UNIVERSITY OF WOLLONGONG IN DUBAI

Laboratory Session 8:

Project 2B – Counterbalance Mass

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Subject number and name:	ENGG102 – Fundamentals of Engineering Mechanics
Subject coordinator:	Dr. Umar Asghar
Title of Assignment:	Project 2B – Cantilever Beam Design
Date and time due:	07-03-2024, 23:59:59
Lab Number:	1.53
Tutor Name:	Mr. Ahmed Mohamed
Total number of pages:	12

ENGG102 Project 2B Design and Reflection Report: Assessment Sheet

Aspect	Comment	Mark
ENGG102 Project 2B Design and Reflection Report: Assessment sheet	**Minus 3 marks if this Self Assessment Sheet is not included with the Project 2B Design and Reflection Report.**	
Appendix A: Minutes of Team Meetings (evidence of teamwork)	**Minus 5 marks if Minutes of Team Meetings (more than one!) are not included with this Report**	
Structure of report, team information etc. (as per "what report should contain" above)	0.5 marks for including all items 3 - 10 (see Report structure provided above)	/5
Overall Presentation	Neatness, Spelling, Grammar, Diagrams & Professionalism	/10
Problem definition	Define the problem. Identify concepts involved. What you are able to calculate and what you assumed	/5
Analysis and calculations	Clearly present all calculations using the 6-step method. Include all appropriate FBDs with calculations to predict the total mass to give system equilibrium. Concepts or issues that are not yet known and affect the accuracy of calculations should be identified.	/20
Results including comparison with other team(s) WHAT happened!	Comparison table of all results with commentary on table. Discussion of results including comparison of all team's results and main factual findings. Identify best performing teams.	/10
Reflections – identify some reasons for the performance of your beam and other teams. WHY it happened! Consider the various aspects of the task (Challenges with new concepts, assumptions made). Discuss how your predictions and calculations might be improved, what knowledge might be needed, and concepts considered.	To achieve top marks (35-40/40) in this section your report must demonstrate clear and insightful reflection considering own solution and others in the class. Demonstrates further reading and critical analysis. To achieve 25-35/40 your report must describe the performances of your solution and some others. Itemization of knowledge gaps and some critique of yours and others predictions. To achieve 0-25/40: Describes own solution with limited reference to other beams.	/40
Mapping of learning outcomes	Identifies all the relevant outcomes from subject outline and discusses how well each is addressed.	/5
Conclusion	1 or 2 paragraphs that draw appropriate conclusions from evidence presented in report. Include the main results, both numerical and qualitative.	/5
Total		/100

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Statement of Purpose

The primary purpose of this assessment is to examine the behavior of a pulley lift system that has a 500g mass suspended by using a wooden balsa beam. This lift mechanism is driven by a counterbalance mass on an adjustable inclined plane at an angle of 40 degrees. To evaluate the system, a counterbalancing mass will be employed on an inclined friction plane test rig to lift the 500g mass.

Initially, the beam was constructed based on calculated values like cross-section area, section modulus, modulus of elasticity, and maximum stress. At this stage, the test procedure shall be conducted to ensure that the selected design can test the predictions of the counterbalancing mass on the inclined plane test rig by adding masses gradually until a 2 mm defection is achieved.

This concern, however, mainly focuses on predicting the expected counterbalance mass and then comparing the theoretical outcomes against experimental outcomes. This exercise thus seeks to check whether mathematical projections work in the real world, and this gives insight into how reliable beam operations can be.

Upon completion of the lab session, the theoretical value of mass (which was 1.250 kg) will be compared with experimental results obtained from beam testing (which was 1.050kg). This comparison is intended to assess the accuracy of theoretical predictions and the effectiveness of the model's relevance in practical situations.

Since the experimental and theoretical values deviate slightly but still align within a comparable range, it emphasizes the intricacies of engineering systems and underscores its role in enhancing engineering decision-making, showcasing problem-solving abilities, and fostering collaborative efforts to address complex structural challenges.

Predictions & Calculations

Part 1

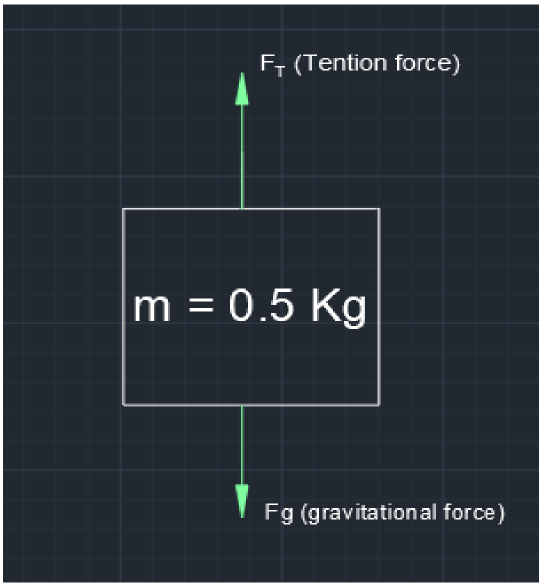

Figure 1: FBD of hanging mass

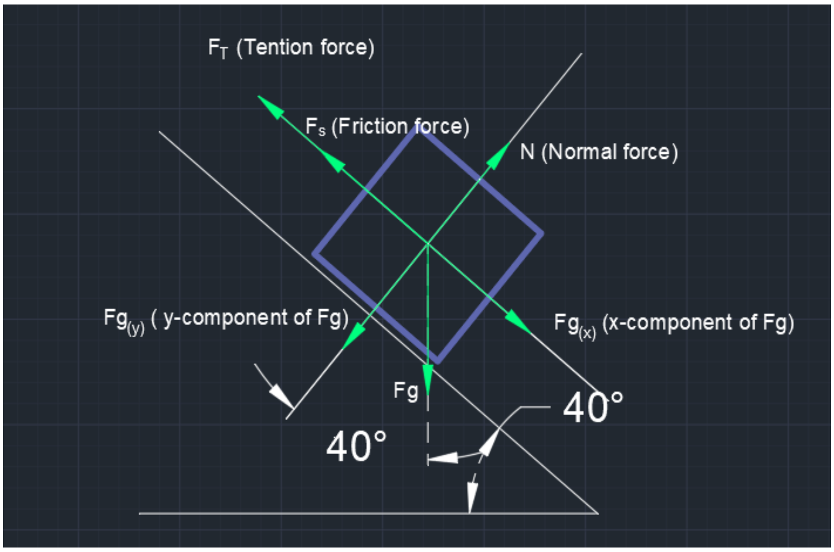

Figure 2: FBD of Counterbalance Mass

$$\Sigma Fy = 0 \implies N - Fg_y = 0 \Rightarrow N = Fg_y$$

$$Fg_y = Mg.\cos\theta$$

$$N = Mg.cos\theta$$

$$\Sigma Fx = 0$$

$$Fg_x - F_s - T = 0$$

$$F_s = \mu_s N = \mu_s(Mg.cos\theta)$$

$$Fg_x = Mg.sin\theta$$

For the 500g-mass to lift up, the tension force should equal its weight.

$$T = W = 500g$$

$$\Rightarrow Mg.sin\theta - \mu_{(s)}(Mg.cos\theta) - 500g = 0$$

(Divide by *g* on both sides and isolate the coefficient of static friction μ_s)

$$\mu_s = tan\theta - \left(\frac{500}{M.\cos(\theta)}\right)$$

where *M* is the required counterbalance mass

$$\Rightarrow \mu_s = \tan(40) - \left(\frac{500}{911.\cos(40)}\right) = 0.123$$

Part 2

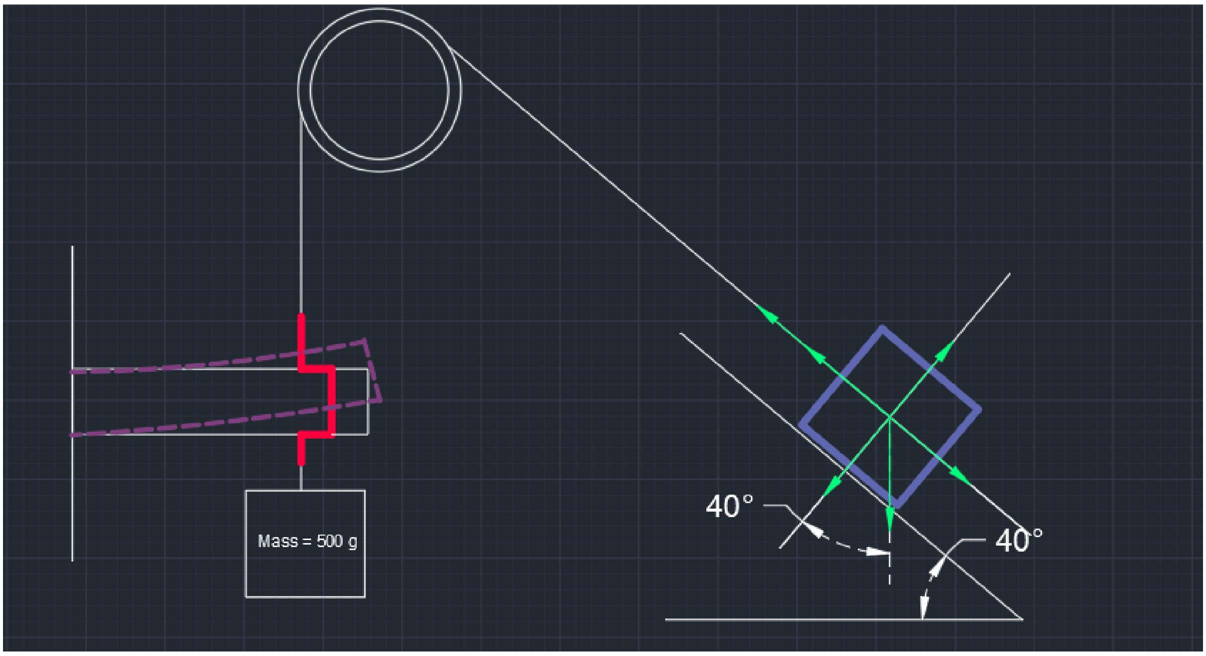

Figure 3: FBD of entire system

For 2.8 mm deflection, the load formula is: $P = \frac{3.\delta.E.I}{L^3}$

$$\delta = 2mm\,,\ E = 1400\ MPa\,,\ I = 50476.19\ mm^4\,,\ L = 500\ mm$$

$$\Longrightarrow\ P = 3.392\ N$$

For the beam to deflect, $p = T - W \iff T = p + W = 3.392 + 500(9.81) = 8.297\ N$

Continuing from this equation: $Fg_x - F_s - T = 0$

$$\Rightarrow Mg.\sin\theta - \mu_s(Mg.\cos\theta) = 8.297$$

Solving for M (theoretical mass needed to achieve the deflection)

$$M = \frac{8.297}{(\sin\theta - \mu_s.\cos\theta) \times 9.81} = 1.5417\ Kg\,,\ where\ \theta = 40°\ and\ \mu_s = 0.123$$

Results

Inclined Plane Angle (θ°)	Hanging Mass (g)	Counter Mass (g)	Coefficient of Friction (μ_s)
40	500	911	0.123

Team	Inclined Plane Angle (θ°)	Beam Free Length (mm)	2nd Moment of Inertia (mm^4)	Target Deflection (mm)	Hanging Mass (g)	Predicted Counter Mass (kg)	Actual Counter Mass (kg)	Ratio of Predicted to Actual
1	40	500	49262	2	500	1.526	1.421	1.074
2	40	500	42976.19	2	500	1.448	1.266	1.144
3	40	500	18250	2	500	1.140	1.501	0.759
4	40	500	50476.19	2	500	1.541	1.341	1.149
5	40	500	72700.32	2	500	1.828	1.126	1.623
6	40	500	50476.19	2	500	1.540	1.600	0.963

Comparison of Results

Looking at the predicted and actual counter masses, all teams, except Team 3 and Team 6, overpredicted the mass needed to achieve the desired deflection. Team 4's predicted mass of 1.541kg follows this trend, being slightly higher than their actual mass of 1.341kg. This translates to a prediction-to-actual ratio of 1.149, which is in the middle range compared to the other teams 0.759 to 1.623 ratios.

In terms of inertia, Team 4 has the second highest inertia of 50476.19 after Team 5's 72700.32. This suggests that Team 4's system had a larger moment of inertia compared to other teams, potentially due to factors like the dimensions or external factors on system setup. Despite the higher inertia, Team 4's prediction-to-actual ratio is closer to the average compared to teams with lower inertia, suggesting that the greater the inertia potentially due to a larger cross-sectional area (which means a thicker beam) might require a greater counter mass to achieve the desired deflection.

 

Reflection

Calculation Process & Challenges

During the analysis of predicting the total counterbalance mass for the equilibrium position, several challenging concepts emerged. Determining the coefficient of static friction and finding the balance mass for counterbalance were one of the obstacles. Force's analysis in vector form could also be undergone by including gravitational forces on inclined planes with frictional forces. The process of reworking predictions using laboratory measurements and logical calculations was laborious and needed time and patience. The implementation of observation measurements into the data calculation process also presented challenges, especially regarding precision and uniformity between measurements. The equations featured in the calculations, mostly pertaining to the determination of the counter-balancing mass, needed careful attention, so that the precision of the calculations was maintained alongside the consideration of all of the variables. In general, the confrontation of these challenges was faced through collective problem solving, iterative refinement, and a systematic approach to data analysis.

Team Performance & Accuracy

The team's anticipated counterbalance mass had a 14.91% overestimation. The anticipated counter mass value was in the lower range than that of other teams. However, comparing the values of the teams to each other, they attained similar findings. Differences in theoretical notions are one factor that contributes to this variance; teams with a better understanding of these concepts may have made more accurate forecasts.

Second, the accuracy of the measurements may have impacted the results. Errors in measurement or inconsistencies in the experimental process may have resulted in departures from the predicted outcomes.

Teamwork and communication among teams might have greatly impacted accurate forecasts and effective experiment implementation. Furthermore, accounting for and calculating the coefficient of kinetic friction inside the system had a substantial influence on the results. Teams who understood the theoretical foundations and can effectively account for frictional effects may produce forecasts that are more closely aligned with the tested results.

Improving Prediction of Calculations

To improve the accuracy of the counterbalance mass prediction, a detailed analysis of frictional forces between the inclined plane and slider, refining the experimental setup, and exploring alternative methods for calculating the counterbalance mass could be conducted. Additionally, upon some research, it was discovered that the pulley radius might alter the expected value; therefore, this could be considered in future computations. Furthermore, the friction coefficient and inclination angle have a mathematical impact on the forecast. Overall, by addressing these considerations, an improvement and refinement to the calculations will be done making more accurate and reliable.

Understanding Sliding Masses

Prior to completing the assigned tasks, the team studied mass behavior on an incline bench, with some superficial knowledge obtained on how to draw the free body diagram of a particle object and knowing that only gravitational force's component along the plane's axis would cause motion.

However, through this experiment, frictional force was added to the analysis of the summation of forces acting on the mass, which is considered a more generalized case since no surface is ideally smooth.

The team managed to complete an intense study of every parameter contributing to shifting the object from a static to a dynamic status. Team was also able to compute calculations to solve and identify any of the factors, compare theoretical results to experimental data observed and finally, link the overall learning outcomes with previously studied concepts about deflection and load applied on a cantilever beam.

For additional sources of knowledge, it is recommended to perform different scenario cases, solve for any missing variable, test the value experimentally and think of solutions to reduce the percentage of error.

Team Decision-Making Evaluation

The lab team engaged in an extended debate about the counterbalance mass needed to balance the static tension throughout the experiment. Initially, the team brainstormed several ideas, considering parameters such as the friction coefficient, gravitational forces, and reaction forces, among others. Following that, the members debated extensively, carefully weighing the benefits and drawbacks of each proposal before reaching an agreement. Several alternatives were investigated, and quite a bit of experimentation occurred before making a final selection. Although the decision-making process took a long time, it represented the commitment to finding the best option. This extensive dialogue meant that all viable solutions were considered, and possible problems were thoroughly anticipated. Overall, the decision-making process struck a balance between efficiency and comprehensive discussion, allowing the lab to successfully fulfill its objectives through teamwork. The various skills and abilities of each member were used to generate an accurate prediction.

Mapping Learning Outcomes

Throughout the duration of the lab sessions, several activities and tasks have been undertaken, aligning with the following learning outcomes:

1. **Describe the role of abstraction, simplification and the use of assumptions and mathematical relationships in solving problems encountered by engineers.**

   In these lab sessions, we have applied the principles of abstraction and simplification by representing complex structural elements as simplified free body diagrams (FBDs). We made assumptions about forces acting at points or along lines/surfaces to set up the equilibrium equations in accordance with Newton's Laws of Motion. Mathematical vector relationships were used extensively to calculate the resulting forces and moments.

2. **Develop free body diagrams to analyze the forces and moments acting on and within structural elements and structural systems.**

   The labs comprehensively covered the creation and utilization of free body diagrams (FBDs) to analyze forces and moments within structural elements and systems, such as forces on inclined planes, trusses, and beams. We practiced drawing FBDs for various scenarios, including beams subjected to various loads and external forces, enabling us to comprehend the importance of FBDs in structural analysis.

3. **Apply logical engineering design practices to multi-faceted problems involving engineering mechanics.**

   Through problem-solving tasks and case studies, we applied logical engineering design practices to analyze the loading on a structure and determine the appropriate size and geometry of components to withstand the loads safely by applying the principles of mechanics. By breaking down complex problems into manageable components and systematically approaching solutions, we demonstrated our ability to apply logical design practices effectively.

5. **Demonstrate self-directed learning related to solving problems in engineering.**

   The subject encouraged self-directed learning by providing resources such as textbooks, online materials, and supplementary readings. The labs required individual research to evaluate the best possible combination of shapes and dimensions for fabricating the beams, incubating a sense of autonomy and self-reliance in learning. Research into real-world applications of the beams fabricated further promoted independent learning.

6. **Undertake and present engineering calculations, designs, research and critical analysis in a professional manner.**

   Assignments and design project reports required thorough quantitative analysis, including detailed computations and graphic representations such as free body diagrams. Evaluating the accuracy of the assumptions established was also an important task. Presenting this technical work in a professional manner, with straightforward language, accurate citations, and comprehensive yet simplified content descriptions, helped us improve our ability to successfully communicate difficult engineering material to varied audiences while retaining accuracy and credibility.

7. **Work as a productive member of a team, recognizing roles, responsibilities, and accountabilities of individuals in a team.**

   The design project fostered teamwork abilities by assigning distinct roles and responsibilities. Effective collaboration was key across various phases - research, preliminary calculations, analyses & reflections, interpretations, and report writing. The research phase required distributing work judiciously. As the project progressed, sharing findings, collective calculations, and insightful discussions were crucial for interpretation.

   Clear accountability was critical throughout, as lapses could hinder progress. The objective was to combine individual efforts into a comprehensive, clear, and concise report. This highlighted the interdependence of members and their roles within the team. Each contribution shaped the final deliverable, instilling shared responsibility. Open communication, mutual respect, and professionalism were emphasized throughout the labs. These labs served as a simulation of real-world engineering teamwork, equipping the team with invaluable skills for their careers and their futures.

Conclusion

The major goal for conducting experiments and assessing deflection was to standardize engineering strategies. The tasks focused on developing revised formula, estimating the predicted deflection of the beam, and determining the needed sliding mass for beam applications. Using such a methodical approach, it was feasible to confirm that the beam design was compliant with the requirements. Nonetheless, the theoretical models were effective in solving static frictional forces and using the parallel axis theorem to calculate the second moment of area. However, while predictions were consistent with expectations, the actual outcomes differed slightly. The differences between them showed the influence of factors including the static friction coefficient of the slider. Therefore, it highlighted the differences between experimental and theoretical values when it came to engineering predictions to attain accuracy and account for “safety factors” in experimental outcomes in the future.

Appendix

Appendix A: Minutes of team meetings

Meeting 1

Date: 02.03.2024

Time: 12:00 – 13:00

Purpose: Discuss roles of each member for completing Lab Report 2B.

Tasks Done:

- Distribute sections of the reports.
- Share calculations and values with every member for smooth completion of report.
- Create the results table.

Attendance

Member	Present	Late	Absent
Ahmed I.	x		
Mohamad Karam	x		
Razan A.	x		
Taha Parker	x		

Meeting 2

Date: 06.03.2024

Time: 17:00 – 18:00

Purpose: Reviewing and proof-reading report to meet assessment sheet requirements. Additionally, adding the finishing touches such as pictures or diagrams.

Tasks Done:

- Proofreading the report.
- Give feedback on various parts of the report.
- Addition of figures and pictures.
- Recheck whether all parts have met the assessment sheet guidelines.

Attendance

Member	Present	Late	Absent
Ahmed I.	x		
Mohamad Karam	x		
Razan A.	x		
Taha Parker	x		

Team Rules:

- Come to class and team meetings on time with assignments and other necessary preparations done.
- Respect one another.
- Help each other when the need arises and participate equally.
- Communicate through designated channels.
- Maintain a consistent format for fonts and writing style.
- Commit to timeline and submit within deadline.
- Give constructive feedback and assist fellow members.
- Record references used and where they are used.
- Follow safety rules and wear gloves whilst using equipment.