

Chapter 1

INTRODUCTION

Reverse engineering a kick scooter involves disassembling and analyzing its components and functionality to understand its design, materials, and operational mechanisms. The process begins by carefully taking apart the scooter to identify its individual parts, such as the deck, handlebar, steering column, wheels, bearings, braking system, and folding mechanism (if present). The goal of reverse engineering may be to replicate the design, improve performance, enhance safety, reduce weight, or learn about the manufacturing and assembly techniques used. This process usually includes documenting the internal and external structure, measuring dimensions, studying material selection, and understanding how different components work together to provide motion, balance, and braking. Throughout the process, care should be taken to follow legal and ethical guidelines, ensuring that any redesign or modification respects intellectual property rights and maintains user safety standards

1.1 Background of study

Reverse engineering can be motivated by several goals, including:

1. **Educational Insights:** Studying the mechanisms of a kick scooter helps learners understand concepts such as load distribution, steering geometry, braking mechanics, and material selection used for structural strength and comfort.
2. **Improvement and Modification:** Analyzing the design allows enthusiasts to enhance features such as ride comfort, stability, folding mechanisms, portability, durability, or braking efficiency.
3. **Product Development:** Manufacturers may reverse engineer existing scooters to evaluate market trends, compare design approaches, incorporate innovative features, or develop more cost-effective and user-friendly models.

4. **Repair and Maintenance:** Understanding the internal and external components of a kick scooter makes it easier to diagnose faults, replace damaged parts like wheels or bearings, and maintain overall performance and safety.
5. **Curiosity and Exploration:** For hobbyists, disassembling and analyzing a kick scooter can be an engaging way to explore mechanical design, improve practical engineering skills, and gain hands-on experience with real-world mobility systems.

1.2 Steps in Reverse Engineering a Kick Scooter

1. Preliminary Assessment

Before disassembly, examine the kick scooter externally to understand its basic features and functionality. Identify the type of scooter (fold able, non-fold able, brake type, wheel size, etc.) and note visible components like the deck, handlebar, wheels, folding joint, and brake system. Testing the scooter in normal use (pushing, steering, braking) can provide clues about how it operates and how loads are transmitted.

2. Disassembly

Carefully take apart the kick scooter to expose its major assemblies and components. Tools such as Allen keys, screwdrivers, and wrenches are commonly required. Document each step by taking photographs or notes so that the scooter can be reassembled correctly after analysis.

3. Component Identification

Once disassembled, identify and classify the individual parts, such as:

- **Deck:** Supports the rider's weight.
- **Handlebar and Steering Column:** Enable control and direction.
- **Wheels and Bearings:** Provide rolling motion and reduce friction.
- **Brake System:** Typically a rear fender brake or disc brake to slow or stop the scooter.
- **Folding Mechanism (if present):** Allows compact storage and portability.
- **Fasteners:** Bolts, nuts, and screws that hold components together.

4. Functional Analysis

Examine how each component interacts within the system. For example:

- How does the steering column transfer motion from the handlebar to the front wheel?
- How does the braking mechanism create friction to stop the scooter?
- How are loads from the rider distributed through the deck and frame?
- How does the folding mechanism lock and unlock safely?

5. Documentation

Create detailed sketches, schematics, or 3D models of the kick scooter and its subsystems. This helps in clearly understanding the design layout, assembly order, and working principles, and supports future replication, redesign, or modification.

6. Material Study

Analyze the materials used in different parts—for example, aluminum or steel for the frame, rubber or polyurethane for the wheels, and plastic components for grips and guards. Understanding material selection reveals strength requirements, weight considerations, manufacturing processes, and cost factors.

7. Testing and Evaluation

Reassemble the kick scooter and test it under controlled conditions to verify your understanding of its mechanisms and performance. Evaluate aspects such as stability, comfort, braking efficiency, and folding ty.

Chapter 2

LITERATURE SURVEY

The reverse engineering of a kick scooter is carried out by combining well-established engineering principles, standard methodologies, and technical guidelines from multiple engineering disciplines. The overall approach to reverse engineering and geometric model reconstruction is based on the methodologies proposed by Raja and Fernandez (2008) [3] and Várady et al. (1997) [4], which provide a structured process for analysing an existing product and recreating its digital model. A clear understanding of the product's operating environment and functional requirements is supported by studies on micro-mobility systems by Shebeen and Cohen (2019) [1] and Jiao and Bai (2020) [2], along with specific research on kick scooter design presented by Chen and Cheng (2016) [9].

Dimensional data is obtained using precision measurement practices described by Hocken and Pereira (2016) [8], while geometric dimensioning and tolerancing follow ASME Y14.5-2018 [12]. The evaluation and management of dimensional variations are guided by the tolerance analysis principles outlined by Chase and Parkinson (1991) [13]. The development of accurate CAD models is carried out using standard modelling techniques described by Tickoo (2018) [15] and Zeid and Kamrani (2018) [16], and engineering drawings and documentation are prepared in accordance with conventions provided by Giesecke et al. (2016) [11].

Structural evaluation of the kick scooter components is informed by frame analysis methods discussed by Thompson and Fidel (2017) [6] and design guidelines for hollow structural sections presented by Packer and Henderson (1997) [10]. General mechanical design principles are referenced from Budynas and Nisbett (2015) and Norton (2014). Material selection and characterization are supported by the material selection methodology of Ashby (2011), fundamental materials science texts by Callister and Rethwisch (2018), ASM International handbooks, and aluminium alloy specifications described by Kaufman (2000)..

Manufacturing considerations, including forming and joining processes, are based on Kalpakjian and Schmid (2014) [14], with welded structure design principles referenced

from Blodgett (1982) [20]. Computational validation of the reconstructed design is performed using finite element analysis methods described by Zienkiewicz et al. (2013) [17] and Cook et al. (2001) [18]. Additional aspects such as contact behaviour, ergonomics, dynamic response, and nonlinear material behaviour are addressed using the works of Johnson (1987), Pheasant and Haslegrave (2016), Pacejka (2012) [19], and Holzapfel (2000). The overall development process follows an iterative approach inspired by Boehm's spiral model (1988) [7].

Chapter 3

LEARNING OBJECTIVES

The learning outcomes of reverse engineering kick scooters encompass a wide range of skills in mechanical design, structural analysis, and user safety. Learners will develop the ability to understand the mechanical systems within a kick scooter, including how components such as the deck, handlebar, steering mechanism, wheels, bearings, and braking systems work together to enable motion, control, and stopping. They will also gain proficiency in reverse engineering techniques such as systematic disassembly, dimensional measurement, 3D scanning, CAD modeling, and material analysis, enabling them to recreate, redesign, and modify existing scooter designs. Additionally, learners will understand material selection and properties, learning how choices such as aluminum alloys, steel, or polymers influence strength, durability, weight, cost, and rider comfort. A key aspect is awareness of safety standards and regulations, ensuring that reverse-engineered scooters comply with structural, stability, and braking safety guidelines. Furthermore, students will be able to innovate and optimize scooter designs by improving ergonomics, folding mechanisms, vibration damping, and overall performance. Lastly, they will recognize ethical and regulatory considerations related to personal mobility products, ensuring designs prioritize rider safety and responsible use.

One of the primary learning outcomes is an enhanced understanding of design and functionality. By reverse engineering kick scooters, learners gain insight into the structural and mechanical systems that make the scooter operate. They study how components such as the steering column, bearings, and wheels interact to provide smooth motion and maneuverability, and how braking mechanisms generate friction to slow or stop the scooter. Learners also explore design factors such as load distribution, fatigue strength, stability, and rider ergonomics, and how these are integrated into the overall product architecture. This understanding develops critical thinking and problem-solving abilities by analyzing how individual components and subsystems work together to create a safe, efficient, and user-friendly mobility device

Chapter 4

METHODOLOGY

Selection of the Product:

The selection process should prioritize kick scooters with sufficient complexity, ideally consisting of a minimum of 15–16 different parts. This level of complexity ensures a comprehensive learning experience and provides rich scope for reverse engineering. A suitable kick scooter may include components such as the deck, handlebar, steering column, fork, wheels, bearings, brake, folding mechanism, and fasteners, allowing detailed study of design, functionality, and assembly.

Measuring All the Parts of the Product:

Measuring individual components of a kick scooter during reverse engineering is a crucial step in understanding its specifications, tolerances, and design challenges. Precision instruments such as vernier calipers, micrometers, steel rulers, measuring tapes, and protractors are used for dimensional inspection. After measuring all the parts, the dimensions are recorded and drafting is carried out on sheets to prepare for 3D modeling.

Modeling All the Parts of the Product:

Modeling of all the components of the kick scooter is carried out using CATIA. Various modeling tools and commands are used to create accurate 3D models based on measured dimensions and drafted drawings. The drawings prepared by the draftsman serve as a reference to accurately replicate the geometry of parts such as the deck, handlebar, fork, and brake.

Chapter 5

PRODUCT SELECTED



Fig 5.1 Selected product of kick cycle

LIST OF COMPONENTS

Table 5.1 : This table presents the Bill of Materials (BOM) for the kick scooter, listing all major components along with their corresponding material types. It highlights the predominance of metal parts for structural strength, while plastic and rubber components are used where flexibility, grip, and impact absorption are required. This helps in understanding material selection, functionality, and manufacture-ability of the product.

SL NO.	Part name	Material type
1	Foam grip	Metal
2	Hex socket head bolt	Metal
3	Hex socket button head screw	Metal
4	Socket head cap screw	Metal
5	Hex nut	Metal
6	roller chain	Metal
7	mounting bracket	Metal
8	eye bolt	Metal
9	T-slot nut	Metal
10	knurled nut	Metal
11	square washer	Metal
12	T-bar	Metal
13	handle bar stem tube	Metal
14	clamping collar	Metal
15	base plate	Metal

REVERSE ENGINEERING OF KICK CYCLE`

16	spacer bush	Metal
17	Threaded head-stock lock nut	Metal
18	deck break	Plastic
19	Wheel	Rubber
20	front fork	Metal
21	break	Plastic

Part body 1:



Fig 5.3 Gripper

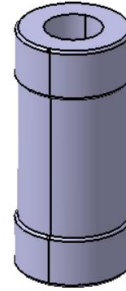


Fig 5.4 3D part of gripper

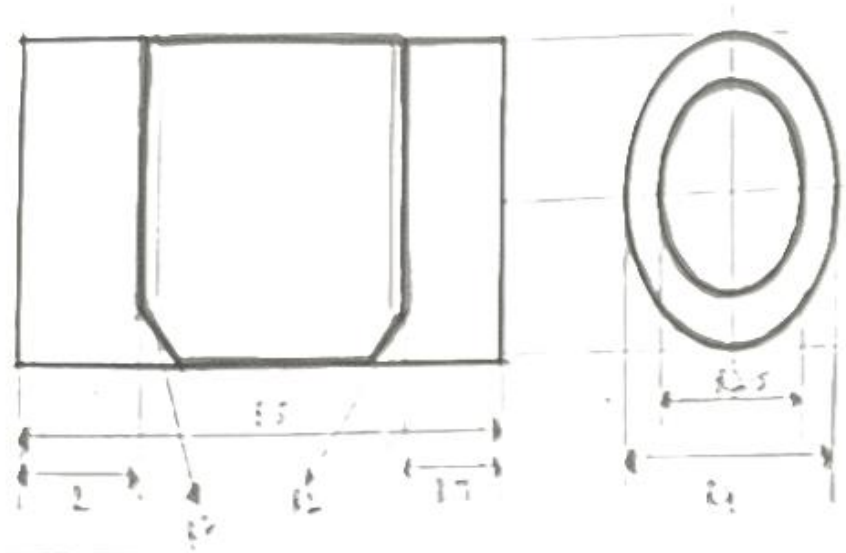


Fig 5.5 2D sketch of gripper

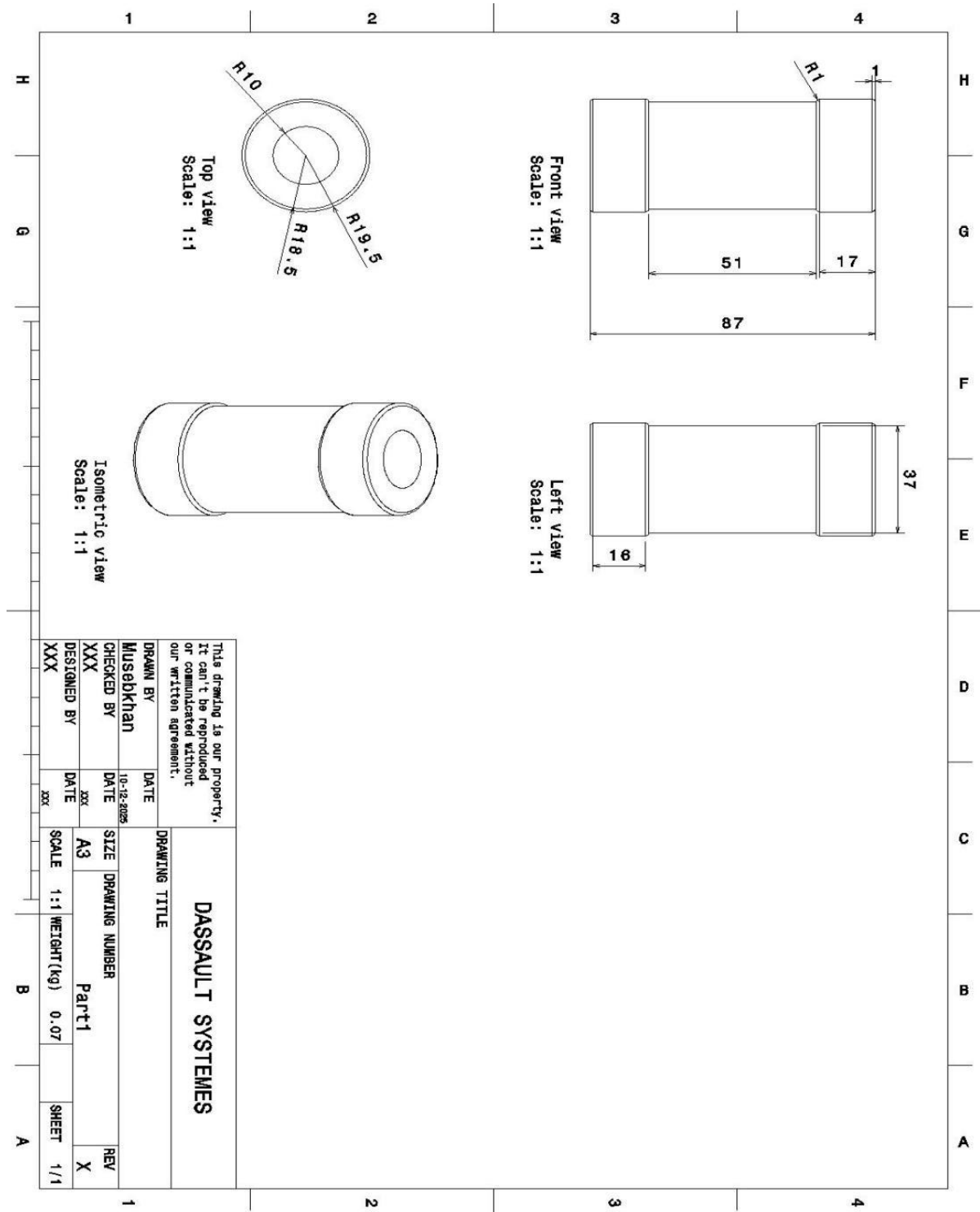


Fig 5.6 Drafting of griper

Part body 2:



Fig 5.7 hex socket

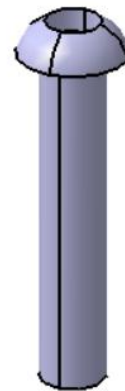


Fig 5.8 3D part of hex socket

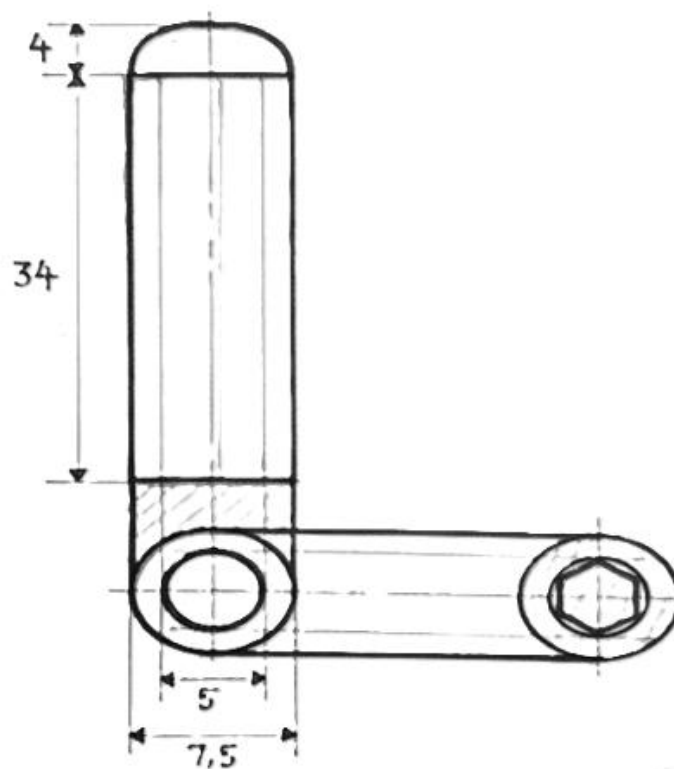


Fig 5.9 2D sketch of hex socket

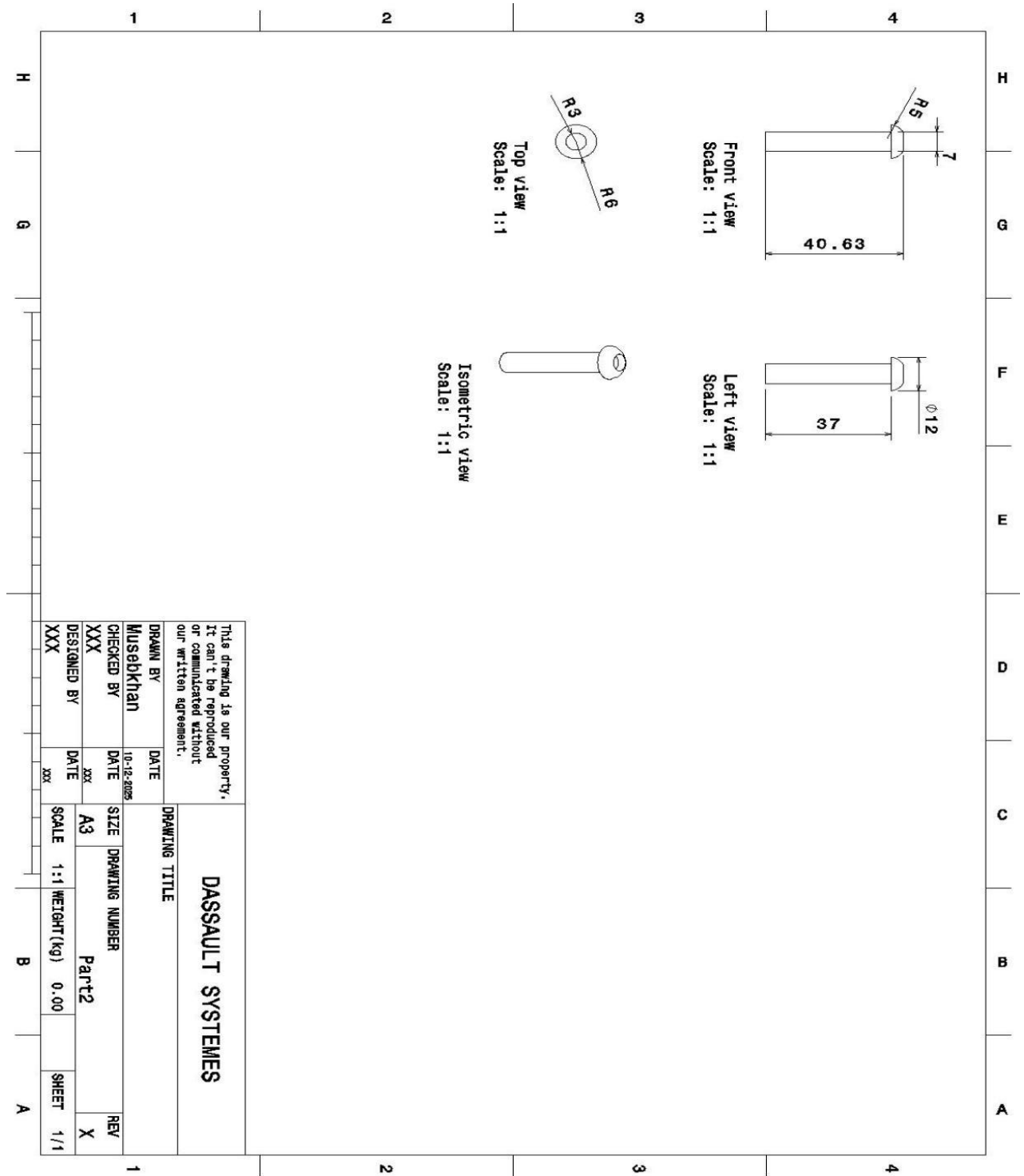


Fig 5.10 drafting of hex socket

Part Body 3:



Fig 5.11 hex socket

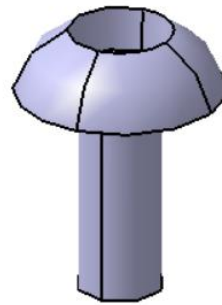


Fig 5.12 3D part of hex socket

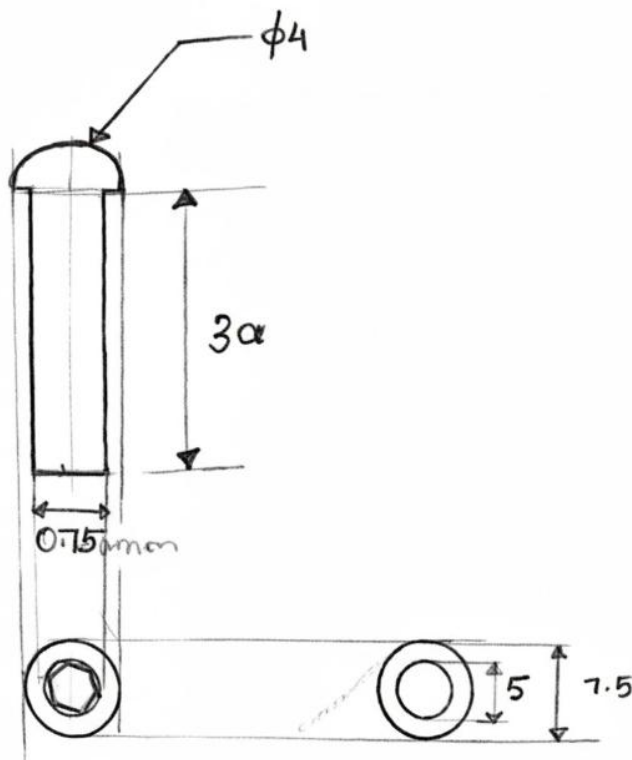


Fig 5.13 2D sketch of hex socket

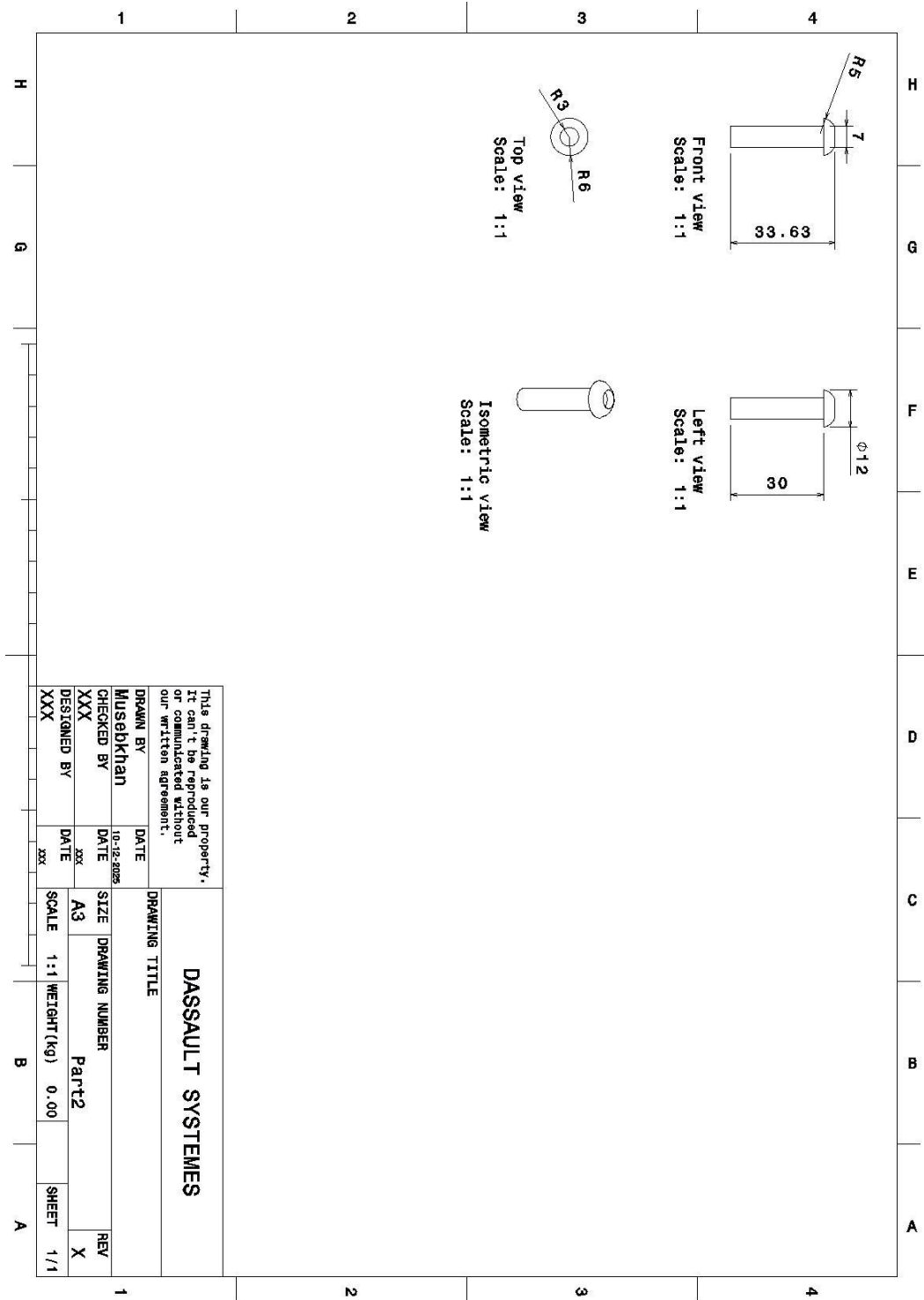


Fig 5.14 drafting of hex socket

Part body 4



Fig 5.15 hex socket button

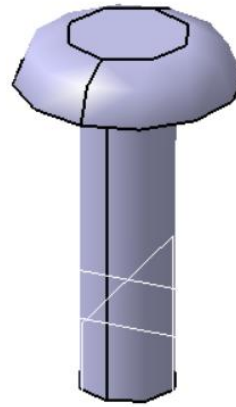


Fig 5.16 3D part of hex socket button

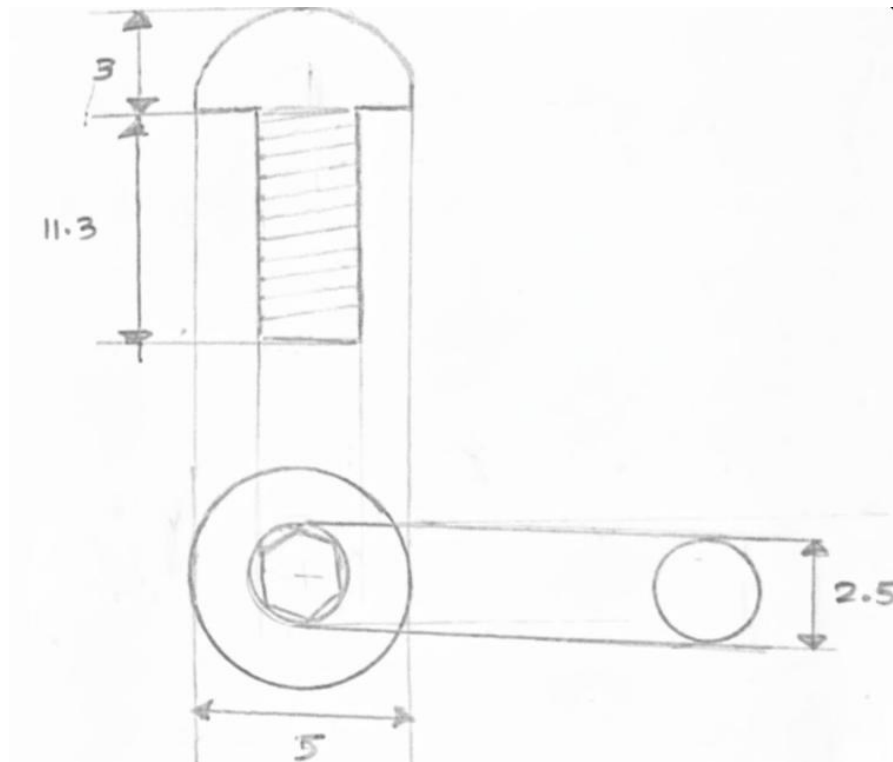


Fig 5.17 2D sketch of hex socket button

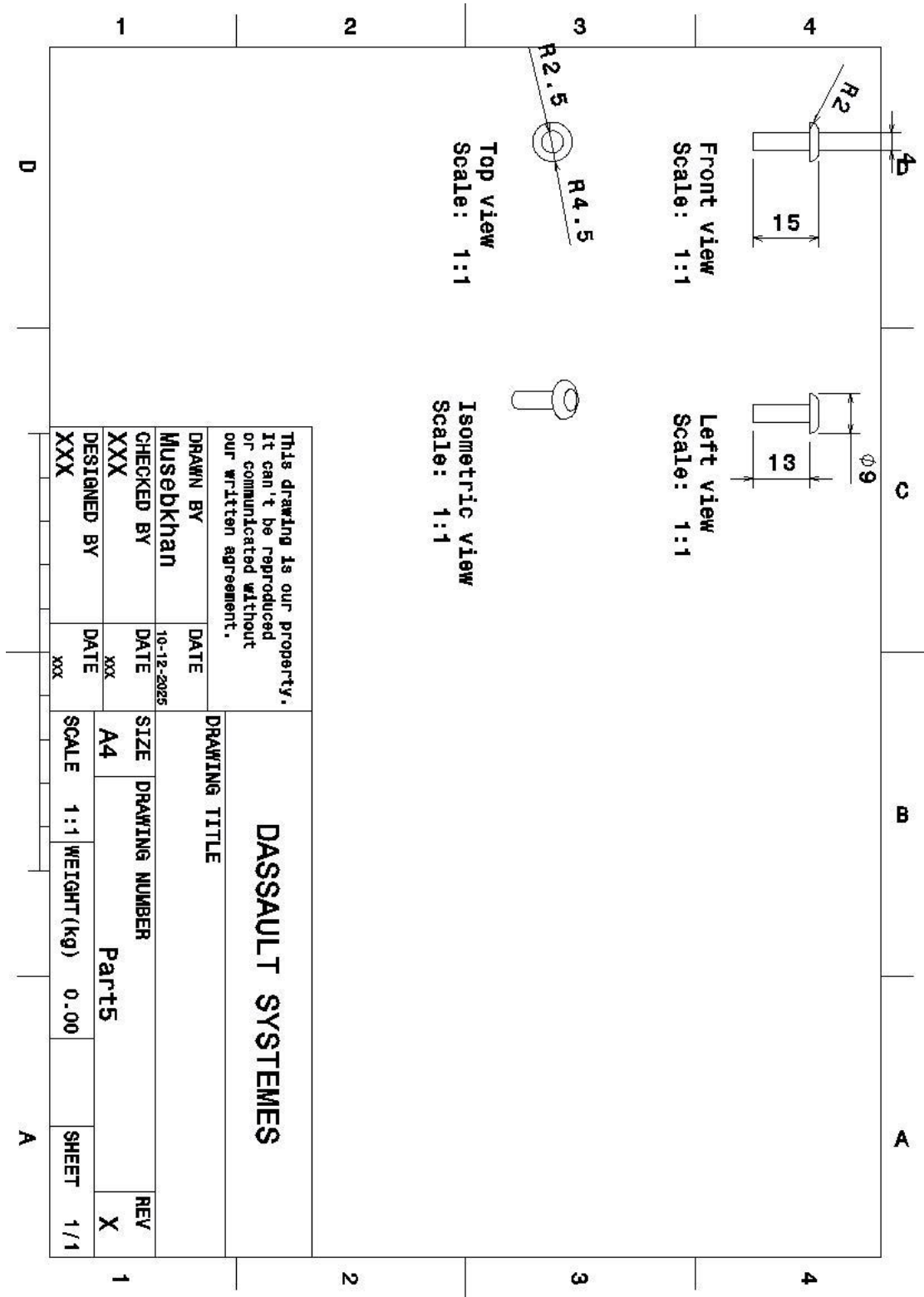


Fig 5.18 Drafting of hex socket button

Part 5



Fig 5.19 head cap screw

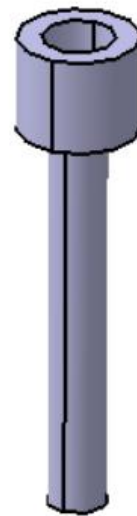


Fig 5.20 3D part of head cap screw

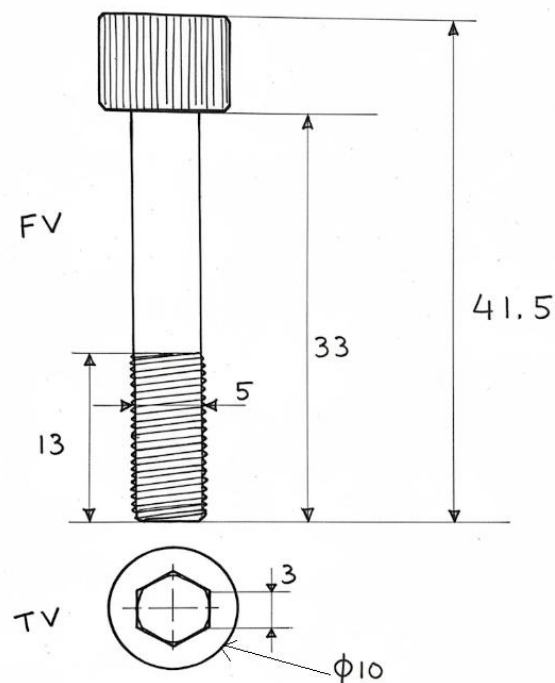


Fig 5.2 2D sketch of head cap screw

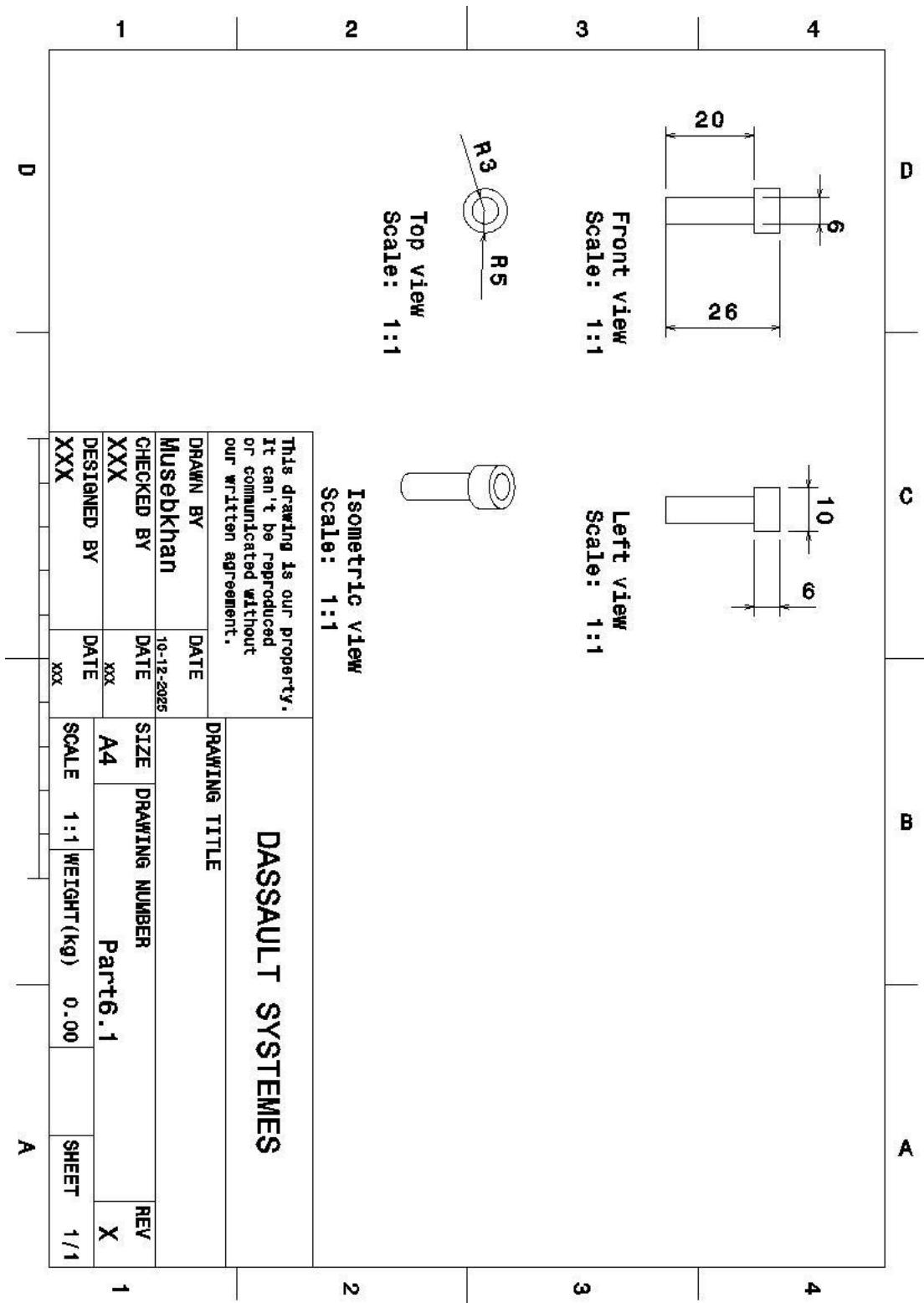


Fig 5.22 Drafting of head cap screw

Part 6



Fig 5.23 head cap screw

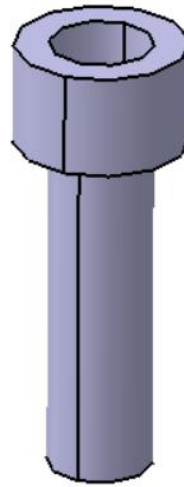


Fig 5.24 3D part of head cap screw

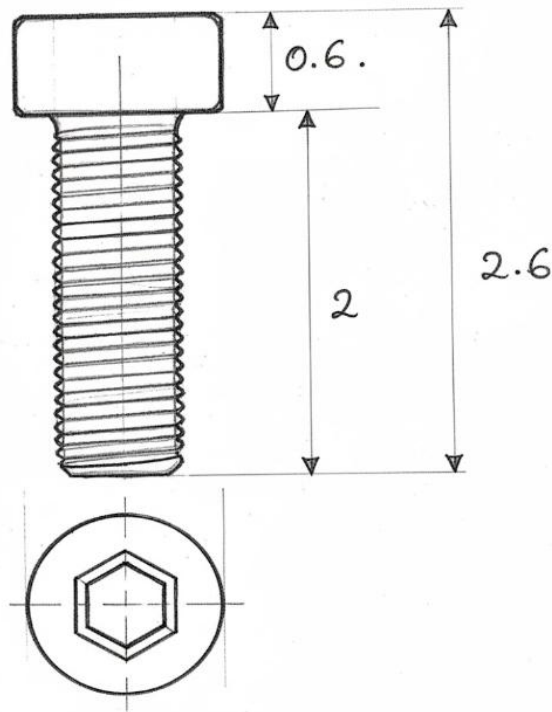


Fig 5.25 2D sketch of head cap screw

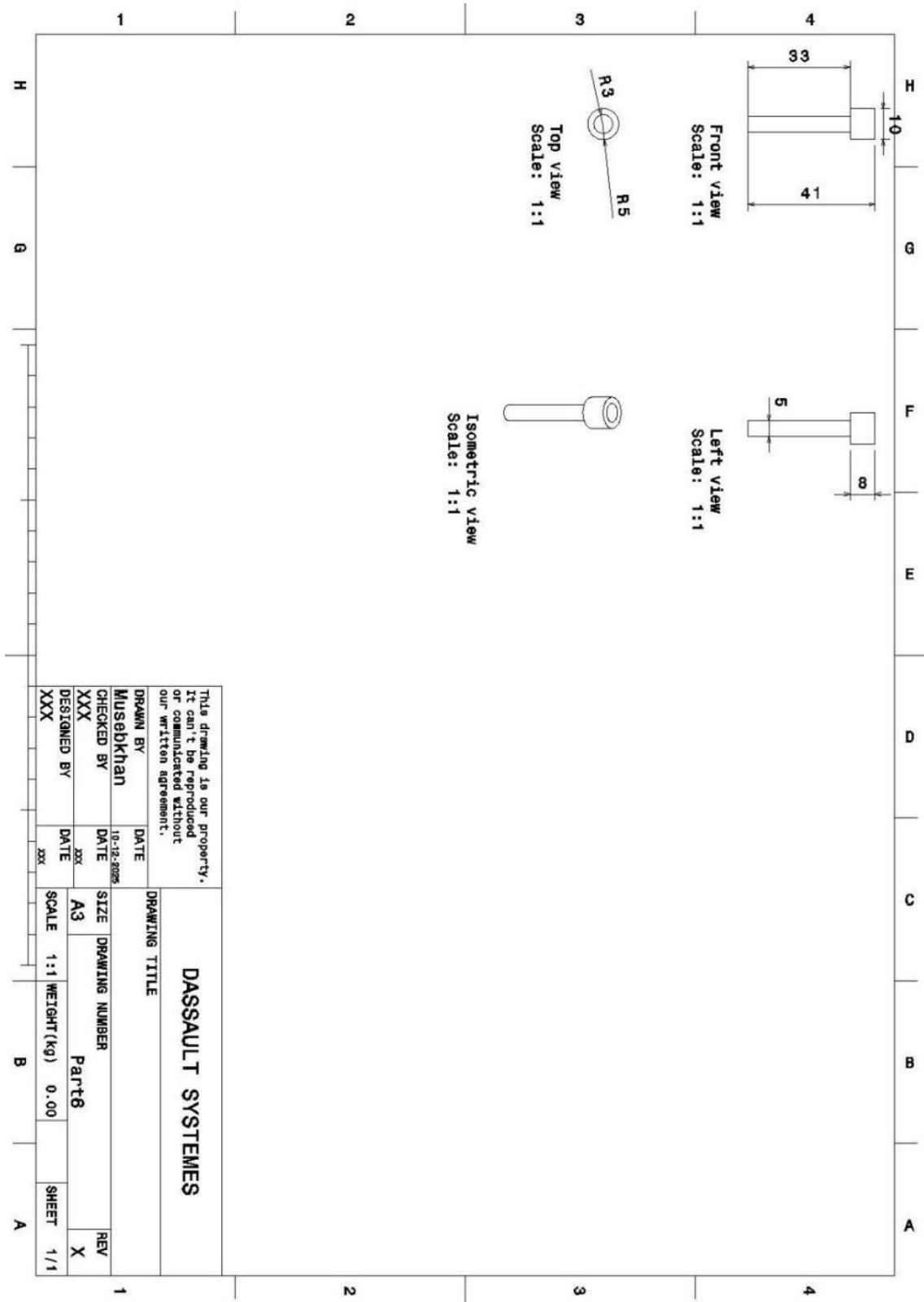


Fig 5.26 Drafting of head cap screw

Part 7



Fig 5.27 hex nut

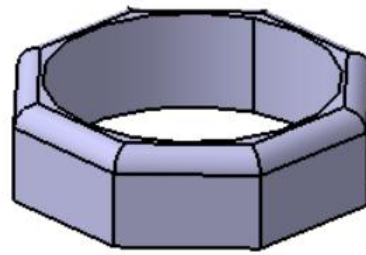


Fig 5.28 3D part of hex nut

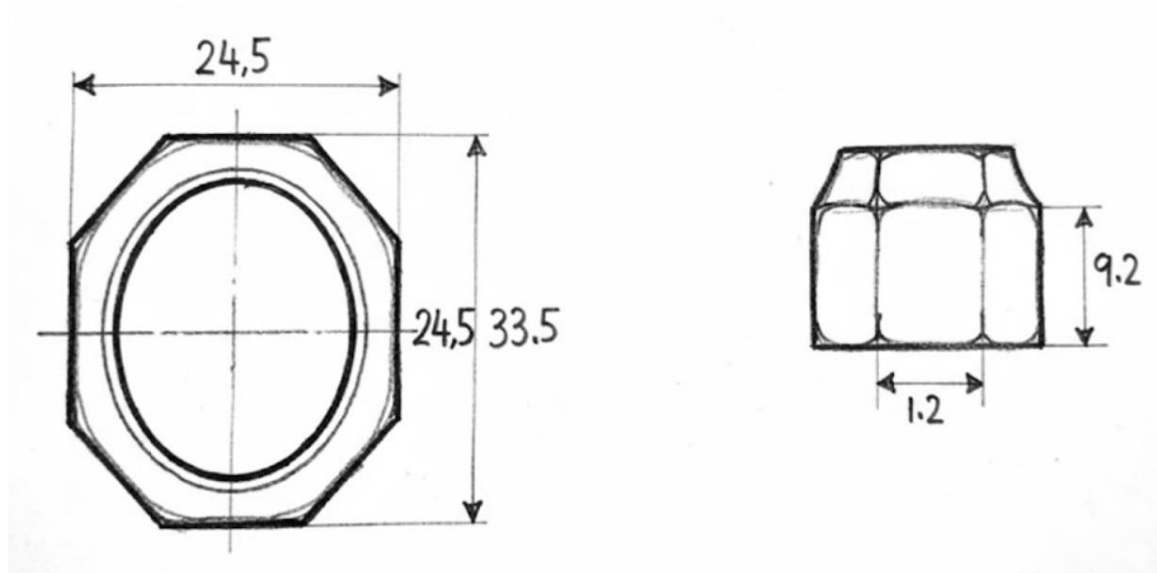


Fig 5.29 2D sketch of hex nut

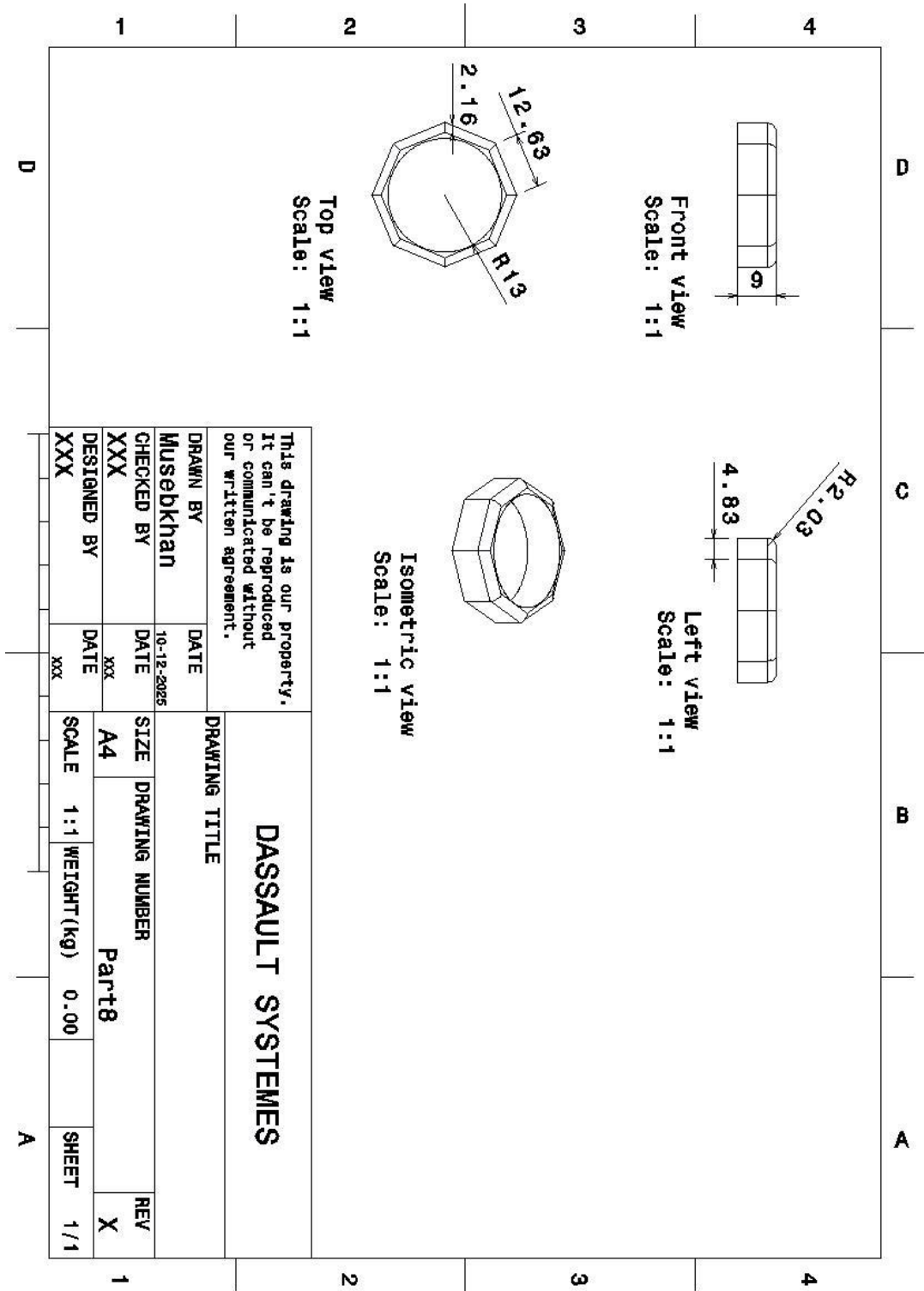


Fig 5.30 Drafting hex nut

Part 8



Fig 5.31 roller chain

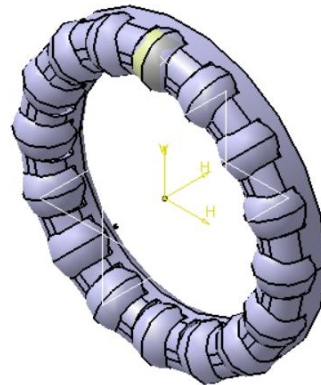


Fig 5.32 3D part of roller chain

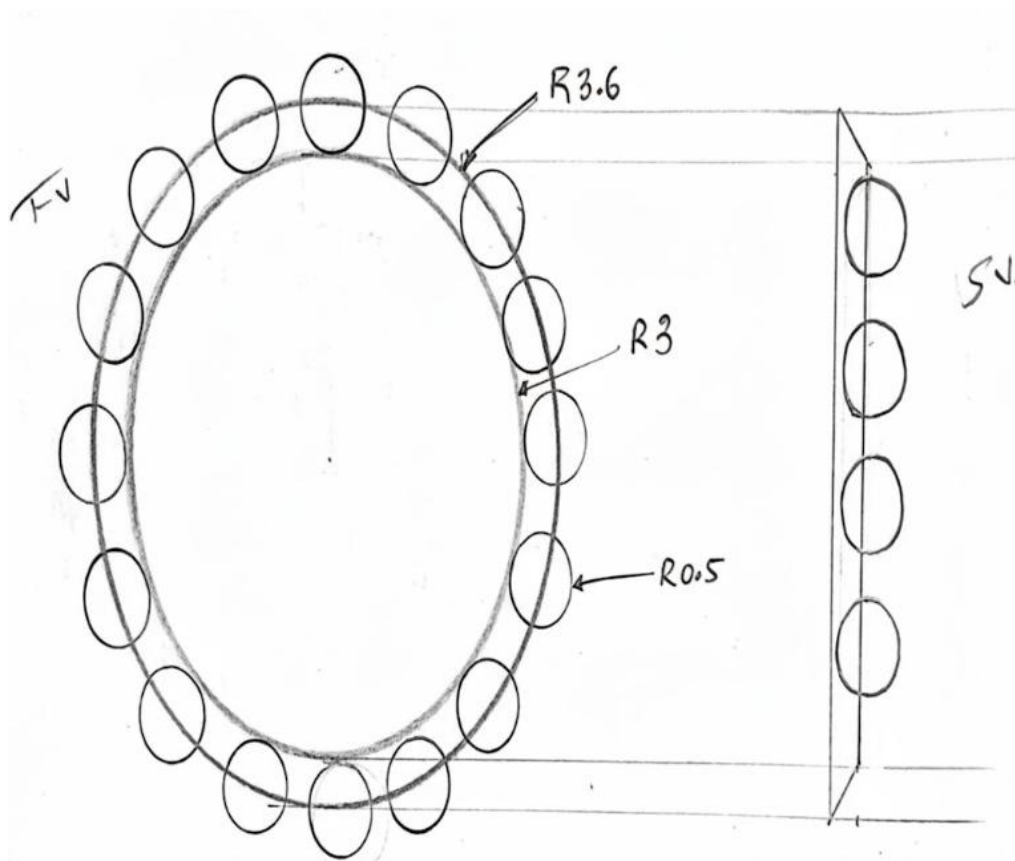


Fig 5.33 2D sketch of roller chain

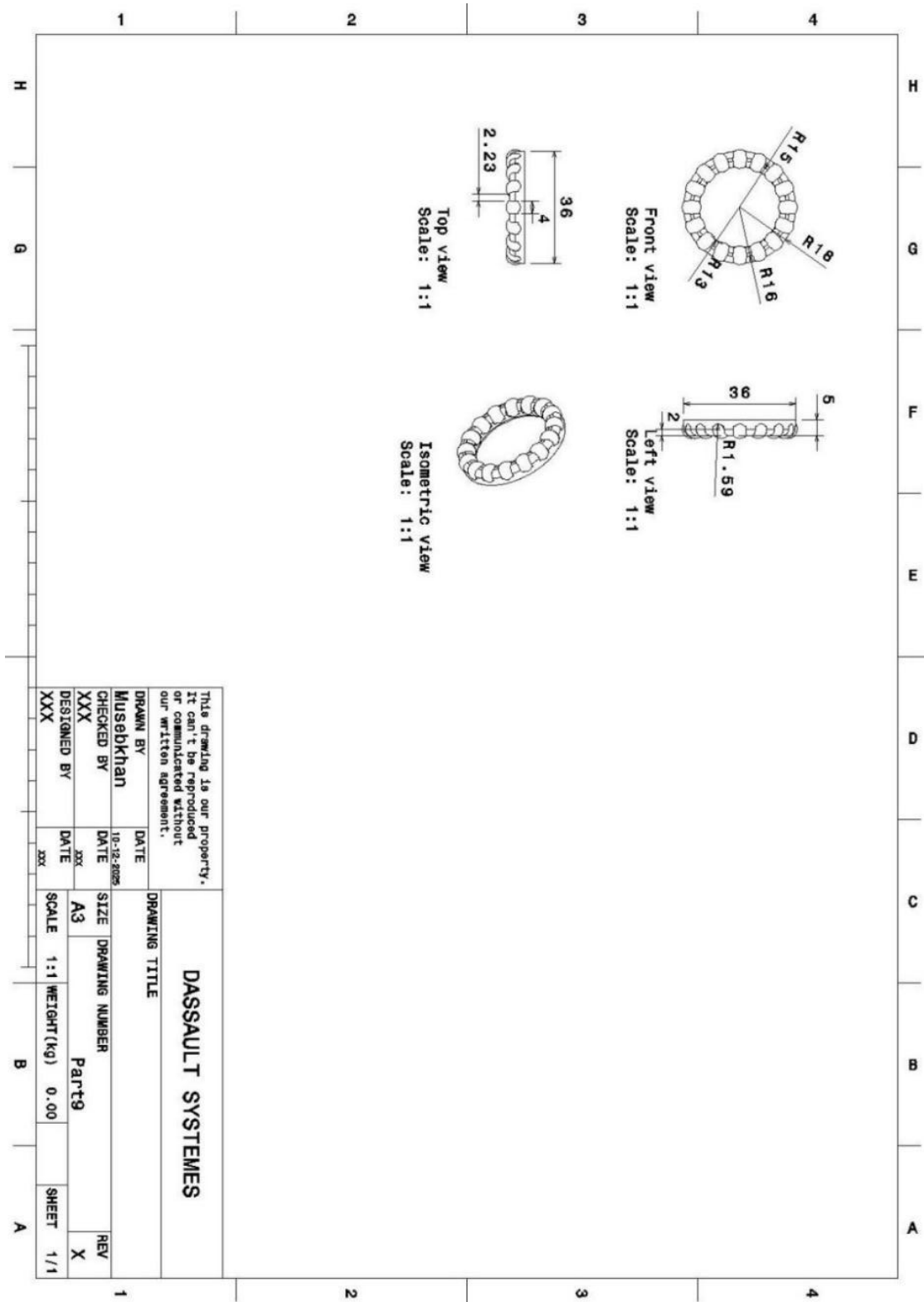


Fig 5.34 Drafting of roller chain

Part 9



Fig 5.35 mounting bracket

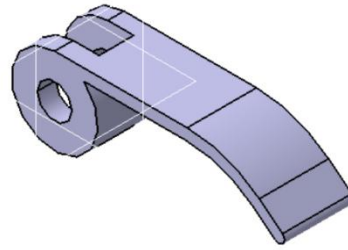


Fig 5.36 3D part of mounting bracket

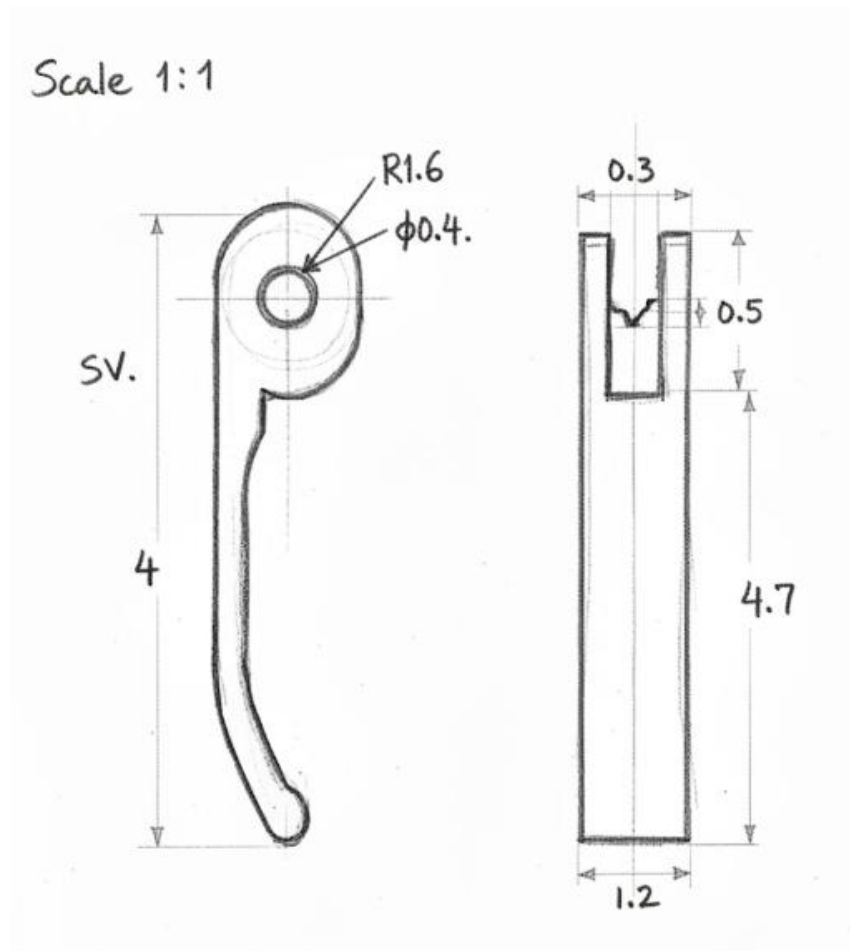


Fig 5.37 2D sketch of mounting bracket

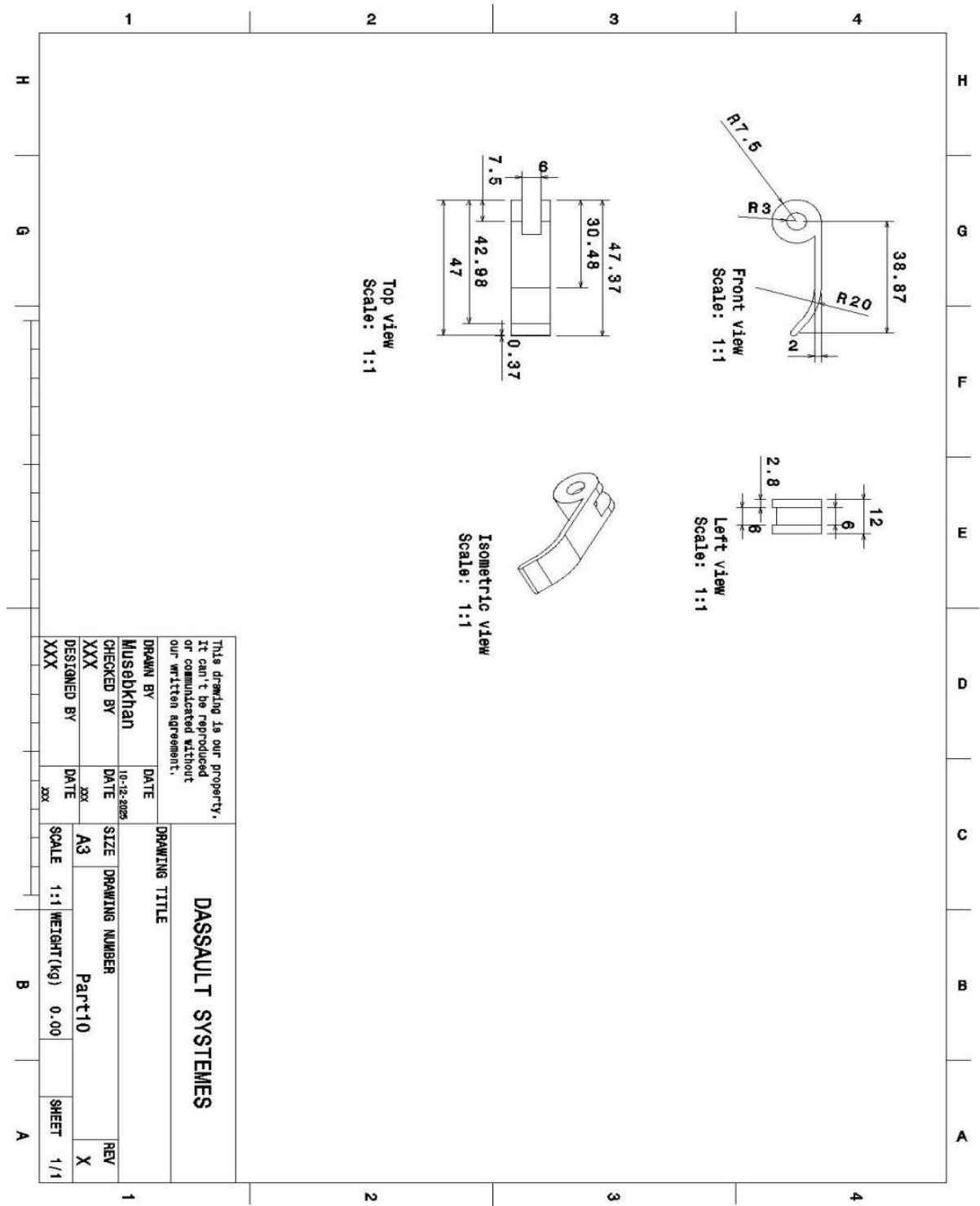


Fig 5.38 Drafting of mounting bracket

Part 10



Fig 5.39 Eye bolt



Fig 5.40 3D part of eye bolt

2D sketch

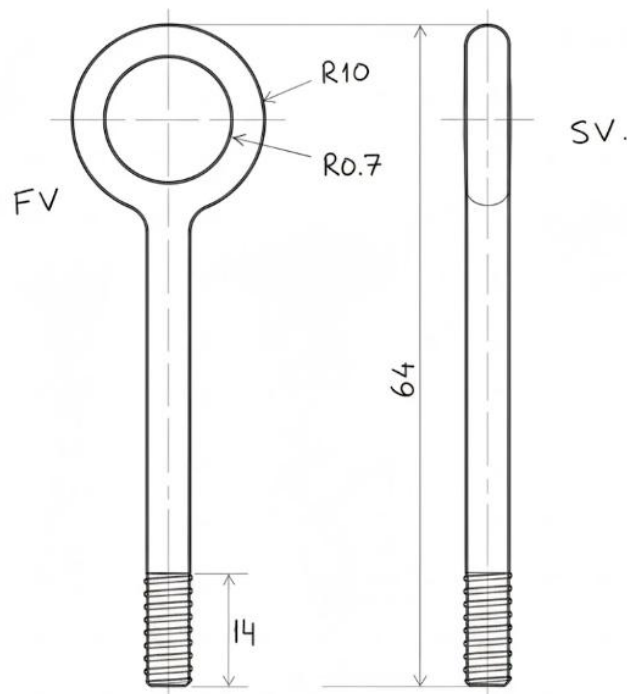


Fig 5.41 2D sketch of eye bolt

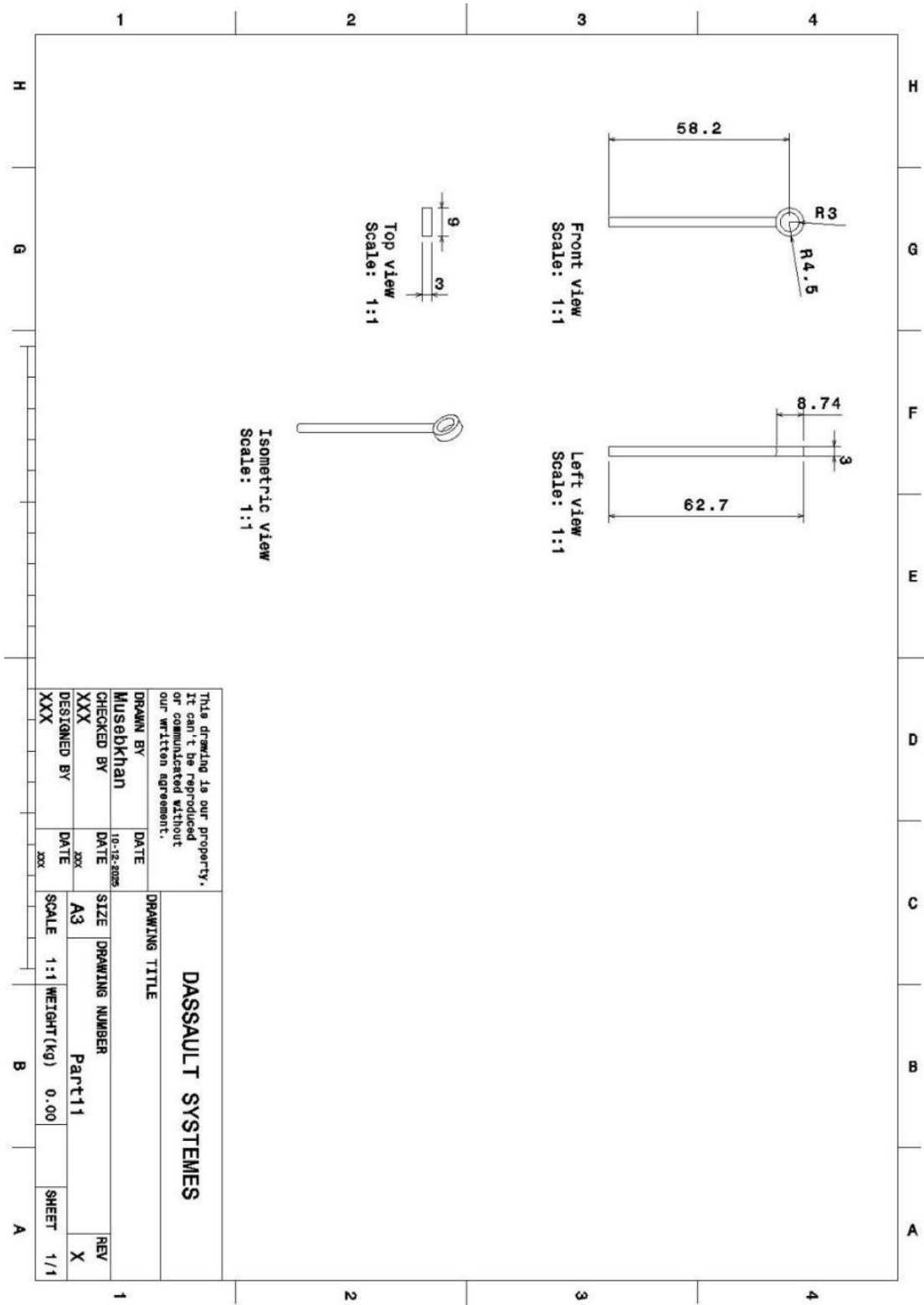


Fig 5.42 Drafting of eye bolt

Part 11



Fig 5.43 T slot nut

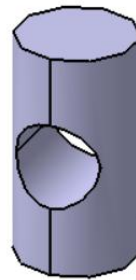


Fig 5.44 3D part of T slot nut

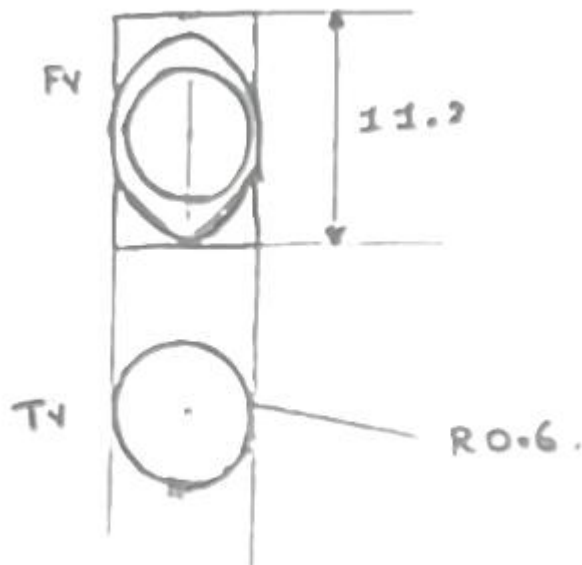


Fig 5.45 2D sketch of T slot nut

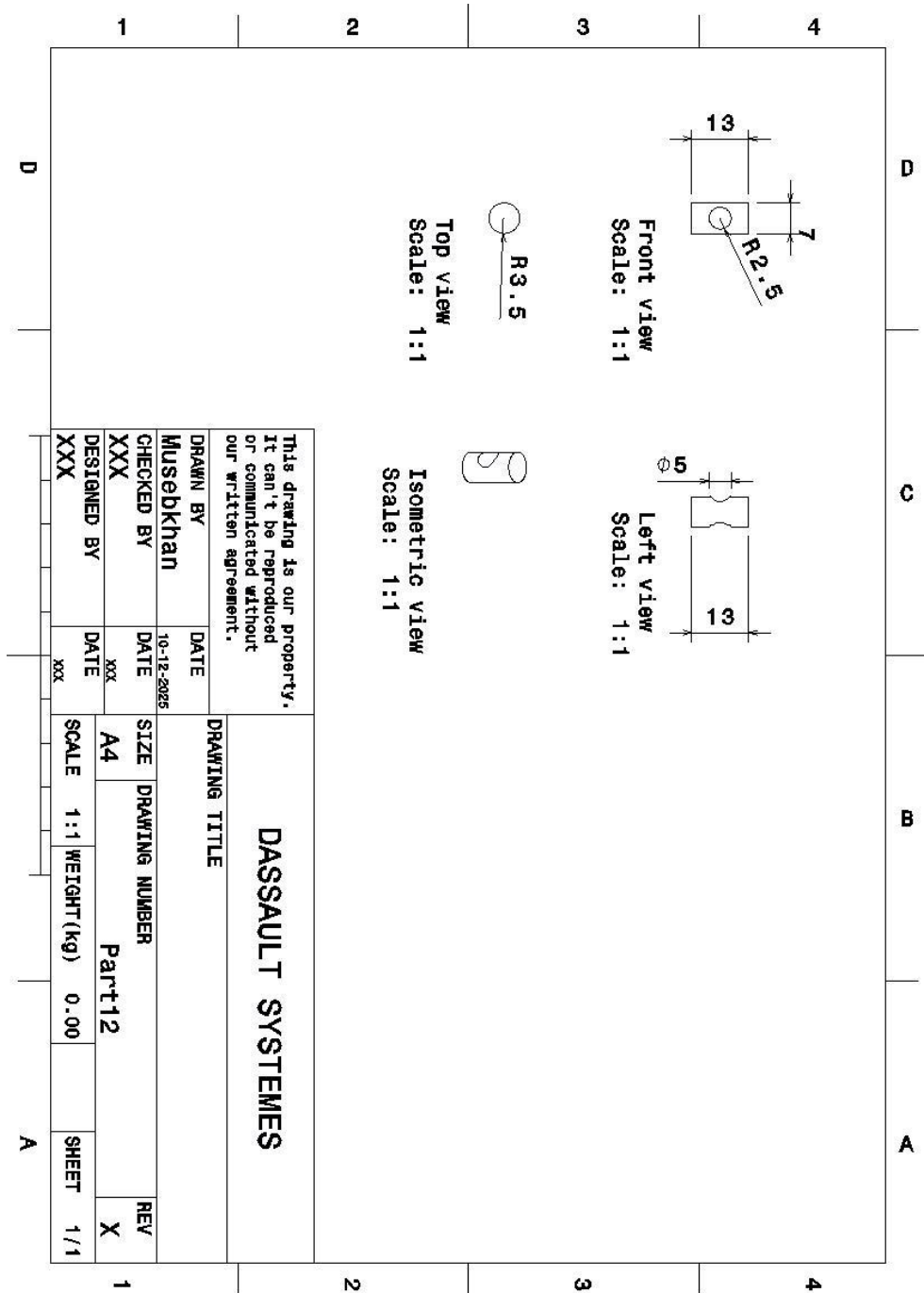


Fig 5.46 Drafting of T slot nut

Part 12



Fig 5.47 knurled nut

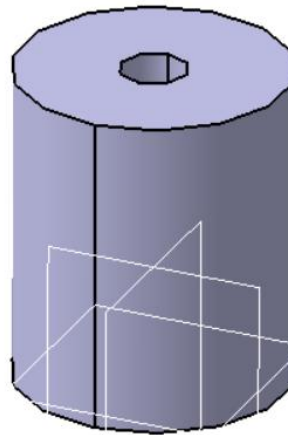


Fig 5.48 3D part of knurled nut

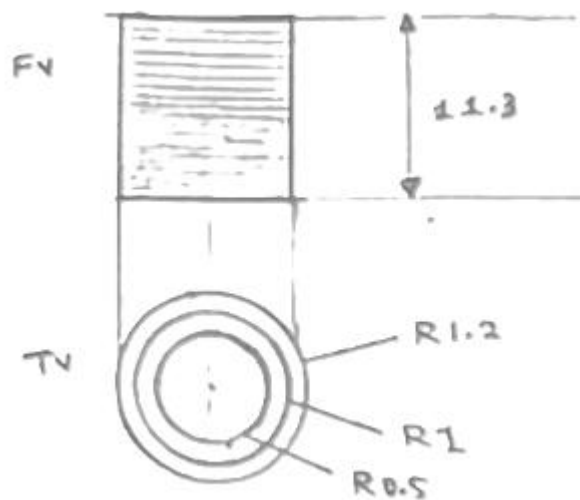


Fig 5.49 2D sketch of knurled nut

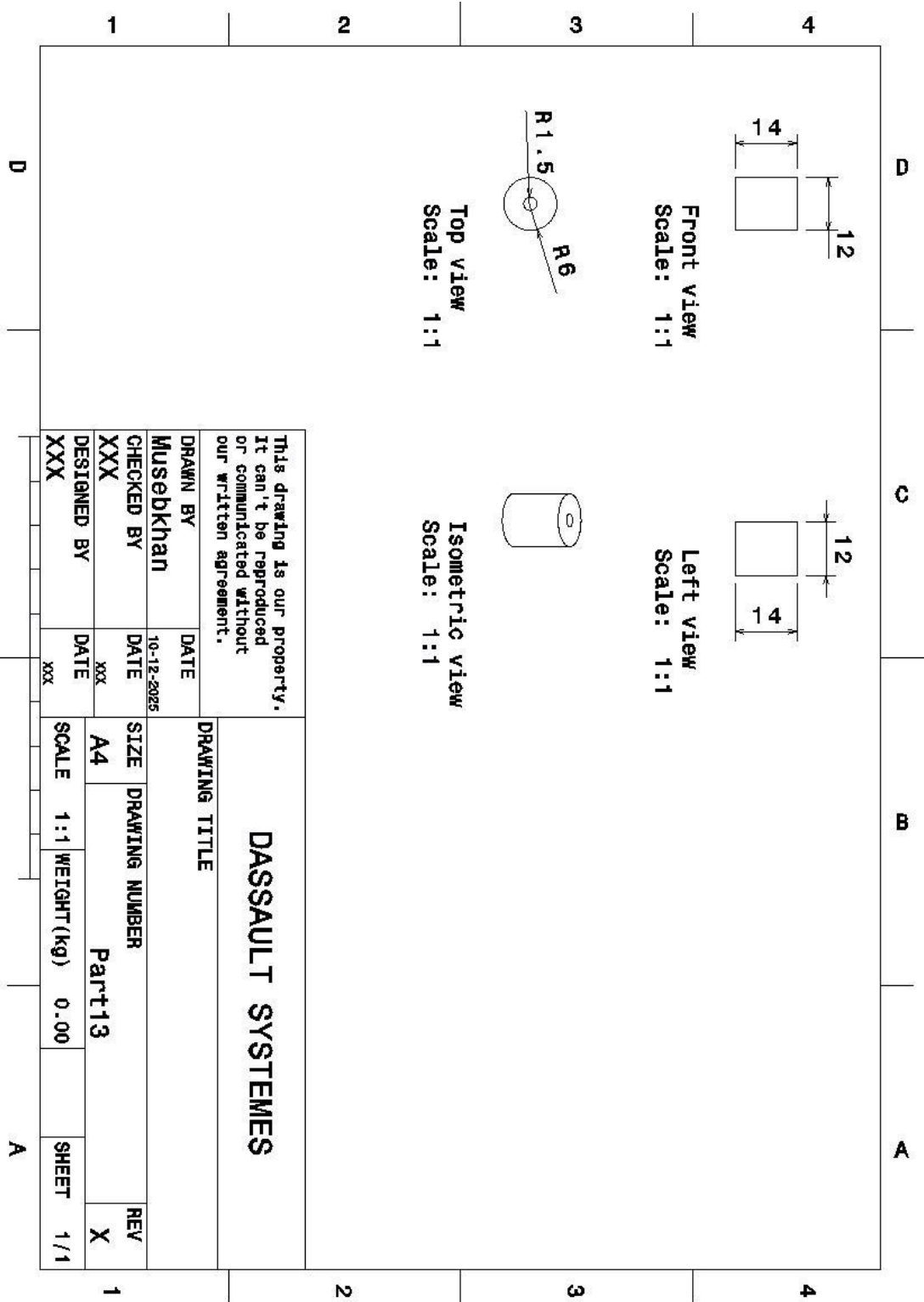


Fig 5.50 Drafting of knurled nut

Part 13



Fig 5.51 square washer

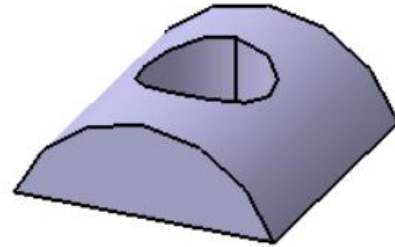


Fig 5.52 3D part fo square washer

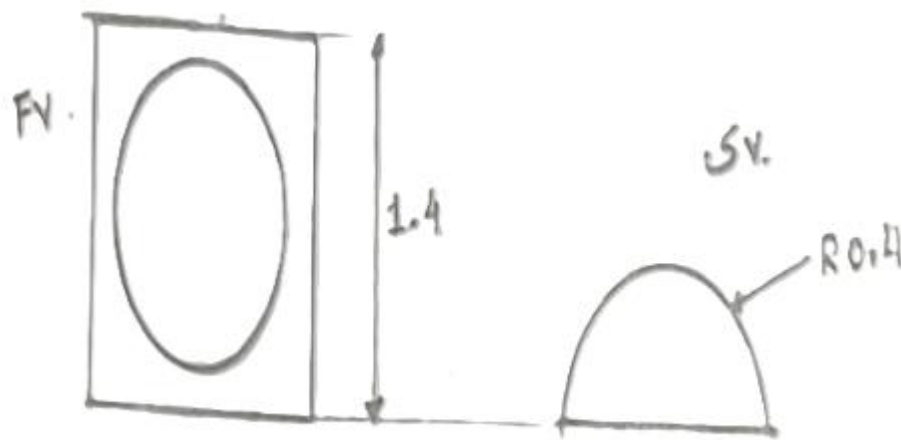


Fig 5.53 2D sketch of square washer

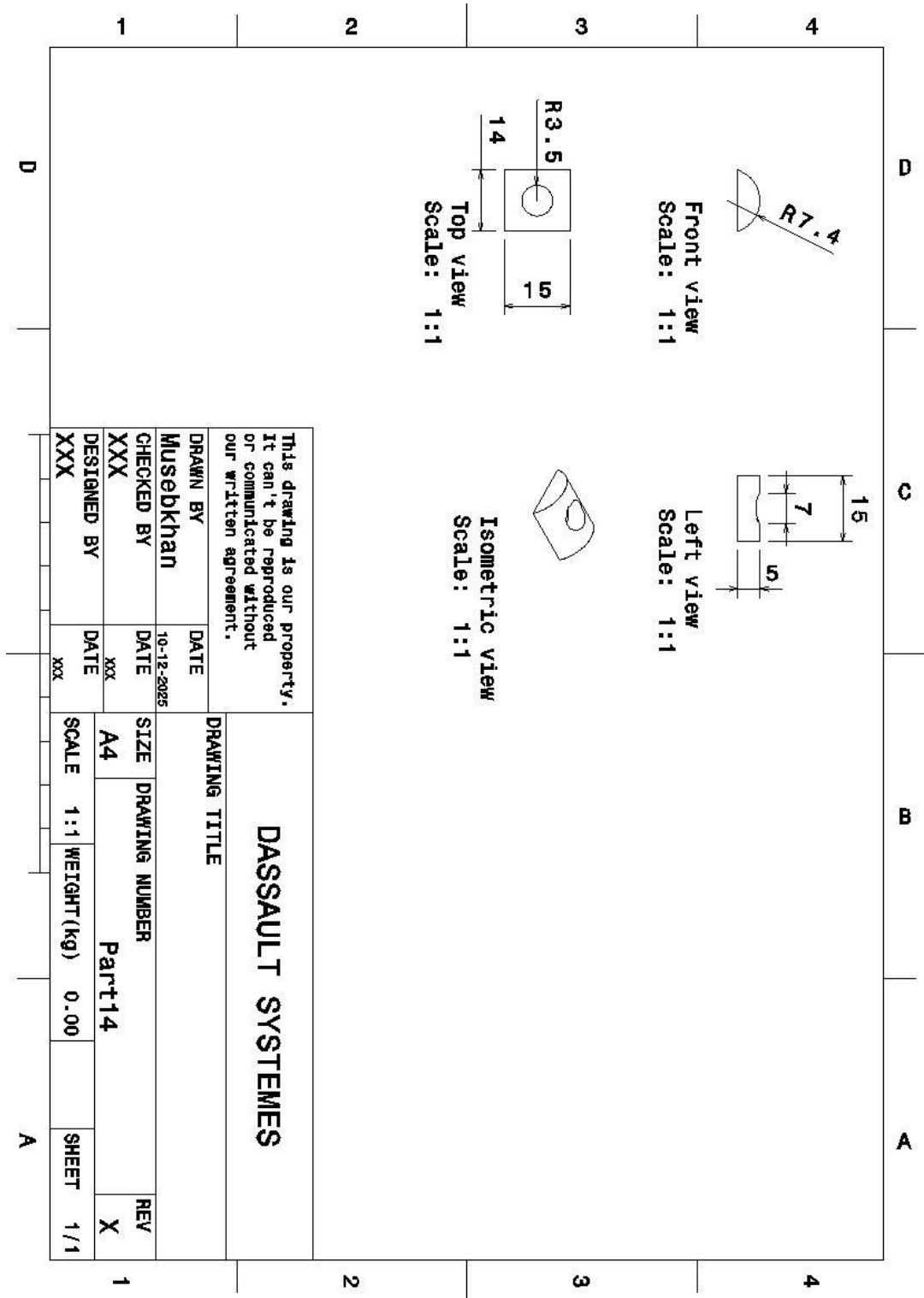


Fig 5.54 Drafting of square washer

Part 14



Fig 5.55 T-bar

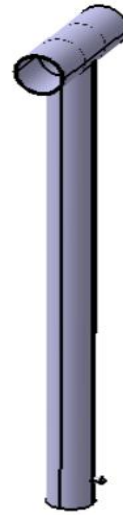


Fig 5.56 3D part of T-bar

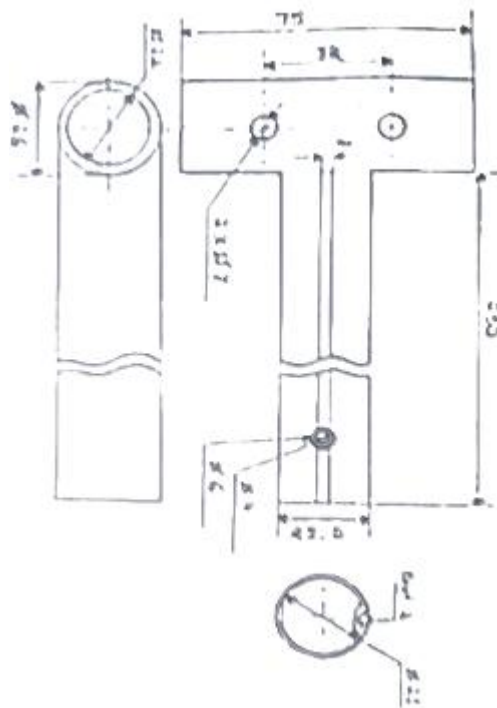


Fig 5.57 2D sketch of T-bar

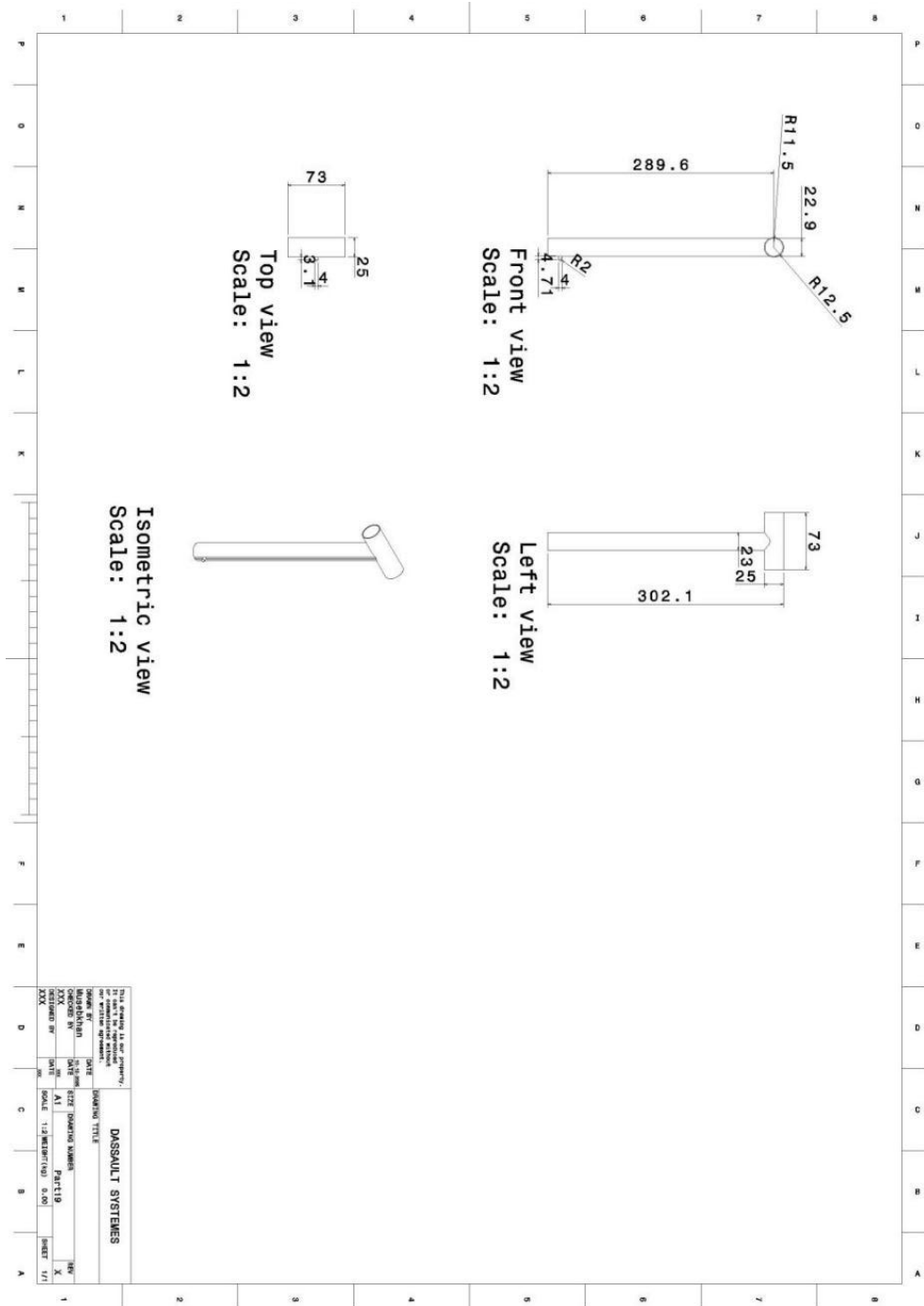


Fig 5.58 Drafting of T-bar

Part 15



Fig 5.59 stem tube



Fig 5.60 3D part of stem tube

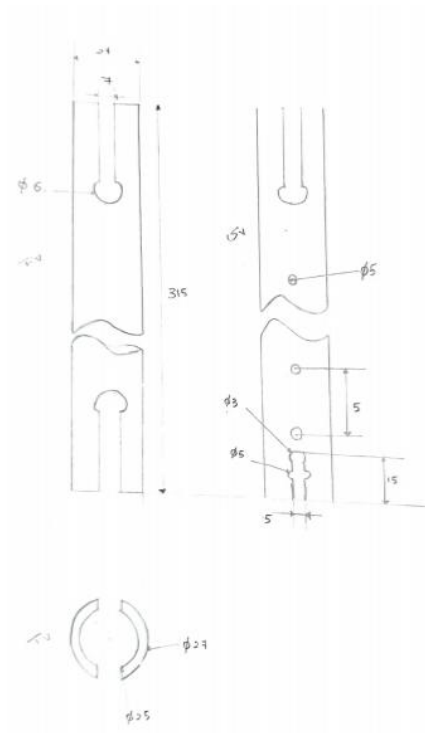


Fig 5.61 2D sketch of stem tube

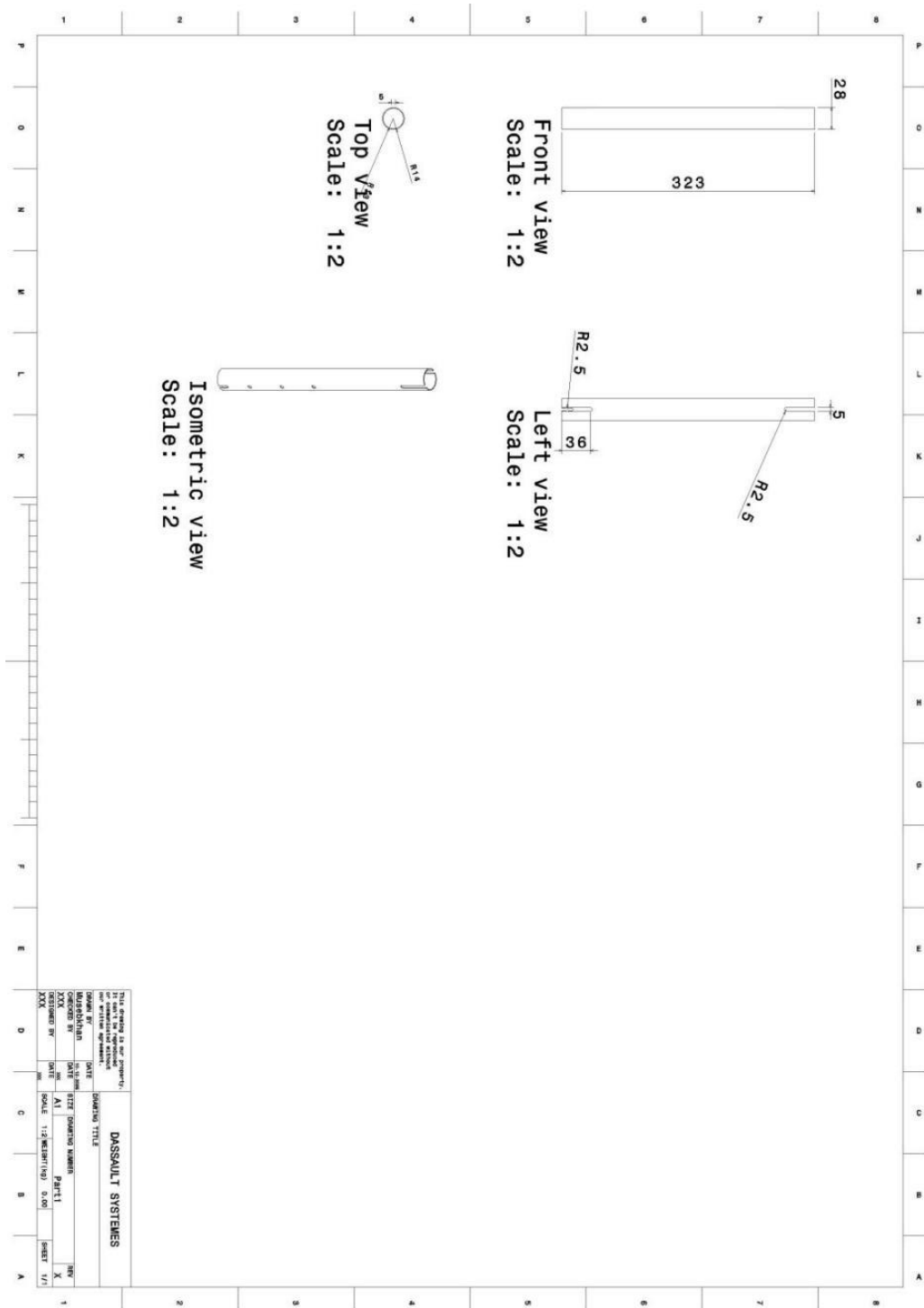


Fig 5.62 Drafting of stem tube

Part 16



Fig 5.63 clamping collar

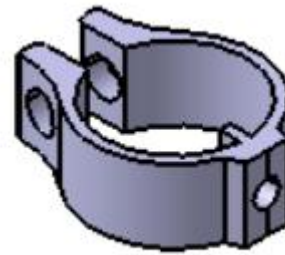


Fig 5.64 3D part of clamping collar

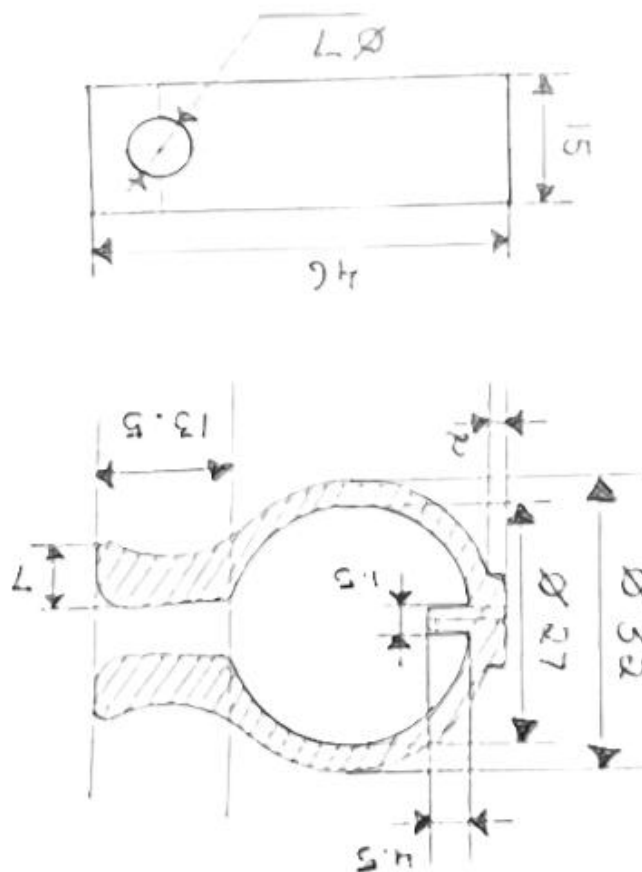


Fig 5.65 2D sketch of clamping collar

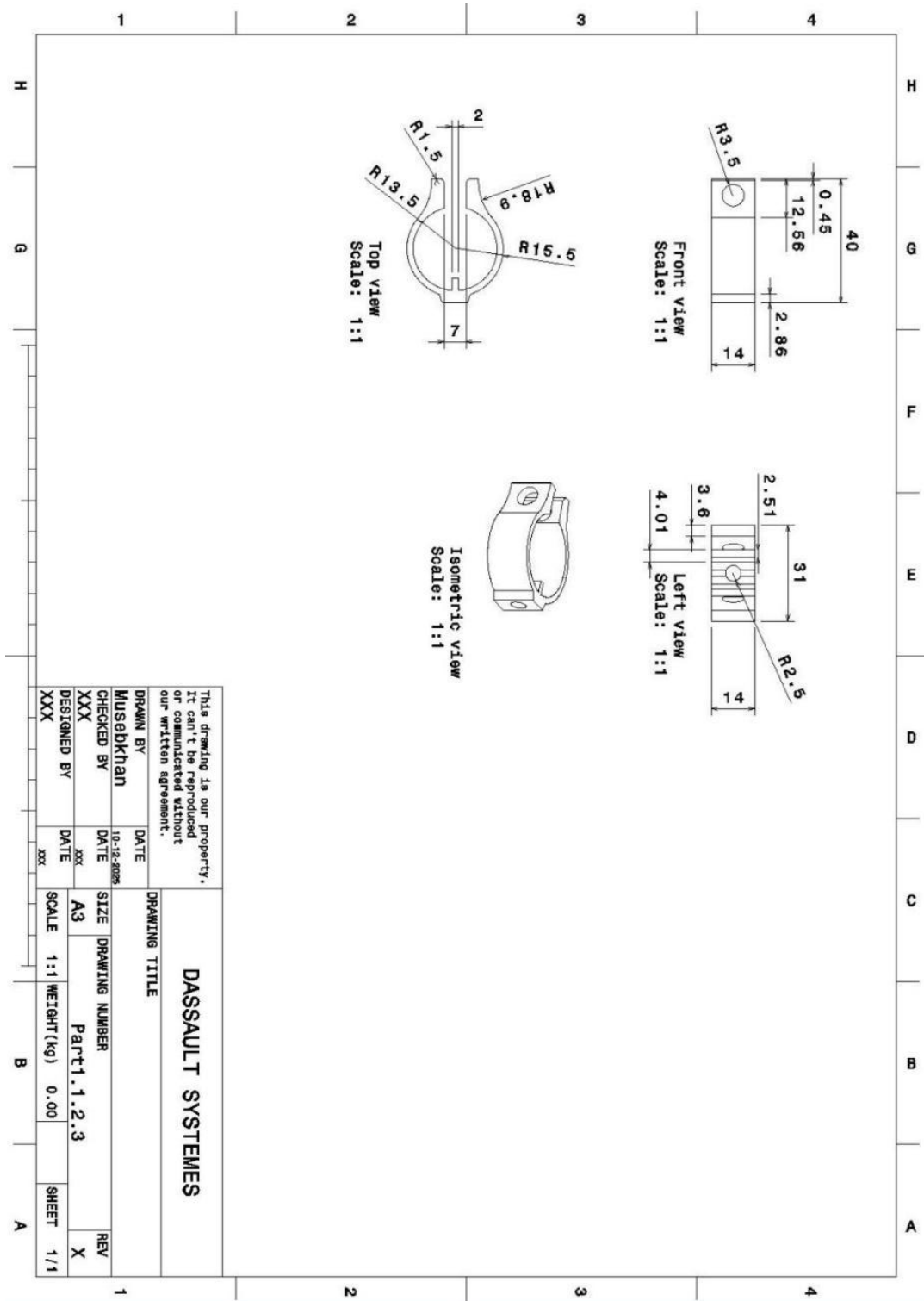


Fig 5.66 Drafting of clamping collar

Part 17



Fig 5.67 Deck

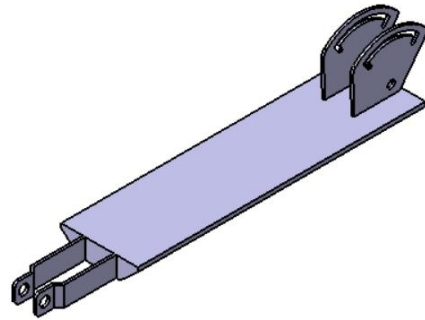


Fig 5.68 3D part of deck

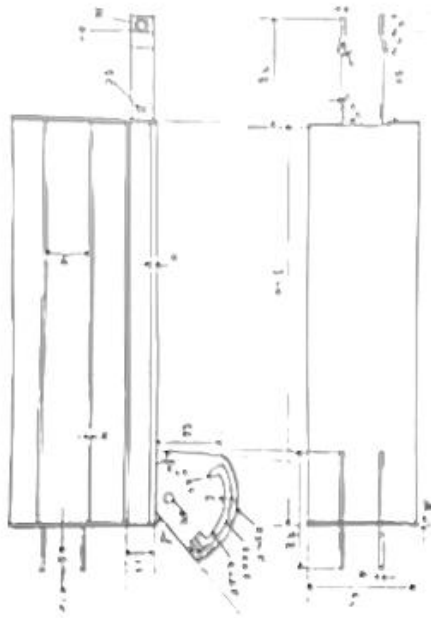


Fig 5.69 2D sketch of deck

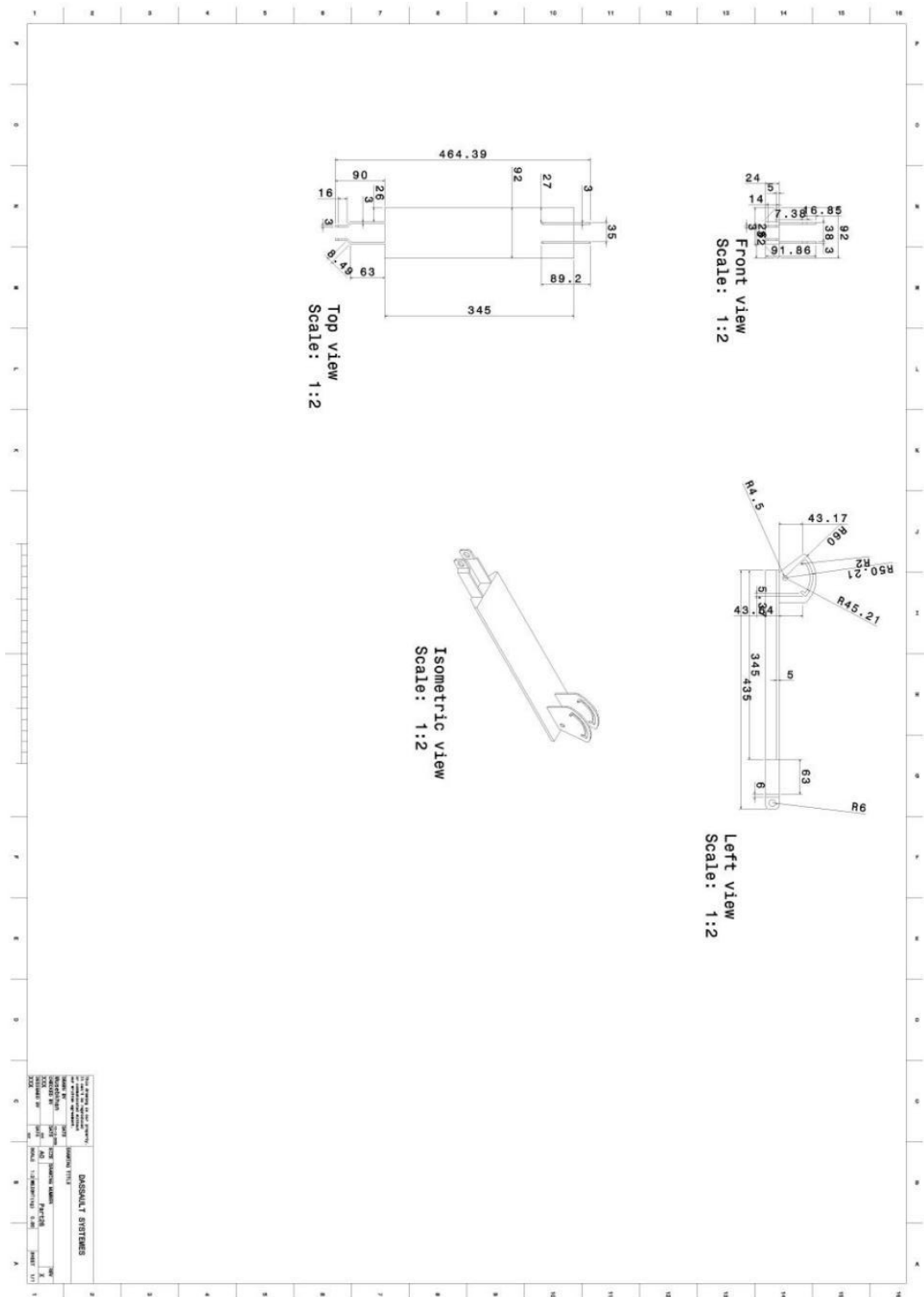


Fig 5.70 Drafting of deck

Part 18



Fig 5.71 spacer bush

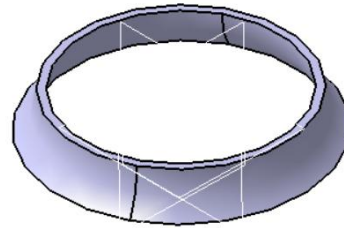


Fig 5.72 3D part of spacer bush

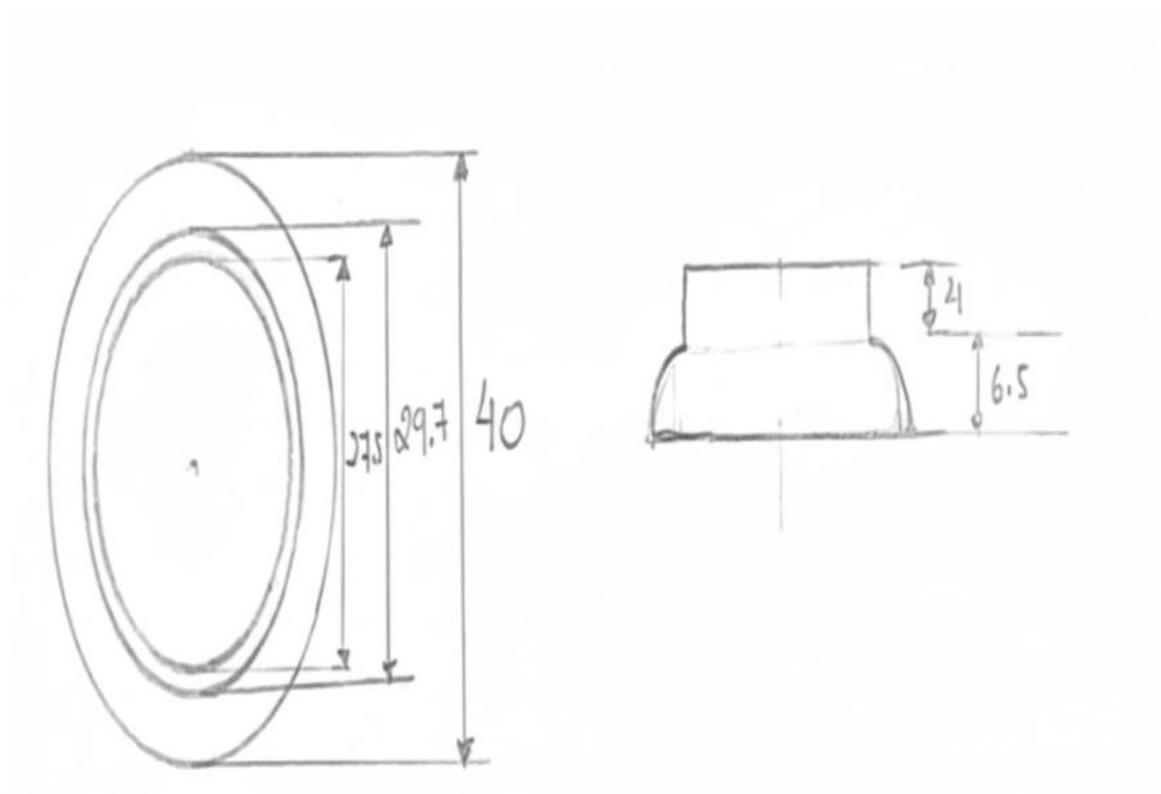


Fig 5.73 2D sketch of spacer bush

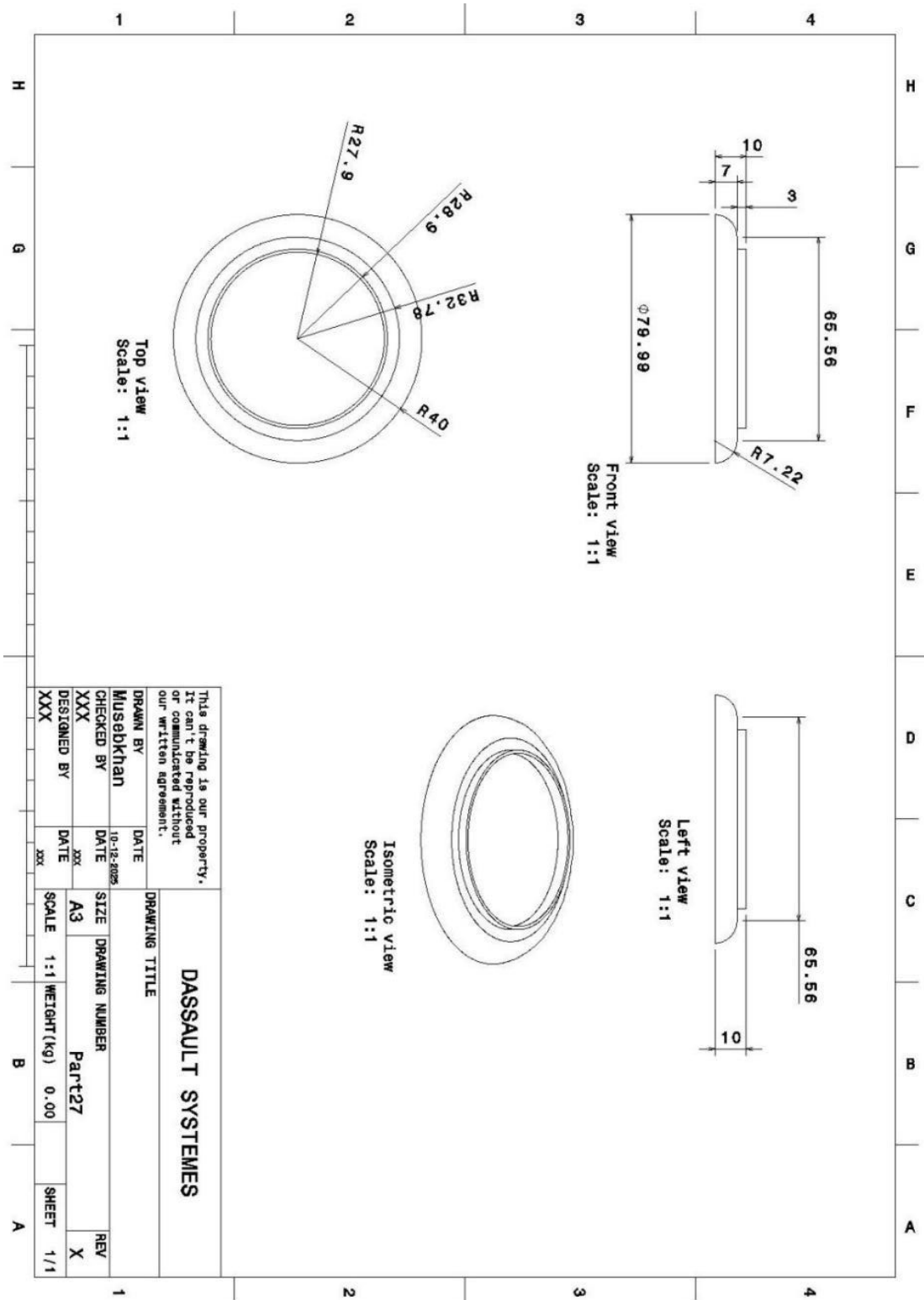


Fig 5.74 Drafting of spacer bush

Part 19



Fig 5.75 headset lock

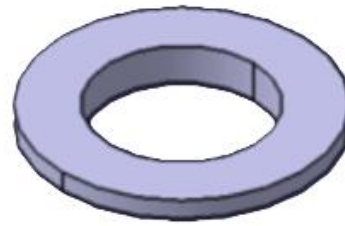


Fig 5.76 3D part of headset lock

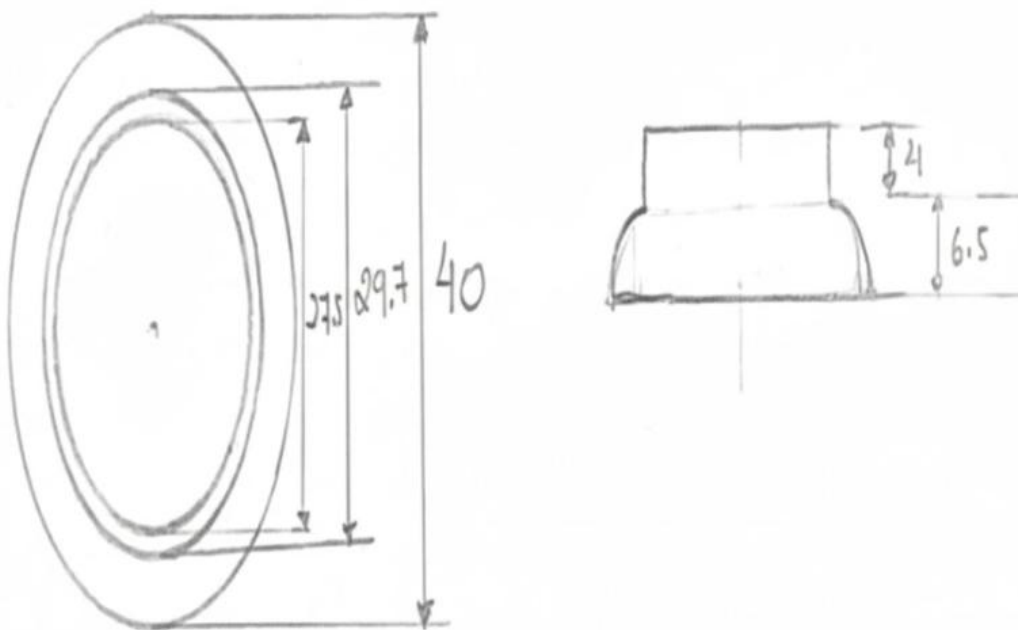


Fig 5.77 2D sketch of headset lock

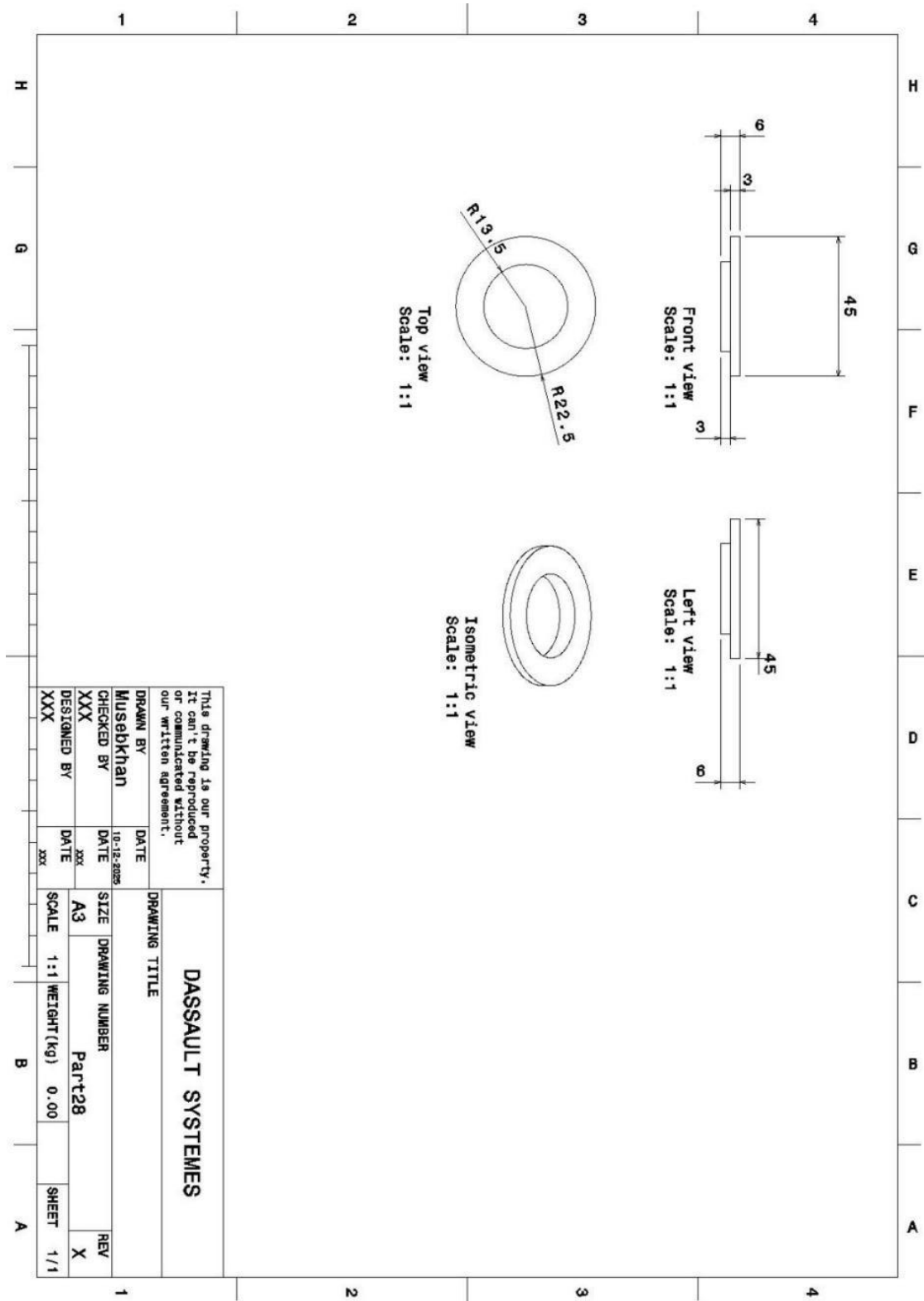


Fig 5.78 Drafting of headset lock

Part 20



Fig 5.79 deck break

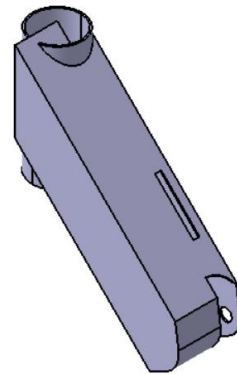


Fig 5.80 2D deck break

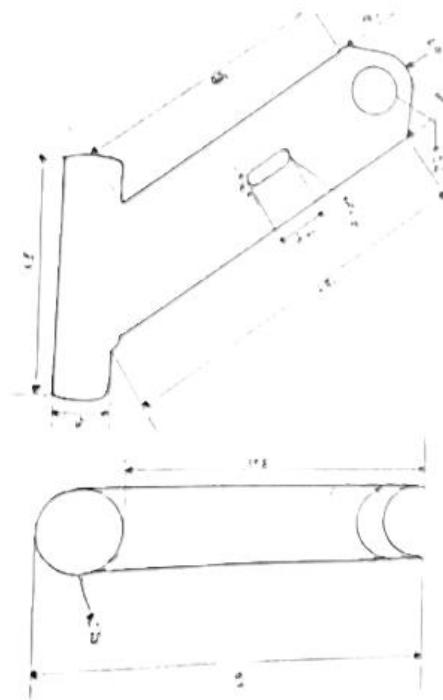


Fig 5.81 2D sketch of deck break

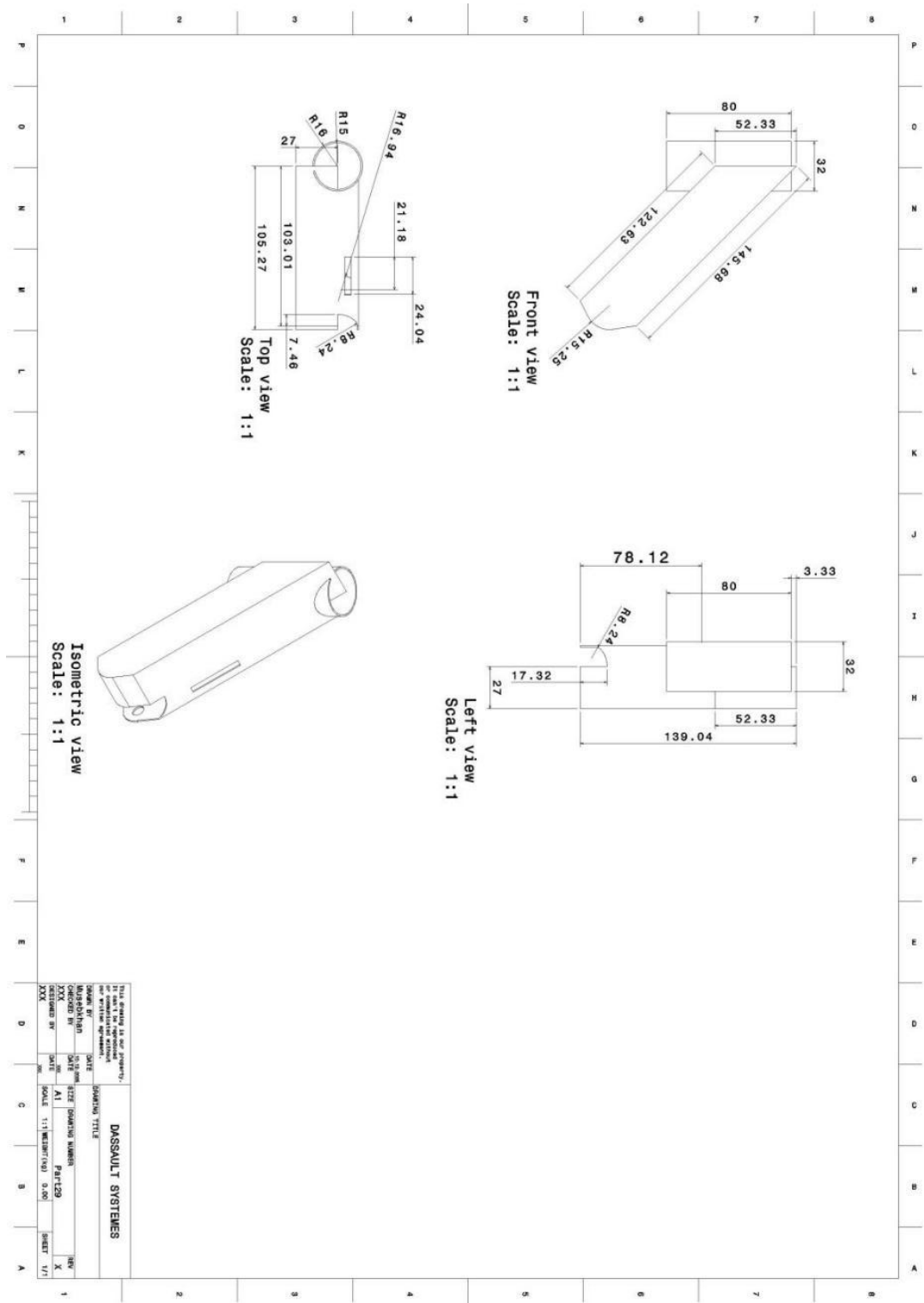


Fig 5.82 Drafting of deck break

Part 21



Fig 5.83 wheel

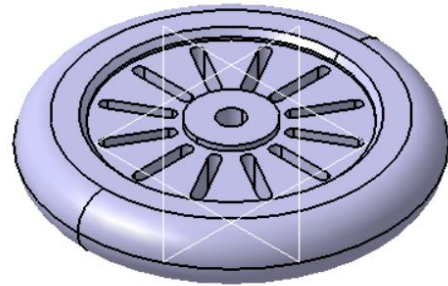


Fig 5.84 3D part of wheel

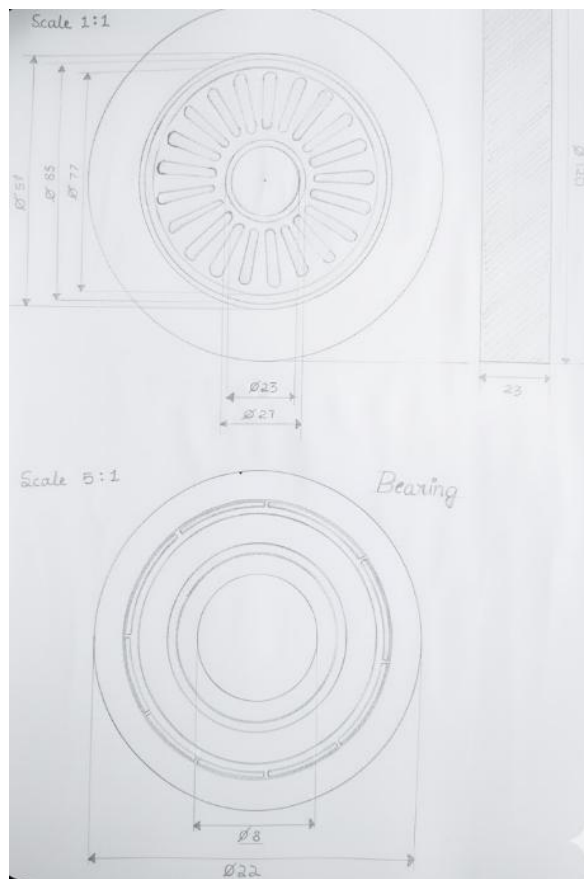


Fig 5.85 2D sketch of wheel

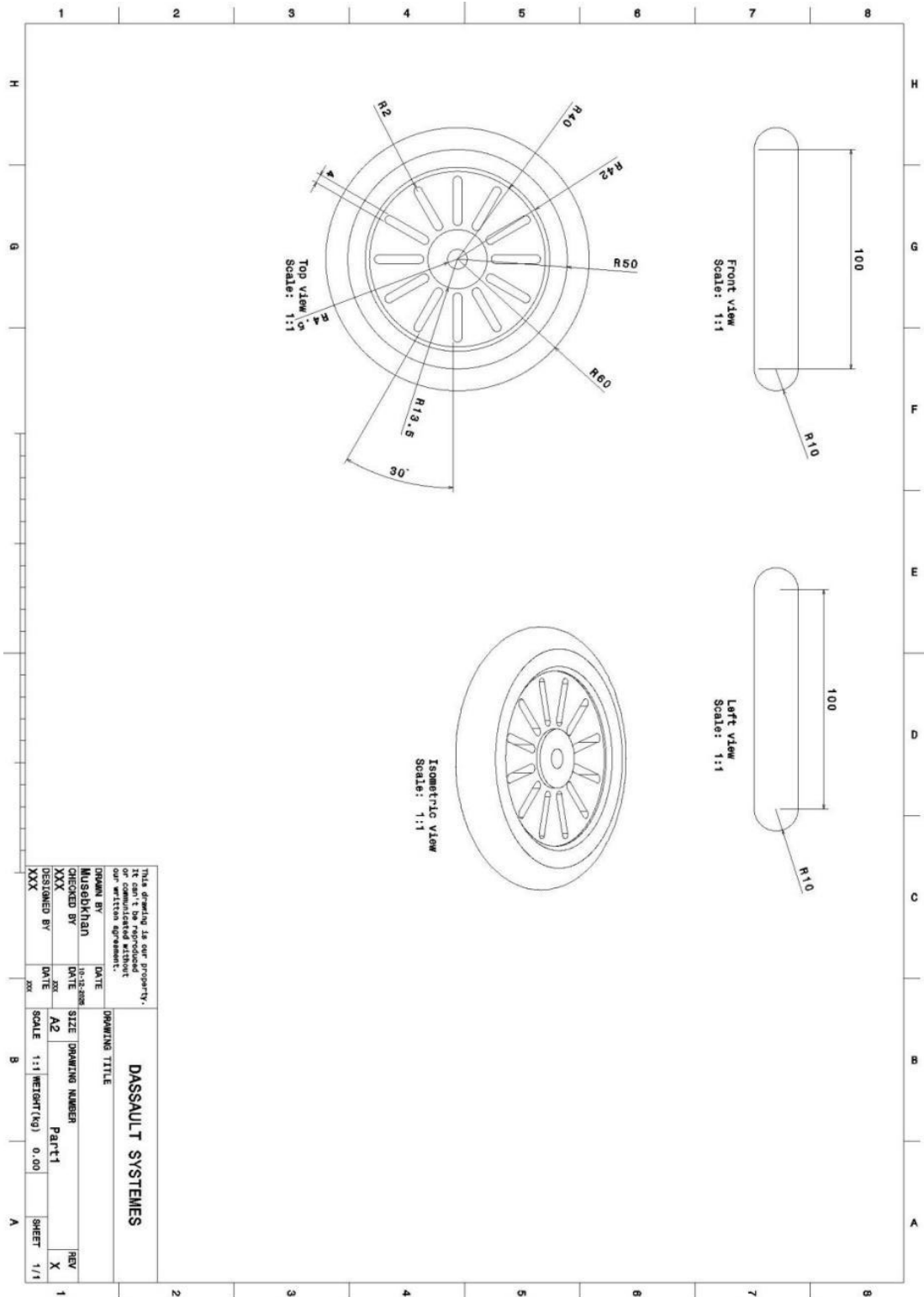


Fig 5.86 Drafting of wheel

Part 22



Fig 5.87 front fork

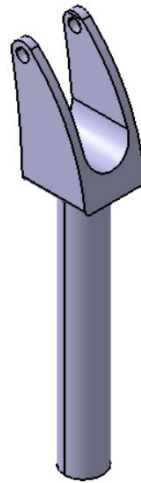


Fig 5.88 3D part of front fork

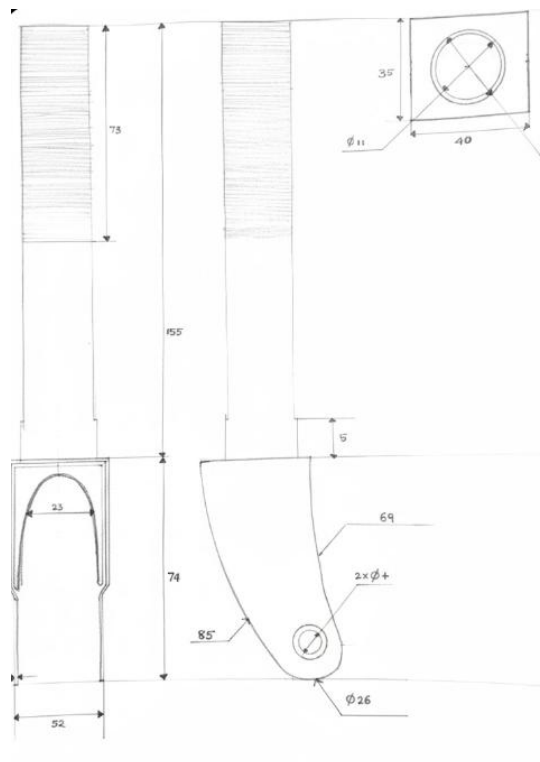


Fig 5.89 2D sketch of front fork

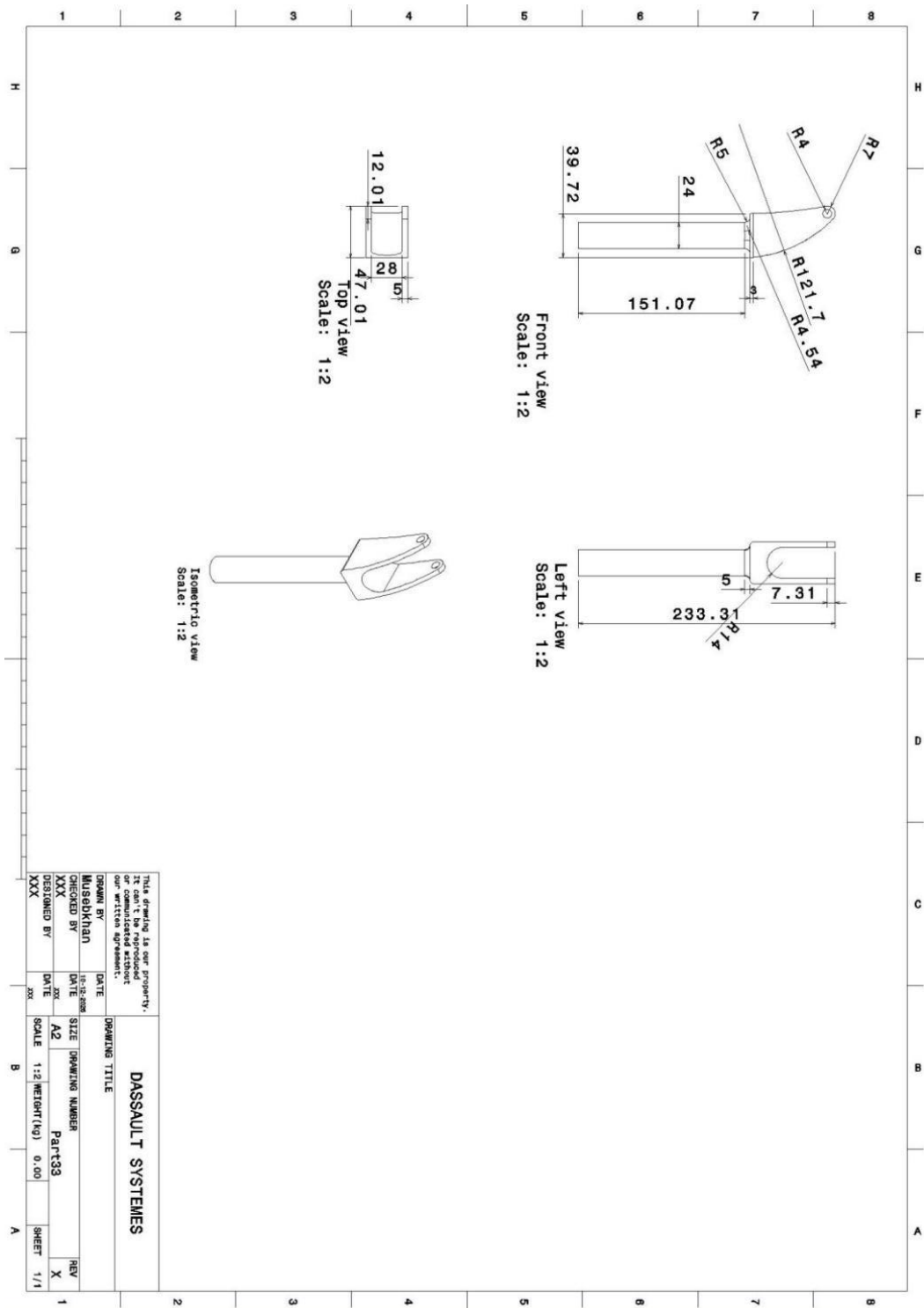


Fig 5.90 Drafting of front fork

Part 23



Fig 5.91 brake

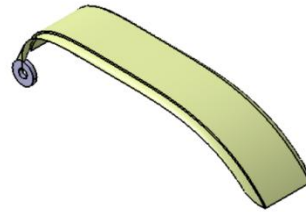


Fig 5.92 3D part of brake

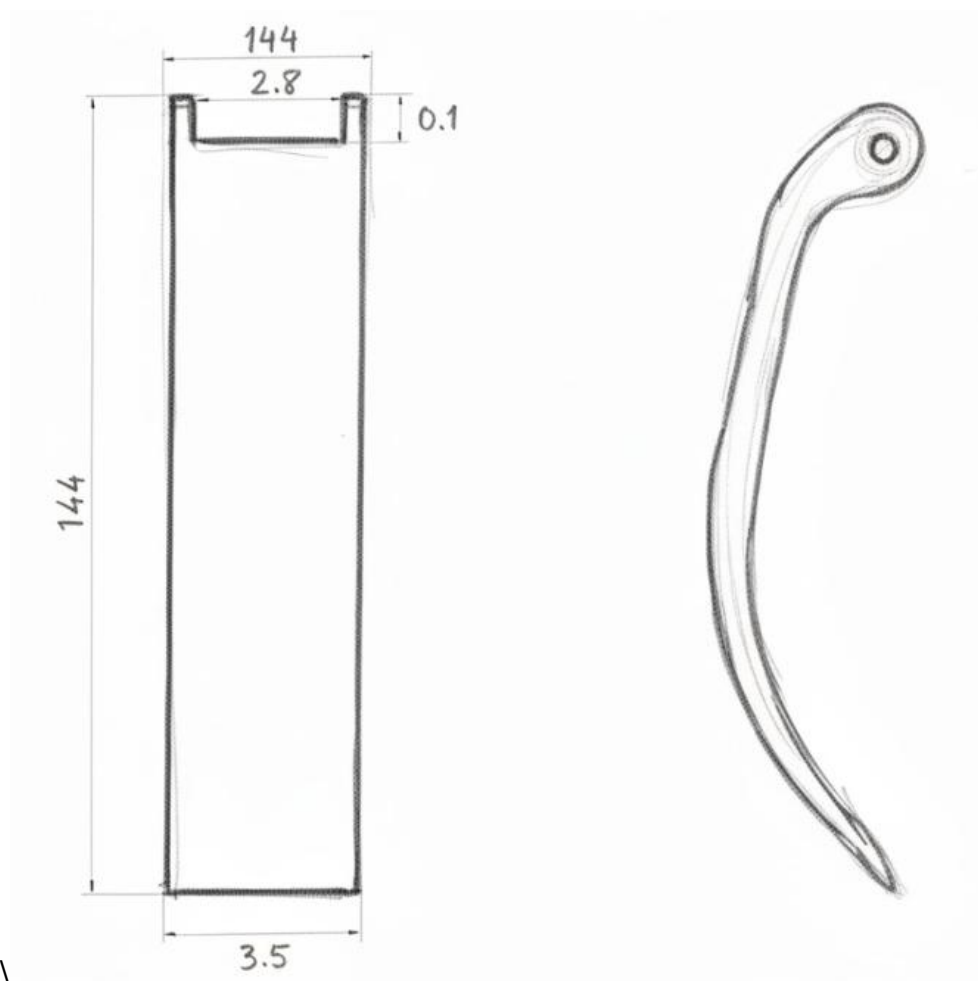


Fig 5.93 2D sketch of brake

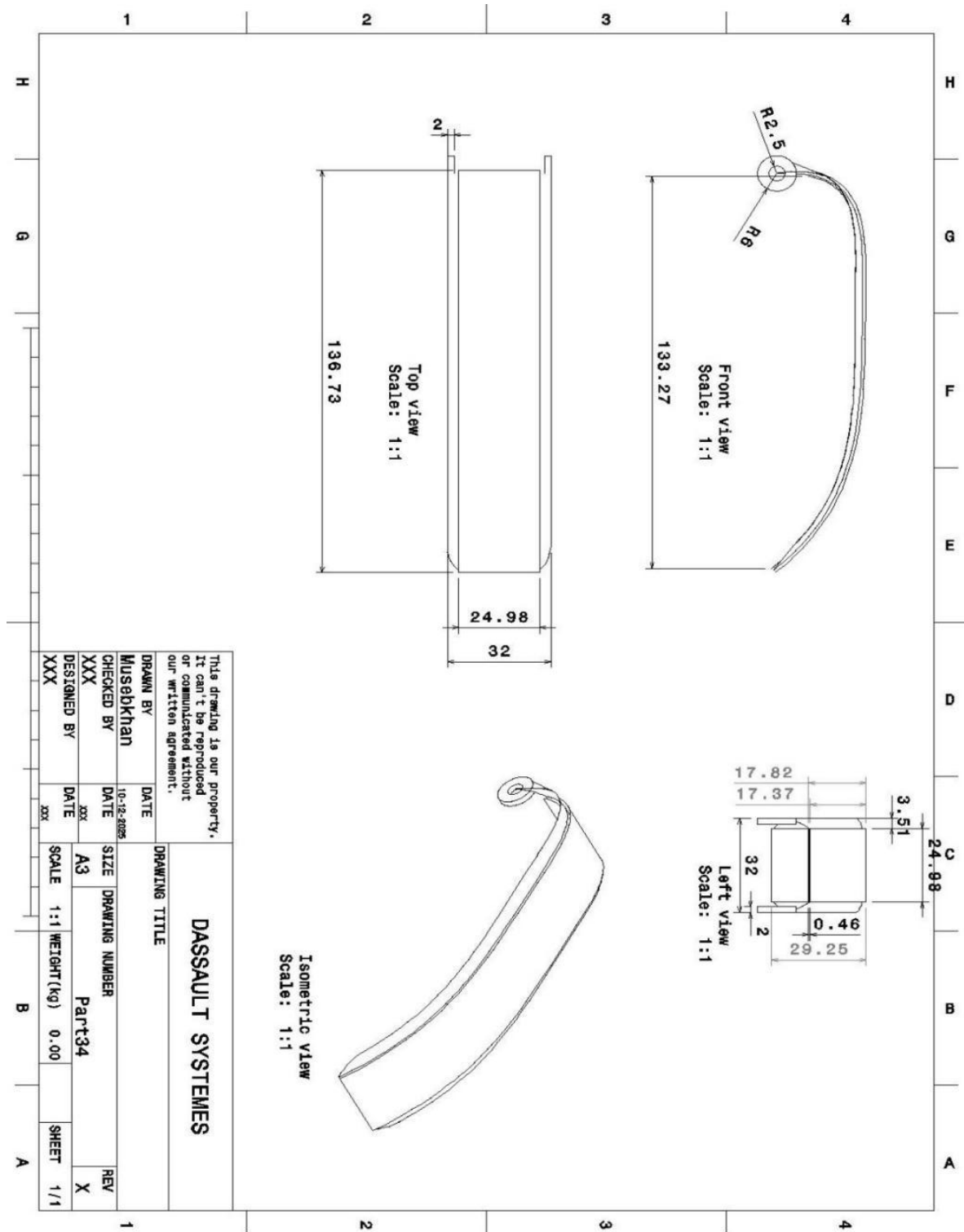


Fig 5.94 Drafting of brake

Part 24



Fig 5.95 button head screw

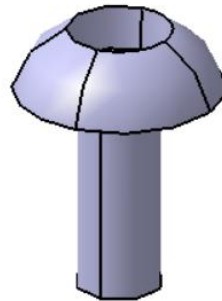


Fig 5.96 3D part of button head screw

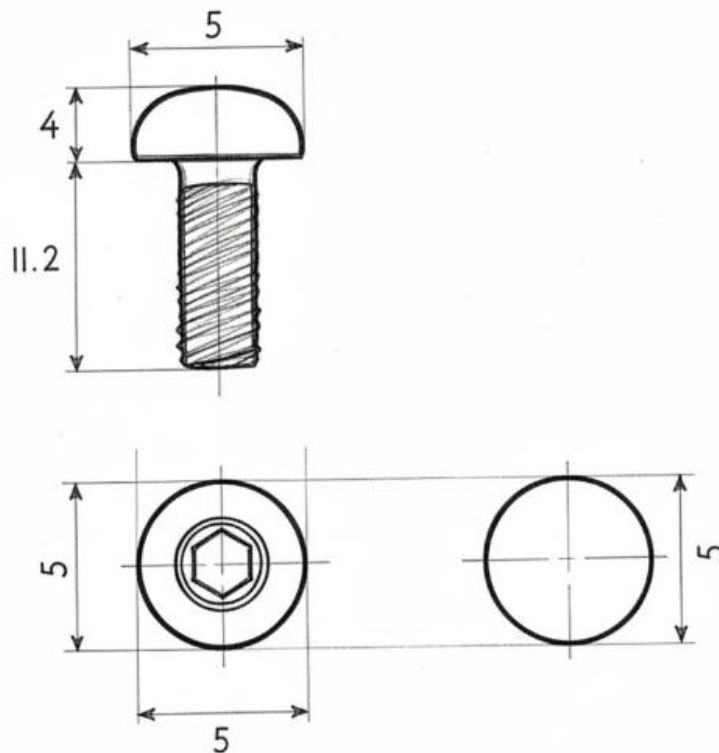


Fig 5.97 2D sketch of button head screw

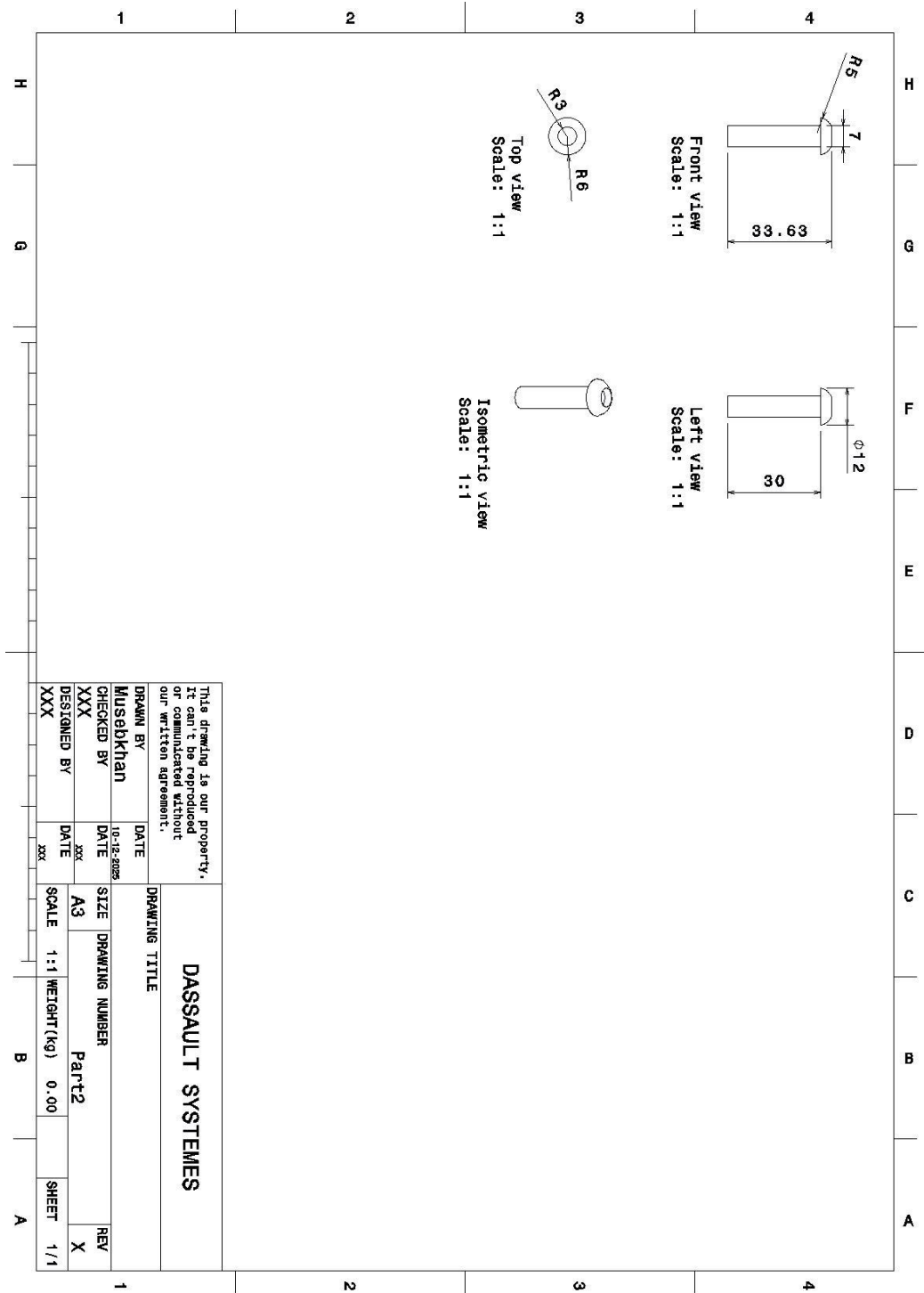


Fig 5.98 Drafting of button head screw

Assembly



Fig 5.99 Assembly

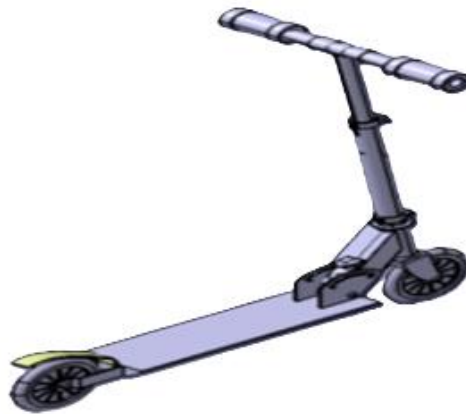


Fig 5.100 3D part ofn assembly

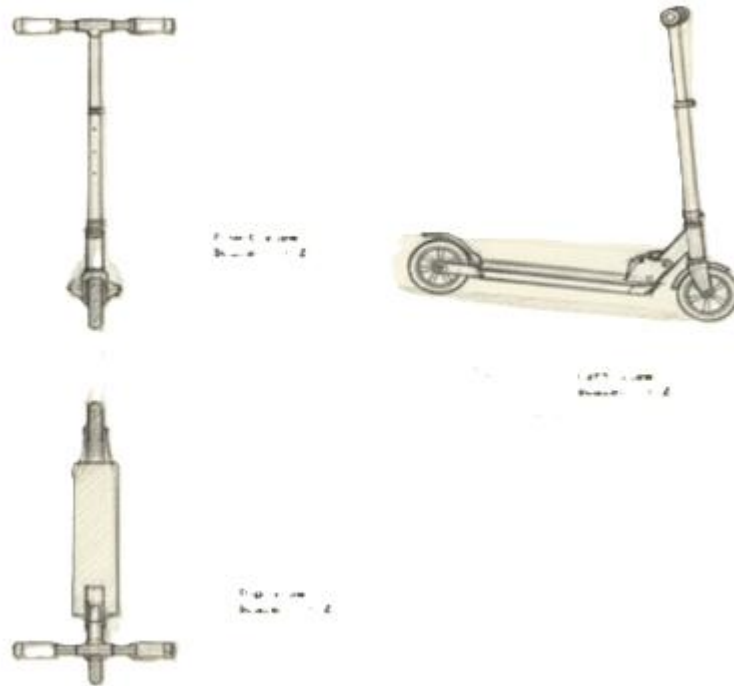


Fig 5.101 2D sketch of assembly using generative AI

Prompt:

A carefully drawn technical pencil illustration of a kick scooter presented using orthographic views. The sketch shows the front, side, and top perspectives, neatly placed on a light, off-white paper surface. It has a hand-sketched engineering feel, with thin graphite lines, soft shading, and accurate proportions. Each view is clearly marked with labels like “Front View,” “Left View,” and “Top View,” along with a scale notation of 1:2. The overall style is simple and classic, inspired by vintage industrial design and mechanical drafting, using only black-and-white pencil tones for a clean, professional look.

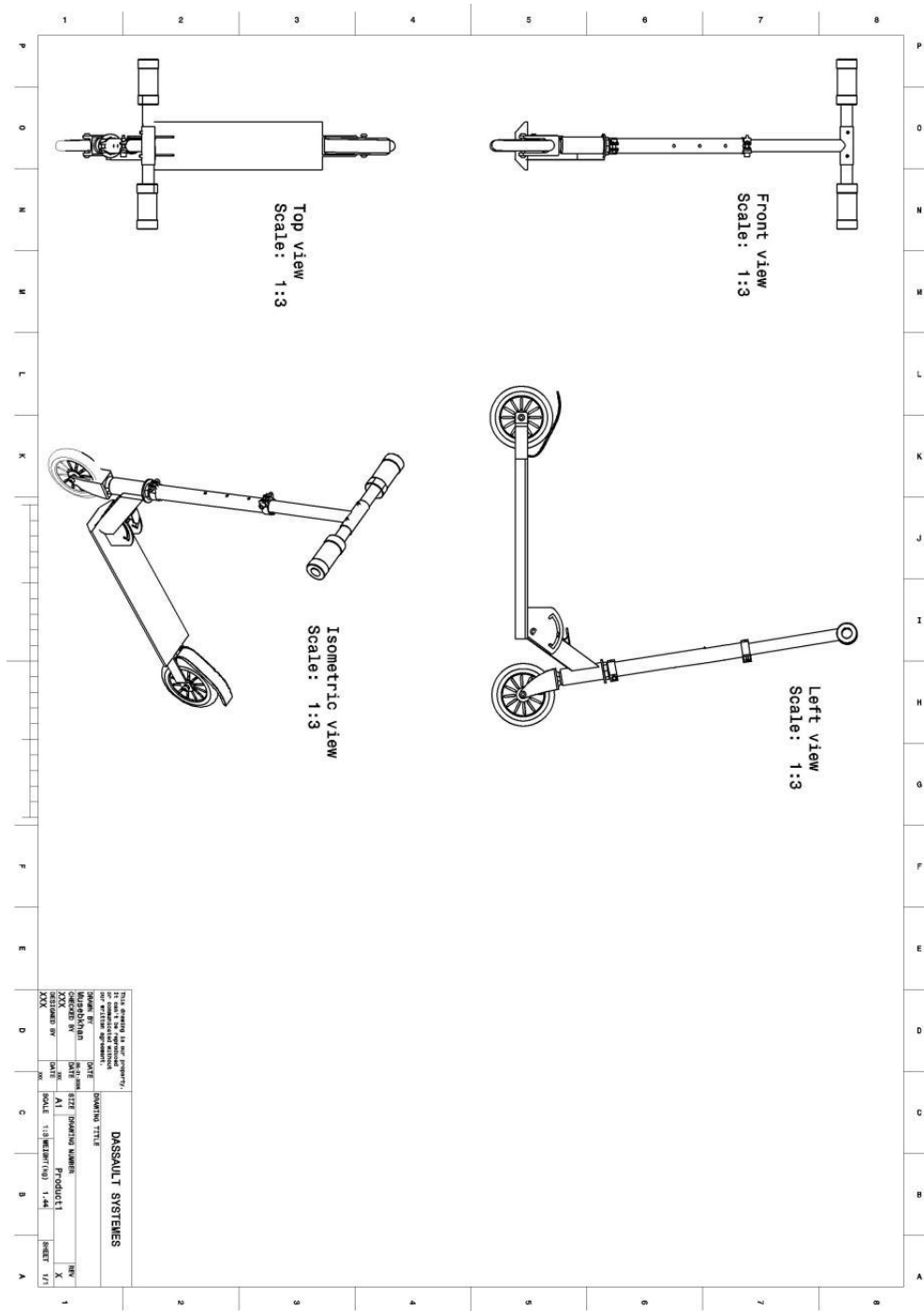


Fig 5.102 Drafting of assembly

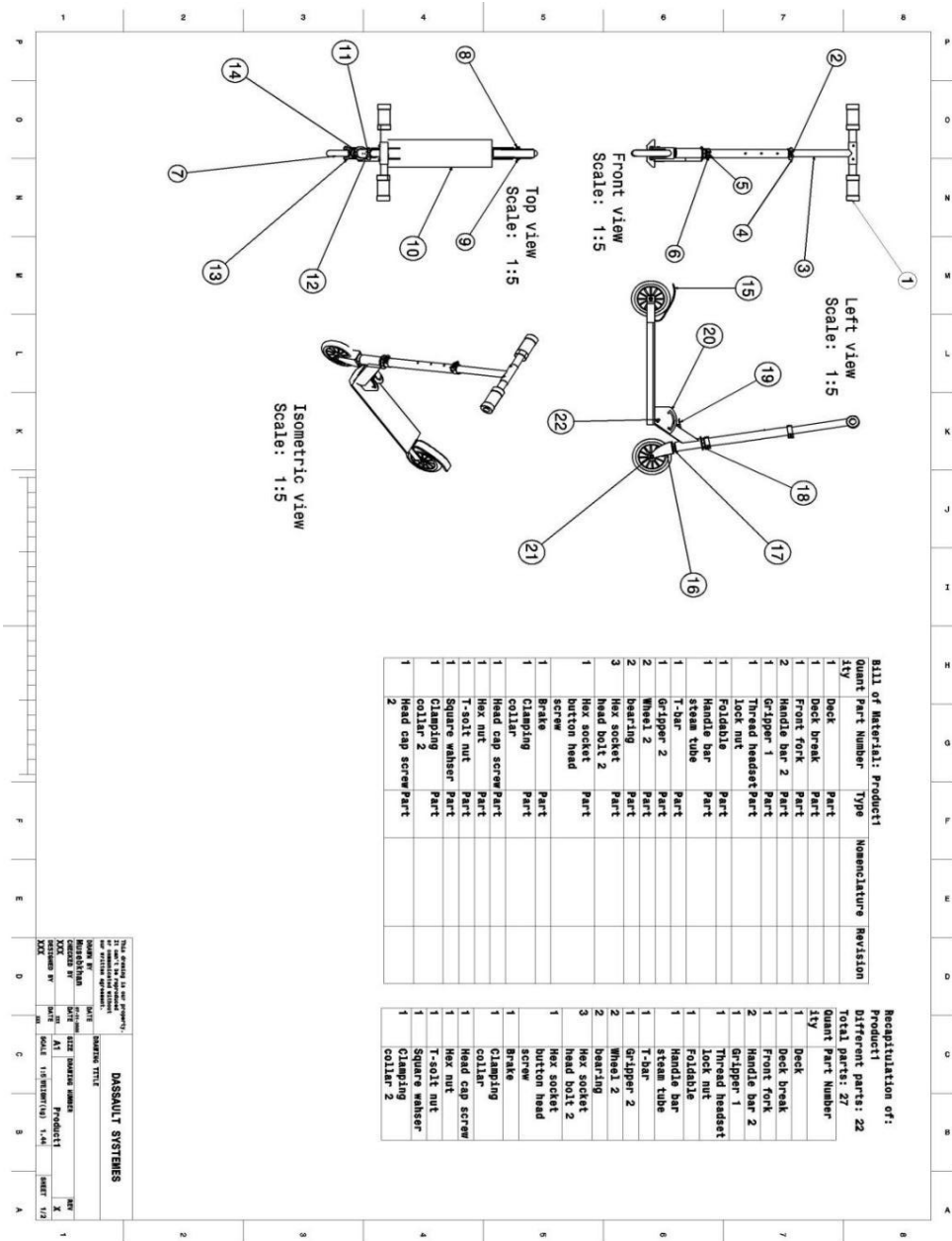


Fig 5.103 bill of materials

Chapter 6

ADDITIONAL PARTS

Table 6.1

This table lists selected kick scooter components along with their material composition. It shows how rubber, plastic, and metal are chosen based on functional requirements such as traction, ease of operation, and structural support.

SL NO.	Part name	Material
1	Double wheel	Rubbr
2	Hand brake	Plastic
3	Stand	Metal

1. **Double wheel:** Provides better balance, stability, and smoother movement of the kick scooter.
2. **Hand brake:** Allows the rider to control speed and safely stop the scooter.
3. **Stand:** Supports the scooter in an upright position when not in use.

Part 1



Fig 6.1Generative AI–Designed Double wheel

Prompt:

A high-quality 3D visualization of a double wheel setup made for a kick scooter. The render shows two matching wheels positioned next to each other, each with a smooth rubber outer surface and a sturdy inner hub featuring evenly spaced slots. The wheels are finished in matte black and dark gray, giving them a clean, modern, and practical look. Soft studio lighting is used to highlight the shape and texture, creating subtle reflections and realistic shadows against a simple light gray background. The overall scene is minimal, focusing clearly on the product with crisp details and a professional industrial design feel.

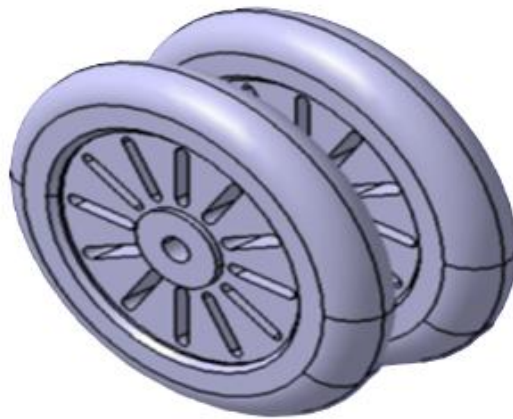


Fig 6.2 3D part of double wheel

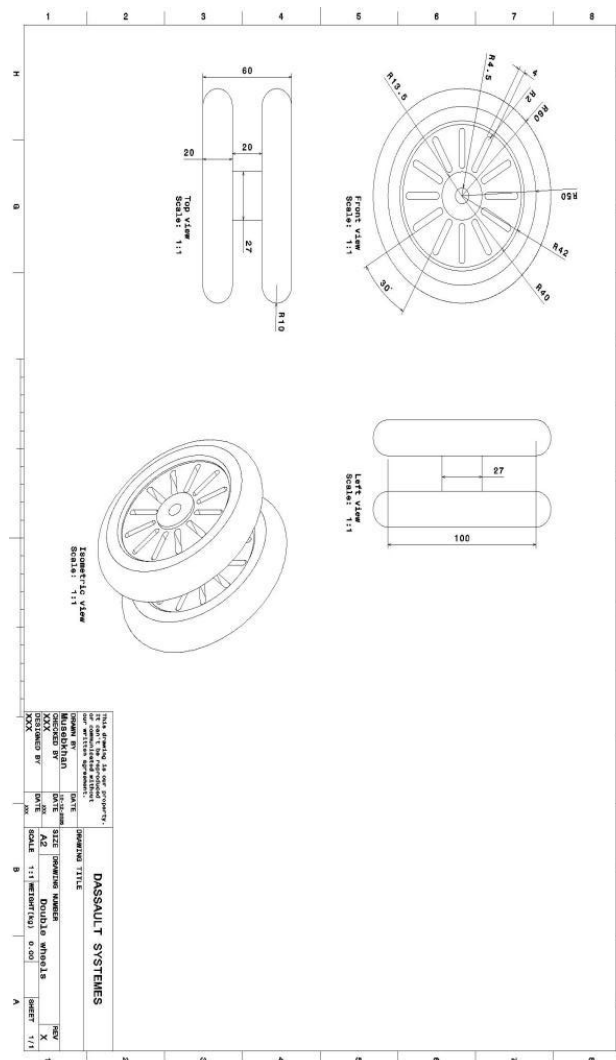


Fig 6.3 Drafting of double wheel





Fig 6.5Generative AI–Designed hand brake wheel

Prompt:

A clear and well-lit image of a hand brake lever used on a kick scooter, shown from the side against a simple, light background. The brake unit includes a smoothly curved metal lever connected to a compact clamp, with bolts and a cable attachment point clearly visible. Finished in matte black, the part looks sturdy, practical, and built for regular use. Soft lighting brings out the contours and surface details while keeping shadows minimal. The overall setup is clean and uncluttered, keeping full attention on the brake lever.



Fig 6.6 3D part of hand brake

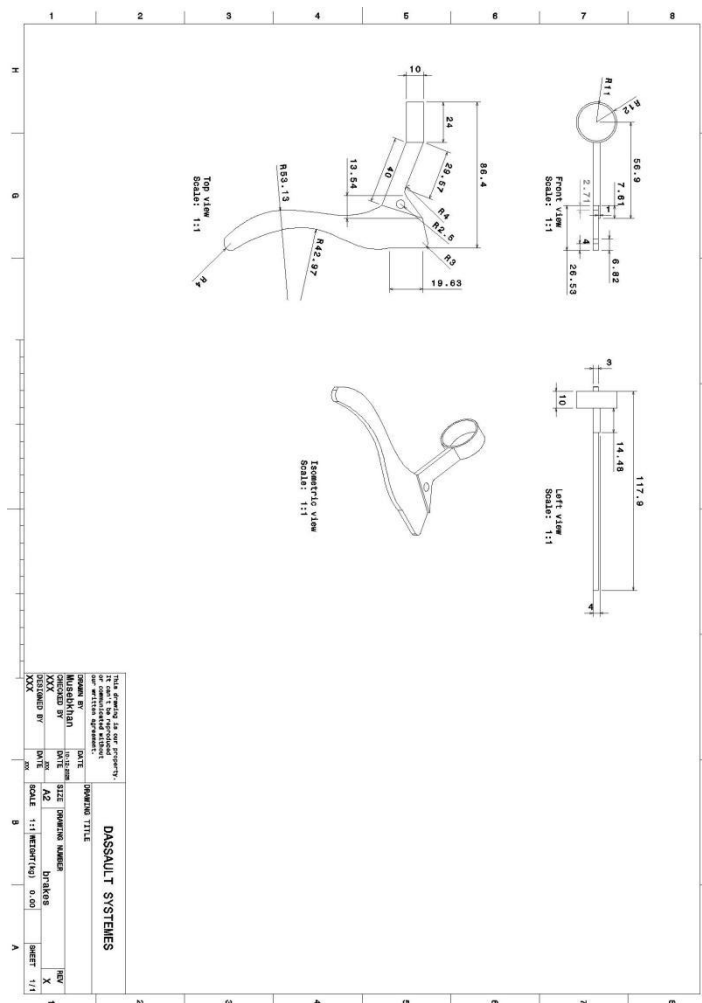


Fig 6.7 Drafting of hand brake



Fig 6.9 Generative AI–Designed stand wheel

Prompt:

A high-quality 3D visualization of a kick scooter stand made from metal, shown upright on a smooth indoor workshop floor. The design includes a flat base plate with mounting holes and an angled support arm that ends in a gently rounded foot. The stand has a matte metal finish with sharp, clean edges, giving it a strong and practical feel. Soft indoor lighting highlights the surface details, creating realistic reflections and shadows. The background is slightly out of focus, suggesting a workshop or garage environment, while keeping the attention on the stand itself.

3D part

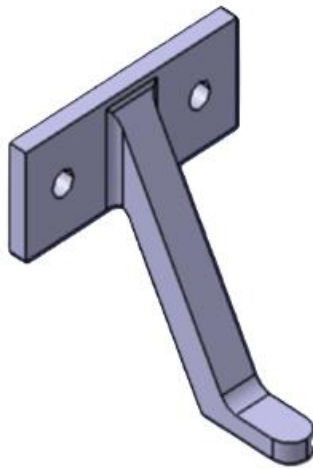


Fig 6.10 3D part of stand

Drafting

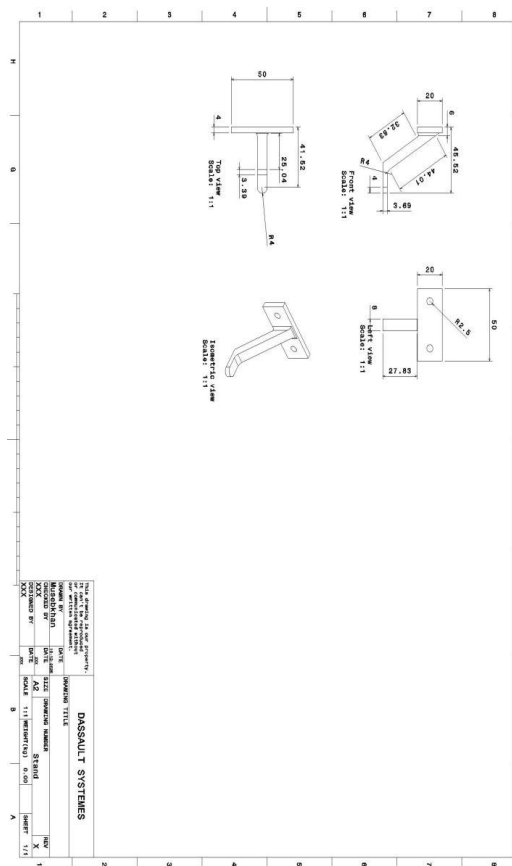


Fig 6.11 drafting of stand



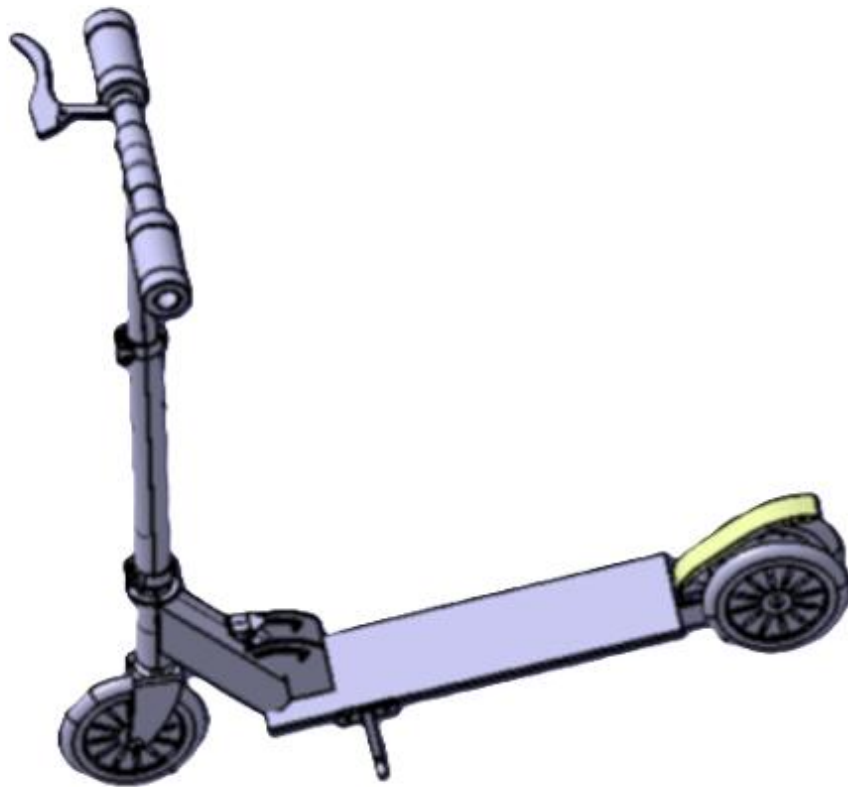


Fig 6.13 Assembly withn additional parts

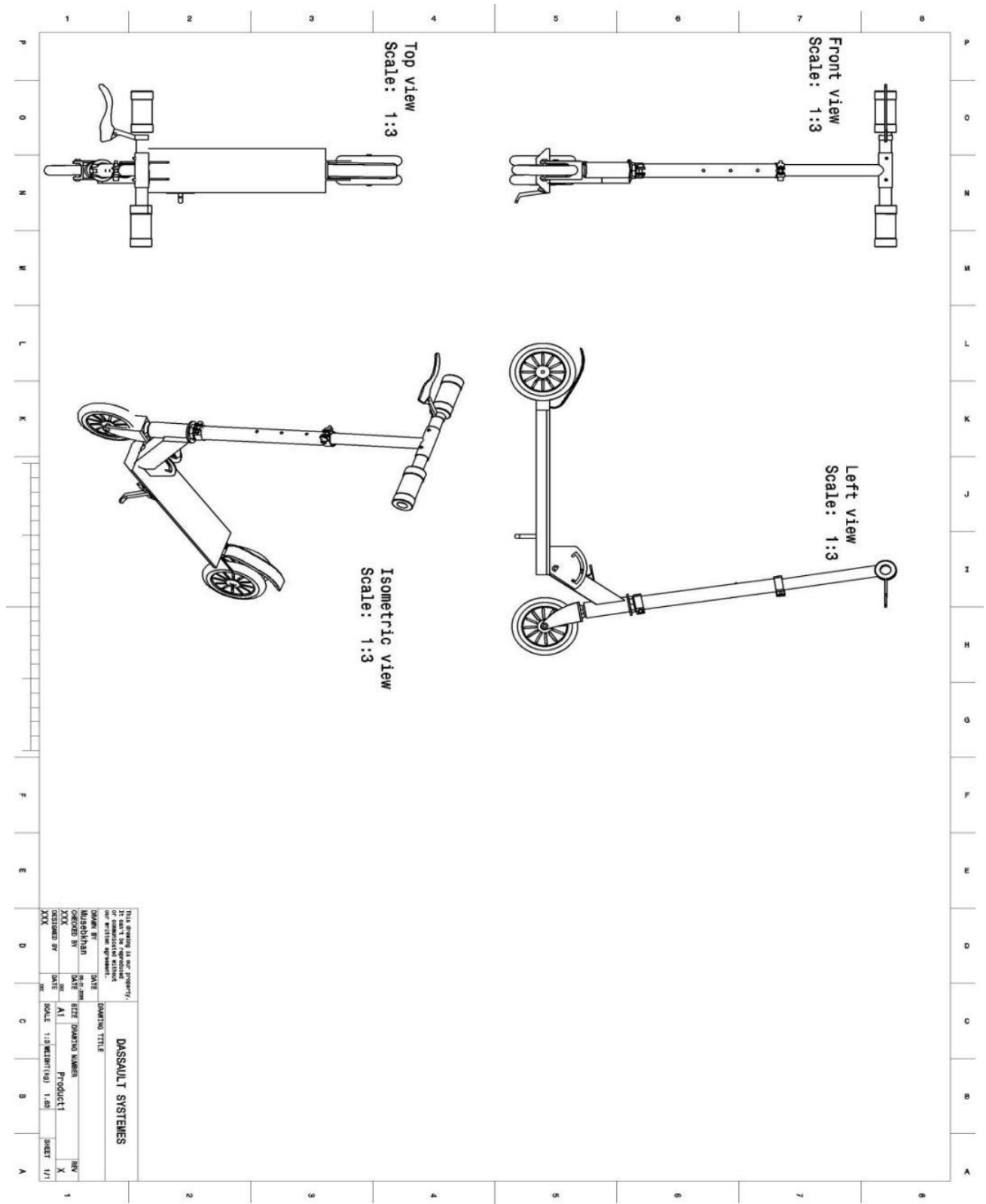


Fig 6.14 Drafting of assembly with additional parts

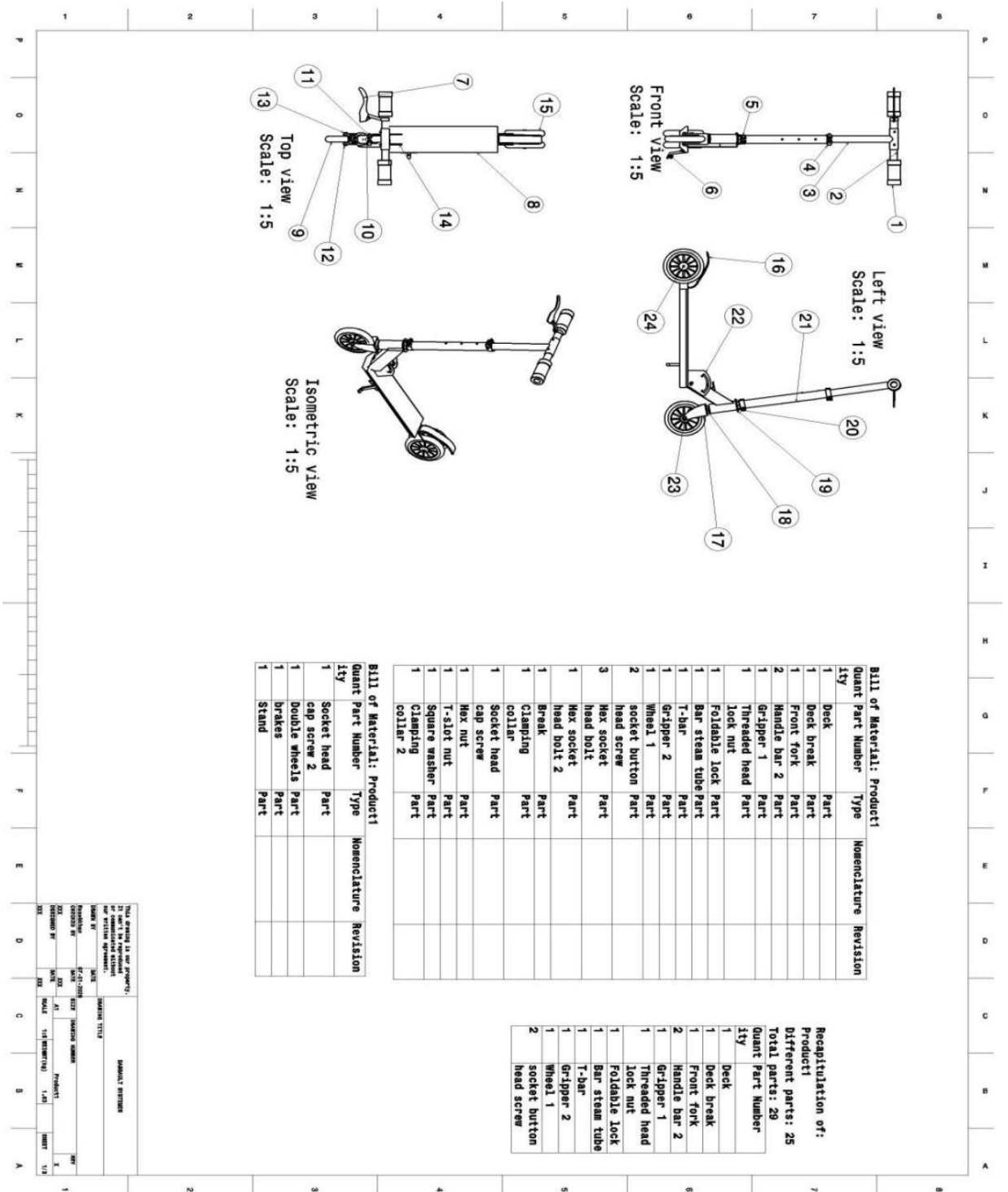


Fig 6.115 bill of materials with additional parts

Chapter 7

FEM Analysis

Table 7.1

This table lists the selected key components of the kick scooter that were considered for detailed analysis. The parts were chosen based on their functional importance, structural role, and relevance to the overall performance and safety of the scooter

SL NO.	Part name
1	Front fork
2	Wheel
3	Deck
4	T-bar

1. **Front fork:** Selected because it carries the front wheel and directly affects steering control and load transfer.
2. **Wheel:** Selected as it is the primary load-bearing and motion-transmitting component during operation.
3. **Deck:** Selected because it supports the rider's weight and experiences maximum bending stresses.
4. **T-bar:** Selected since it is responsible for steering input and undergoes significant handling forces.

Part 1

Front fork

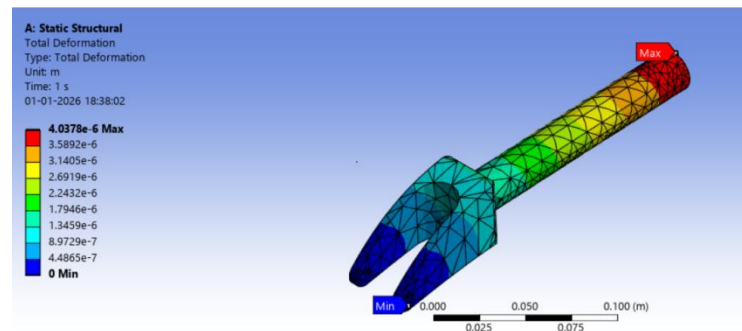


Fig 7.1 Total deformation

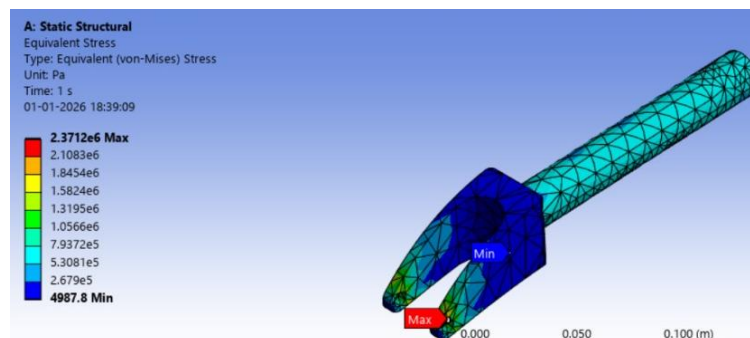


Fig 7.2 Equivalent stress

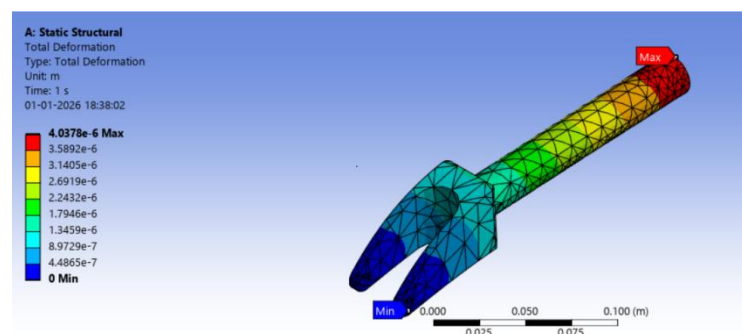


Fig 7.3 Equivalent strain

Part 2

Wheel

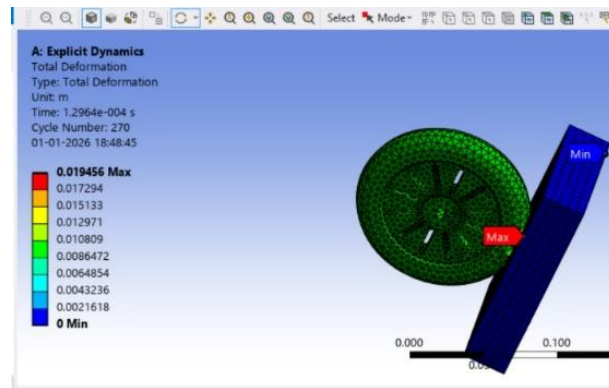


Fig 7.4 Total deformation

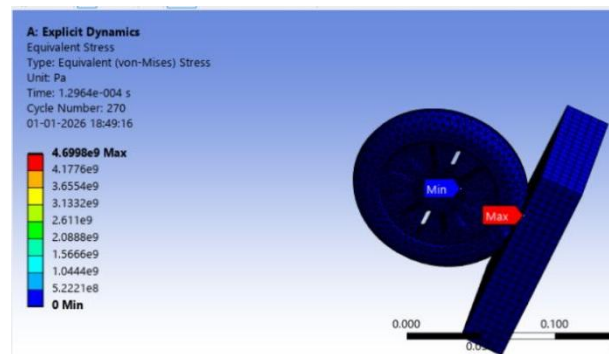


Fig 7.5 Equivalent stress

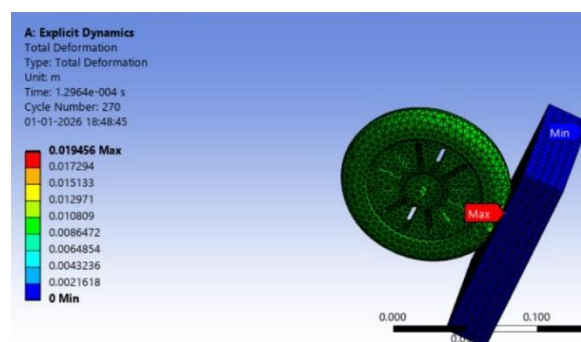


Fig 7.6 Equivalent strain

Part 3

Deck

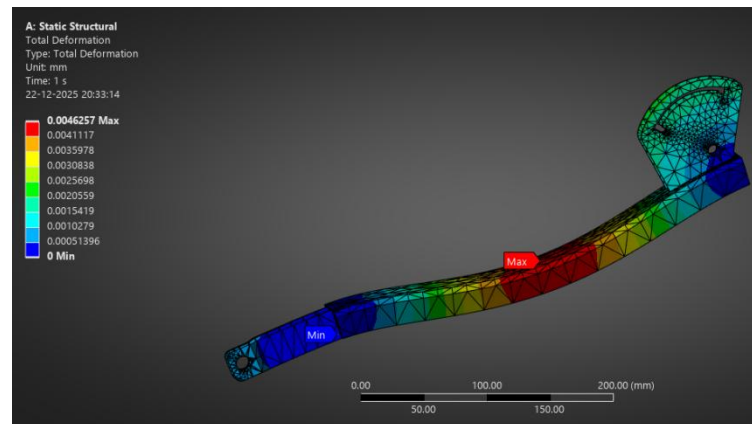


Fig 7.7 Total deformation of deck

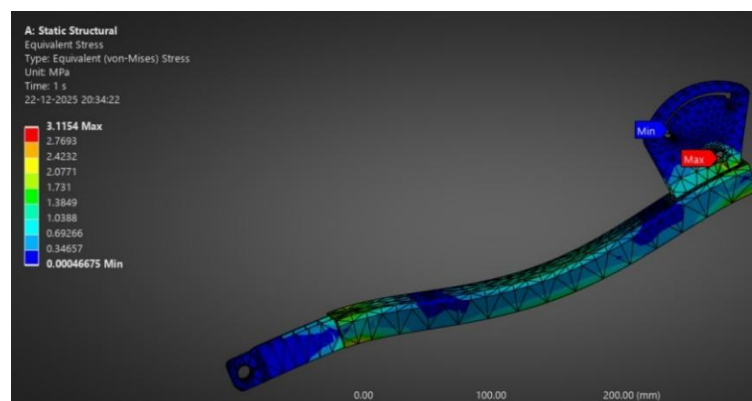


Fig 7.8 Equivalent stress of deck

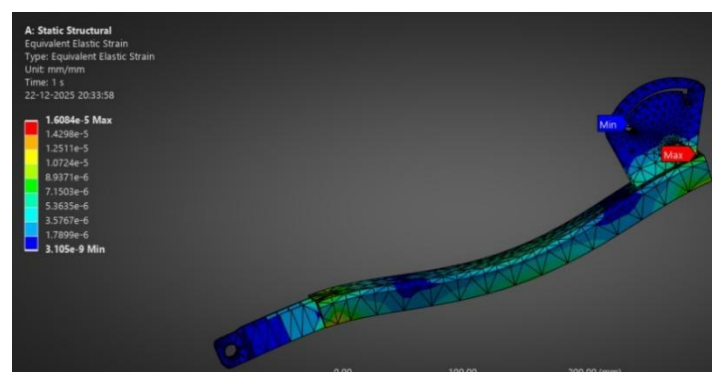


Fig 7.9 Equivalent strain of deck

Part 4

T - Bar

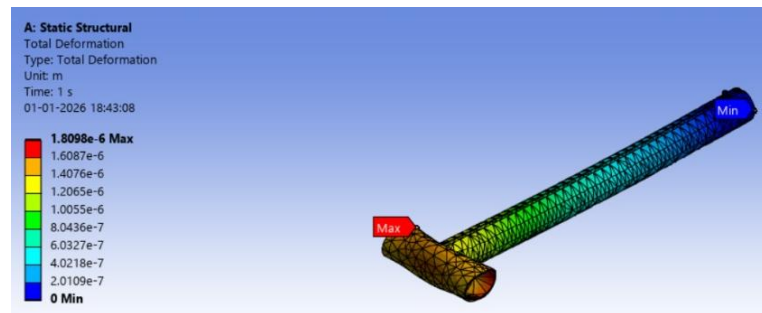


Fig 7.10 Total deformation of T-bar

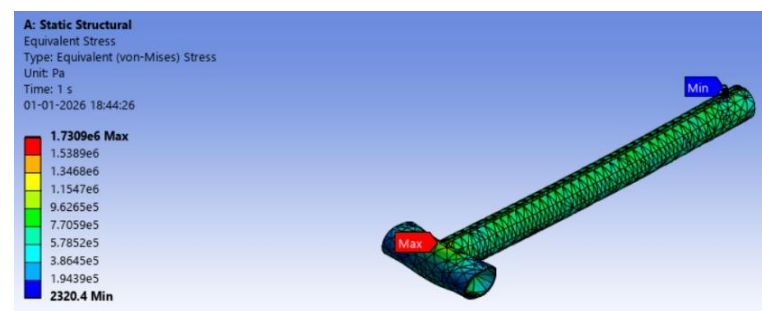


Fig 7.11 Equivalent stress of T - bar

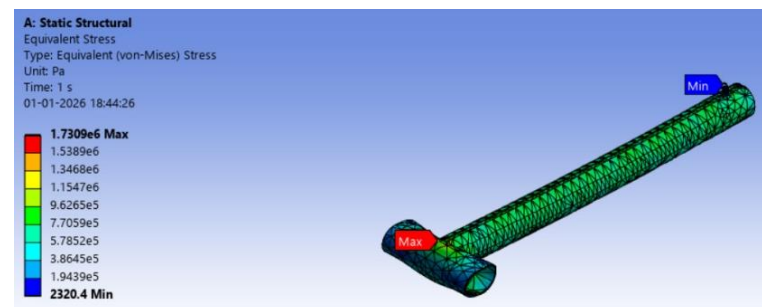


Fig 7.12 Equivalent strain

Conclusion

Reverse engineering of a commercial kick cycle through systematic measurement, CAD reconstruction in CATIA V5R20, and finite element analysis successfully quantified structural performance under operational loading conditions. The parametric modeling approach captured geometric fidelity sufficient for computational analysis while maintaining editability for design exploration. Static structural analysis demonstrated substantial safety margins across all primary components, with minimum safety factors exceeding 80 relative to material yield limits. Peak stresses of 3.12 MPa and maximum deformations of 0.0046 mm under 1750 N loading indicated highly conservative structural design. The extremely low stress levels suggested the design prioritized manufacturing simplicity, fatigue resistance, and user-perceived rigidity over weight optimization. Explicit dynamic simulation at 40 m/s impact velocity revealed dramatic stress amplification reaching 1,508 times static values and deformation increases of 4,205 times baseline. Peak stresses of 4.70 GPa in the wheel deck contact zone exceeded material yield strength by factors of 13, indicating localized plastic deformation would occur under such extreme loading. These results highlighted the structure's vulnerability to severe impact scenarios while confirming adequate performance under normal operational conditions. The methodology proved effective for educational and practical engineering purposes. The reverse engineering process reinforced dimensional metrology skills, tolerance analysis, and assembly constraint management essential for mechanical design practice. Finite element validation provided quantitative insight into load paths, stress distributions, and design sensitivities unavailable from analytical calculations alone. Future work could extend this investigation through experimental validation via static load testing and instrumented impact experiments, material nonlinearity modeling to capture plastic deformation effects during extreme loading, and fatigue life prediction under representative operational load spectra.

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