MIT | Academy of Engineering
(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

School of E&TC Engineering (SEE)

Project Implementation Sem IV/SY B.Tech.

Automating telescope and digitizing picture of celestial bodies

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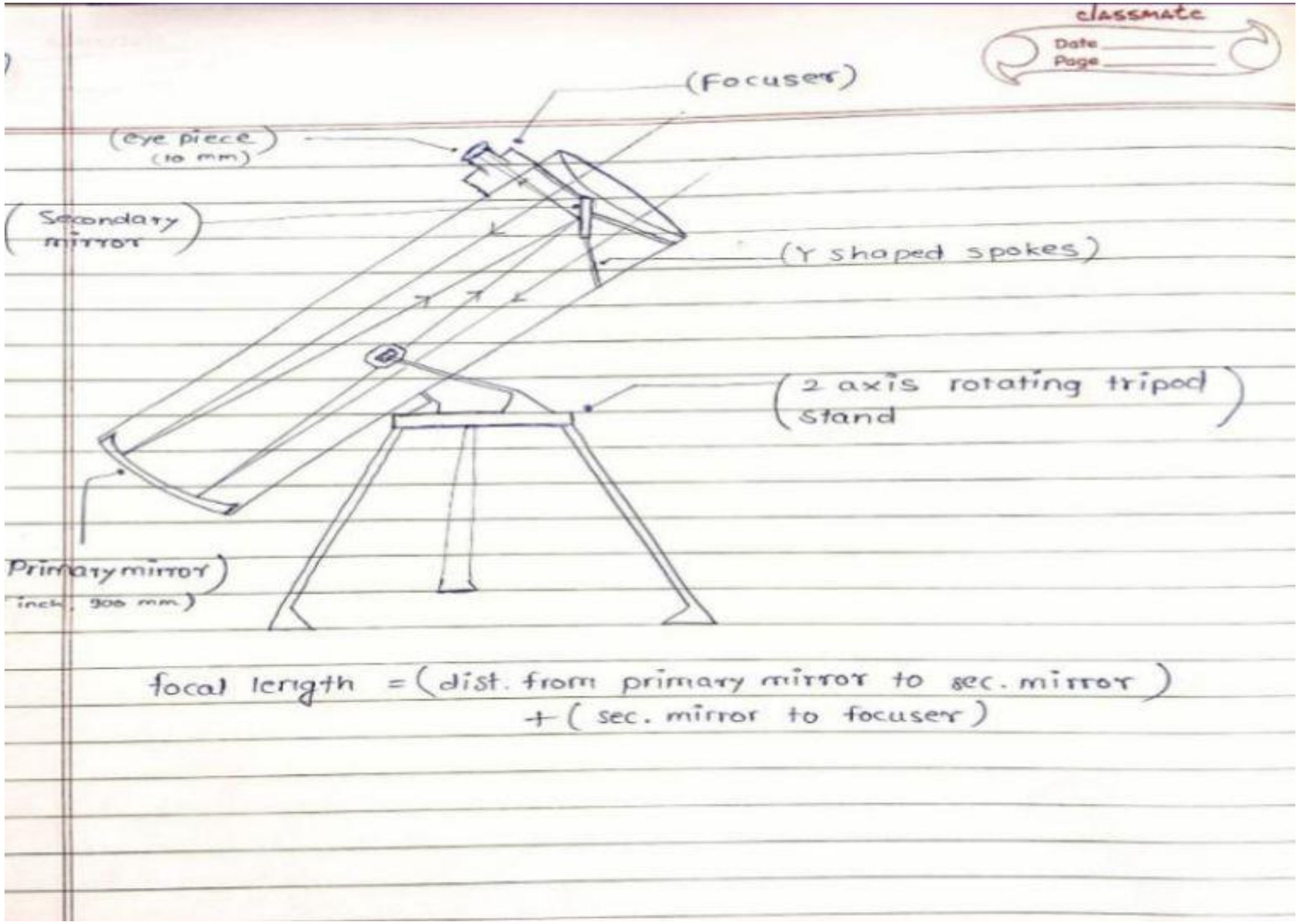
Contents

Idea of project

- A normal telescope helps us to observe large celestial bodies like planets, stars, etc.
- It is impossible to configure the telescope and observe the celestial bodies at the same time
- It is difficult to monitor and capture an event simultaneously.
- To resolve this we are attaching a camera which will help us to observe the bodies in real time on a big screen so that we can adjust the telescope mount easily



- Tube length - 900mm
- Diameter - 140mm
- Mirror diameter - 125mm
- Mirror thickness - approx 12mm
- Mirror focal length - 900mm
- **Weight - 3.150kg**
- **Total Length - 88.9 ± 0.1cm**
- **Length (Center to Bottom) - 42.3 ±0.1cm**
- **Length (Center to Top) - 46.9 ± 0.1cm**
- **Circumference - 44.2cm**
- **Diameter – 14.06 cm**

Eyepiece dimensions :

- External diameter of the tube - 3.53cm with an uncertainty of 0.01cm
- Internal diameter 2.40cm with an uncertainty of 0.01cm

Problem Statement

Title:

- Automating telescope for digitizing pictures of celestial bodies

Problem statement :

- Our project aims to create an automated telescope to observe celestial bodies and capture their images so that we can study them more efficiently.

Need of project:

- Digitizing the observed entities from a Telescope
- Automating the process ensures consistent data collection, including studying the movement and properties of celestial bodies.
- Digitizing images allows for easy storage, sharing, and analysis. It also makes it possible to apply image processing techniques to enhance details that may not be visible in raw images.

Feasibility Check

Camera Module:

- Raspberry pi Camera Module - 3**(12MP)**
- Official Raspberry Pi High Quality Camera Mount - C/CS Mount**(12.3 mp/ Adjustable Focus – 12.5 mm–22.4 mm)**

Micro Controller:

- Raspberry Pi 4 Model-B with 4 GB RAM
- Raspberry Pi 4 Model-B with 8 GB RAM

3D Printing Software:

- Autodesk Fusion 360 (online)
- FreeCAD

Operating Systems:

- RetroPie
- Ubuntu
- Raspberry pi OS

Comparisons for the tools used

Feature	Raspberry Pi Camera Module 3	Raspberry Pi Camera Module 2	Arducam 5MP OV5647	Raspberry Pi High Quality Camera
Price (Approx.)	₹2,949	₹1,770	₹1,271	₹4,479
Sensor	12MP Sony IMX708	8MP Sony IMX219	5MP OV5647	12.3MP Sony IMX477
Lens Type	Autofocus	Fixed Focus	Fixed Focus	Interchangeable (C/CS-mount)
Field of View	75° (Standard), 120° (Wide)	62.2°	54°	Adjustable with lens
Low-Light Performance	Available (NoIR Variant)	Moderate	Moderate	High (Adjustable Lens + Large Sensor)
High (Adjustable Lens + Large Sensor)	Yes	No	No	No
Video Resolution	1080p30, 720p60	1080p30, 720p60	1080p30, 720p60	1080p30
Best Use Case	Balanced Telescope Imaging	Budget Telescope Setup	Entry-Level Projects	High-End Telescope Applications

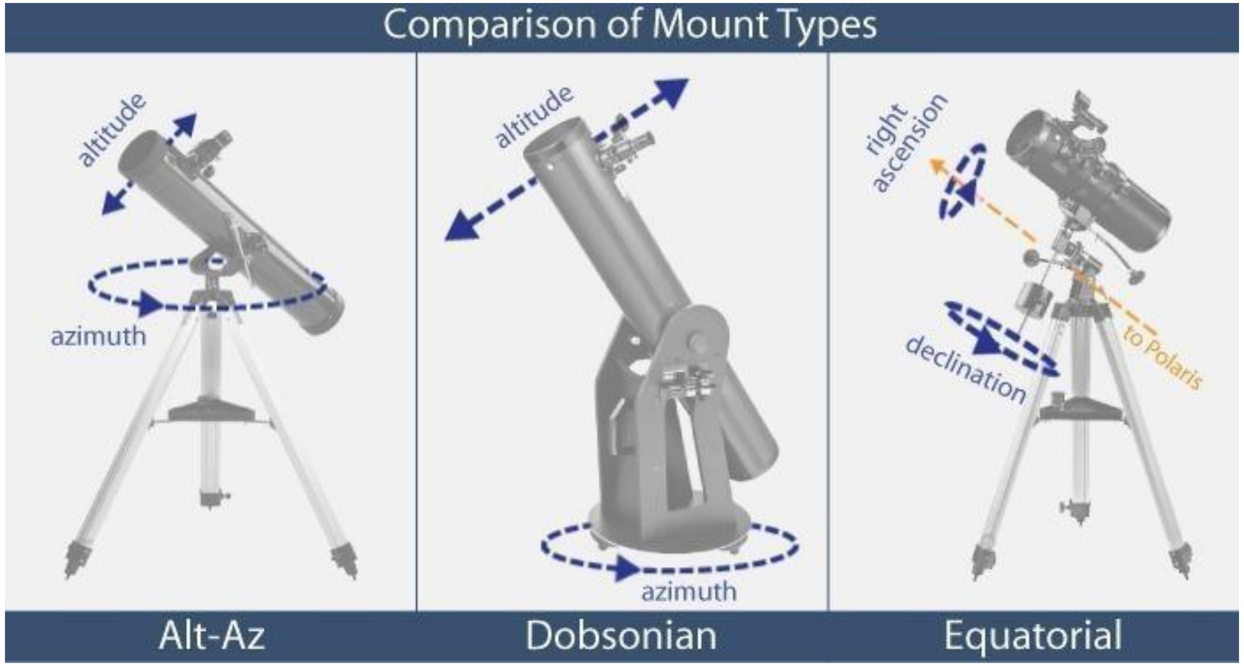
Comparisons for the tools used

Feature	Raspberry Pi 4 Model-B (4 GB/8 GB RAM)	Raspberry Pi 4 Model B (2GB RAM)	Arduino Uno	Arduino Nano
Price (Approx.)	₹4,500 - ₹8,500	₹3,500 - ₹4,500	₹500 - ₹700	₹300 - ₹500
CPU	Quad-Core Cortex-A72 (1.5 GHz)	Quad-Core Cortex-A72 (1.5 GHz)	ATmega328P (16 MHz)	ATmega328P (16 MHz)
RAM	4GB or 8GB LPDDR4-3200	2GB LPDDR4-3200	None (uses Flash Memory)	None (uses Flash Memory)
Storage	microSD, USB Boot, SSD	microSD, USB Boot, SSD	Flash Memory (32KB)	Flash Memory (32KB)
Graphics	Broadcom VideoCore VI	Broadcom VideoCore VI	None	None
USB Ports	2x USB 3.0, 2x USB 2.0	2x USB 3.0, 2x USB 2.0	1x USB Type-B	1x USB Type-B
Networking	Gigabit Ethernet, Wi-Fi 802.11ac	Gigabit Ethernet, Wi-Fi 802.11ac	No Ethernet/Wi-Fi	No Ethernet/Wi-Fi
GPU Processing	Supports OpenGL, OpenCL, Vulkan	Supports OpenGL, OpenCL, Vulkan	None	None
Power Requirements	5V/3A via USB-C	5V/3A via USB-C	Basic control applications	Basic control applications
Best Use Case	General Purpose, Media Centers, IoT	General Purpose, Media Centers, IoT	Home security, surveillance, casual use	Video conferencing, professional streaming, and content creation

Tools	Price	Availability
Raspberry Pi Camera Module-3	₹2,949.00	Available
Pro-Range NEMA17 PR42HS40-1504 4.2 kg-cm Stepper Motor -D Type Shaft	₹449.00	Available
Raspberry Pi 4 Model-B with 4 GB RAM/ 8GB RAM	₹5,298.00 - ₹7,199.00	Available
Autodesk Fusion 360 (online)	Free	Available(online)
Raspberry pi OS	Free	Available(online)
RetroPie	Free(open source)	Available(OS)
Ubuntu	Free(open source)	Available(OS)

Challenges

- When we first used an Alt-Azimuth mount, we encountered limitations in the range of motion due to the tripod legs.
- To overcome this limitation, we opted for a Dobsonian mount, which offers a more flexible and unrestricted range of motion.
- While automated equatorial mounts are readily available in the market, automated Dobsonian mounts are relatively rare.
- To achieve our desired level of automation, we decided to undertake the task of automating the Dobsonian mount ourselves.



Telescope Mount Comparison

Features	Alt-Az Mount	Dobsonian Mount	Equatorial Mount
Description	Moves up/down and left/right	Specialized Alt-Az mount for large telescopes	Compensates for Earth's rotation
Advantages	Simple, inexpensive	Stable, large aperture, affordable	Ideal for astrophotography, long-exposure imaging
Disadvantages	Objects drift quickly, not ideal for astrophotography	Objects still drift, can be bulky	Complex setup, more expensive
Best for	Beginners, casual observing	Visual observing, some astrophotography	Serious astrophotography, long-term tracking
Automation	Can be automated with computer control	Can be automated, but less common	Well-suited for automation

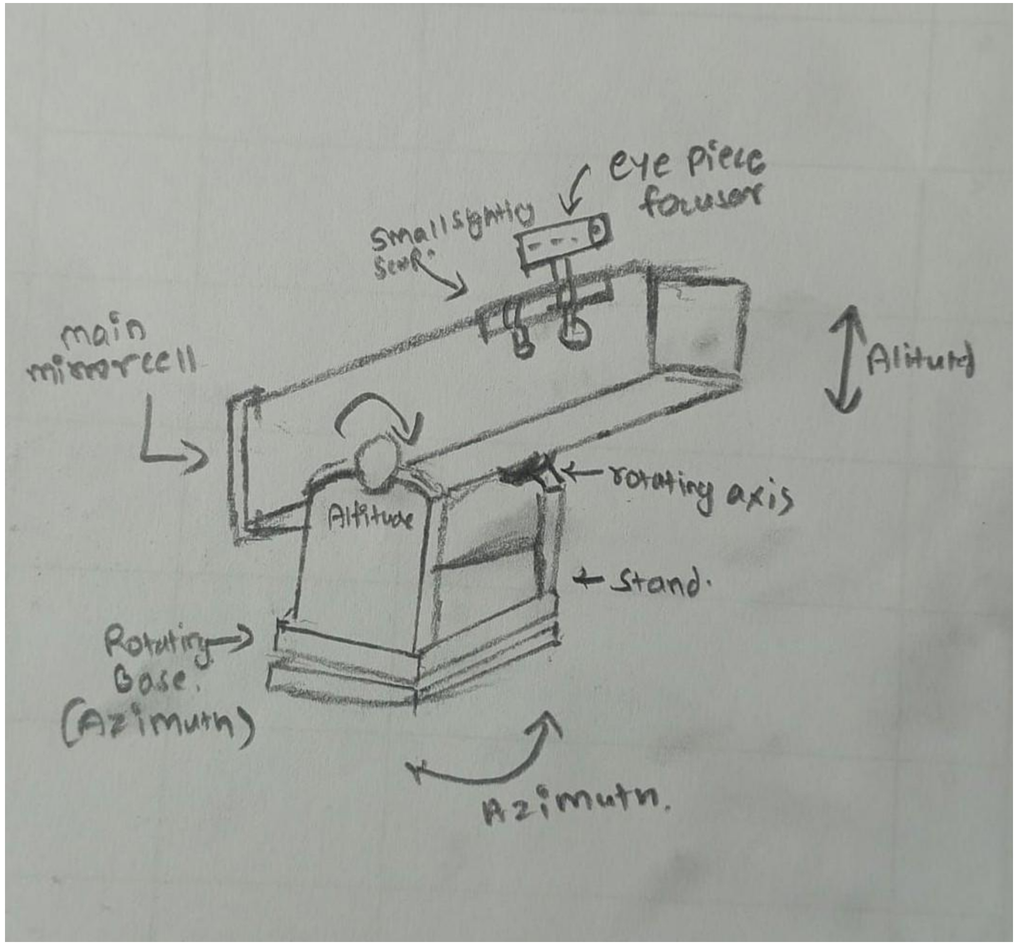
Dobsonian

1. **Azimuth and altitude :** The mount works on two perpendicular axes, which are altitude and azimuth, thus it is very simple for manual use only.

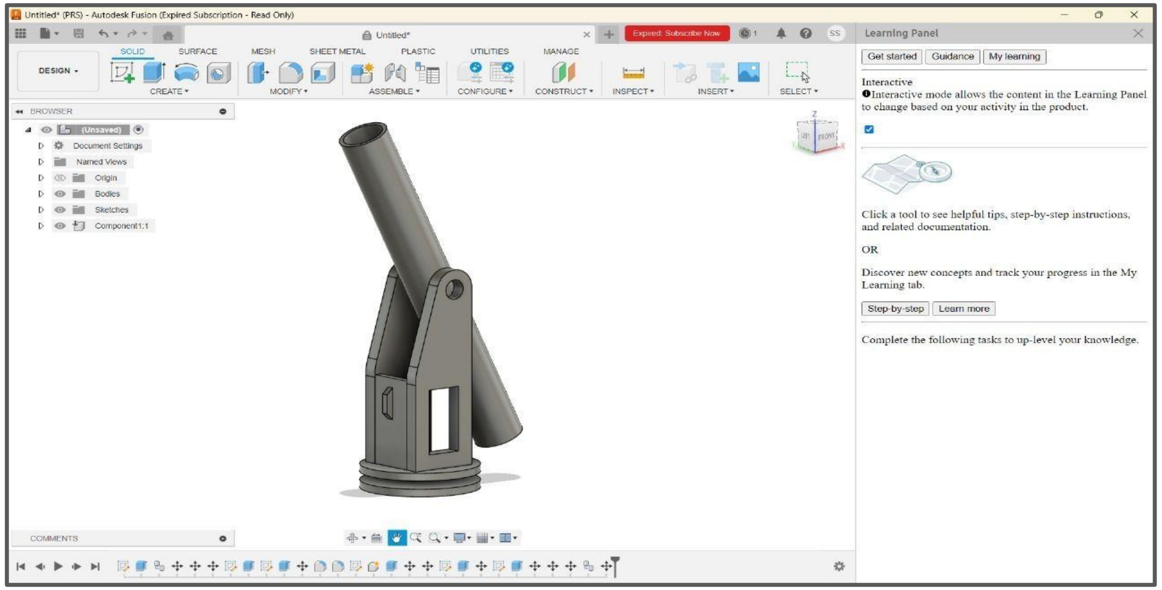
2. **Low Mass-to-Aperture Ratio:** The Dobsonian mount's structure has a minimal overall weight and supports large apertures, hence it is easy to handle.

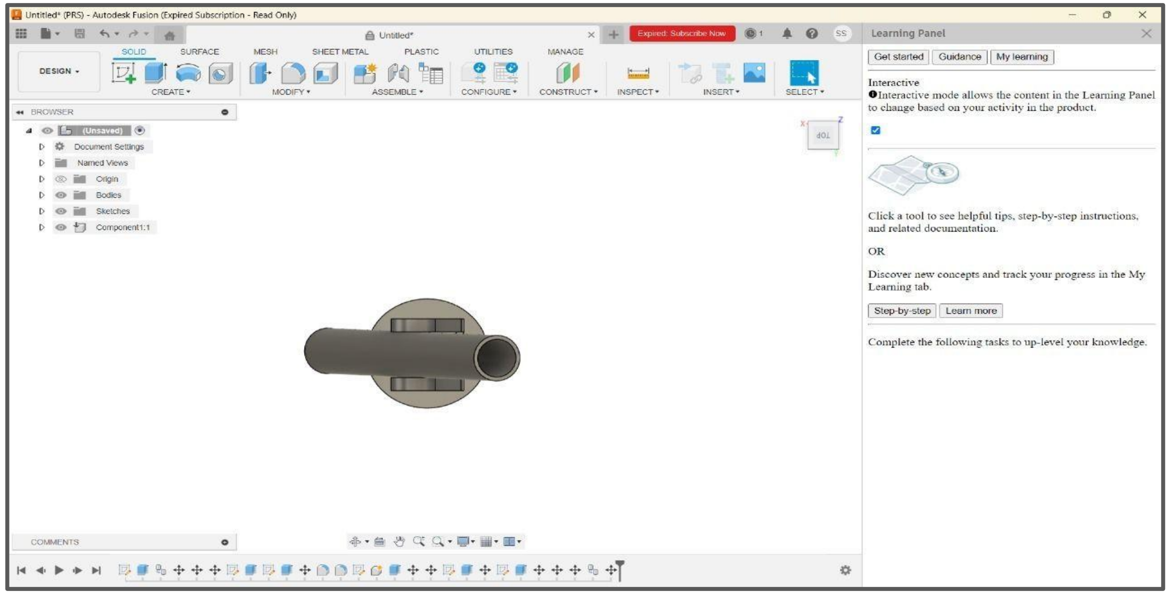
3. **Reduced Backlash:** Large joint surfaces evenly distribute weight, so there is smooth and precise movement of the telescope tube so it can operate smoothly.

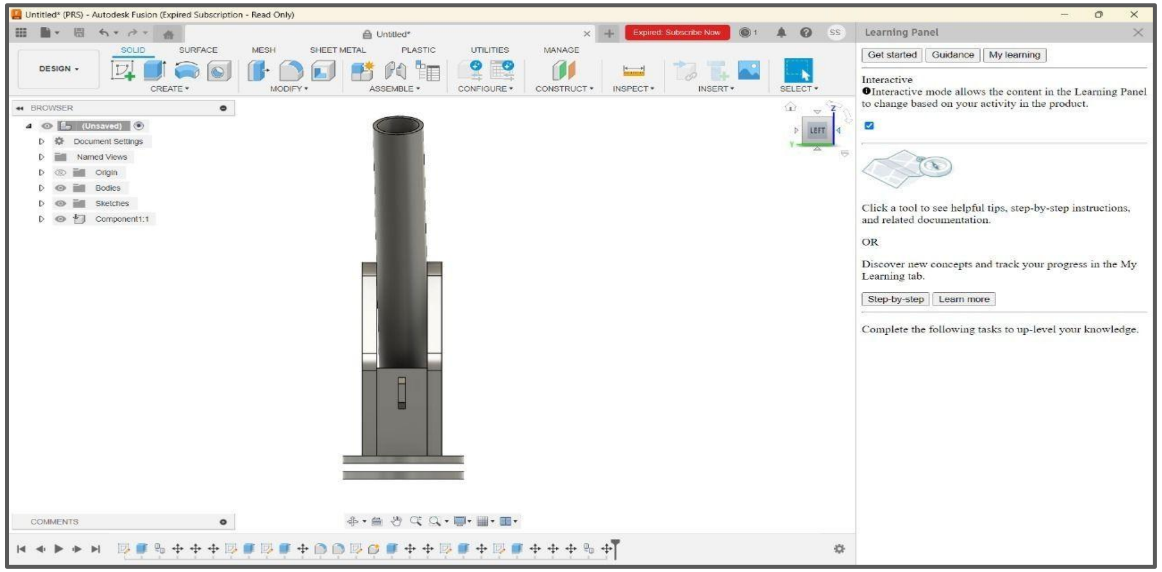
4. **No Counterweight needed:** It does not require any counterweight, which in turn helps in simplifying the setup and reducing the mount's overall bulk.



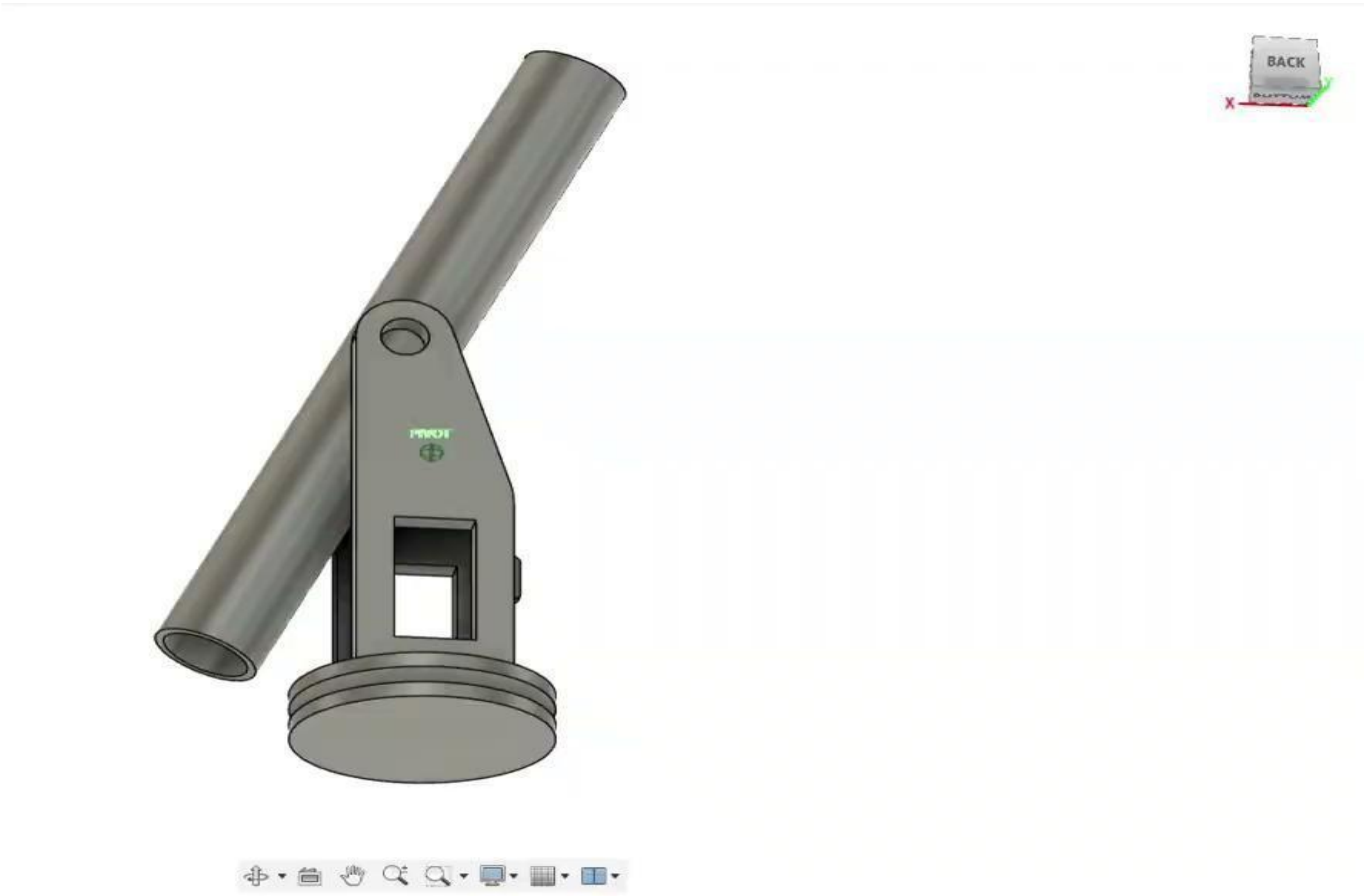
3D Model of Dobsonian



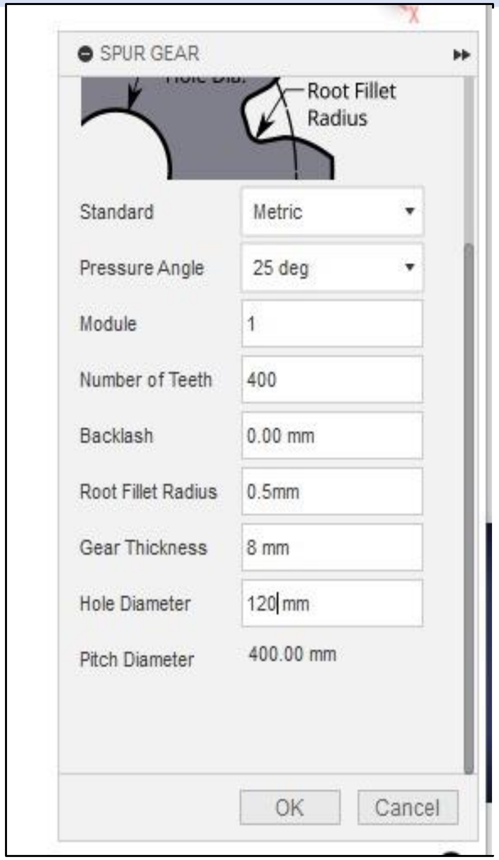


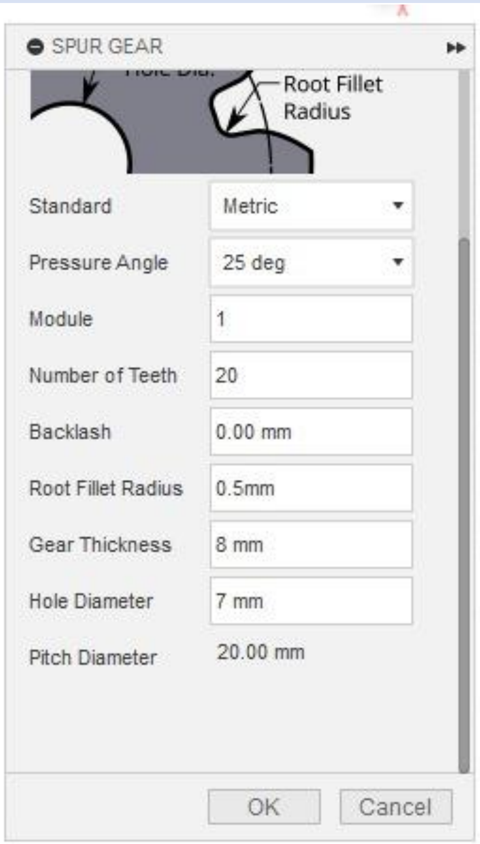


3D Model of Dobsonian



Setup 1


SPUR GEAR
Root Fillet Radius
Standard
Metric
Pressure Angle
25 deg
Module
1
Number of Teeth
400
Backlash
0.00 mm
Root Fillet Radius
0.5mm
Gear Thickness
8 mm
Hole Diameter
120 mm
Pitch Diameter
400.00 mm
OK
Cancel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Metric
Pressure Angle
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Gear Thickness
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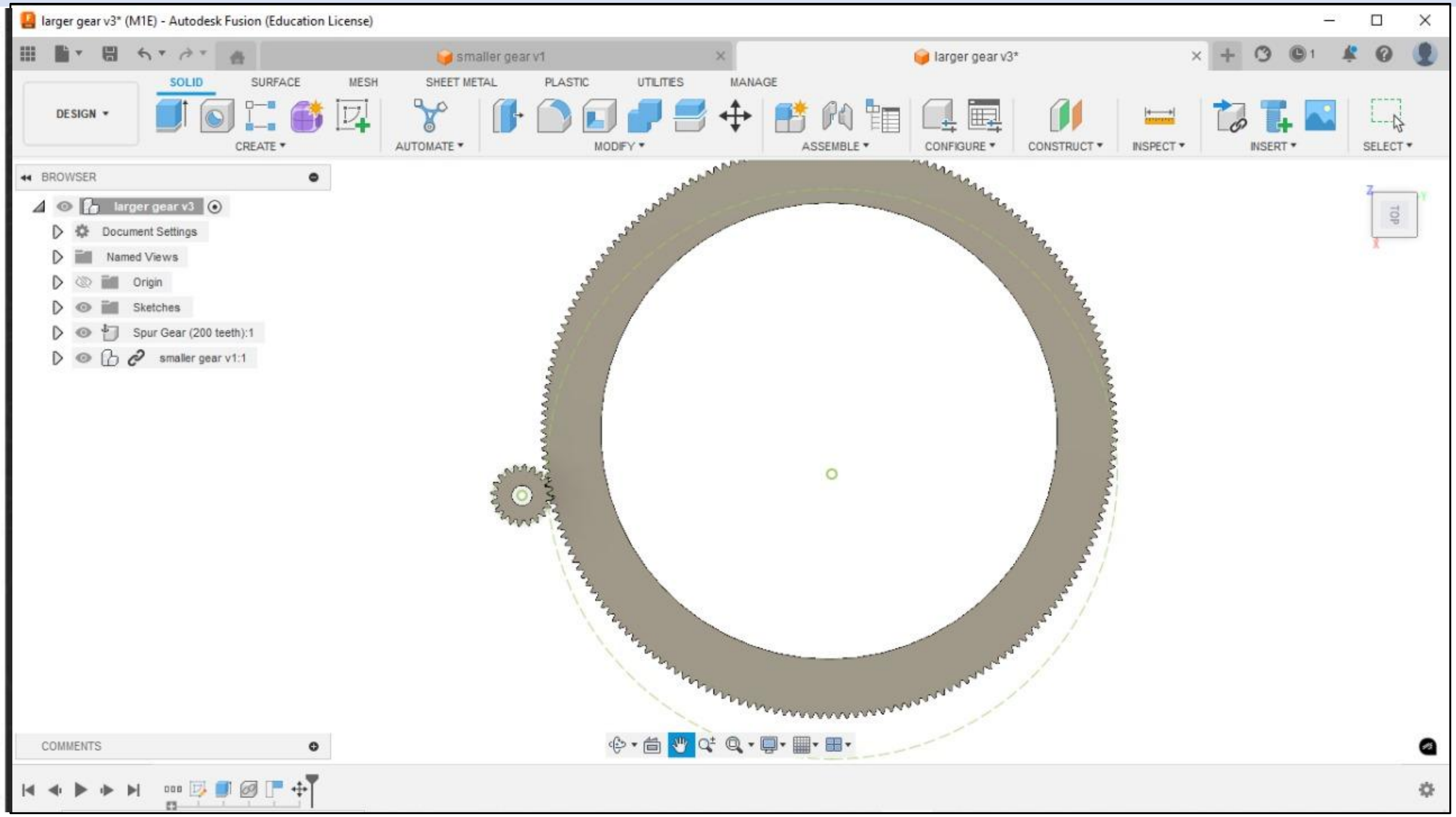
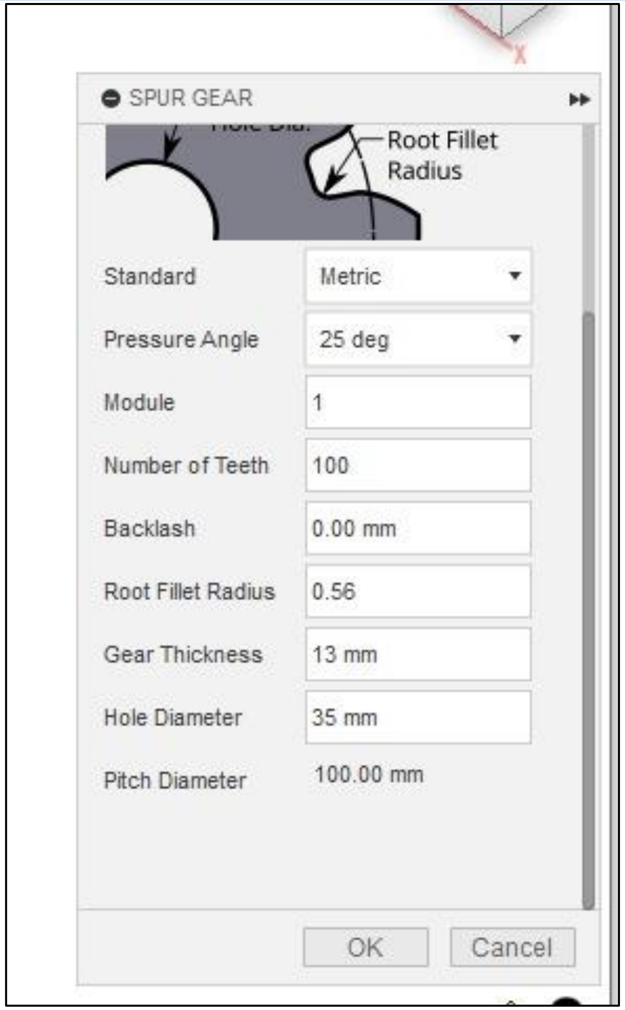

larger gear v3* (M1E) - Autodesk Fusion (Education License)
smaller gear v1
larger gear v3*
SOLID
SURFACE
MESH
SHEET METAL
PLASTIC
UTILITIES
MANAGE
DESIGN
CREATE
AUTOMATE
MODIFY
ASSEMBLE
CONFIGURE
CONSTRUCT
INSPECT
INSERT
SELECT
BROWSER
larger gear v3
Document Settings
Named Views
Origin
Sketches
Spur Gear (200 teeth):1
smaller gear v1:1
COMMENTS

Setup 2


SPUR GEAR
Root Fillet Radius
Standard
Metric
Pressure Angle
25 deg
Module
1
Number of Teeth
100
Backlash
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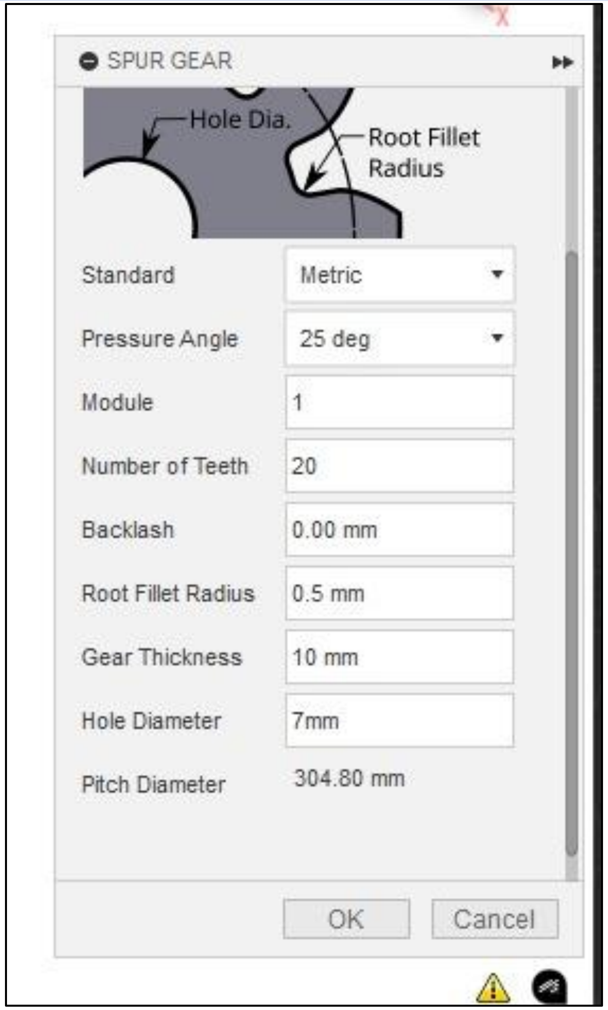
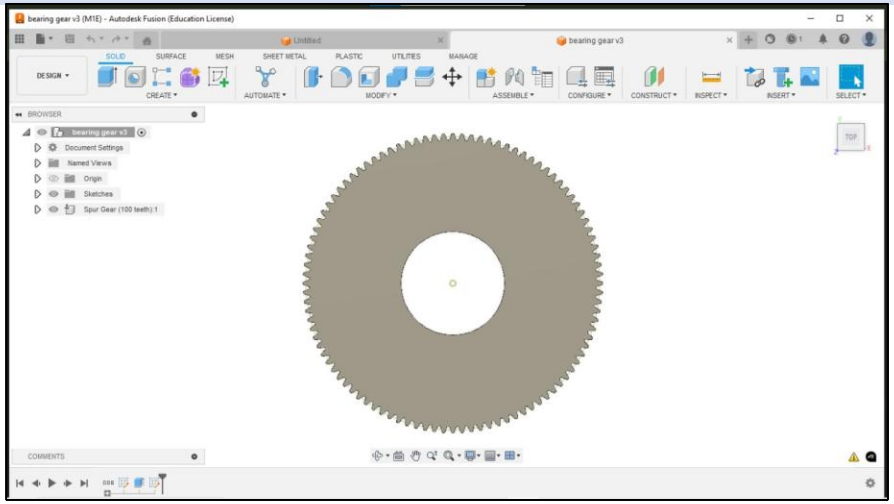
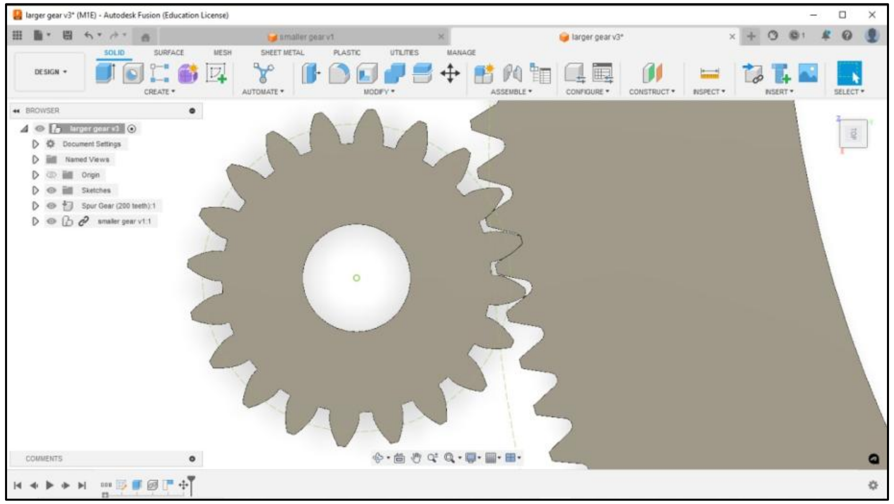
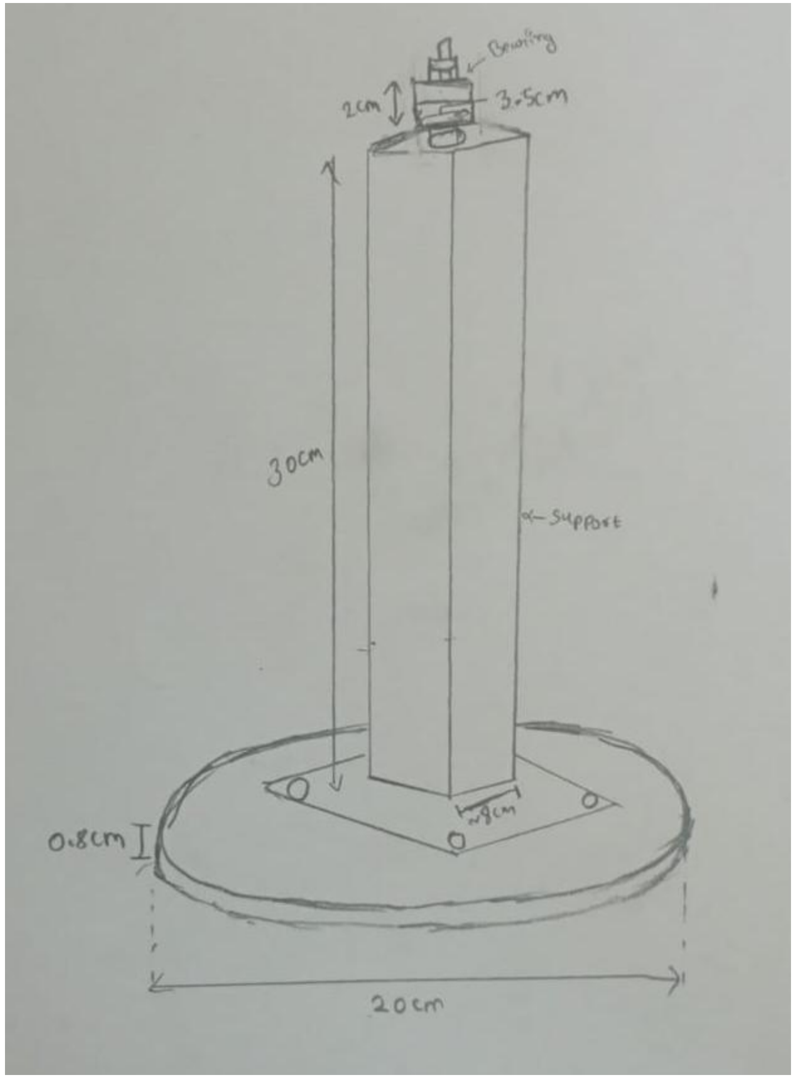
Root Fillet Radius
0.56
Gear Thickness
13 mm
Hole Diameter
35 mm
Pitch Diameter
100.00 mm
OK
Cancel

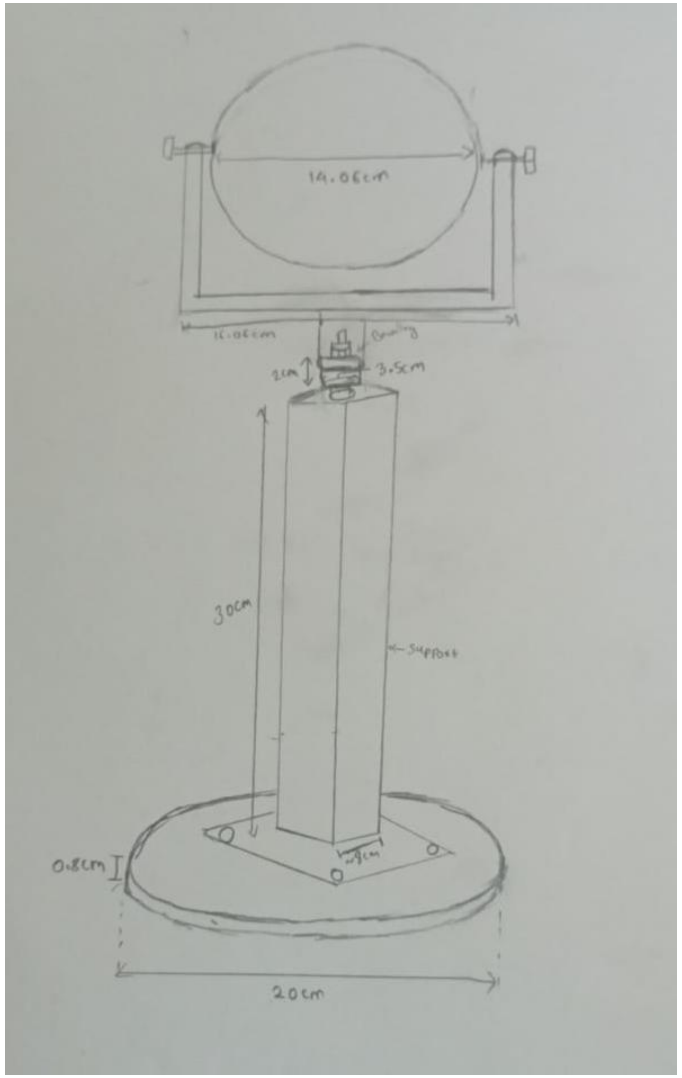

SPUR GEAR
Hole Dia.
Root Fillet Radius
Standard
Metric
Pressure Angle
25 deg
Module
1
Number of Teeth
20
Backlash
0.00 mm
Root Fillet Radius
0.5 mm
Gear Thickness
10 mm
Hole Diameter
7mm
Pitch Diameter
304.80 mm
OK
Cancel


bearing gear v3 (M1E) - Autodesk Fusion (Education License)
DESIGN
BROWSER
COMMENTS

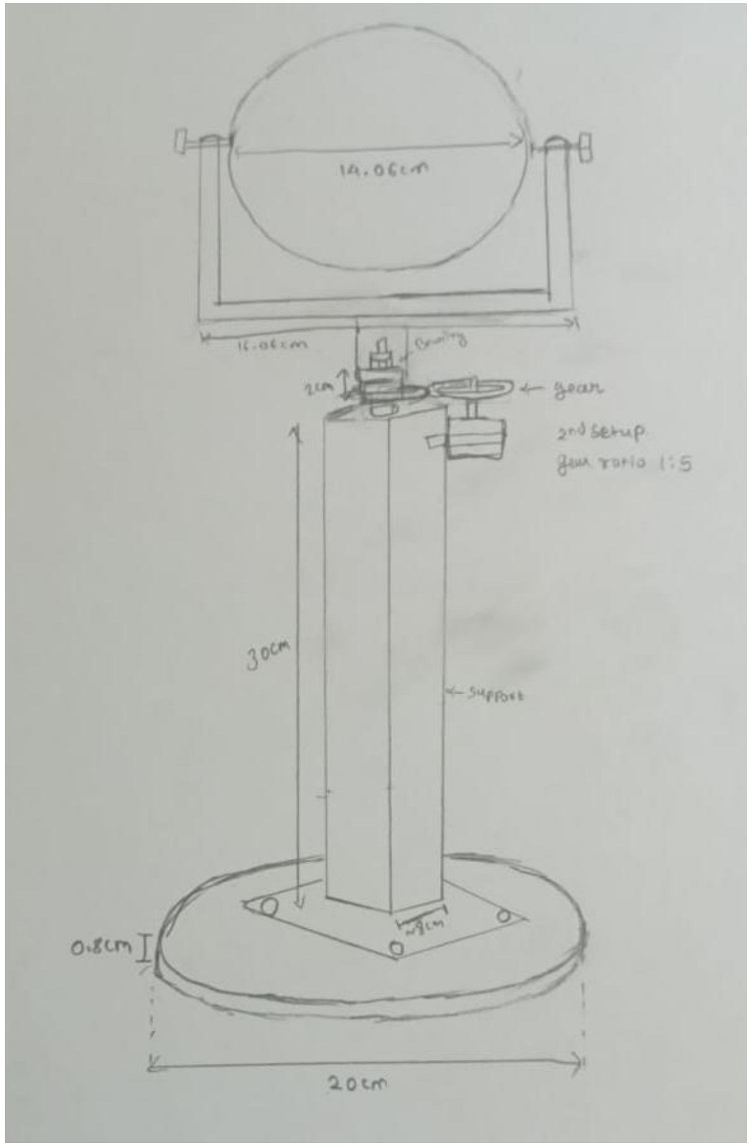

larger gear v3* (M1E) - Autodesk Fusion (Education License)
DESIGN
BROWSER
COMMENTS

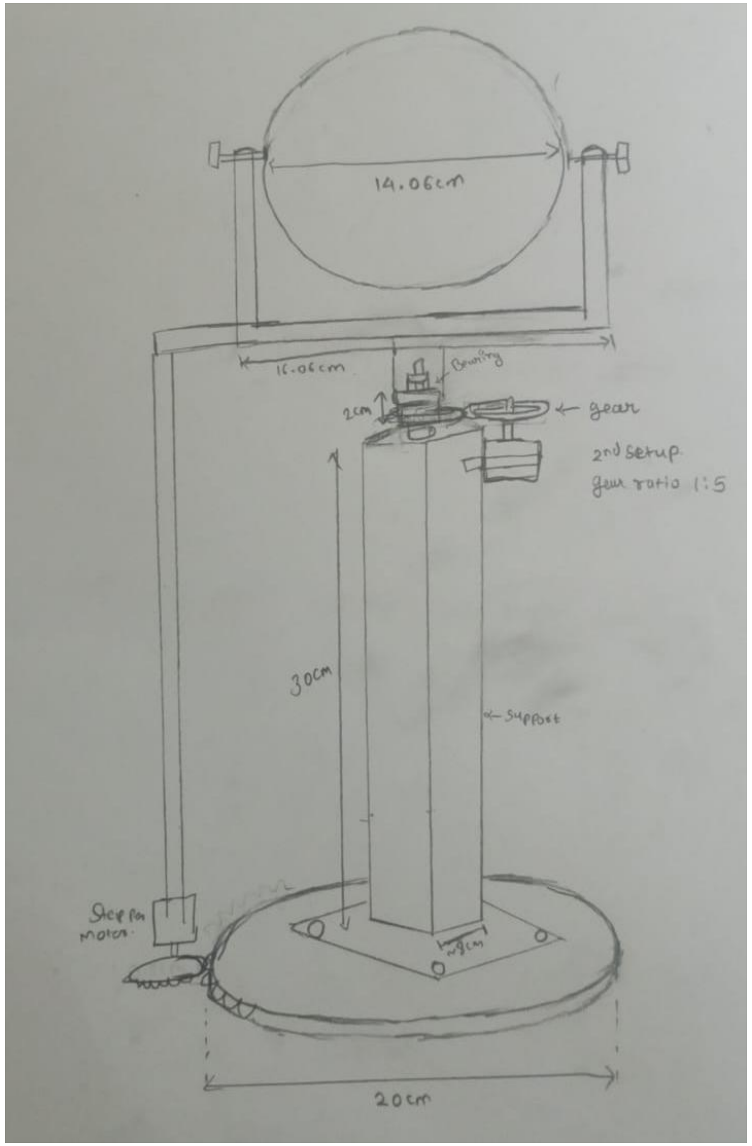
Sketch of Stand



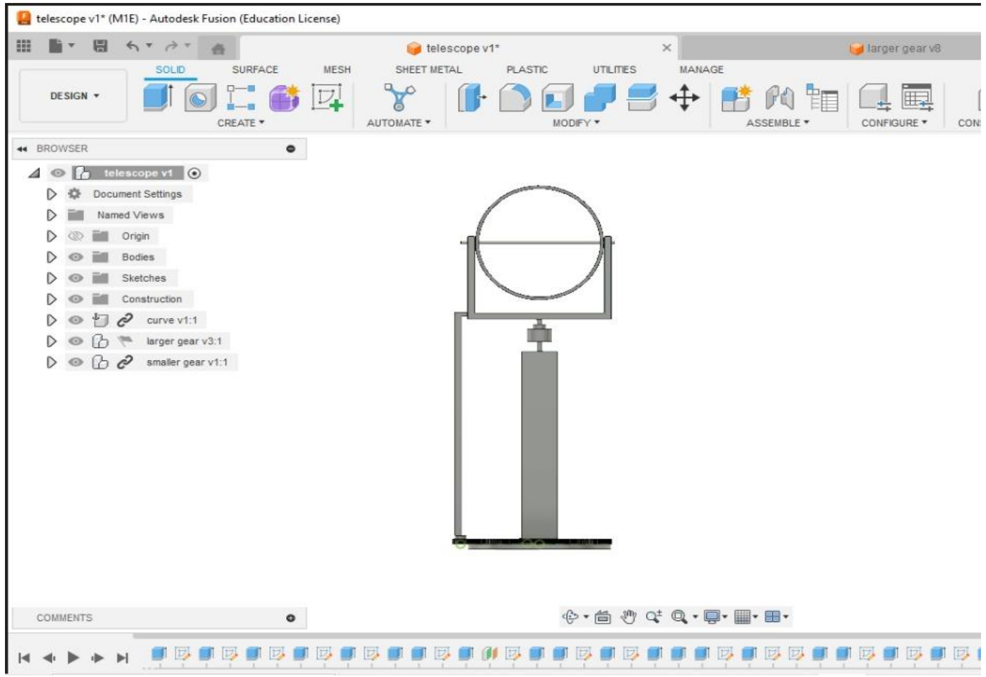


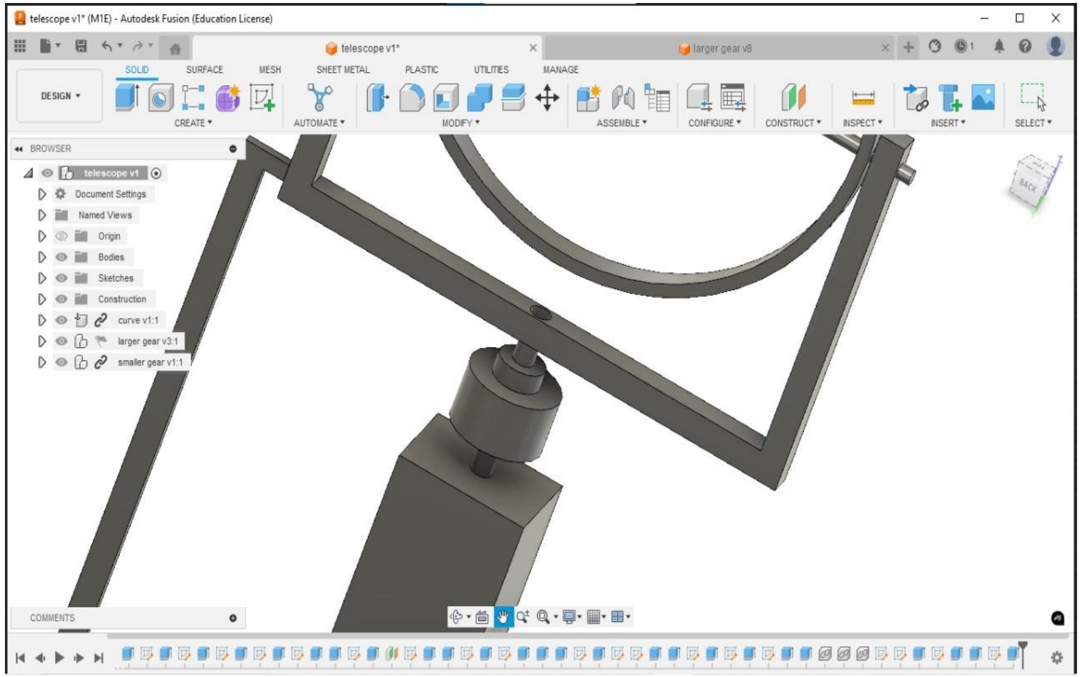
Sketch of Stand

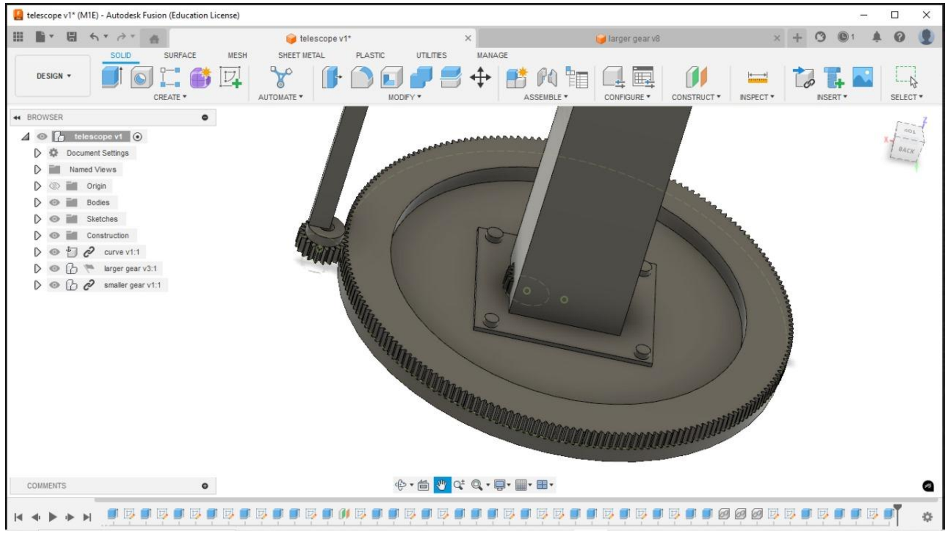




Sketch of Stand



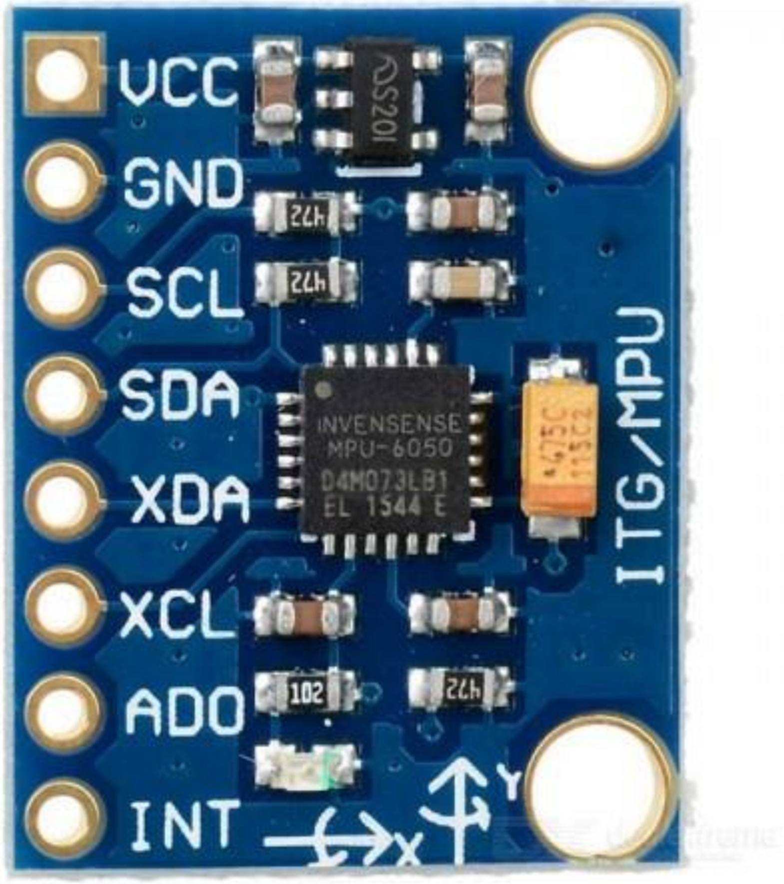




Telecsope Stand

Testing of MPU6050

- MPU6050 is a 6-axis motion tracking device.
- Combines a 3-axis accelerometer and 3-axis gyroscope in one chip.
- Communicates using I2C protocol.
- Measures acceleration, angular velocity, and detects motion/orientation



Accelerometer:

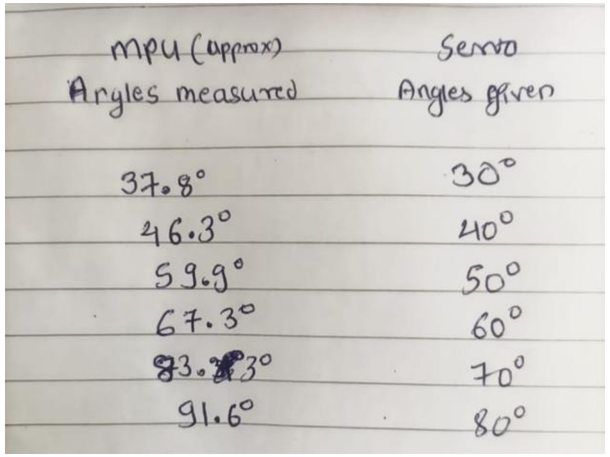
- Detects static forces (like gravity) and dynamic forces (like movement or vibration).
- Uses tiny micro-electromechanical systems (MEMS) that deflect under acceleration.

Gyroscope:

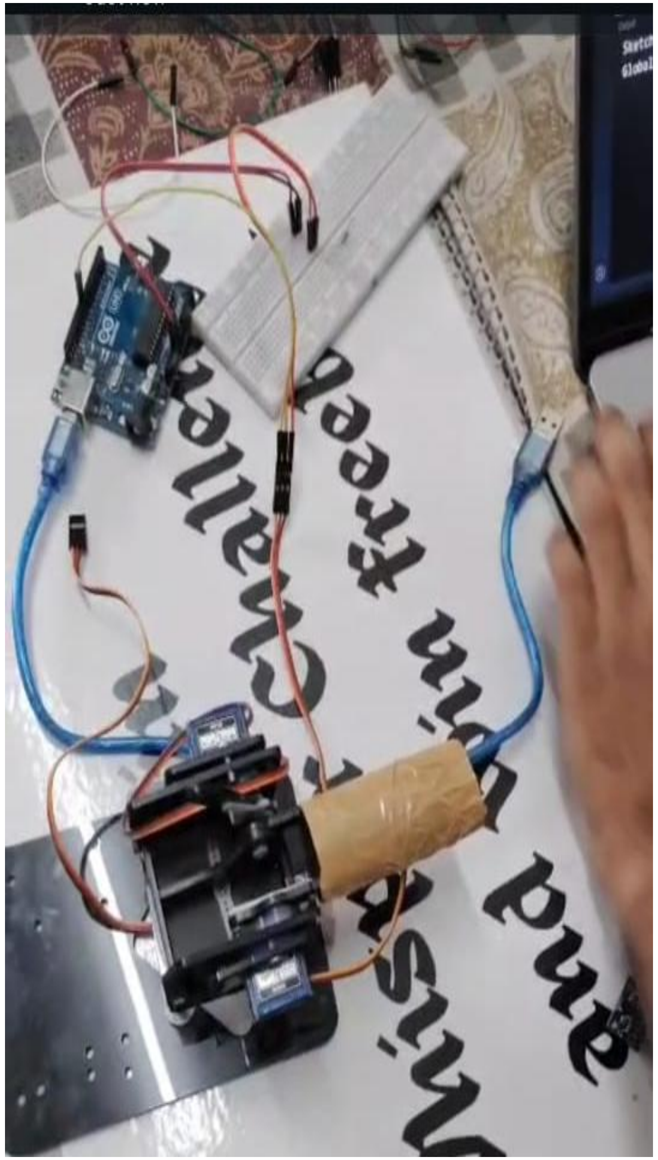
- Measures the rate of rotation around the X, Y, Z axes.
- Also uses MEMS, where tiny vibrating structures shift when the sensor rotates.

Testing of MPU6050

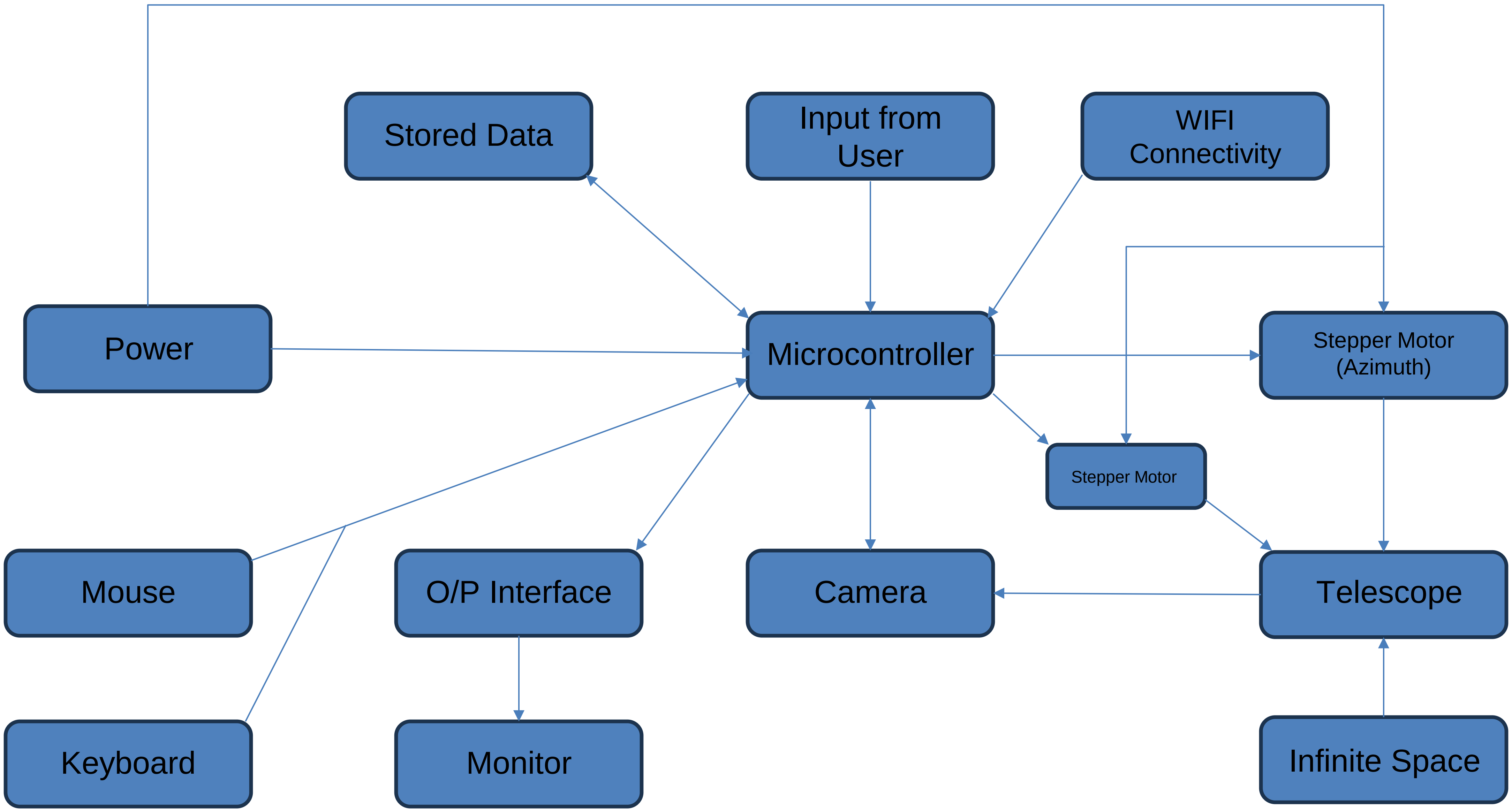
- On testing the sensor, we found some unwanted results.
- We got to know that there is a deflection of 5° - 10° in tracking the angles.
- Even when it is on a stable base it shows a deflection.
- So we arrived to the conclusion that this sensor would not be suitable for the accurate tracking of the angles.



MPU (approx) Angles measured	Servo Angles given
37.8°	30°
46.3°	40°
59.9°	50°
67.3°	60°
83.3°	70°
91.6°	80°



Proposed Block Diagram



Scope of Project [SY Sem III & IV]

Phase 1 (Sem III)

1. Researched on types of telescope mounts: Alt-Azimuth, Dobsonian and Equatorial.
2. Came to a conclusion that we require a stand similar to Dobsonian due to the absence of the tripod legs.
3. Our idea of the stand gives us the very large freedom of movement that will help us track the celestial bodies.
4. Made a 3D Model of the stand which later had to scrapped.

Phase 2 (Sem IV)

1. Tested MPU6050 for accurate tracking of long term angles. Concluded that the sensor is not suitable for the required output.
2. Designed structures of gears required to rotate the telescope on the stand and the stand itself.
3. Designed a stand for the telescope for ourselves for the required freedom of movement.

Phase 3 (TY)

1. We will Automate the Telescope to adjust its own position to a particular angle in two axis.
2. With the help of list of Coordinates of planets we will make the telescope automatic to go and adjust itself on a particular position from where additional external data of planets will be added.
3. Making into the final part that is **(Planet Detection)** and step by step also heading up for Moon.

Applications

- **Exoplanet Discovery:** Automated telescopes can efficiently monitor stars for periodic dimming, a sign of a planet passing in front of it.
- **Transient Events:** Detecting and studying transient events like supernovae, gamma-ray bursts, and asteroids.
- **Long-Term Monitoring**: Continuously observing celestial objects over extended periods to study their variability.
- **Remote Observatories:** Enabling people from around the world to access and control telescopes remotely.
- **Educational Use:** Can be used in schools and colleges to teach the basics of telescope mechanics and celestial navigation.
- **Space Debris Tracking:** Monitoring and tracking space debris to prevent collisions
- **Military and Intelligence:** Surveillance and reconnaissance.

Conclusion

This automation technology is designed to align and track celestial objects such as the Moon, . We chose each component based on precision and reliability. The Raspberry Pi Camera Module 3 will provide high-resolution imaging as well as live feedback from the camera feed. And with a 4.2 kg-cm of torque, the Pro-Range NEMA17 PR42HS40-1504 stepper motor would make smooth as well accurate movements. We are employing raspberry Pi 4 Model-B with 4 GB as well as 8 GB RAM options to offer the level of computational power required in real-time calculation of azimuth, altitude, and hour angles.

After checking and going through all the mount options, we decided on the Dobsonian mount as it is stable and very easy to use, ideal for automation. To make our design more precise, we created a detailed 3D model of the setup, ensuring that all the components fit together smoothly. This combination of selected components and innovative design allows the telescope to automatically adjust its position according to the changing positions of celestial bodies.

Supporting References

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