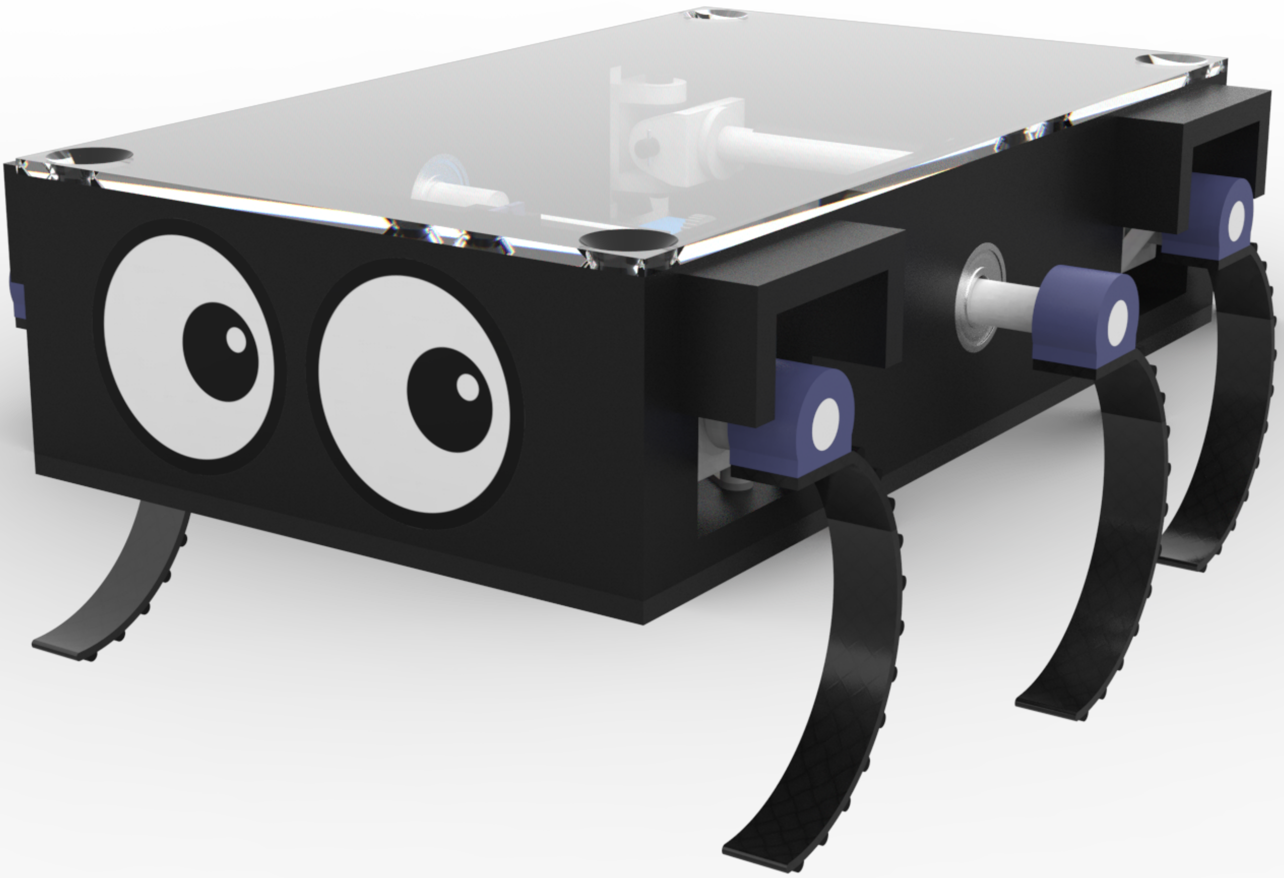
RHEX
DESIGN PROPOSAL



Gizmo - Physical Computing

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Contents

1 Nomenclature and abbreviations

Physics Constants

g	Gravitational Acceleration	$9.81ms^{-2}$

Other Symbols

a	Half Wheelbase distance, m
G	Modulus of Rigidity, Pa
h	Obstacle Height, m
J	Polar Moment of Inertia, m^4
L	rHex Body Length, m
m	Mass, kg
n	Speed of Gear, rpm
N	Number of Gear Teeth
P	Power, W
r	rHex Leg Radius, m
R	Turning Radius, m
s	Displacement, m
S_f	Safety Factor
T	Leg Track Width, m
u	Initial Velocity, ms^{-1}
v	Linear Velocity, ms^{-1}
α	Angular Acceleration, $rads^{-2}$
$\alpha, \beta, \delta, \theta$	Angles
τ	Torque, Nm
σ	Shear Stress, Pa
ω	Anglular Velocity, $rads^{-1}$

Subscripts

cr	Critical Value
est	Estimated Value
N	Normal
o	Minimum Turning Radius
tp	Typical Pivot

2 Abstract

This report aims to illustrate the design process for a new RHex robot design. As the RHex is a miniature bio-inspired robot designed for locomotion in rough terrain and hard to reach areas; heavy emphasis was made to design a reliable and cost effective system that fits with the specification from the brief. To achieve this, different mechanical requirements were characterised and solved to find a suitable motors for locomotion and appropriate steering systems. Further hand-calculations were then made on designing a fitting gearbox for power transmission. Then, different Finite Element Analysis methods were applied on crucial components of the system (being the leg and the shaft) to confirm prior calculations. Lastly, different iterations of the main chassis of the RHex were generated to improve on space-efficiency, ingress protection, weight saving, and more. In conclusion, the proposed RHex design was able to meet all of the requirements set by the brief except the weight, exceeding the specification by $11.4g$. Although the weight did exceed the requirement, due to safety factors applied into the drivetrain systems, the proposed RHex design is

expected to work normally. As the chassis is the main contributor to the overall weight, this report recomend further topography optimisation studies to address the weight while ensuring the chassis original structural integrity.

3 Introduction

RHex is a bio-inspired hexapedal robot designed for mobility in rough and uneven terrains: mud, snow, swamp, and more. Initially funded by DARPA, The Defense Advanced Research Projects Agency, the six-legged platform has proven to be more optimised for traversing into cramped spaces where humans could not traditionally fit or travel.

Therefore, this report aims to outline the design process for a low-profile and miniaturised RHex platform outlined in the specification, as shown in table 1, while ensuring that the platform retains its diverse use and application.

Parameters	**Specifications**
Body length	$\leq$ 165 mm
Body height	$\leq$ 40 mm
Body width	$\leq$ 100 mm
Leg length	$\leq$ 50 mm
Leg radius	$\leq$ 35 mm
Weight	$\leq$ 300 g
BoM cost	$\leq$ 100 GBP
Turning circle	$\leq$ 165 mm
Payload	$\geq$ 300 g
Speed	$\geq$ 0.5 m/s
Drop height	$\geq$ 300 mm
Climb obstacle	$\geq$ 200 mm
Electronics package	45 x 20 x 10 mm (excl. battery)
Ingress Protection	IP 53

Table 1: Project Specifications

4 Mechanical System Characterisation

4.1 Obstacle Climbing Studies

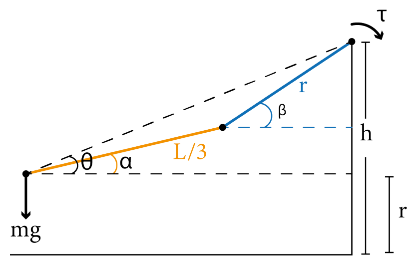


Figure 1: Free body diagram of simplified system

As the main characteristic of the RHex is its ability to navigate rough terrains, one of the significant factors in its performance is its ability to transverse across obstacles: meaning there must be sufficient torque for the RHex to climb said obstacles. A simple lever mechanism can be used to characterise the system to sanity-check the minimum required torque with payload of $300g$.

$$\tau = F \cdot rsin(\theta) = (m_{robot} + m_{payload}) \cdot g \cdot \frac{L}{3} cos(\alpha) + rcos(\beta) \tag{1}$$

To calculate the torque required, a few assumptions were made. Firstly, the obstacle is 200mm high. Secondly, the front leg is fully extended from the body, resulting in a 45 deg angle from the ground. Thirdly, the centre pair of legs are upright when the front and back legs are moving, however acting as a safety factor in the calculation. An assumption was made so that said pair of legs does not support any weight.

$$\tau_{required} = (0.3 + 0.3) \cdot 9.81 \cdot \frac{0.0825}{2} cos(0.14) + 0.035cos(45) = 0.268Nm \tag{2}$$

4.2 Steering System

Initially the use of 6 motors for each leg was considered as it was a common setup in a traditional rHex design, offering independent controls for each leg. However, said configerations are difficult to implement in a smaller frame and would exceed the specification budget. Therefore, a rack and pinion steering system was implemented on the front and rear driveshaft to minimise turning radius. Using Ackermann Steering Geometry and assuming the wheel base is the length of the rHex, we can calculate the maximum turning angle of the design. The 4WS system has the main advantage of having the smallest turning radius, crucial for the RHex platform.

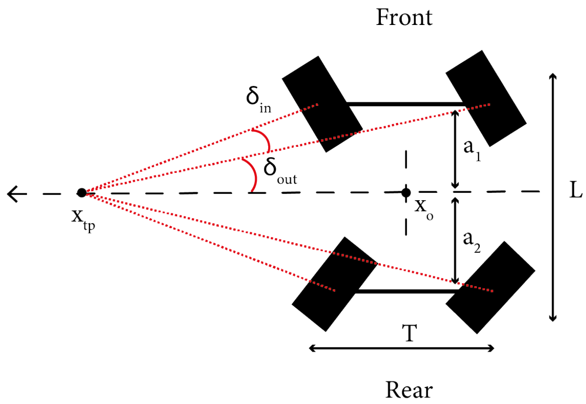


Figure 2: 4WD Ackermann Geometry

$$\delta_{in} = \tan^{-1}\left(\frac{L_{est}}{R - \frac{T}{2}}\right) \qquad \delta_{out} = \tan^{-1}\left(\frac{L_{est}}{R + \frac{T}{2}}\right) \tag{3}$$

$$\delta_{in} = 55.12^\circ \qquad \delta_{out} = 37.5^\circ$$

$$R = a_2^2 + L^2 \left(\frac{\cot \delta_{in} + \cot \delta_{out}}{2}\right)^2 = 0.034m \tag{4}$$

With the current setup, using the 4WD steering system, the turning radius is $0.034m$, much less than the specified value. Taking said calculations into consideration, the *Rack and Pinion* steering system was selected for its simplicity and light-weight. To drive the steering system, the tangental force of the rack and pinion must be calculated for the correct selection of the servo motor.

$$F_N = mg\mu + ma + F_{other} \tag{5}$$

$$T_N = \left(\frac{F_N \cdot d}{2000}\right) \cdot S_f \tag{6}$$

From the calculations, HS-40 servo motor was chosen due to its low cost and suitable torque. To reduce costs, only one servo motor is used, with the output driving two other bevel gears to redirect the power to the rack and pinion.

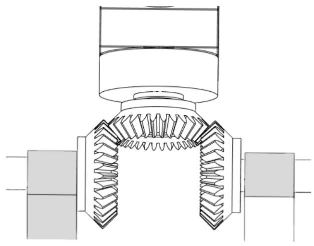


Figure 3: Bevel Gear Alignment

5 Drivetrain Study

5.1 Motor Selection

Three primary performance factors of a motor are power delivery, power consistency, and maximum speed. While other types of motors were considered, a brush DC motor was ultimately chosen for its cost-effectiveness and simple controls. Additionally, the maximum rated voltage of chosen motor must not exceed 9V to maximise useable space and minimise weight.

As mentioned in subsection 4.1, the RHex platform require a minimum of $0.268Nm$ to operate within the specification. The first step is to calculate the acceleration torque:

$$\omega = \frac{v}{r} = \frac{0.5}{0.035} = 14.286rads^{-1} = 136.4rpm \tag{7}$$

$$\alpha = \frac{\omega}{\delta t} = \frac{14.286}{2} = 7.14rads^{-2} \tag{8}$$

$$I = \frac{mr^2}{3} = \frac{0.6 \cdot 0.05^2}{3} = 0.0005T_\alpha = \alpha I = 7.14 \cdot 0.005 = 3.57 \times 10^{-3}Nm \tag{9}$$

Then, the load torque distributed across 3 legs must be found:

$$F = \frac{m_b + m_p}{3} g = 1.962N \tag{10}$$

$$T_l = F \cdot r = 0.0981Nm \tag{11}$$

Therefore, the total torque distributed across 6 legs is found:

$$T_{total} = (T_l + T_\alpha) \cdot 6 \cdot 2 = 1.22Nm \tag{12}$$

$$P = T \cdot \omega = 1.22 \times 14.28 = 17.42W \tag{13}$$

As the torque from the calculations above is greater than the minimum torque required to climb the $200mm$ obstacle, this value would be used when considering the motor. Applying a safety factor of 1.1, the selected motor must have power greater than $20W$. Fitting the specification of having a small profile and sufficient power, RS PRO Geared (21.2 W) motor was chosen. In addition to meeting the power requirements, as the motor already contains internal gearbox, less space is needed for more gearbox.

5.2 Gearbox

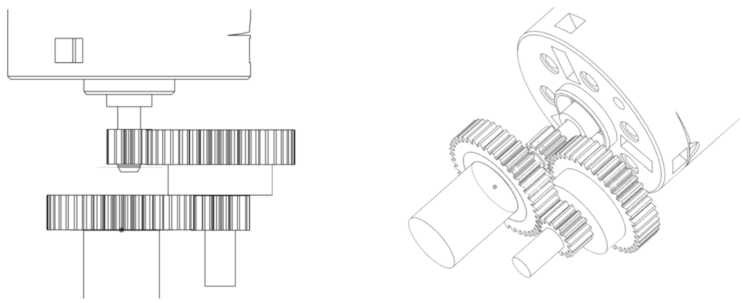
Knowing that the chosen motor have greater power output than the specification, the target top speed was set to $2ms^{-1}$, 4 times the specified value. Spur transmission was chosen as the preferred system over planetary transmission. Although planetary transmission are compact and efficient, due to its complexity, their components are dificult to source and more expensive in a small scale application. To minimise costs, injection moulded polyacetal gears with $94MPa$ ultimate tensile strength from *RS Pro* were chosen.

$$\sigma = \frac{K_v F t}{b_a M Y} \tag{14}$$

Knowing that the input nominal speed of the motor is $560rads^{-1}$, the total gear ratio of the system can be calculated; with non-integer ratio taken into account when designing the two reduction stages. While the three reduction stage system was considered as it would require less lubrication and have better manufacturing tolerances; its advantages does not outweigh the increase in complexity and costs. Furthermore, as the polyacetal gears are self-lubricating, this further reduces the suitability of three reduction stage system.

$$GearRatio = \frac{\omega_{in}}{\omega_{out}} = 11.74 \tag{15}$$

$$n_2 = \left|\frac{N_1}{N_2} n_1\right| = \left|\frac{d_1}{d_2} n_1\right| \tag{16}$$



(a) Top View (b) Dynamic

Figure 4: Views of proposed gearbox

Number of Teeth	**Speed** ($rads^{-1}$)
11	560
41	150.24
15	150.24
41	54.97

Table 2: Gear Ratio

The proposed design calls for 2 sets of gears reducing the output speed to $54.97rads^{-1}$ in order to achieve the expected output speed of $2ms^{-1}$. The small amount of gears allows greater reduction efficiency while the polyacetal material reduces the need for lubrication, hence greater suitability for operations in harsh terrains. After the type of gears required were identified, the final design proposal rearraged the position of each gears to better suit the limited spaces available in the chassis of the proposed RHex.

5.3 Power Transmission

As a cost reduction design choice of using a single drive motor emphasise the importance of a efficent power delivery system, numerous systems were considered. Initially, a chain drive was examined as they are able to efficiently deliver high-speed and torque; making it ideal for an all-terrain application such as the RHex. However, the system was not implemented due to part complexity, costs, and lubrication needs. Logically, the belt system was considered due to its constant speed ratio between the gears and the legs. Additionally, the belt system does not require lubrication or cleaning, increasing its suitability to the RHex. However, the system will experience greater power loss and is more expensive to manufacture.[1]

Ultimately, the shaft system was implemented in the RHex due to its smooth power transmission, and minimal number of parts. Most importantly, the driveshaft is the most reliable option meaning that it is the most suitable for operations in harsh terrains with limited human access for maintainance.

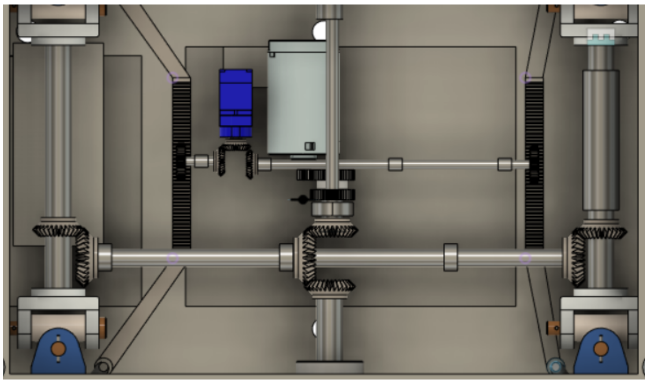


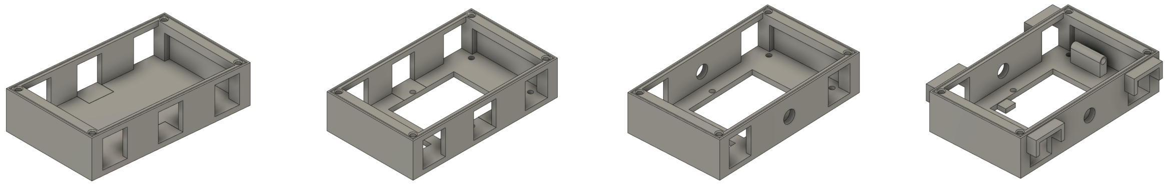
Figure 5: Driveshaft

6 Main Chassis

6.1 Geometry

In the design process, many frame geometry were considered. One consideration taken during the selection process was to ensure the final shape of the RHex do maximise the internal volume to accomodate a large amount of mechanical and electrical systems, where any excess space can be allocated for battery storage. Another criteria was to ensure that the final shape accomodate further modifications that may be applied to the RHex, allowing the platform's use to remain flexible. With all options weighed, it was decided that a rectangular prism shape would be the most suitable. Additionally, as the chassis are intended to be manufactured using injection moulding of polymers, complex shapes and turns were kept to the minimum during the design process. The following section details the iterations of the chassis geometry where FEA were regularly applied in the process to ensure structural stability.

After thorough investigation, the opening for the front and back pairs of legs cannot completely sealed to prevent water and dust from entering. Therefore, the final iteration of the chassis design extruded the upper part of the opening to ensure that no water that is splashing at the RHex at



(a) Simple Box (b) Material Reduction (c) Reduce Openings (d) Water Guard Extrusion

Figure 6: Main Chassis Iterations

an angle greater than 60*deg* can damage the components as per IP53 specficiations. Furthermore, the final iteration of the design introduces supports for the axles to reduce the number of joints, ultimately reducing the costs and weight of using connectors (such as screws).

6.2 Cover Accessibility

At its core, RHex is a versitile robot platform, able to facilitate different roles depending on its intended use. Therefore it is crucial that the main chassis allow for easy access to all components while ensuring that more equipments can be implemented on the platform. One step taken was the addition of removeable casing lid (held down by screws), allowing users to change the covers as fit, increasing customisability for different usage. The design choice would also decrease part complexity of the main chassis (sharp turns and other complex geometry is difficult to injecton mould), resulting in cheaper manufacturing costs.

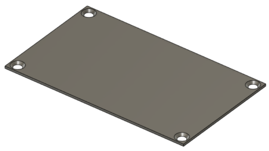
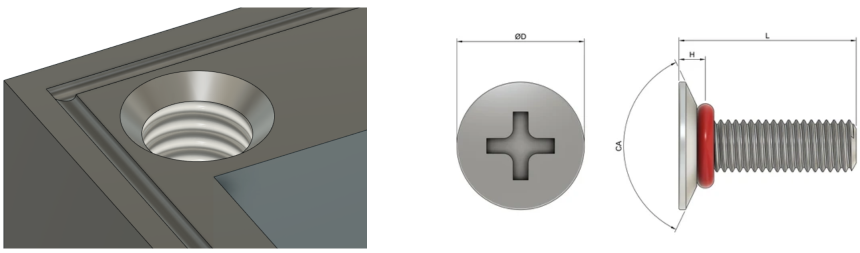


Figure 7: Top Cover with 4 screwholes

6.3 IP53 Ingress Protection

As specified by the brief, different steps were taken to ensure that the proposed design is protected against "intrusion of solid objects", dust, and water spray up to 60^o.[2] One was to implement o-rings into both of the chassis cover as it occupies little space and seals very efficiently in static applications. Another step taken was to use sealing screws. As the proposed design's emphasis on customisability results in large amount of screws used, it is crucial that no water nor dust enters the chassis through the screws. Therefore, the application of sealing screws are recomended for certain parts of the RHex where crucial electronics are near the screw holes.



(a) O-ring Grooves (b) Sealing Screws

Figure 8: Ingress Protection Methods

7 Engineering Analysis

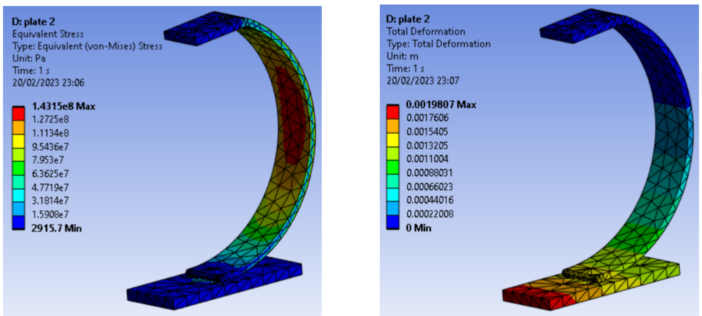
7.1 Leg

A simulation was ran to determine whether the proposed leg design of the RHex would withstand the $300mm$ fall specified in the brief. The force that the leg would experience from the fall was calculated.

$$v^2 = u^2 + 2gs \tag{17}$$

$$F = \frac{m(v-u)}{\delta t} \tag{18}$$

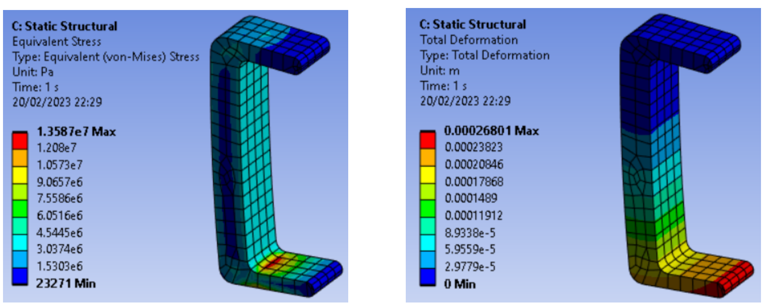
The total mass of the RHex was assumed to be $600g$, hit the ground at $2.426ms^{-1}$, and expected to stop in $0.1s$. This means that the leg would experience the maximum force of $14.56N$ before coming to a stop. When running the simulation, it was assumed that only one leg would make contact with the ground, meaning the load would not be shared between other components. The assumption was to ensure that the RHex would still be able to operate after hitting the ground at the worst possible position.



(a) Static Stress (b) Total Deformation

Figure 9: Initial Design Proposal

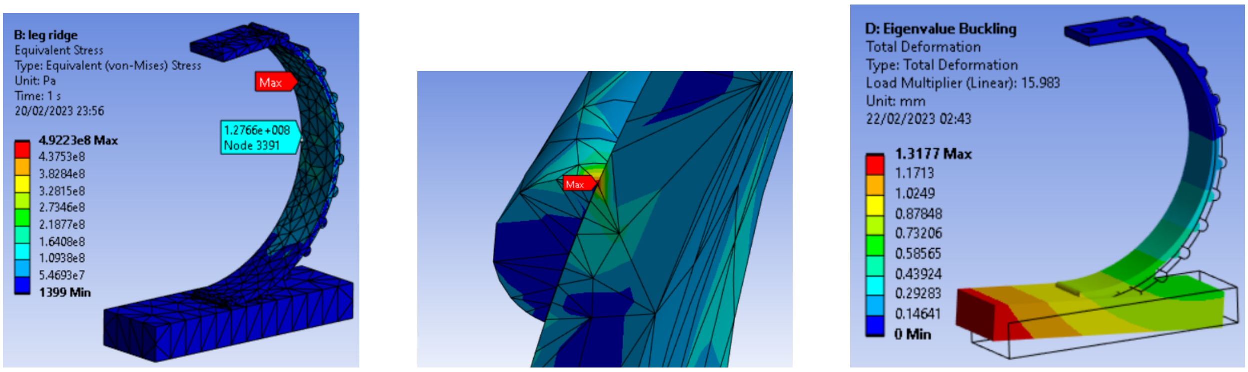
The initial design proposal is inspired by many of the RHex original designs where the curved leg is being used instead of a straight cantilever to improve off-road mobility. Through analysis, it was found that the maximum stress the leg would experience from the fall is $143MPa$, which is within the ultimate tensile strength of the carbon-fibre material chosen for the leg. However, as the centre part of the leg, where the structre curves out the most, is most susceptible to failure: the final design would have greater thickness to reduce deformation.



(a) Static Stress (b) Total Deformation

Figure 10: Cantilever Proposal

In comparison to the cantilever design, it is clear that the curved leg experience significantly more stress, making it more susceptible to fatigue and damages. The simulation shows that the majority of stress is concentrated at the edge of the leg and not at the centre, unlike the result shown in figure 9. This means that the cantilever design is less susceptible to failure. However as the chosen material are not significantly impacted by stress experienced from a fall specified in the brief, the all-terrain capabilities offered by the curved design proves more useful to the proposed RHex.



(a) Static Stress (b) Maximum Stress Close-up (c) Buckling Analysis

Figure 11: Revised Design Proposal

Therefore, to further improve the RHex's off-road capabilities, rubber ridges were added to the design: increasing grip when in motion. Additionally the thickness of the leg was also increase to reduce stress at the curve section of the structure. In figure 11, although the maximum stress has increased, it was found that the stress is concentrated at the boundary between the carbon-fibre and the rubber: meaning that said increase can be safely ignored. As the main shape of the leg was retained, the total deformation of the structure remain constant. Buckling analysis was made on the final iteration of the leg design where the force subjected to the structure is $1N$ as the relationship is linear. From the analysis it was found that the leg could withstand up to $15.98N$, slightly higher that the force expected from a $300mm$ fall. However, the real value is expected to be greater. This is because the area that experienced the most stress is at the ground included in the simulation, and not at leg itself, suggesting that the actual maximum allowable load is greater than suggested. Therefore, the application of the proposed leg design is validated.

7.2 Front & Rear Axle

As a starting point for the axle analysis, the 6mm diameter axle was selected as it is most susceptible to fall and shock damages. It is to be noted that while smaller axle diameter was considered, such choices were not available from the bearing manufacturer. Therefore, a suitable material must be found through maximum shear stress calculations:

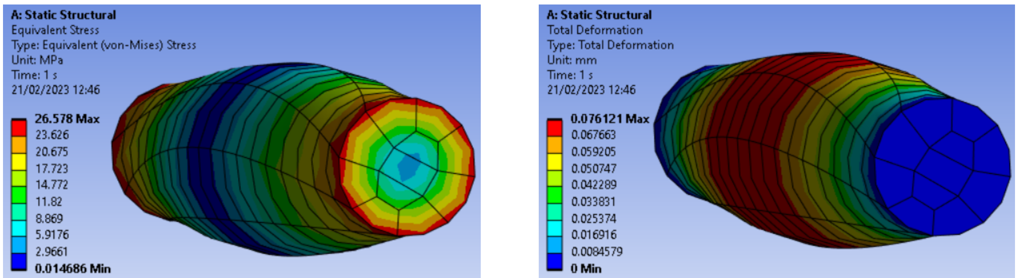
$$J_{cylindrical} = \frac{\pi \cdot r^4}{2} \tag{19}$$

$$\sigma_{max} = \frac{T \cdot r_{shaft}}{J} = 28.8MPa \tag{20}$$

Applying a safety factor of 1.5 means that ideally the axle material should withstand $43.2MPa$ of shear stress, one-eleventh of steel alloy's ultimate shear stress.[3] Therefore, to reduce weight and meet the specification, the axle will be constructed from ABS/PC blend.[4] Furthering the justification for the use of said blend, maximum angular deflection of the axle can be calculated, where modulus of rigidity is $6.1GPa$[5]:

$$\theta = \frac{T \cdot l}{G \cdot J} = 0.089rad \tag{21}$$

While the deflection of plastic shaft is greater than its metallic counterparts, the difference is small enough to validate its usage. Said deflection can be reduced by using a stiffer material or having a thicker axle, but any increase in the axle diameter will have dimishing returns as it would take up more space while requiring more power to move. To validate hand-calculations, Finite Element Analysis were made on the shaft:



(a) Stress (b) Total Deformation

Figure 12: Proposed Axle Design

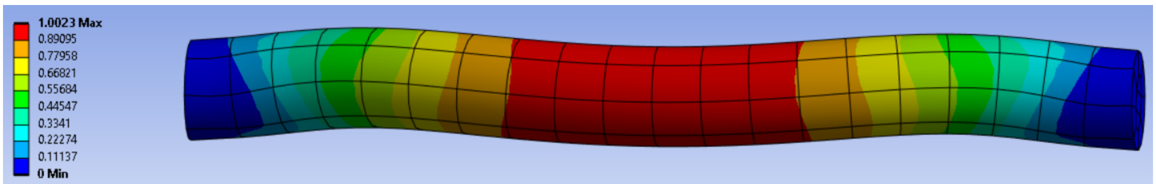
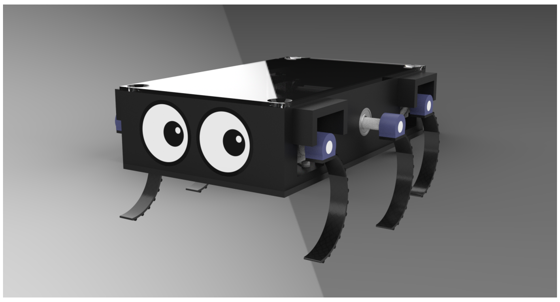


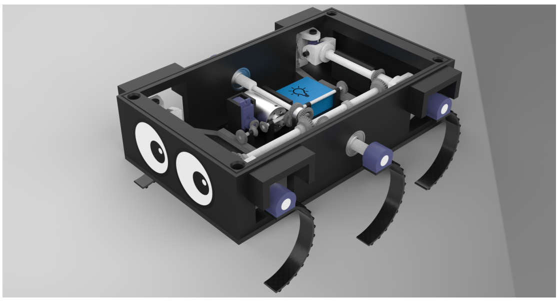
Figure 13: Proposed Axle Buckling Analysis

From the analysis, the results do correlate with the hand calculations made where the maximum stress experienced was $26.6MPa$ and the total deformation was $0.076mm$. Using buckling analysis it was found that the proposed axle can withstand up to $265N$ of force before failure. As the force from the impact would be significantly less, the simulation suggests that the axle will not buckle in normal operation conditions. Therefore in conclusion, while implementing a 6mm diameter steel axle would similarly meet the specification, the increase in weight and manufacturing costs means that the application of ABS/PC blend is preferred.

8 Final Design



(a) Hero Image of Proposed RHex



(b) Proposed RHex with exposed components

Figure 14: Dynamic View of Proposed RHex

In the final design, the total dimension of the RHex is $136mm \times 161mm$, where the total width is slightly larger than the specified body width. Meaning in terms of the main chassis, the dimension requirement was met. The reason for the additonal width was to prevent the centre pair of legs from making contact with the other pairs and the 'waterguard extrusion'. The total leg length is $46.9mm$, where the radius is $25.92mm$, also meeting the specficiation from the brief. With all parts combined and excluding the legs and batteries; the total mass is $279g$, all within the threshold of the specification.

Component	Quantity	Mass	Cost
DC Motor	1	$95g$	£43.09
Servo Motor	1	$5.2g$	£14.75
1.5V Batteries	4	$46g$	£0.98
Chassis & Cover	-	$170g$	£1.69
Drivetrain	-	$33g$	£27.24
Steering System	-	$8.2g$	£1.2

Table 3: Summaried Bill of Material

In total, the cost of the proposed RHex is just within the £100 limit as the majority of the parts are cheaply manufacturable using injection moulding. However, the weight (excluding legs and batteries) exceeded the specified by $11.4g$, where the majority of the weight is due to the chassis. Therefore, in future improvements, further topography optimisation must be studied on the chassis to reduce the weight down to the specified value. While the drivetrain and the steering system are relatively heavy, less design options could be made to further reduce the weight. The primary reason is due to the fact that the material for the gears and shafts are already made of polymers, meaning few material exists that are lighter and have the same mechanical properties as ABS and polyacetal. While said materials are available in the market, the significant increase in costs makes them unsuitable for this application.

In terms of technical specifications, as said requirements were taken into consideration during the design process, the proposed RHex is able to traverse obstacles over $200mm$, travel up to $2ms^{-1}$, and able to survive a $300mm$ drop.

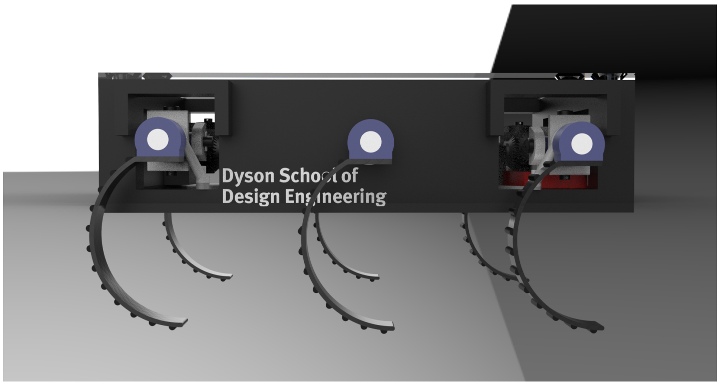


Figure 15: Side-View of Proposed RHex

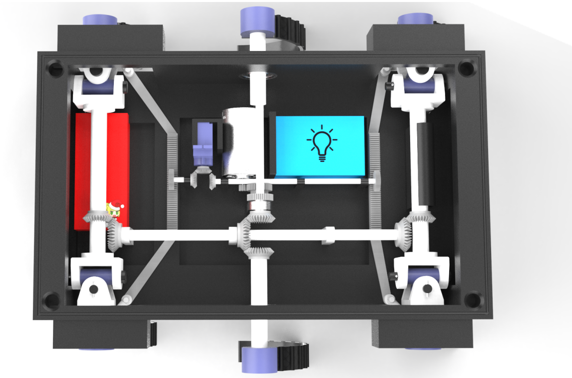


Figure 16: Top-View of Proposed RHex (Electronics highlighted in red & Battery Pack in blue)

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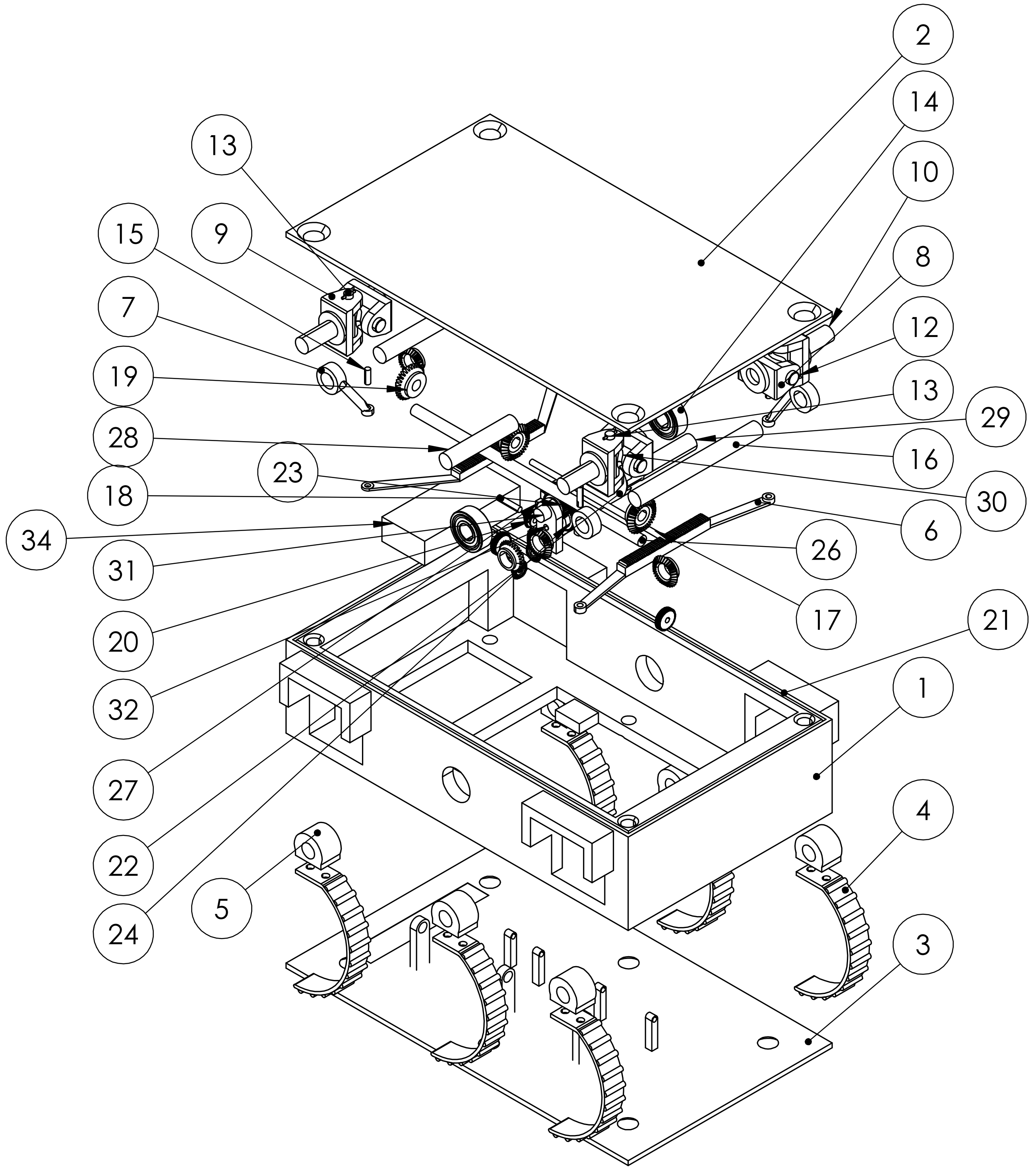
ITEM NO.	PART NAME	DESCRIPTION	QTY
1	MAIN CHASSIS		1
2	TOP COVER		1
3	BOTTOM COVER		1
4	Leg		6
5	Leg Fastener		6
6	Rack Spur		2
7	Steering Hinge		4
8	Driving Yoke		4
9	Driven Yoke		4
10	Yoke Shaft		4
11	Universal Connector Pin	Hold the yoke and the bearing cross together	8
12	Driving Yoke Pin		4
13	Driven Yoke Pin		4
14	6mm Diameter Bearing		2
15	Steering Pin	Holds rack spur and steering hinge together	4
16	6mm (Front & Rear) Driving Shaft		2
17	Rear Steering Shaft		1
18	Front steering Shaft		1
19	6mm Bore Custom Spur Gear		8
20	2mm Bore Custom Spur Gear		2
21	O-Ring	Prevent water from entering the case from the cover	2
22	RS-Pro Geared Motor		1
23	ISO Spur Gear - 41T		2
24	ISO Spur Gear - 11T		1
25	ISO Spur Gear - 15T		1
26	Driveshaft		1
27	HS-40 Servo Motor		1
28	Centre Left Driving Shaft		1
29	Centre Right Driving Shaft		1
30	Bearing Cross		4
31	Gearbox Output Shaft		1
32	Gearbox Intermediary Shaft		1
33	Gearbox Input Shaft		1
34	Electronics Compartment		1
35	6V Battery Pack		1
36	DIN7991 M6 Screws		22



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION

	NAME	SIGNATURE	DATE
DRAWN	Raphassit Suwiwatchai		
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

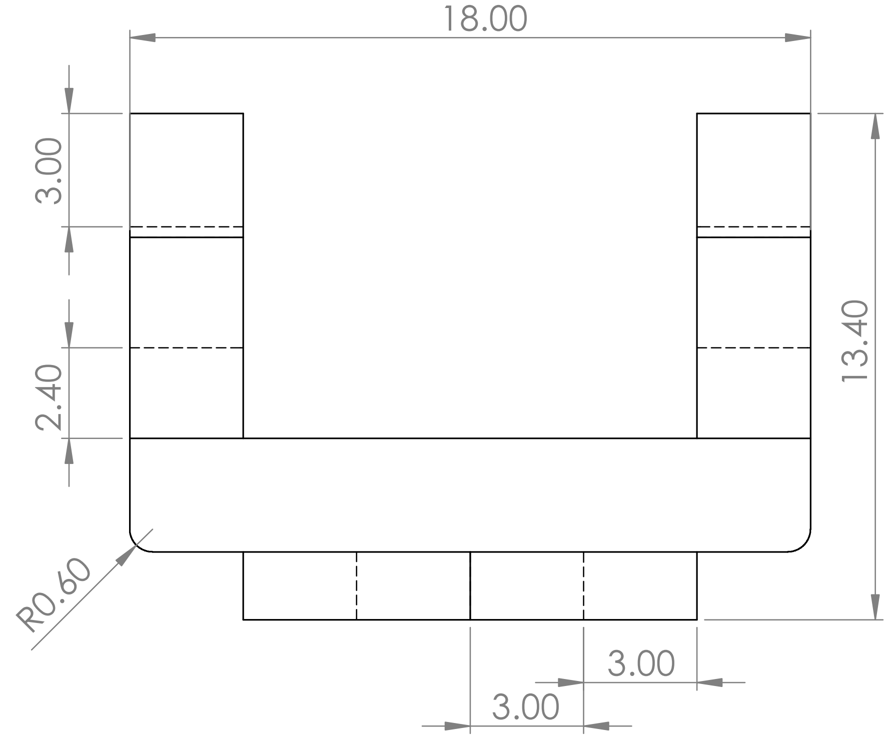
TITLE:
General Assembly Drawing

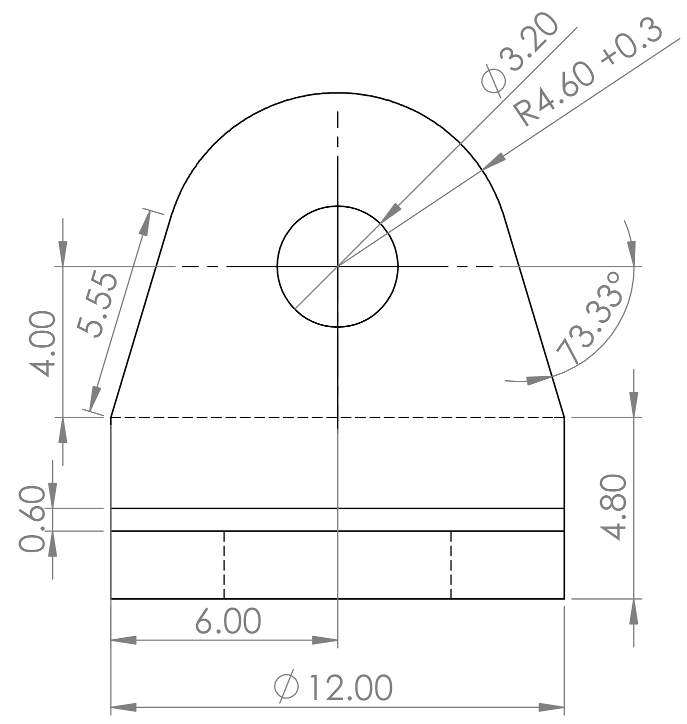
DWG NO.
RHex

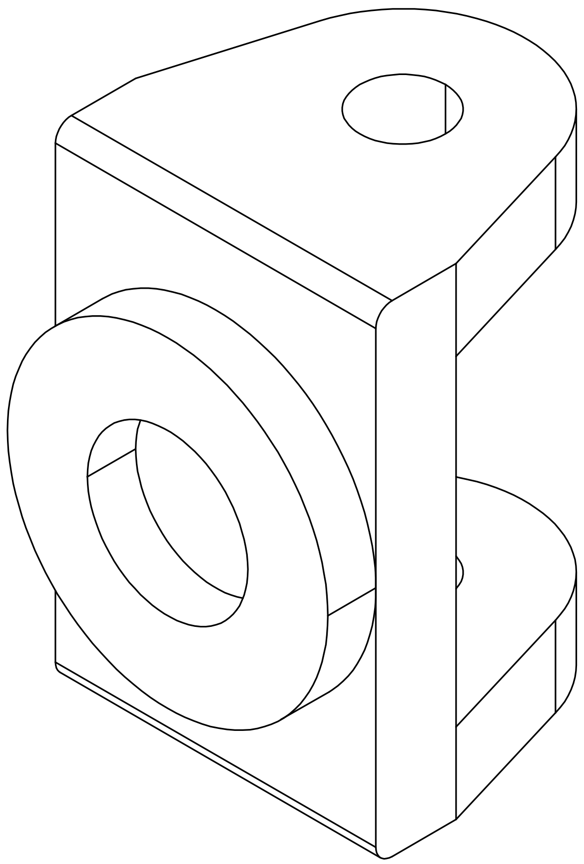
A3

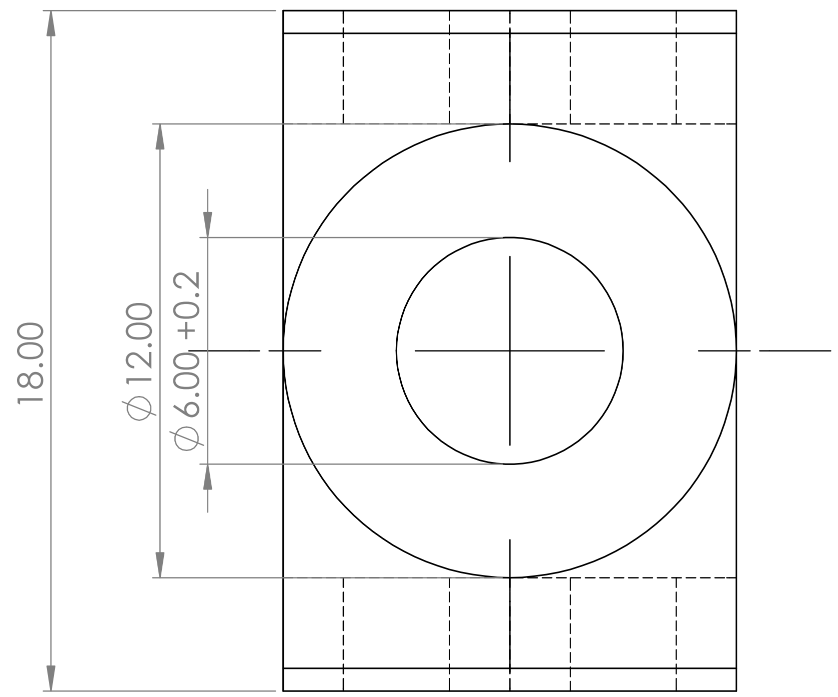
SCALE:1:2

SHEET 1 OF 1









UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: 10 TOLERANCES: 0.1 LINEAR: ± 0.01 ANGULAR: ± 0.15 deg	FINISH: AS INJECTION MOULDED UNLESS OTHERWISE SPECIFIED	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	Raphassit Suwiwatchai		
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: ABS

WEIGHT: 1.3g

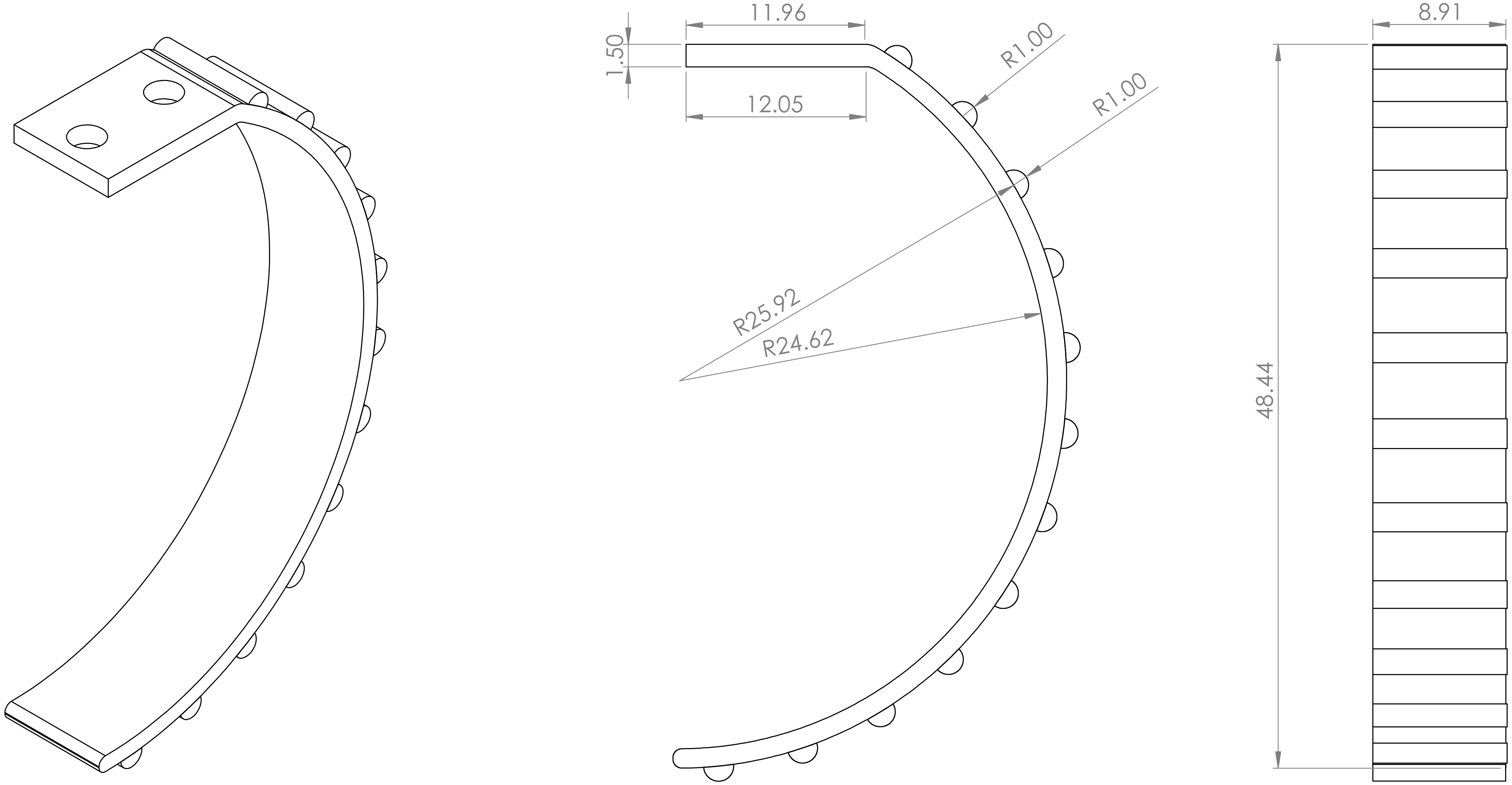
TITLE: Universal Joint Driving Yoke

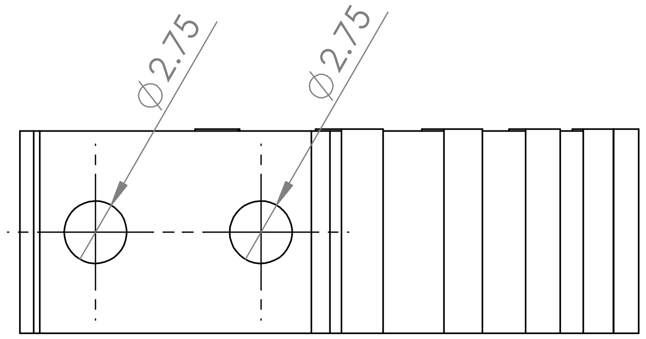
DWG NO. Driving Yoke

A3

SCALE:5:1

SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Raphassit Suwiwatchai		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Proposed RHex Leg

MATERIAL:
Carbon Fibre, Rubber

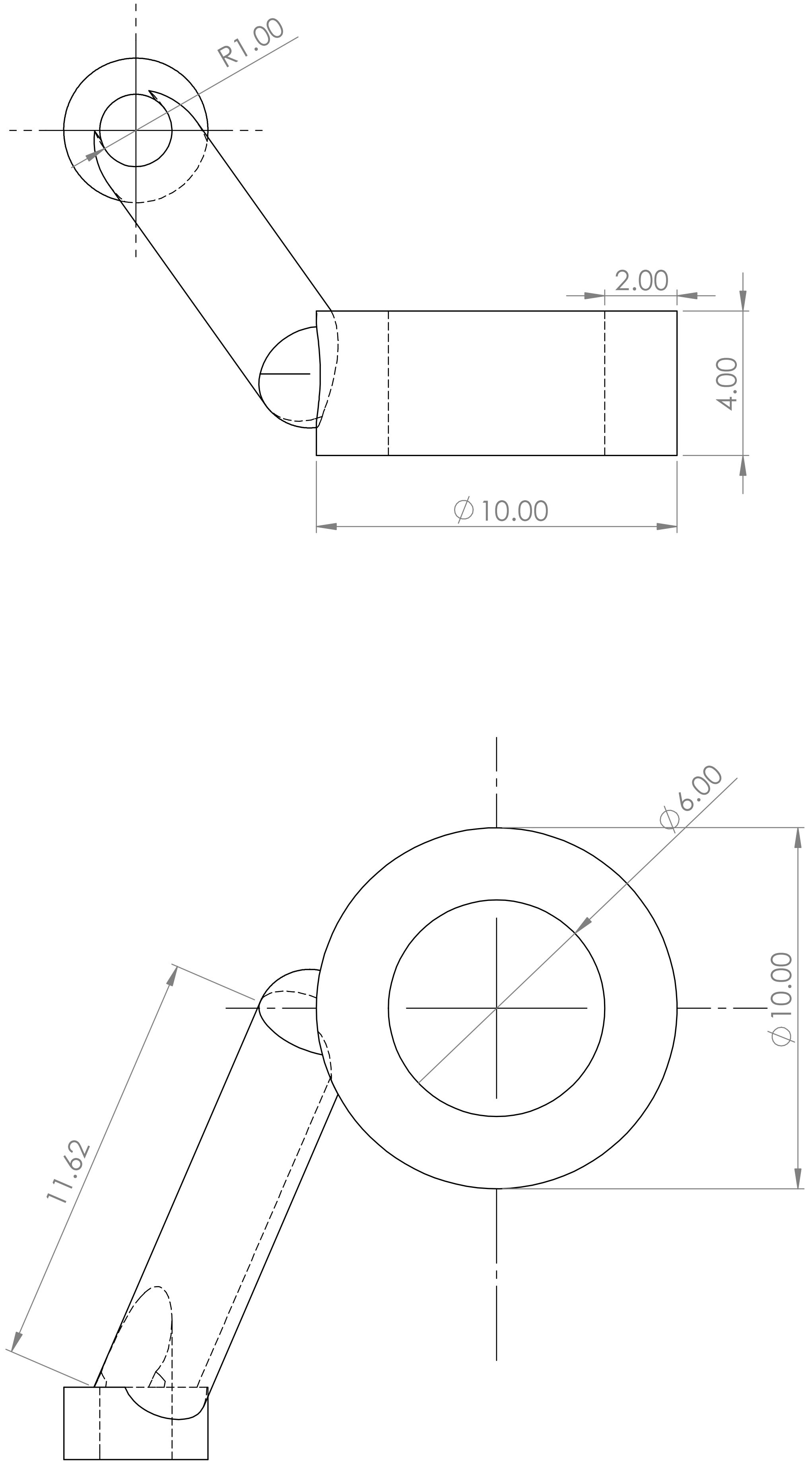
DWG NO.
final leg

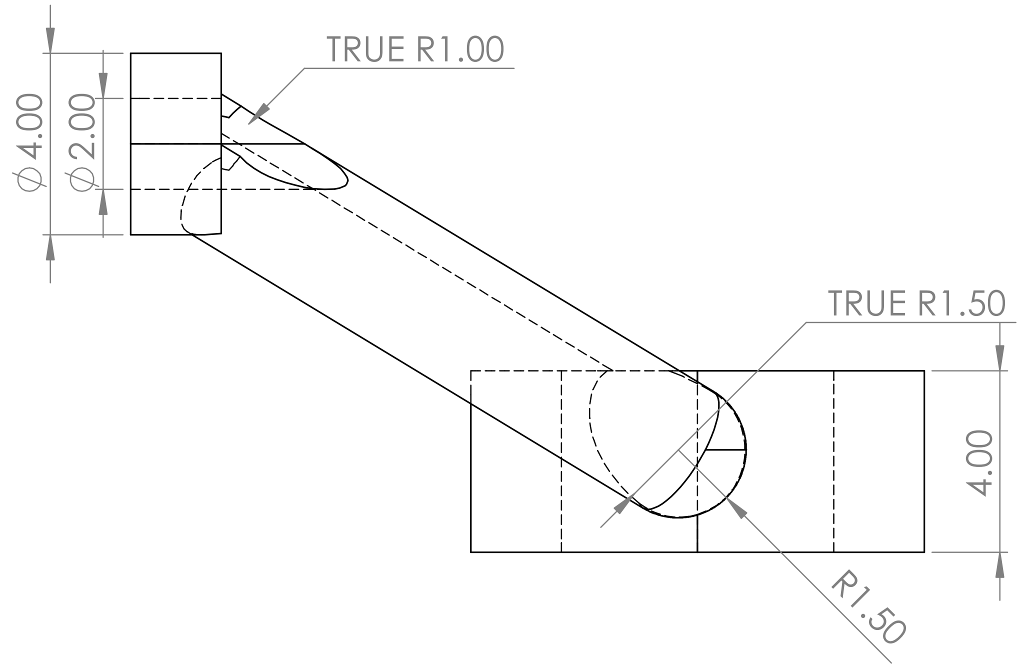
A3

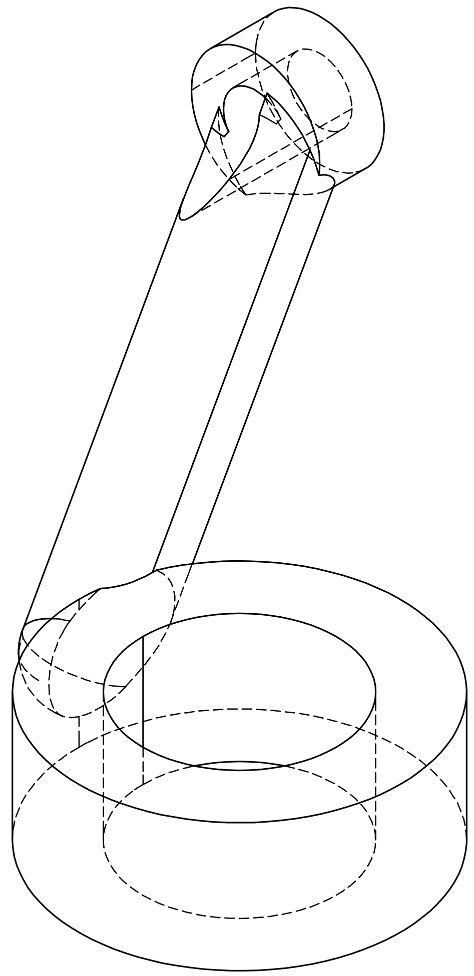
WEIGHT: 1.9g

SCALE:3:1

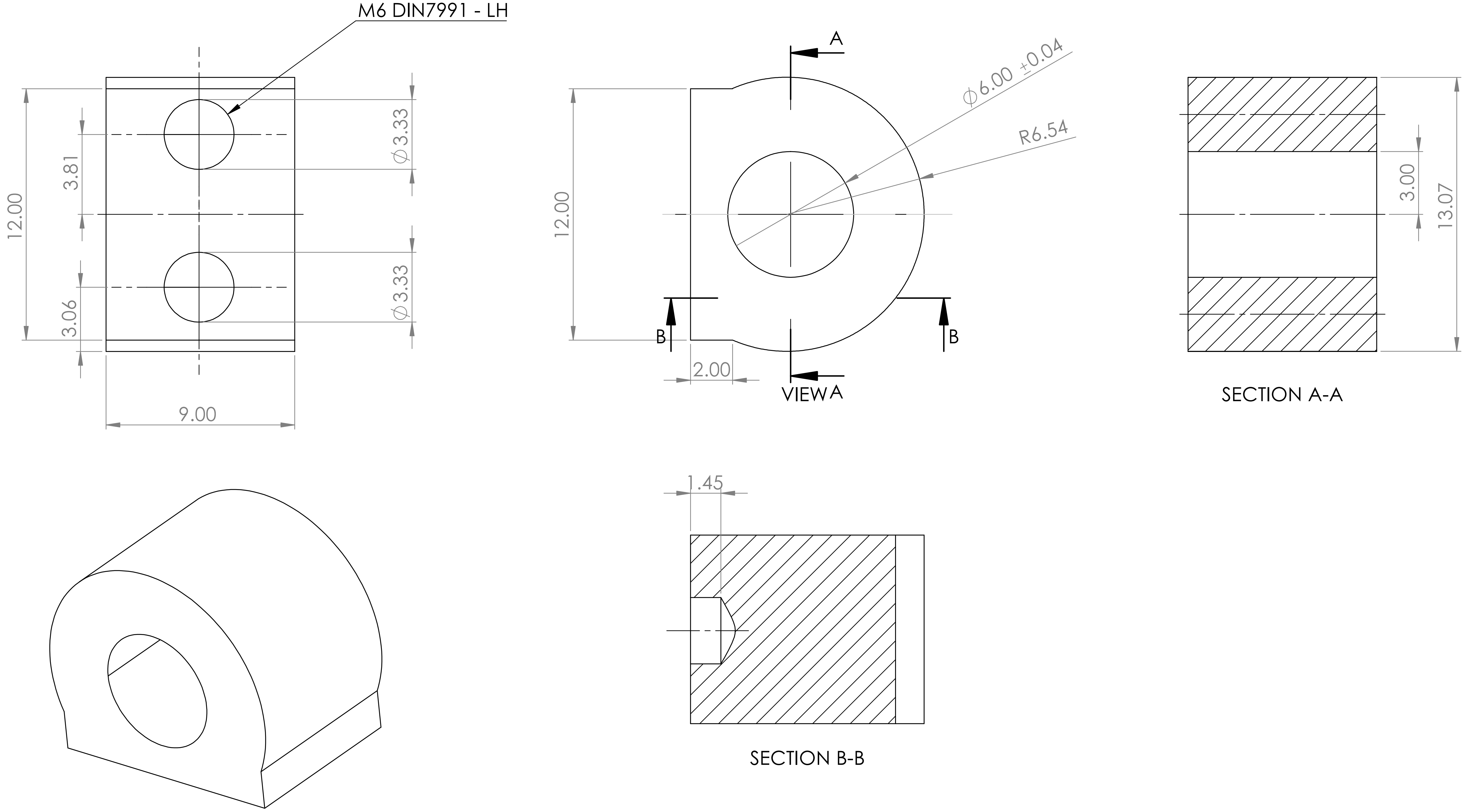
SHEET 1 OF 1







UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE	TITLE: Steering Hinge (Left)	
DRAWN	Raphassit Suwiwatchai				
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: ABS	DWG NO. connector 1 v1	A3
			WEIGHT: 0.34g	SCALE:6:1	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: 10
TOLERANCES: 0
LINEAR: IT11
ANGULAR: 0.3 deg

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Raphassit Suwiwatchai		
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Leg Fastener

MATERIAL: ABS

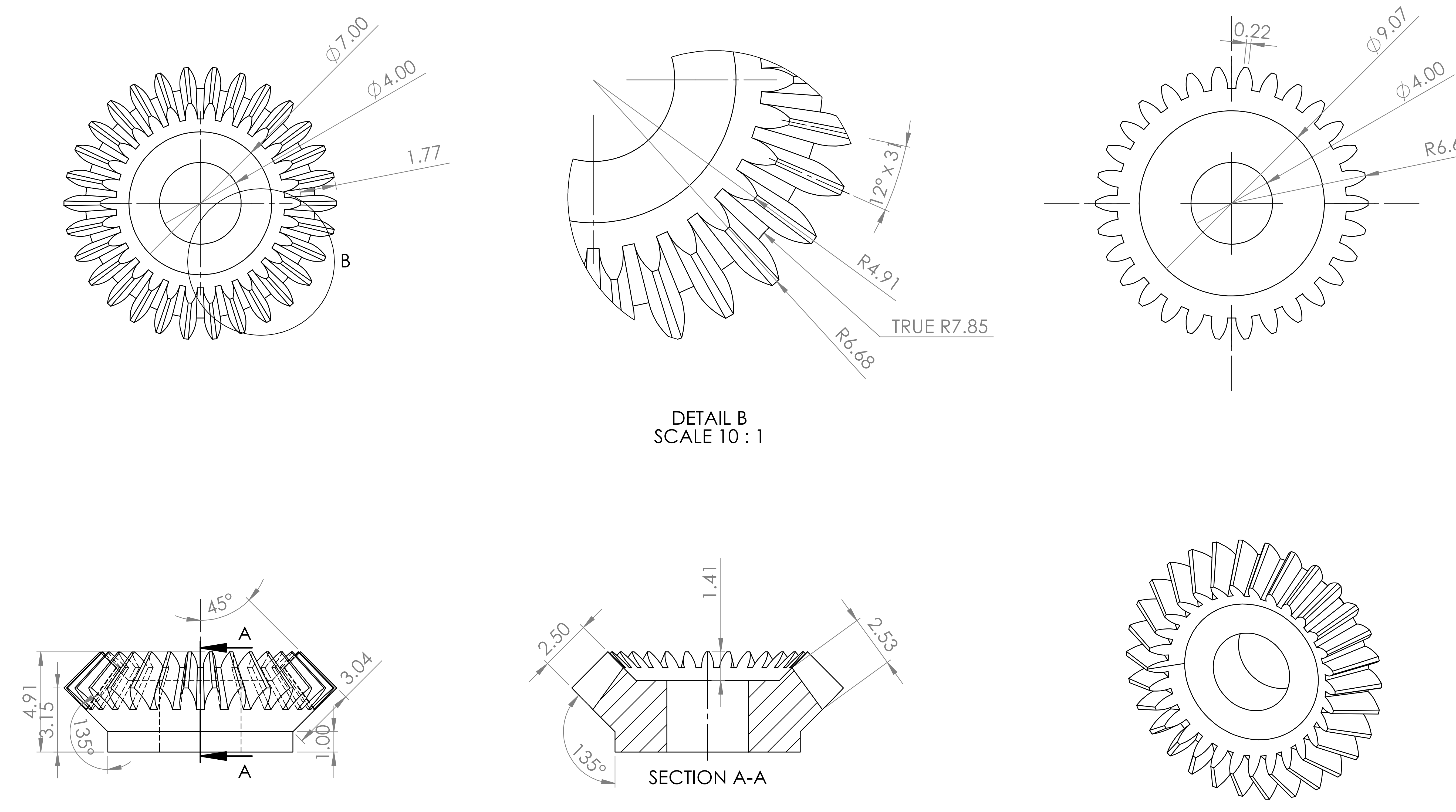
DWG NO. Leg fastener

A3

WEIGHT: 0.89g

SCALE:5:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	Raphassit Suwiwatchai		
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Polyacetal

WEIGHT: 4.1e-4 g

TITLE: Shaft Bevel Gear

DWG NO. Shaft bevel gear

A3

SCALE:5:1

SHEET 1 OF 1