ME 206

STATICS & DYNAMICS

Professor : Jayaprakash K R

ASSIGNMENT 1

TENSEGRITY MODEL

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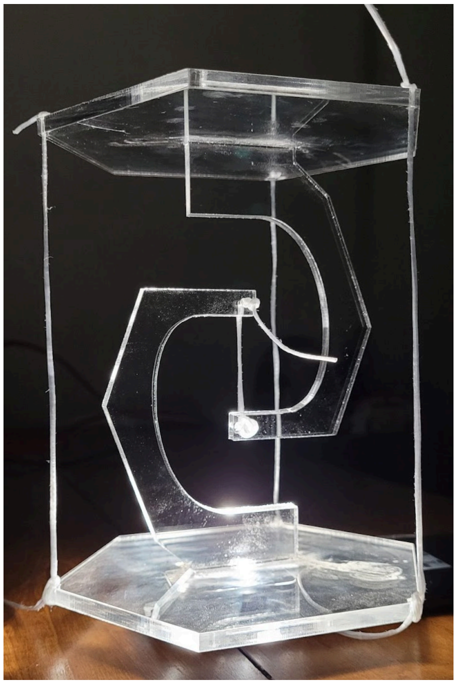

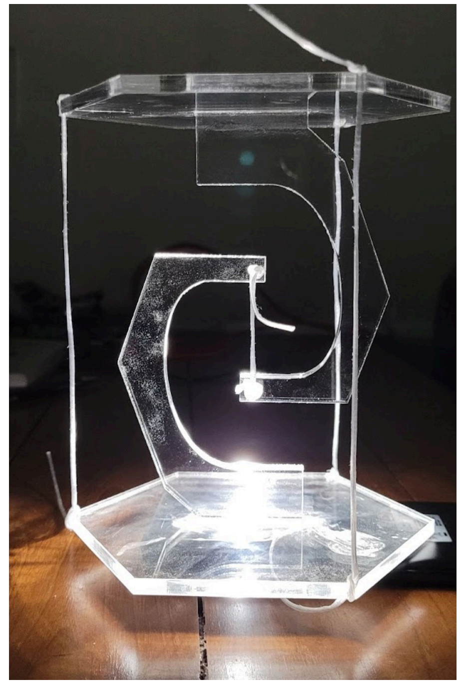

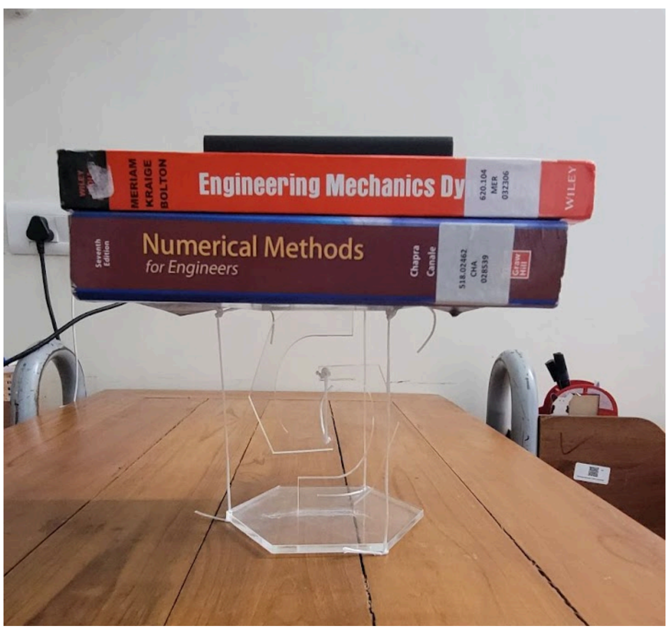
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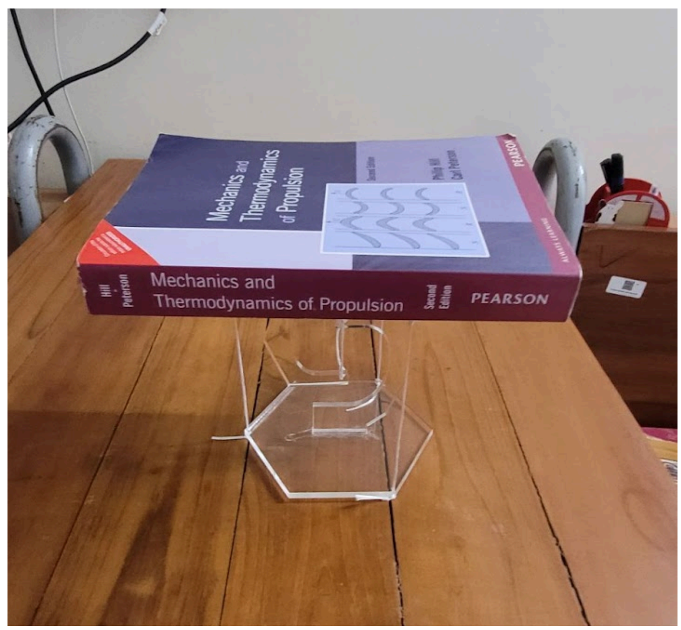
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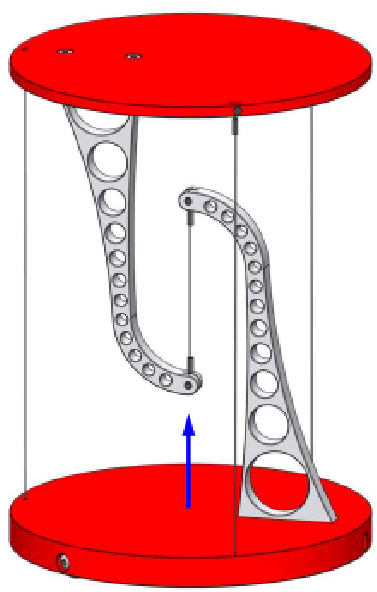
Abstract :

This experimental study focuses on constructing and analyzing a tensegrity table, a unique structural configuration that challenges conventional load-bearing principles. Tensegrity structures exhibit a balance between tension and compression forces, resulting in lightweight and flexible designs with remarkable load-bearing capacities.

Objectives:-

Construct a tensegrity table with a maximum load-bearing capacity of 3kg.

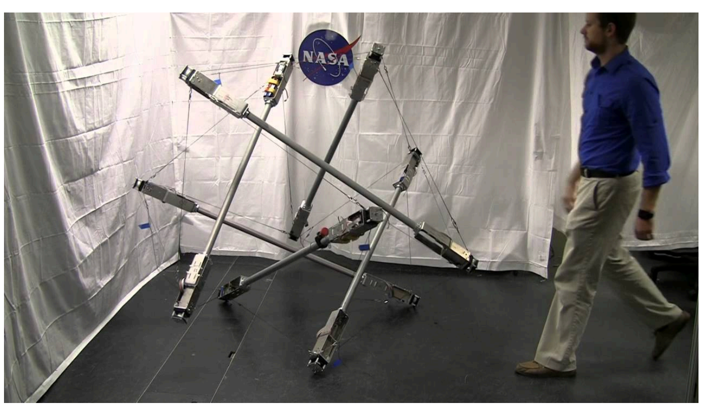
> a.) Find the cable tensions by increasing the load up to 3kg and plot it. Show its comparison with your analytically obtained results.
>
> b.) Experimentally find the frequency of torsional oscillations (about the arrow shown) for the above-described loads on the structure.



https://www.stirlingengine.co.uk/d.asp?product=TENSEGRITY

Educational Alignment and Practical Engagement:

- **Alignment with Learning Objectives:** The experiment directly aligns with the core learning goals of the statics and dynamics course, facilitating a practical application of theoretical concepts.
- **Bridging Theoretical and Practical:** By involving hands-on activities, the experiment effectively bridges the gap between abstract theoretical ideas and their real-world implementations.
- **Hands-On Analysis:** Engaging in actual analysis and problem-solving related to structural behavior, enhancing their grasp of foundational physics principles.
- **Structural Dynamics Focus:** The experiment centers on a tensegrity structure, allowing us to explore the dynamic behavior of systems under varying forces.
- **Tension-Compression Balance:** Through the tensegrity structure, the experiment vividly illustrates the equilibrium between tension and compression forces, a fundamental aspect of structural physics.
- **Real-World Relevance:** By simulating challenges faced by engineers and architects, the experiment provides a tangible representation of the complexities encountered in the field.
- **Preparation for Complexities:** The hands-on approach readies us to tackle intricate scenarios in structural dynamics, fostering a deeper comprehension of physics concepts.
- **Practical Understanding:** Practical applications enhance students' understanding of structural responses to forces, enabling them to apply theoretical knowledge effectively.



NASA Super Ball Bot is an all-in-one landing and mobility platform based on tensegrity structures, allowing for lower-cost, and more reliable planetary missions. (https://spectrum.ieee.org/nasa-super-ball-bot)

The Kurilpa Bridge was designed by Cox Rayner Architects and Arup Engineers as the world’s largest hybrid tensegrity bridge. It is approximately 1,500 feet long and balances between large aluminum masts and light steel cables to accomplish the tensile structure. (https://en.wikipedia.org/wiki/Kurilpa_Bridge)

Application of Fundamental Principles:

Utilization of Equilibrium Principles: The experiment rigorously applies the principle of equilibrium, grounded in Newton's Second Law ($\Sigma F = 0$). This ensures that the forces acting on the tensegrity structure are balanced, resulting in a stable configuration.

Force Analysis in Tensegrity Elements: Through Newton's Third Law (action and reaction), the forces within the cables and struts are analyzed in accordance with the principle of force analysis. This scrutiny establishes the tension forces within the cables, which counterbalance the compression forces in the struts.

Incorporation of Dynamics: By integrating Newton's Second Law ($F = ma$), the experiment accounts for the dynamic response of the tensegrity structure. The acceleration resulting from external forces aids in predicting the subsequent motion and oscillations.

Deconstruction into Basic Principles: The experiment promotes a systematic approach rooted in physics laws. The complex behavior of the tensegrity structure is deconstructed into fundamental principles, aligning with the core tenets of classical mechanics.

Equilibrium of Forces:

Newton's Second Law: $\Sigma F = 0$, where the vector sum of forces in equilibrium is zero. This law is fundamental in ensuring the stability and balance of forces within the tensegrity structure.

Cable Tensions and Compression Forces: The equilibrium of forces in cables and struts is defined by the tensions in the cables counteracting the compression forces in the struts. This interplay is a result of the tension-compression balance inherent in tensegrity systems.

Force Analysis and Interaction:

Newton's Third Law: The principle of action and reaction (equal and opposite forces) is integral in the analysis of forces within the cables and struts. This law allows for the determination of cable tensions and their impact on the overall structure.
Tension-Compression Balance: Newton's Third Law directly contributes to maintaining the balance between tension and compression forces in the tensegrity elements. Cable tensions interact with strut compression to establish the structural equilibrium.
Dynamics and Motion:

Newton's Second Law in Dynamics: $F = ma$, where the force applied to an object is proportional to its mass and acceleration. This law is employed to predict the response of the tensegrity structure to external forces and loads.
Torsional Oscillations Prediction: The dynamic response of the structure to torsional forces can be determined using Newton's Second Law. The acceleration due to the twisting force leads to oscillations, which are quantified using angular frequency equations.

Systematic Problem-Solving:

Application of Laws in Practical Scenarios: The experiment guides students to apply the principles of equilibrium, force analysis, and dynamics to a tangible problem—predicting the behavior of a tensegrity structure. This application reinforces their understanding of physics concepts in real-world contexts.

Foundational Concepts Integration: By dissecting the complex behavior of the structure, students develop a systematic problem-solving approach. This approach encapsulates the essence of physics by unifying diverse principles to analyze intricate scenarios.

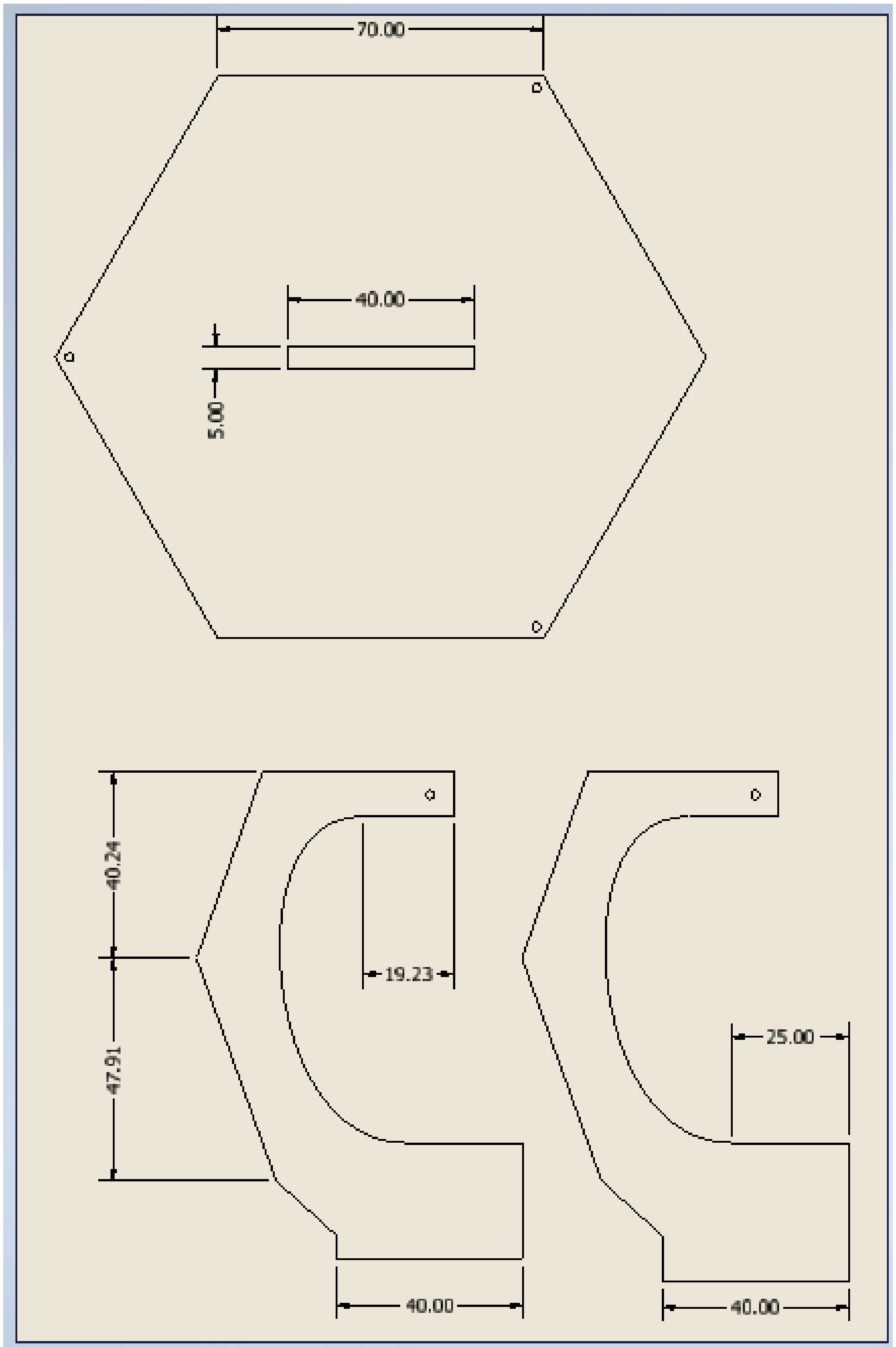
Materials used in the Experiment :

The combination of acrylic sheets and tensioning strings allowed for the construction of functional tensegrity table.

1. **Acrylic Sheets :-**
   Transparent acrylic sheets were used to create the top part, bottom part and the struts of the tensegrity table.

2. **Plastic Strings :-**
   These strings are being used as tensioning elements in the tensegrity model. These strings provides the necessary tension forces to keep the structure balanced and stable. They are strategically attached to the hooks on the hooks on the acrylic struts and anchor points, forming a network of tension element critical for load distribution.

3. **Other Elements :-**
   Supplementary elements like scissors and fevi-quick were utilised on joining the different sections of the tensegrity structure.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Fabrication Details :

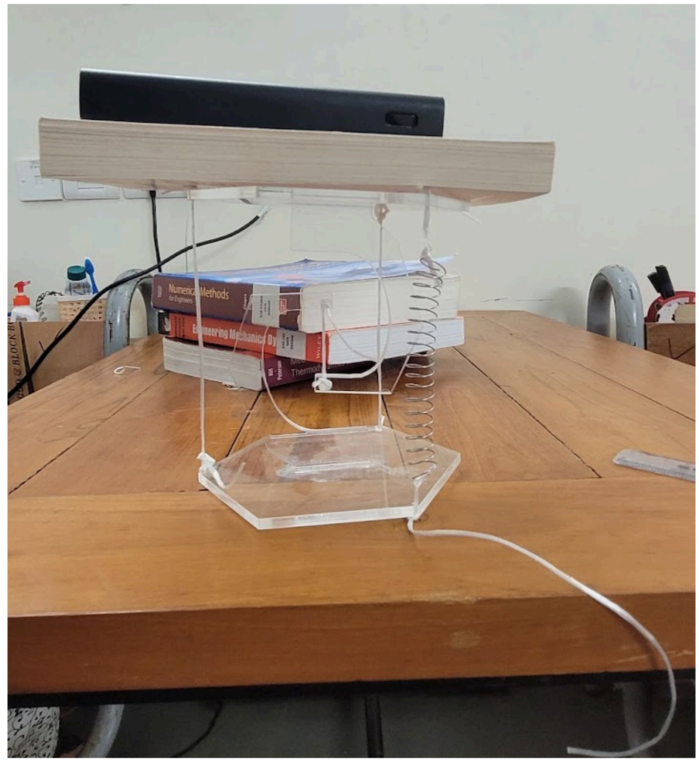
Here are the fabrication details:

1. **Design and Planning :-**
    - We use a computer software Autodesk Inventor to create a detailed design of our Tensigrity Table. The dimensions of the acrylic parts, were specified.

2. **Laser Cutting :-**
    - We input our design into the software of the laser cutting machine, specifying the dimensions and details of the acrylic sheets we needed.
    - Utilizing the laser cutting machine, we precisely cut the acrylic sheets according to our design's specifications. This ensured accurate and consistent components for our project.

3. **Assembling Struts and Cables :-**
    - Following our design, we began assembling the acrylic parts. This step formed the basic framework of our tensegrity structure.
    - We carefully attached the strings to the connectors on the acrylic parts while ensuring appropriate tension. The tension in the strings played a pivotal role in providing the necessary stability to our structure.

4. **Final Adjustments :-**
    - We carefully examined the stability and balance of the tensegrity structure to ensure it met our expectations and design specifications.
    - If needed, we adjusted the tension in the strings to achieve the desired form and optimal stability for our structure. This step played a crucial role in fine-tuning the configuration to match our intended outcome.


Numerical Methods
Engineering Mechanics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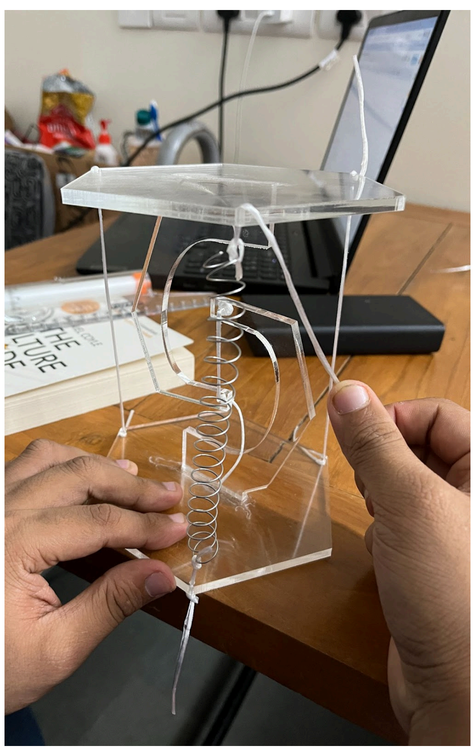
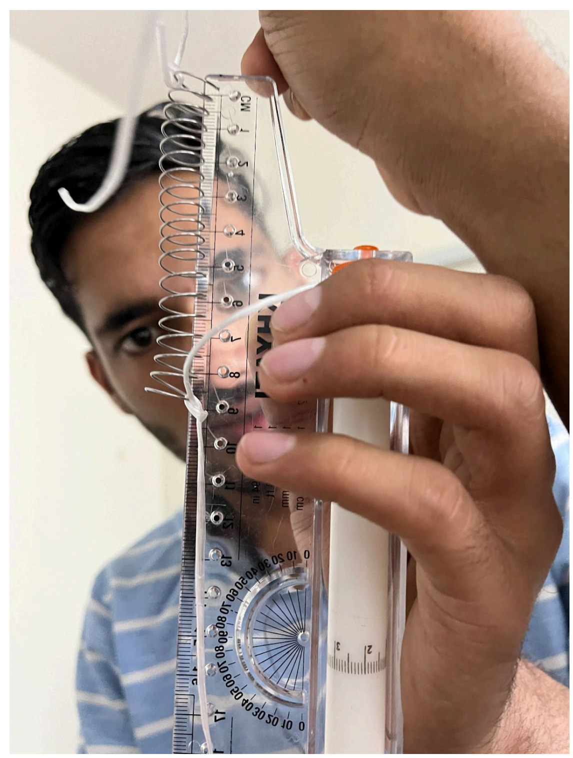
1 cm = 0.394 in
1 m = 3.28 ft
1 in = 25.4 mm
1 ft = 30.48 cm

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Objective A :

Find the cable tensions by increasing the load up to 3kg and plot it. Show its comparison with your analytically obtained results.

Approach->

Step 1-To calculate the experimental values, we use the spring. First we calculated the natural length of the spring which is 0.063m.

Step 2-Then we attached the spring to one of the outer strings of the tensegrity table (Neglecting the mass of the spring as it is too small).

Step 3-After that we measure the value of stretched length of the spring when none of the weight is put on the table which comes out to be 0.101m.

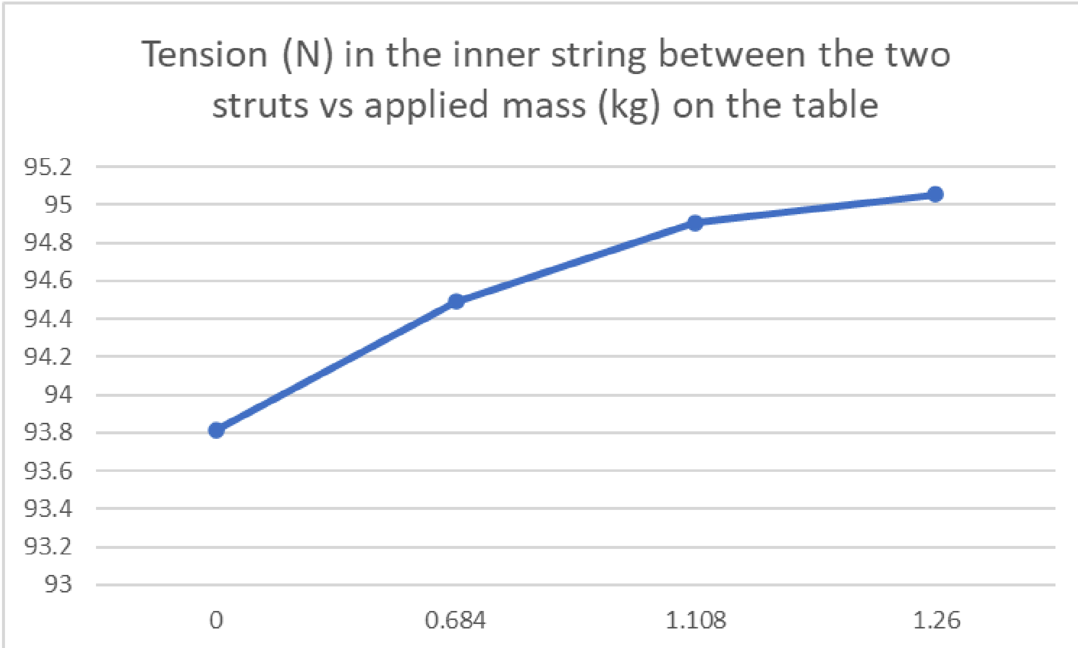
Step 4-Then we start putting measured weights (books) on the table and calculated stretched length one by one.

Step 5-We calculated the value of spring constant by-

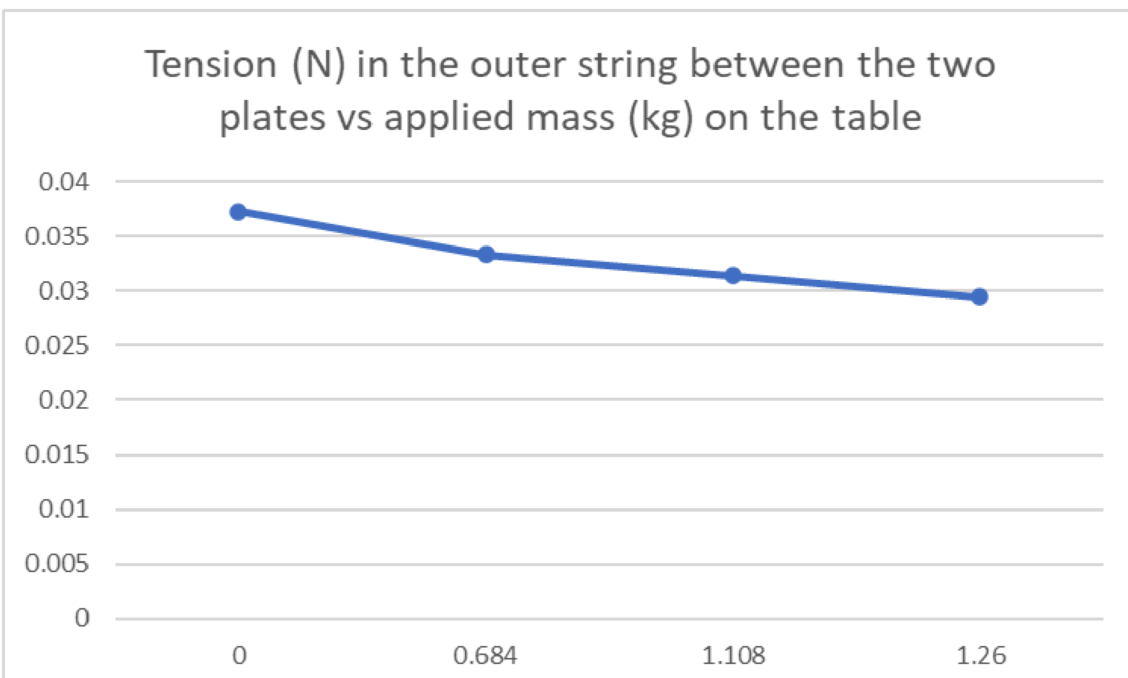
Applied Weight (0.3 kg x 9.8 m/s^2) = Spring constant (k) x change in length of spring from the natural length (0.093-0.063)

Step 6-Similarly, we calculated the tension in the outer strings between the two plates by using the value of spring constant and change in length of spring from the natural length.

Sl. No.	Applied Mass (kg)	Tension in the outer strings between the two plates.(kg-m/s^2)	Tension in the string between the two struts. (kg-m/s^2)
1	0	0.037278	93.816834
2	0.684	0.033354	94.489062
3	1.108	0.031392	94.907176
4	1.260	0.02943	95.05329



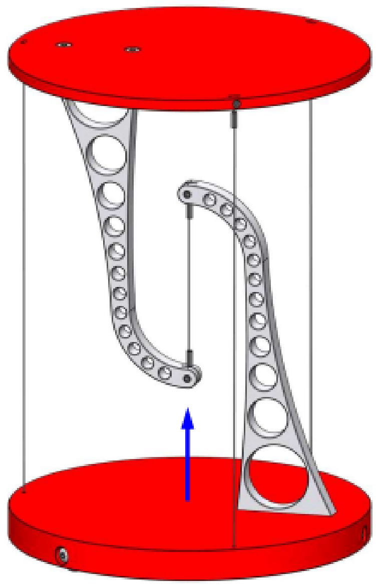
The above plot shows the graph between Tension (N) in the inner string between the two struts on y-axis and Applied mass (kg) on the tensigrity table at x-axis



The above plot shows the graph between Tension (N) in the outer string between the two plates on y-axis and Applied mass (kg) on the tensigrity table at x-axis

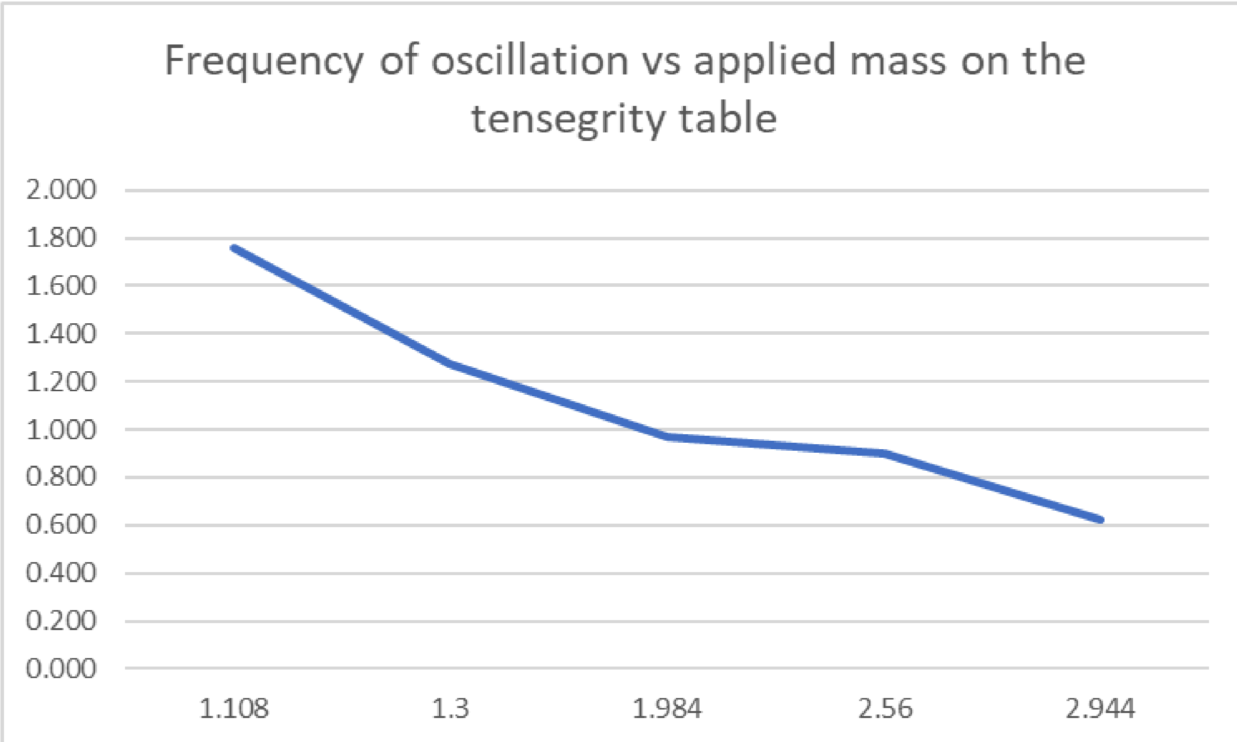
Objective B :

Experimentally find the frequency of torsional oscillations (about the arrow shown) for the above described loads on the structure



https://www.stirlingengine.co.uk/d.asp?product=TENSEGRITY

Sl. No	Applied Mass (kg)	Time taken for 10 Osciallations (in s)	Frequency of torisonal oscillations
1	1.108	5.68	1.761
2	1.3	7.87	1.271
3	1.984	10.33	0.968
4	2.56	11.15	0.897
5	2.944	16.12	0.620



The above plot shows the graph between Frequency of oscillation (Hz) on y-axis and Applied mass (kg) on the tensegrity table

Results and Discussion

Experimentally we could calculate the requirements mentioned in the objective.

Since the analytical solution of a Tensegrity structure is inderminant to find the tensions independently we were unable to compare with the analytical solution. Though we could derive the expression.

The Spring which we used to measure the tensions we observed that post usage there was a deformations observed in the spring. There was a 0.2 cm deformation obseved in the spring compared to before its usage.

Conclusions:

1. The graph between Tension (N) in the inner string between the two struts and mass applied (kg) on the tensigrity table tells us that as applied mass increases, tension in the inner string increases.
2. The graph between Tension (N) in the outer string between the two plates and mass applied (kg) on the tensigrity table tells us that as applied mass increases, tension in the inner string start decreasing.
3. The graph between Frequency of oscillation (Hz) and mass applied (kg) on the tensigrity table tells us that as applied mass increases, frequency of oscillation decreases across the plot.

Learnings:

Initially, we didn't take into consideration material properties. We made a bigger tensegrity table with struts made of acrylic sheet and plates made of MDF board.

Acrylic sheet is a strong material but the size was too big that the struts made with acrylic sheet were unstable for higher applied mass on the tensegrity table and we broke the piece of strut by doing so. Moreover we also observed that on higher weights the struts were bending.

Also the thread we used was made of multiple turnings of jute which made it difficult to tie with the plates.

The tension too was also not so strong in those threads which was making the table difficult to remain stable.

So, we made the new tensegrity table smaller with taking everything into consideration. Moreover we realized that when we do things numerically a lot of calculations are taken in ideal state. When physically modeling that system we face the real circumstances.

What could have been done better?

When we were measuring tension experimentally, we neglect the mass of spring as we were not able to weigh the mass of the spring, although value was too small to neglect.

We might have use wood to make the tensegrity table instead of acrylic sheet to increase the stability.

Also, we might have increase the distance between two ends of struts, to calculate the experimental value of inner string with the help of spring. Instead, we calculated tension in outer string and the by the help of analytical solution , we calculated the tension in inner string.

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