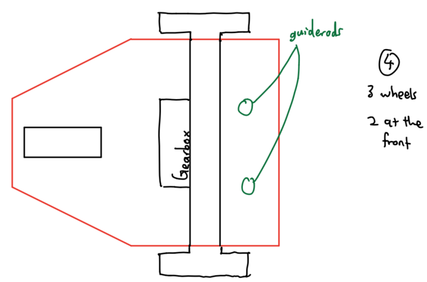




*Figure 2.1: Top view four wheels design (left)*
*Figure 2.2: Top view three wheels design variant 1 (centre)*
*Figure 2.3: Top view three wheels design variant 2 (right)*

For the shape of the chassis we decided to cut the edges off the corners to give it a sort of triangle front end. We chose this for several reasons; first one being to decrease the weight of the car which will result in a quicker time as there would be less total weight of the car compared to a rectangular chassis. We were able to do this because that part of the chassis was not being occupied by anything. Secondly we did this because it has a much more aerodynamic shape which will further help increase the speed of the car by reducing the drag.

The dimensions of the car were also precisely measured. For the length of the car, we needed to figure out the suitable length that we were going to use because If the car was too long, it would contribute to more weight of the chassis and the car may snap due to a weak centre caused from uneven weight distribution, however if the car was too short, the car may be flip backwards. While for the width at the back of the car, we just let it be 195mm to ensure that the long axle can be placed to merge the two wheels. At the front of the car, the width will be 65mm to remove the extra weight. It will be possible to do so because there would only be one wheel at the front.

We decided we needed two guide rods instead of one because we have to ensure the car does not fall off the track if it veers off in either direction. Additionally, the general position of the guide rods had to be in the front due to the fact that the gearbox were at the back; the guide rods served another purpose, which was to counterbalance the weight of the gearbox as well as the 2.5kg weight that would be attached to it. The guide rods chosen were NGR2 due to there being a larger mass, and the final position were decided when we created the CAD drawings. Furthermore, we decided to add bearings to the end of the guide rods in order to stop the guide rods from making contact with the race track, which would have generated a significant amount of friction.

For the size of the wheels, we decided to choose W2 at the front and W4 at the back. This is because the difference between the diameter of the wheel was small. If the difference between the diameters of the wheels were too big, the car would have tilted downwards. This would cause the front of the car to hit the track if the car is pointed downwards or the bearings attached to the guide rods may end up being at an angle to the track, causing extra friction. We also chose the medium size wheel because if the size of the wheel is too large, the guide rods that we are placing may not be fully in contact with the side of the track. This could cause unnecessary friction to the car.

Another element that we had to consider were the gear ratios for the gearbox. We chose the 1:1 ratio in the end because the 1:2 ratio for the gearbox would mean we have a high acceleration but a much lower final velocity than a 2:1 ratio, but the 2:1 ratio would have a much lower acceleration. A 1:1 gear ratio means the car would have a balance between a high final velocity and a high acceleration and was a compromise between the 3 gears.

We chose the drive pulley (PDP1) because for rear wheels (W4) we worked out we needed 20 revolutions of the rear wheels for the car to travel a distance of 5m, and for our front wheel (W2) we worked out we needed 27 revolutions to travel the full 5m. Based on this information we chose the drive pulley (PDP1) as this was the only drive pulley that was able to rotate enough times to allow the wheels to rotate enough to get to the 5m mark and keep the weight attached to the string from touching the floor.

### 2.2. Evaluation/Test

#### 2.2.1. Make session:

During the make session, there was trouble obtaining some of the parts, mainly the 20mm M4 bolts. Therefore, we had to compromise and use some of the 25mm M4 bolts, which would have increased the weight. Also, we realised during the session that we needed to change NGR2 guide rods into NGR1 since they were too long, which meant that the bearings attached to the guide rods were not touching the race track. Besides these, the car design were unchanged from the CAD drawings that were submitted during that session.

2.2.2. Test session:

Due to the success of our car in the test race, our only feedback for the car during the session was to enhance the quality of our build through sanding the chassis to get rid of the splinters that were caused whilst manufacturing the car and adjust the large axle bracket slightly to reduce the rattling of the large axle. Despite this, we knew the weight of the car could further be reduced by reducing the size of the M4 25mm bolts to M4 20mm bolts.

2.2.3. Remake session:

For the remake session we just needed to add finishing touches to the car, which included sanding off all the rough edges and all the places where cuts and holes were made. This was to ensure that there were no splinters on the car and we did this to ensure high quality of build. Furthermore we decided to change some of the 25mm bolts back to 20mm bolts in order to reduce the weight of the car further and therefore improve our performance indicator mark, as this was part of the original plan.

The final mass of the car is ***686*** grams, with the final cost being ***£38.77***.

## 3 - FMEA (FAILURE MODE AND EFFECT ANALYSIS):

The FMEA is a technique for failure analysis also used to identify possible risks associated with design as well as the causes and effects. The FMEA consists of cause, effect, occurrence, severity, detection, risk priority number and action columns. We conducted the FMEA twice so we could get an indication of how we have modified our design for the better. We conducted the second FMEA for an improved design (see figure 3.2) after the test session and before the remake session to ensure that the feedback given to us following the test session was incorporated into our design. By conducting this before the remake session, we were certain that the car produced in that session, was our final and fully developed car, with all problems and resulting modifications that we had considered previously being taken into consideration.

**KEY: DNF = Does not finish. NFA = No further action. O= Occurrence. S=Severity. D= Detection. RPN= risk priority number (the product of occurrence, severity and detection ratings)**

### 3.1. FMEA 1: Initial design

The Risk Priority Number (RPN) for FMEA 1 is ***1,404***.

| Failure | Cause | Effect | O | S | D | RPN | Action |
|---|---|---|---|---|---|---|---|
| Chassis snapping | Poorly designed, having a weak midsection of the | The vehicle does not move and could fall off the | 3 | 10 | 5 | 150 | Minimise the weight of the car and keep the chassis short without it being too |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | car or having too much weight on top of the chassis | ramp and hit someone resulting in injuries | | | | | short such that it tips over |
| Chassis tips over/ too back heavy | Components are concentrated on one side/end of the chassis resulting in an uneven weight ratio between the front and rear axle | DNF | 4 | 8 | 5 | 160 | Design the vehicle so components are evenly distributed and try to achieve a ratio between 50/50 and 70/30 across the rear and front axle respectively |
| Screws unwind | Plywood being soft wood, and poor tightening of the screws during the build process | Parts falling off or the car stops during the race | 3 | 10 | 3 | 90 | Ensure during the manufacturing process of the car that all the screws are securely tightened |
| Vehicle moves too slow | Poor choice of gear ratio and wheel size | DNF | 6 | 6 | 2 | 72 | Ensure the calculations for all the different gear ratios are done and then choose the one which gives the best results |
| Guide rods cause too much friction | The guide rods rub against the race track | Reduces speed of the vehicle and it may not travel the full 5m track resulting in a DNF | 6 | 6 | 5 | 180 | Add bearings to the guide rods to reduce friction |
| String breaking | String may have been deformed during the make or test session or the strings received were damaged | Weight falls and may land on someone resulting in injuries, and there would be no more power propelling the car forward which results in a DNF | 3 | 9 | 4 | 108 | Make sure to check after test runs that the string has not been deformed in any way. Also, check to see there is no physical damage to the string when given |
| Nuts fall off bolts | Poor assembly of the car | Important components of the car could become loose or fall off resulting in | 3 | 8 | 2 | 48 | Take extra precaution during the manufacturing stage to ensure everything is fully tightened |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | a DNF | | | | | | |
| Gears do not engage properly | This could happen due to poor design of the car or poor assembly of the car during manufacturing | The car won't move resulting in a DNF | 2 | 10 | 4 | 80 | | Take extra precaution during the manufacturing process to ensure everything is well spaced |
| Bearings do not spin smoothly | Low quality of products may be used | A large amount of friction is generated resulting in a very slow car or a DNF may occur | 5 | 8 | 2 | 80 | | During the manufacturing process check to see if the bearings are smooth and of a good quality |
| The plywood near the holes of the screws cracks or splinters | The nuts may have been tightened too much and the low quality of the soft plywood material may not be able to hold up the torque of the screws | The small cracks may result in larger cracks, which may result in the car snapping | 4 | 6 | 4 | 96 | | Take extra precaution to tighten the screws to the required torque and not any more. Use washers so that the force exerted by the screws would be spread out over a larger area |
| Wheel spin at the beginning of the track | Too much torque may be produced | The car would get off to a very slow start and have a poor finish time. May result in a DNF | 2 | 6 | 10 | 120 | | Ensure the calculations prior to the manufacturing process are done and are accurate |
| The string is tangled in the drive pulley | The winding of the string was poorly done and not evenly spaced | Would result in the car stuttering or not moving at all resulting in a DNF | 5 | 8 | 3 | 120 | | When winding up the string make sure to take time and make sure the string is evenly spaced out and not tangled up |
| Car going backwards away from the track | The string being tied in the incorrect direction | DNF | 5 | 10 | 2 | 100 | | Double check to see the strings are wound up the correct way |

*Figure 3.1: FMEA 1 for initial design*

### 3.2. FMEA 2: Improved design

The Risk Priority Number (RPN) for FMEA 2 is ***928***, which is less than the RPN for FMEA 1 despite there being extra possible failures.

| Failure | Cause | Effect | O | S | D | RPN | Action |
|---|---|---|---|---|---|---|---|
| The gears hitting the chassis | The hole for the gearbox is too small | The gear may get stuck resulting in a DNF | 3 | 10 | 3 | 90 | Sand and widen the hole |
| The large axle rattles | The holes for the large axle brackets are slightly shifted from the drawing's position | The car moves slower | 8 | 4 | 3 | 96 | Adjust the large axle slightly to ensure the long axle can be fit in perfectly |
| Chassis snapping | The chassis being bent or weak from the excess sanding | The vehicle does not move and could fall off the ramp and hit someone resulting in injuries | 1 | 10 | 5 | 50 | Use the vice when sanding and ensure the plywood does not become too weak during the remake session |
| Chassis tips over/ too back heavy | The car being placed incorrectly on the race track | DNF | 2 | 8 | 3 | 48 | Ensure the wheels are on the race track and the guide rods are in the correct position during the race |
| Screws unwind | Poor tightening of the screws during the remake session | Parts falling off or the car stops during the race | 3 | 10 | 2 | 60 | Ensure that every screw is tightened before submission |
| Vehicle moves too slow | | DNF | 3 | 6 | 2 | 36 | NFA |
| Guide rods cause too much friction | | Reduces speed of the vehicle and it may not travel the full 5m track resulting in a DNF | 1 | 6 | 5 | 30 | NFA |
| String breaking | String may have been deformed | Weight falls and may land on | 2 | 9 | 4 | 72 | Make sure to check during the remake session that the |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | during the remake session | someone resulting in injuries, and there would be no more power propelling the car forward which results in a DNF | | | | | string has not been deformed in any way |
| Nuts fall off bolts | Poor reassembly of the car during the remake session | Important components of the car could become loose or fall off resulting in a DNF | 2 | 8 | 2 | 32 | Take extra precaution during the remake session to ensure everything is fully tightened |
| Gears do not engage properly | The string interfering with the gears | The car won't move resulting in a DNF | 1 | 10 | 2 | 20 | Ensure that the string is taut around the drive pulley during the race |
| Bearings do not spin smoothly | | A large amount of friction is generated resulting in a very slow car or a DNF may occur | 3 | 8 | 2 | 48 | NFA |
| The plywood near the holes of the screws cracks or splinters | The nuts may have been tightened too much and the low quality of the soft plywood material may not be able to hold up the torque of the screws | The small cracks may result in larger cracks, which may result in the car snapping | 4 | 6 | 4 | 96 | Take extra precaution to tighten the screws to the required torque and not any more |
| Wheel spin at the beginning of the track | The nuts for the wheels are not tightened enough | The car would get off to a very slow start and have a poor finish time. May result in a DNF | 1 | 6 | 5 | 30 | Ensure the nuts for the wheels are tightened |
| The string | The winding of | Would result in | 5 | 8 | 3 | 120 | When winding up the string |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| is tangled in the drive pulley | the string was poorly done and not evenly spaced | the car stuttering or not moving at all resulting in a DNF | | | | | make sure to take time and make sure the string is evenly spaced out and not tangled up |
| Car going backwards away from the track | The string being tied in the incorrect direction | DNF | 5 | 10 | 2 | 100 | Double check to see the strings are wound up the correct way |

*Figure 3.2: FMEA 2 for improved design*

## 4 - GANTT CHART:

As a Gantt chart is a clear, visible representation of the tasks at hand, and is used frequently in project management, one has been generated for this Design 1 project. The aim of this was to maintain a good level of productivity, as well as ensure everyone in D9 were aware of the tasks needed for completion and their respective deadlines. As it is a visual tool that can be edited and updated, it is more efficient than manually distributing tasks and has helped with time management and tracking progress. The details of the individual tasks are shown in the figure below, figure 4, our Gantt chart for the project.

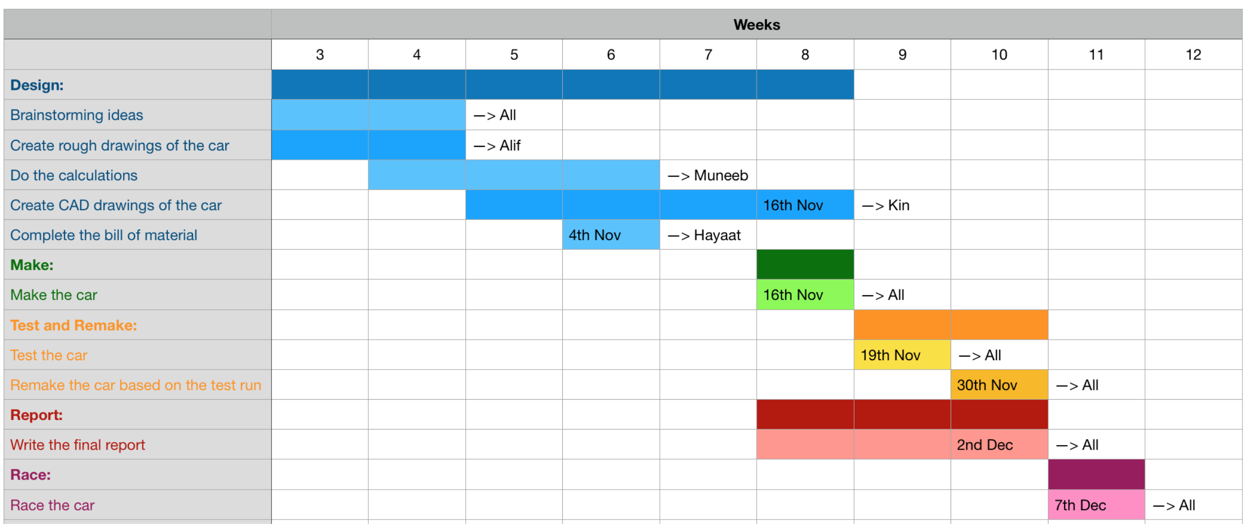



*Figure 4: Gantt Chart for the project*

The nature of the tasks has been separated into the following five sections and color coordinated the details of the task to make it easier for members of the group to identify the type of tasks they need to do. The sections were: design, make, test and remake, report and race. Each section has a deadline for completion, which allowed us to ensure our car was progressing in reasonable stages and times. This is visible in the Gantt chart above, figure 4 as the dates placed on each bar.

Due to the series of deadlines, some of which were less than a week apart, some tasks for certain sections had to be executed simultaneously, for example writing the final report, creating CAD drawings for the car and then testing and modifying the car within the same time frame. In situations like these, we had to designate which tasks could be carried out by one person and which had to be a collaborative effort. The test and remake section of the Gantt chart is a good example of a process that couldn't be completed without one task being carried out before the next, which the Gantt chart was especially helpful in noticing this, as it visually represents this (since the taskbars do not overlap). Contrasting to this is the design section, which again, the Gantt chart was extremely helpful with tracking progress, as you can see that tasks could be carried out simultaneously (as taskbars overlapped), therefore one task was not reliant on the other for completion. This helped us plan when we would do things as it was clear that as long as the task was completed before their respective weeks/deadlines, we would still be on track to complete the section and were still making progress with our design.

As we would all need to be involved in each section at one point or another, we knew it was a necessity to designate tasks to each member of the group in order to complete sections faster. For the design section, all group members were involved in brainstorming: meeting up as a group to discuss ideas, as well as problems and solutions associated with initial designs. In these sessions, we determined details like the number of wheels, shape of the car, gear ratios and other general features of the car which we needed further information to fully complete. After this and after receiving more theory from the Design 1 lectures, Alif was able to complete his task of creating rough drawings of the car. Muneeb was then able to do calculations after we reached a certain level of completion for drawings of the car and Derek was able to create CAD drawings immediately after the drawings of the car were made. I was able to complete the Bill of Materials after the drawings of the car were finalized and the design section was collaboratively completed soon after. For the following sections: make, test and remake, report and race, some of which had to be done on certain days where all group members had to attend these sessions (make, test, remake and race) and then the task of writing the final report, which we completed together, there was no need to divide and designate tasks. Therefore for these sessions, we labeled the tasks as 'All', meaning all members of the group were to complete these tasks. For the make, test, remake and race sessions where the tasks could only be completed on specific days, the Gantt chart taskbars and headers for these sections visibly align with each other, indicating that the sections and tasks had to be completed on these days (see figure 4).

## 5 - FINAL DRAWINGS (CAD):

This section contains a set of three CAD drawings of the final design of our car. The first drawing, figure 5.1 is a 'fully dimensioned first angle orthographic projection of the chassis'. The second drawing, figure 5.2 shows a dimensionless assembly drawing of the car and the third drawing, figure 5.3 shows an exploded view of the car, including a list of parts.

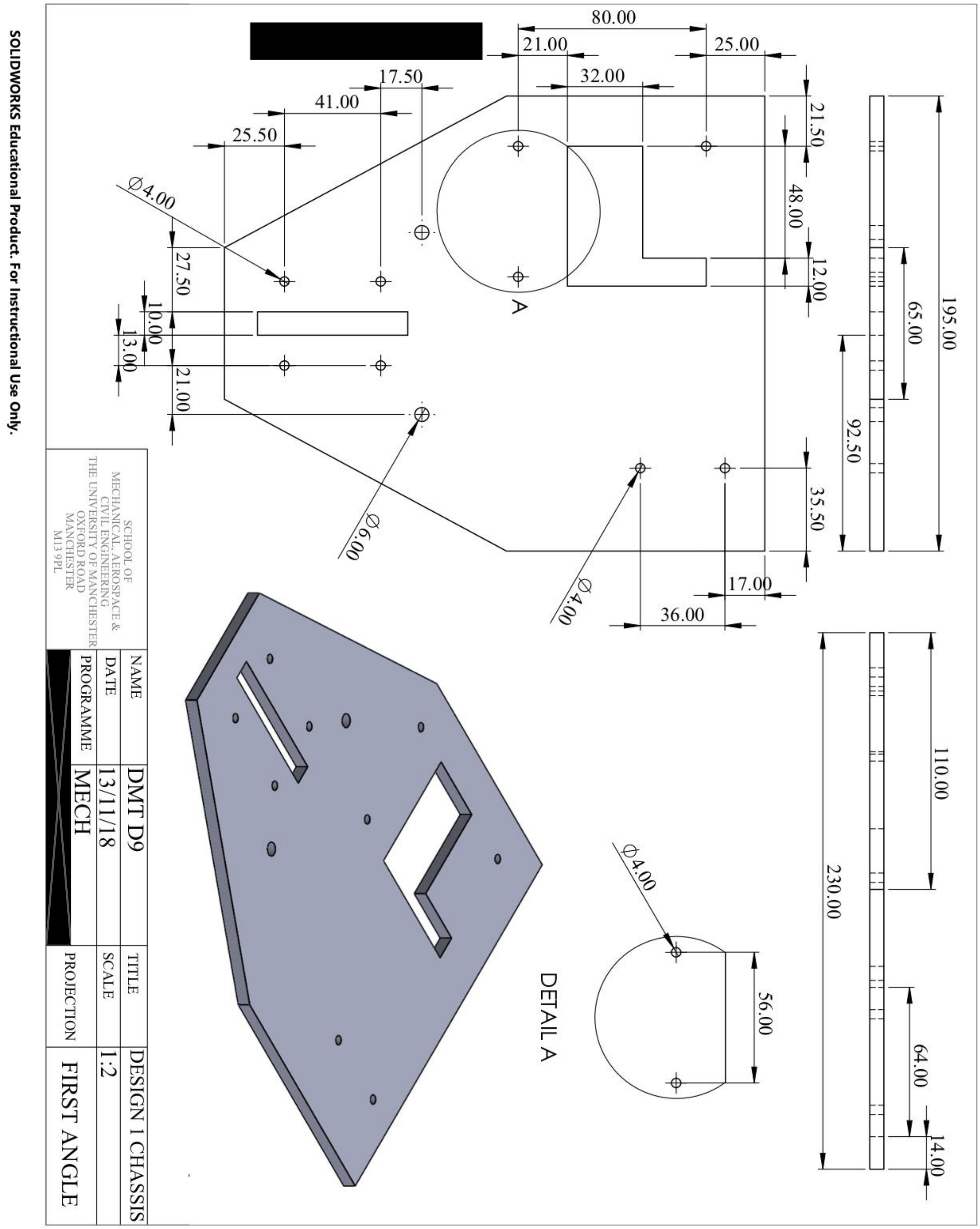



*Figure 5.1: CAD drawing of the 1st angle orthographic projection of the chassis*

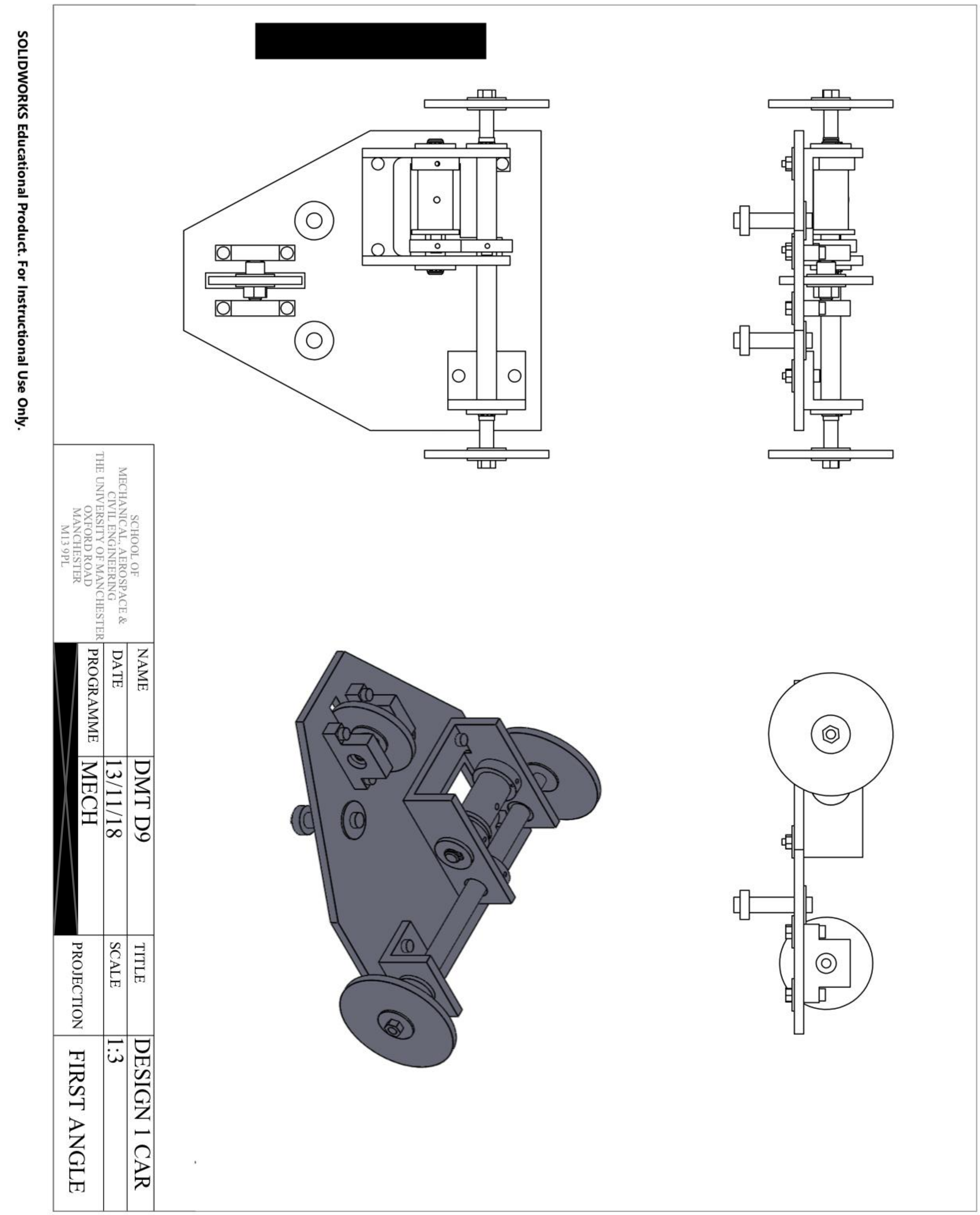
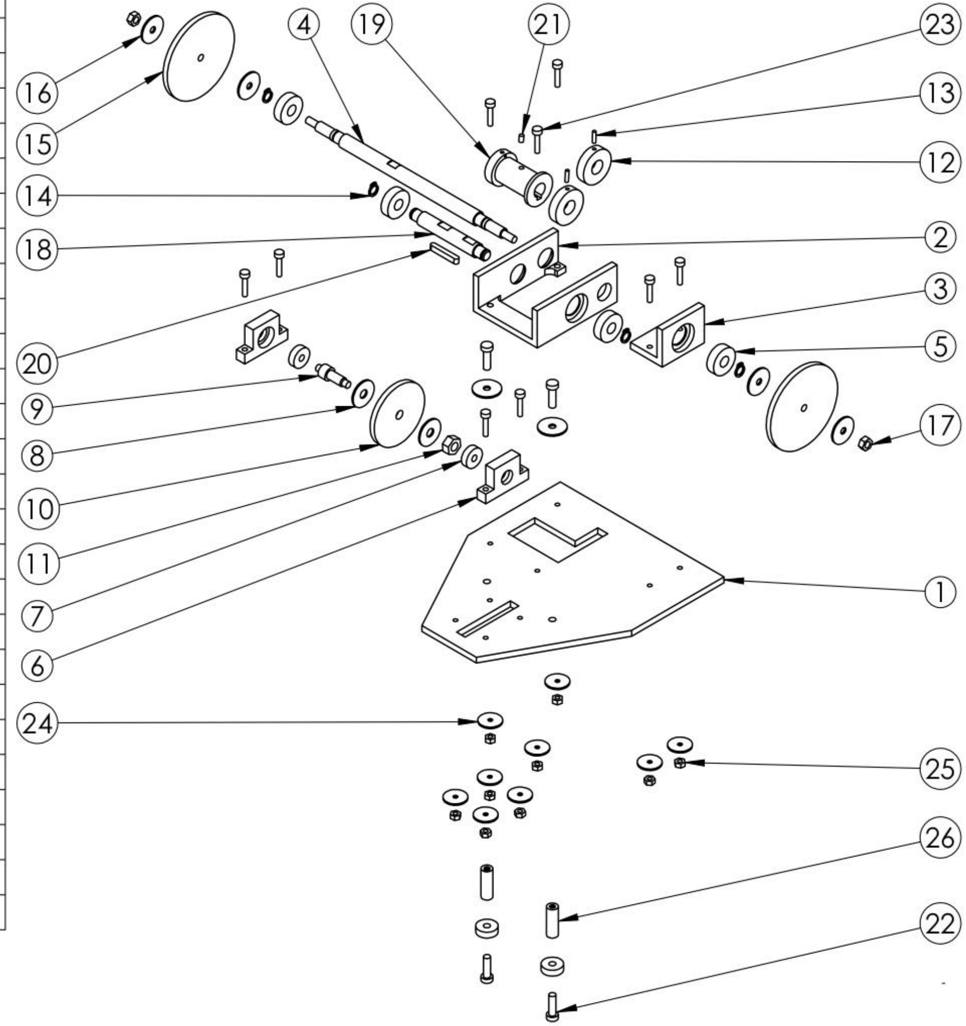



*Figure 5.2: CAD drawing showing the assembly drawing of the car*

| ITEM NO. | PART NUMBER | QTY. |
| --- | --- | --- |
| 1 | Chassis | 1 |
| 2 | Gear casing | 1 |
| 3 | Large axle bracket | 1 |
| 4 | Long axle | 1 |
| 5 | Large bearings | 4 |
| 6 | Small axle bracket | 2 |
| 7 | Small bearings | 4 |
| 8 | Washer M8 | 2 |
| 9 | Short axle | 1 |
| 10 | Wheel W2 | 1 |
| 11 | Nut M8 | 1 |
| 12 | Gear wheel GW2 | 2 |
| 13 | Grub screw M3 | 2 |
| 14 | Circlips | 4 |
| 15 | Wheel W4 | 2 |
| 16 | Washer M6 | 6 |
| 17 | Nut M6 | 2 |
| [redacted]8 | Pulley shaft | 1 |
| [redacted]9 | Drive pulley (PDP1) | 1 |
| [redacted]0 | Parallel key | 1 |
| [redacted]1 | Grub screw M4 | 1 |
| [redacted]2 | M6x20mm bolt | 4 |
| [redacted]3 | M4 bolt | 9 |
| [redacted]4 | Washer M4 | 9 |
| [redacted]5 | Nut M4 | 9 |
| 26 | Guide rod NGR1 | 2 |

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| --- | --- | --- | --- | --- |
| SCHOOL OF MECHANICAL, AEROSPACE & CIVIL ENGINEERING THE UNIVERSITY OF MANCHESTER OXFORD ROAD MANCHESTER M13 9PL | NAME | DMT D9 | TITLE | DESIGN 1 CAR |
| | DATE | 11/11/18 | SCALE | 1:5 |
| | PROGRAMME | MECH | PROJECTION | FIRST ANGLE |
| | [redacted] | | | |



*Figure 5.3: CAD drawing showing the exploded view of the car including list of parts*