TEAM ASSIGNMENT COVER SHEET

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Subject number and name	ENGG103 – Materials in Design
Subject coordinator	Mr. Mohammad Yousuf
Title of Assignment	Experiment 1 – Bending Test
Date and time due	October 8, 2023, 23:59:59
Lab Number	1

Student declaration and acknowledgement (must be read by all students)

By submitting this assignment online, the submitting student declares on behalf of the team that:

1. All team members have read the subject outline for this subject, and this assessment item meets the requirements of the subject detailed therein.
2. This assessment is entirely our own work, except where we have included fully documented references to the work of others. The material contained in this assessment item has not previously been submitted for assessment.
3. Acknowledgement of source information is in accordance with the guidelines or referencing style specified in the subject outline.
4. All team members are aware of the late submission policy and penalty.
5. The submitting student undertakes to communicate all feedback with the other team members.

Results

A. Force Deflection Graphs

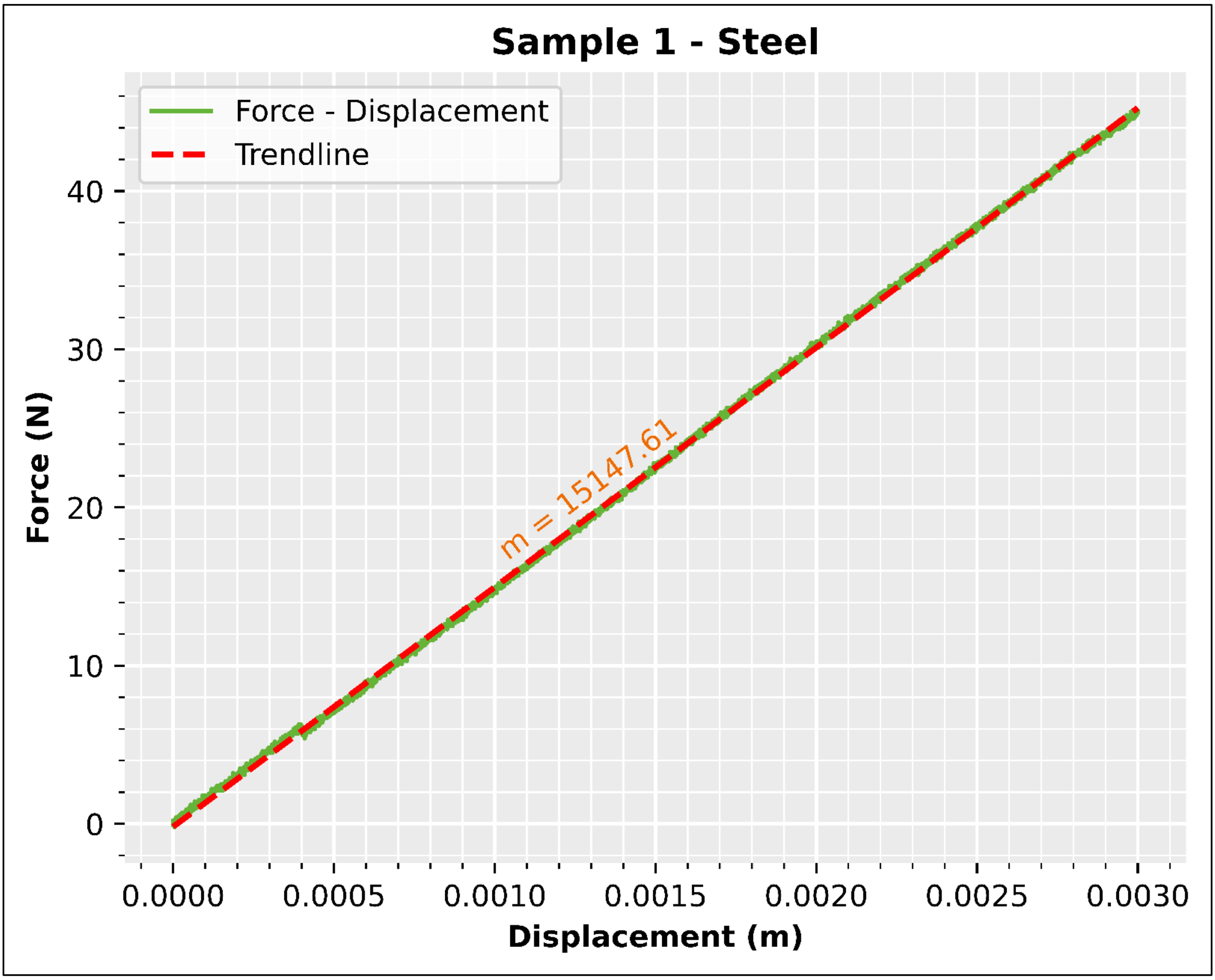

Figure 1 – Force – Displacement graph of Sample 1 (Steel)

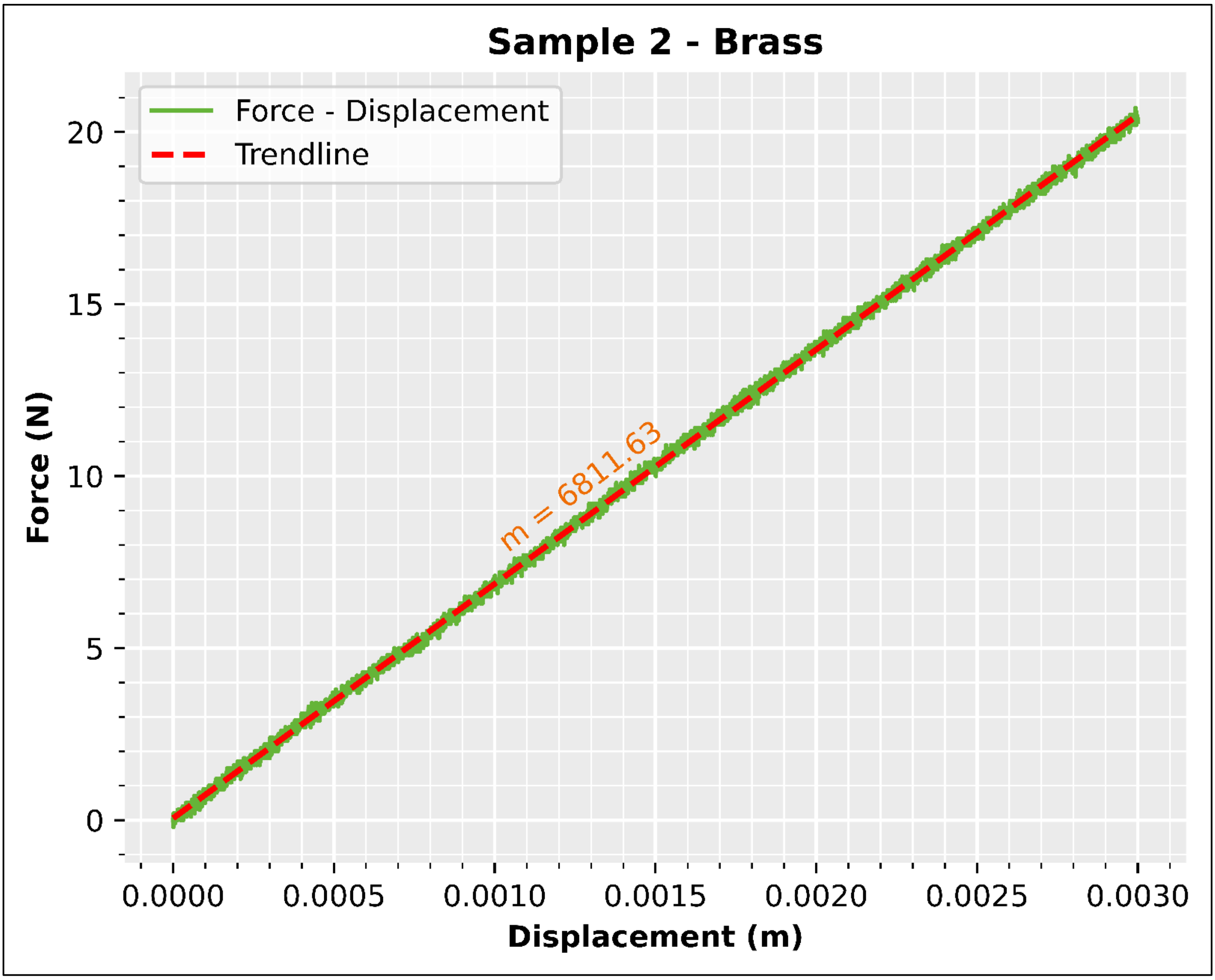

Figure 2 – Force – Displacement graph of Sample 2 (Brass)

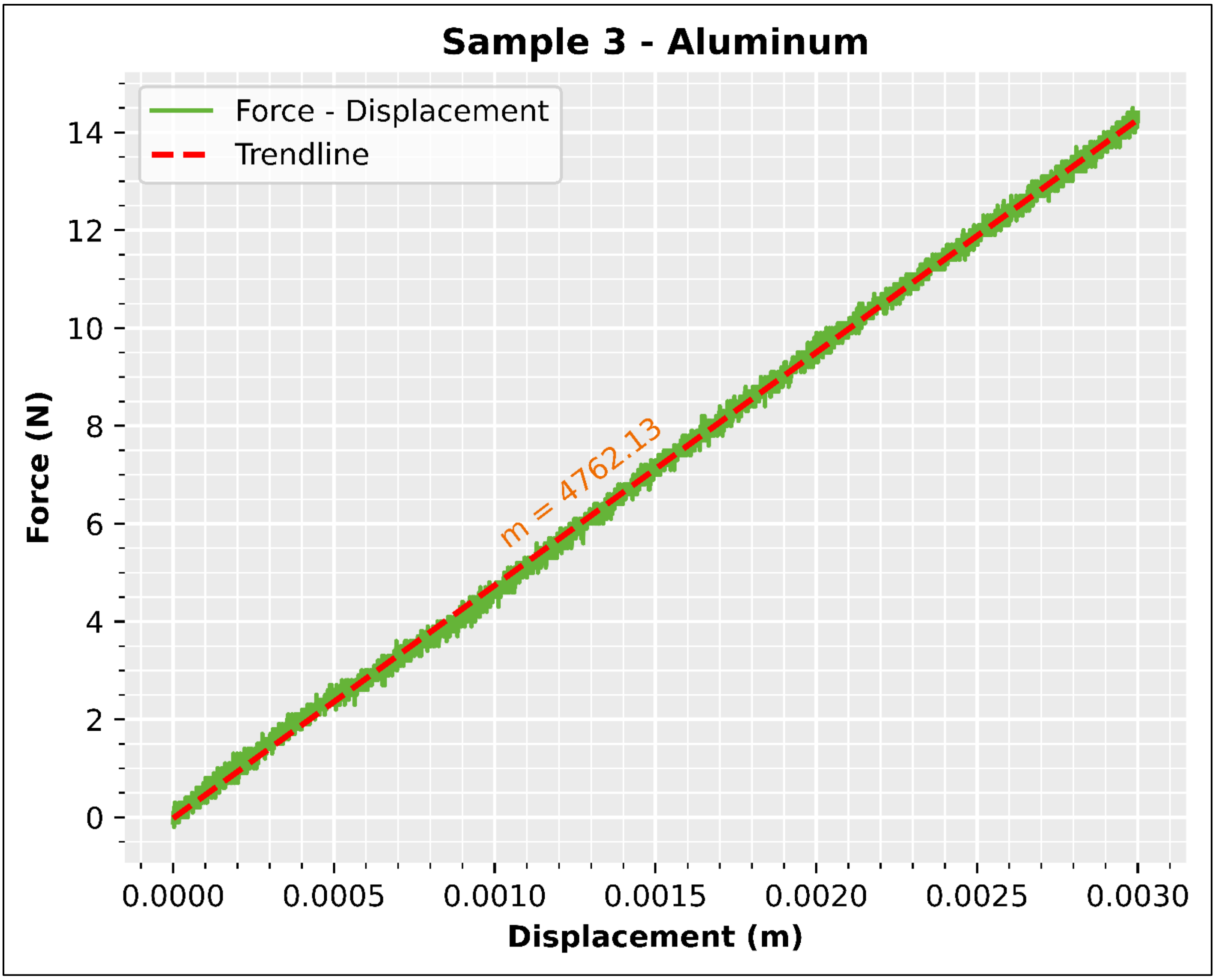

Figure 3 – Force – Displacement graph of Sample 3 (Aluminum)

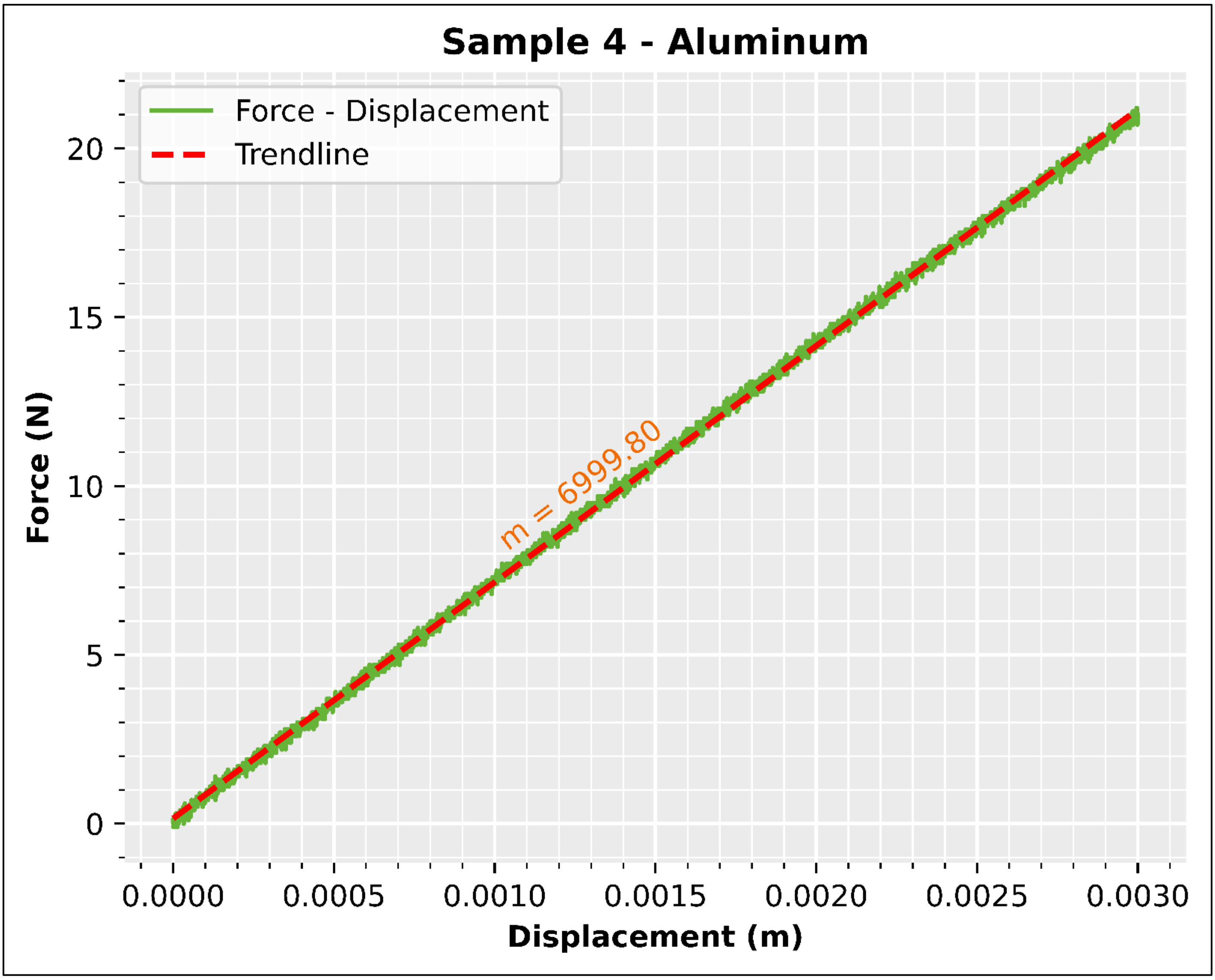

Figure 4 – Force – Displacement graph of Sample 4 (Aluminum)

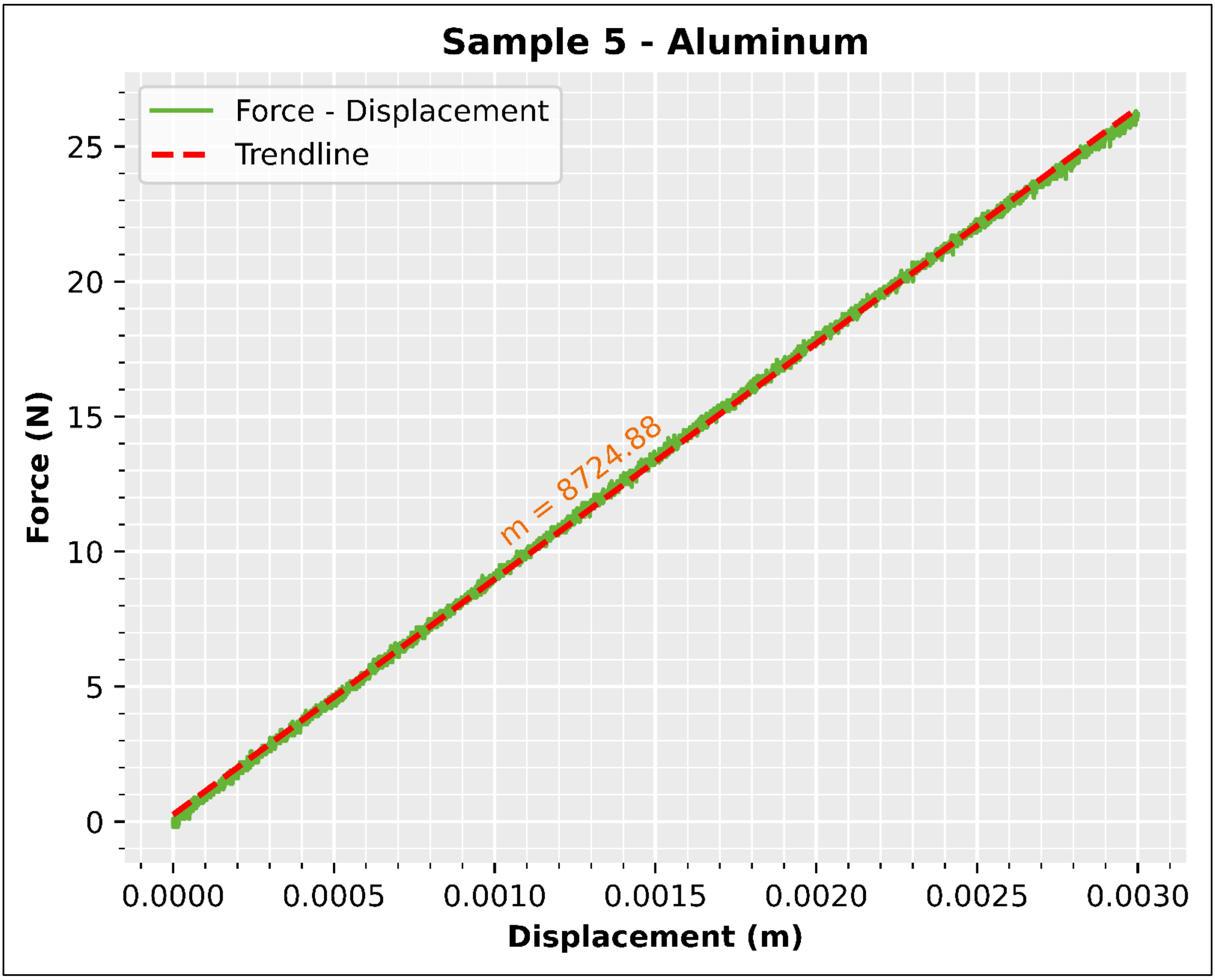

Figure 5 – Force – Displacement graph of Sample 5 (Aluminum)

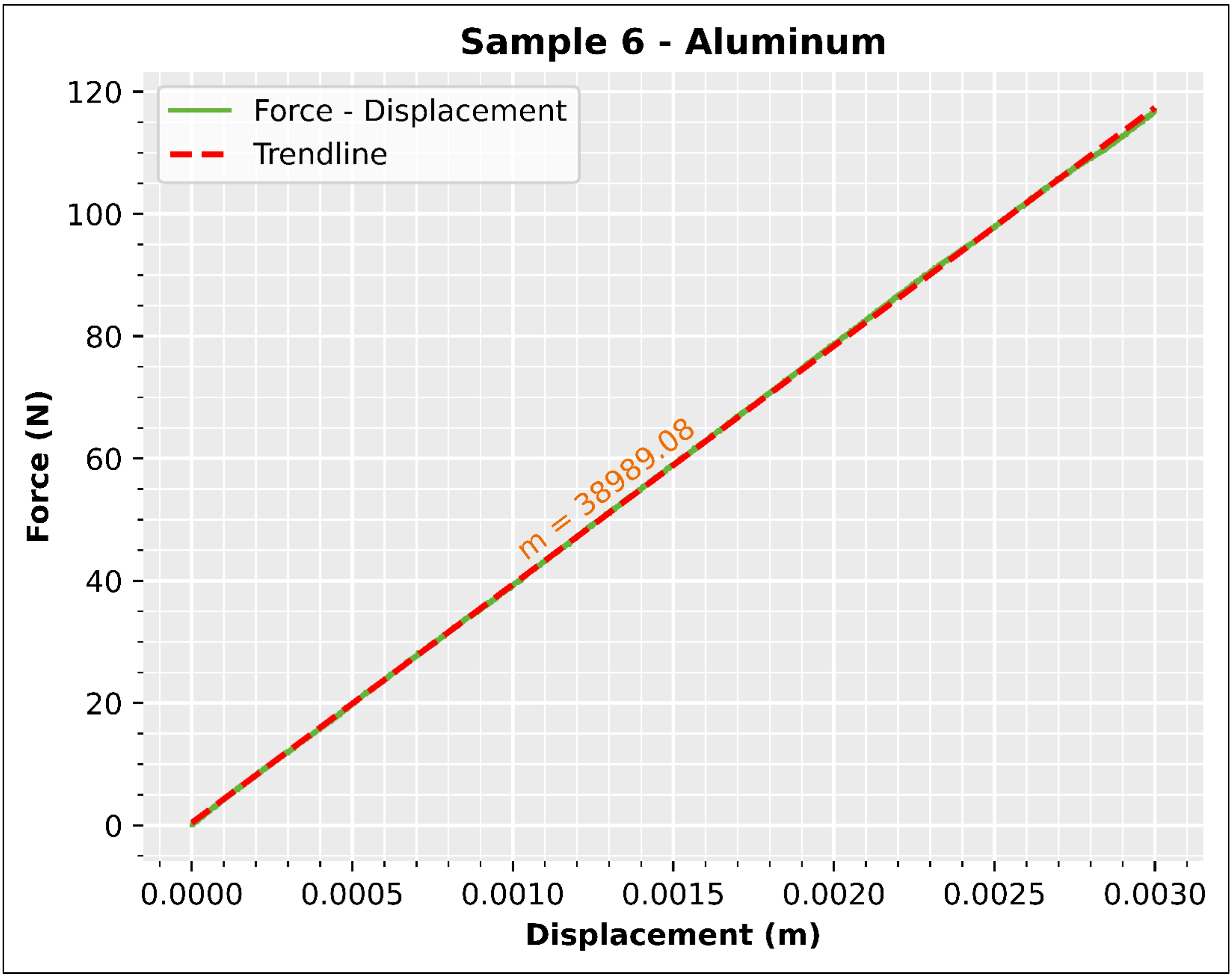

Figure 6 – Force – Displacement graph of Sample 6 (Aluminum)

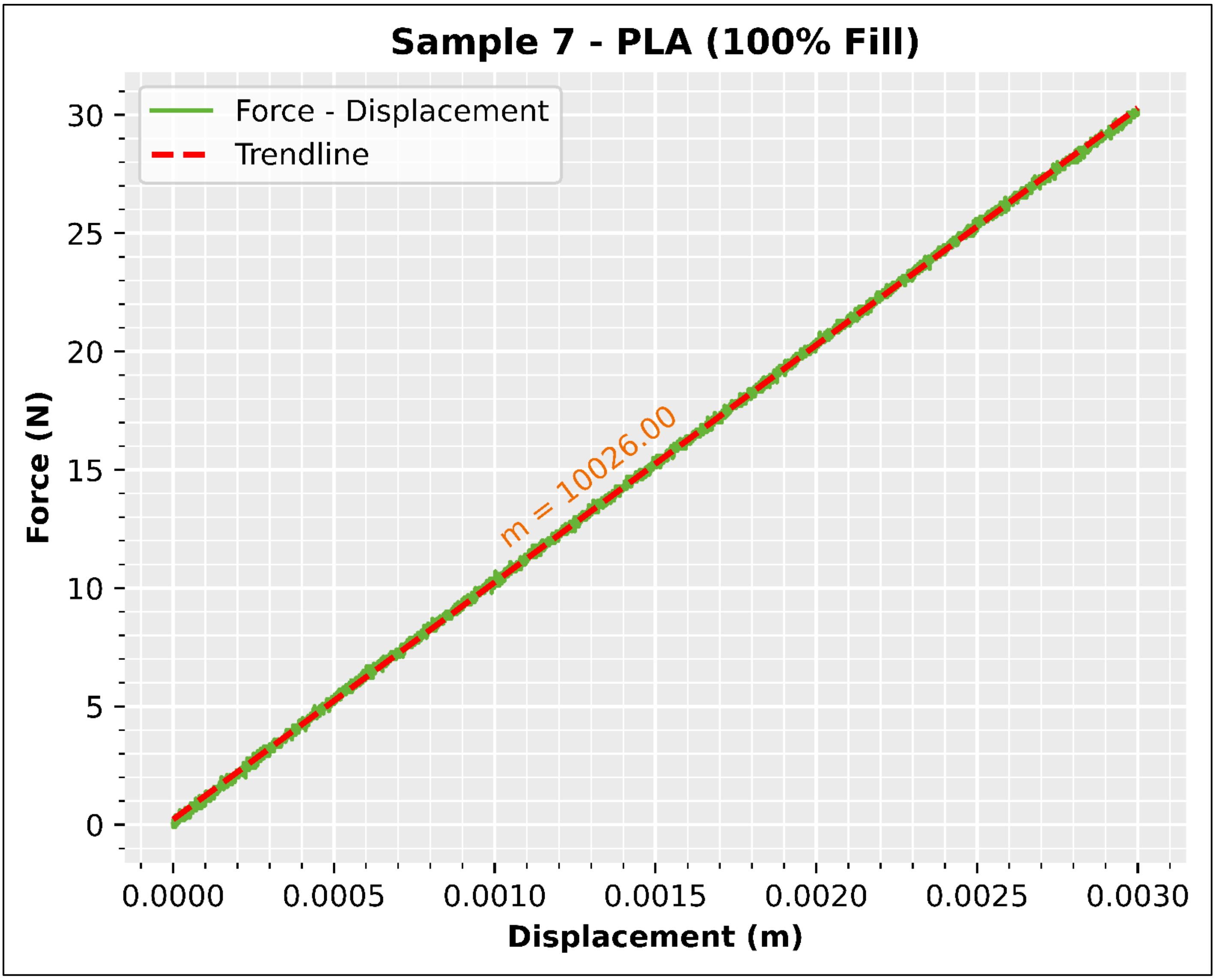

Figure 7 – Force – Displacement graph of Sample 7 (PLA – 100% Fill)

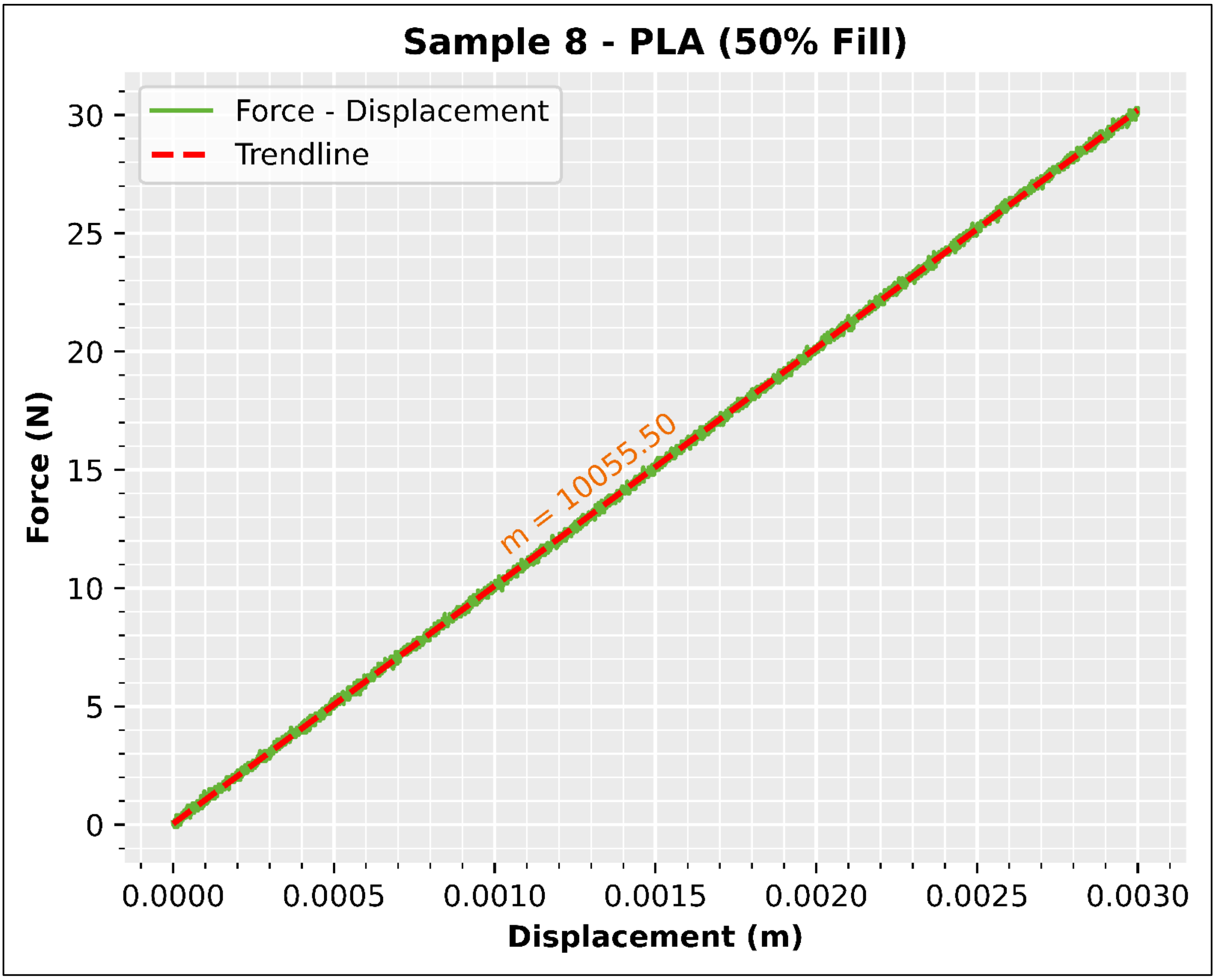

Figure 8 – Force – Displacement graph of Sample 8 (PLA – 50% Fill)

B. Estimated Modulus of Elasticity

Sample Number	Estimated Modulus of Elasticity (E)
1	$2.191 \times 10^2\ GPa$
2	$9.855 \times 10^1\ GPa$
3	$6.889 \times 10^1\ GPa$
4	$6.751 \times 10^1\ GPa$
5	$6.311 \times 10^1\ GPa$
6	$7.051 \times 10^1\ GPa$

Calculation of Young's Modulus (Sample 3)

$$E = \frac{FL^3}{\delta KI} \text{ --------(1)}$$

$$L = (250 \times 10^{-3})^3\ m$$

$$I = \frac{(10\times10^{-3})(3\times10^{-3})^3}{12}$$

$$K = 48$$

$$\frac{F}{\delta} = \frac{Force}{Deflection} = \text{Slope of graph } = 4.762 \times 10^3$$

Plugging the values into Equation 1, we get

$$\boldsymbol{E} = 6.889 \times 10^{10}\ Pa = \boldsymbol{6.889 \times 10\ GPa}$$

Beam Number	Beam Material	Estimated Elastic Modulus	Theoretical Elastic Modulus
1	Steel	$2.191 \times 10^2\ GPa$	$2 \times 10^2\ GPa$
2	Brass	$9.855 \times 10^1\ GPa$	$1 \times 10^2\ GPa$
3	Aluminum	$6.889 \times 10^1\ GPa$	$6.9 \times 10^1\ GPa$
4	Aluminum	$6.751 \times 10^1\ GPa$	$6.9 \times 10^1\ GPa$
5	Aluminum	$6.311 \times 10^1\ GPa$	$6.9 \times 10^1\ GPa$
6	Aluminum	$7.051 \times 10^1\ GPa$	$6.9 \times 10^1\ GPa$

Reference for Theoretical Elastic Modulus:

The Engineering ToolBox (2003). *Young's Modulus, Tensile Strength and Yield Strength Values for some Materials.* [online] Available at: https://www.engineeringtoolbox.com/young-modulus-d_417.html [Accessed 06 October 2023]

Discussion

a. **Which of the samples will you consider to have a fair comparison between the elastic moduli of the different materials? And why? Which material is stiffer?**

A. We will consider Sample 1 (Steel) and Sample 2 (Brass) to have a fair comparison between the elastic moduli of the different materials.

Sample 1 has higher elastic modulus and therefore has higher stiffness, as stiffness is directly proportional to elastic modulus.

$\text{Specific Modulus (Stiffness)} = \frac{\text{Elastic Modulus}}{Density} \frac{Pa}{mg/_{m^3}}.$

b. **Which of the samples will consider to study the effect of the beam width (b) on the Force? Why? What is the effect of the Beam width (b) on the measured force? Does your answer confirm the theoretical equations? Include the equations.**

A. We will consider Sample 3 & Sample 5 to study the effect of beam thickness on the measured Force.

The material (Aluminum), span length (250mm) and thickness (3mm) are the same for both the samples. Only a difference in beam width (10mm vs 20mm) is present.

Therefore, these two samples will be used to study the effect of beam width as other variables are kept constant.

Sample 3:	Sample 5:
Material: Aluminum	Material: Aluminum
Span length (L): 250mm	Span length (L): 250mm
Beam Thickness (t): 3mm	Beam Thickness (t): 3mm
Beam Width (b): 10mm	**Beam Width (b): 20mm**

Equations:

Equation of Deflection: $\delta = \frac{F \cdot L^3}{48 \cdot E \cdot I}$

Derivation to find Force from Equation of Deflection: $F = \frac{48 \cdot \delta \cdot E \cdot I}{L^3}$

$F \propto I$

$F \propto \frac{b \cdot t^3}{12} \qquad (\because I = \frac{b \cdot t^3}{12})$

$\therefore F \propto b \;\&\; F \propto t^3$

Force vs Displacement (slope of graph) for Sample 3 = 4762.13 $N/_{m}$

Force vs Displacement (slope of graph) for Sample 5 = 8724.88 $N/_{m}$

Our answer confirms the theoretical equations as the force required to displace Sample 5 by 3mm was more than double the force required to displace Sample 3. This shows that force is directly proportional to the beam width.

c. **Which of the samples will you consider to study the effect of beam thickness (t) on the measured Force? Why? What is the effect of the Beam thickness (t) on the measured Force? Does your answer confirm the theoretical equations? Include the equations.**

A. We will consider Sample 3 & Sample 6 to study the effect of beam thickness on the measured Force. The material (Aluminum), span length (250mm) and width (10mm) are the same for both the samples. Only a difference in thickness (3mm vs 6mm) is present.
Therefore, these two samples will be used to study the effect of beam thickness as other variables are kept constant.

Sample 3:
Material: Aluminum
Span length (L): 250mm
Beam Width (b): 10mm
Beam Thickness (t): 3mm

Sample 6:
Material: Aluminum
Span length (L): 250mm
Beam Width (b): 10mm
Beam Thickness (t): 6mm

Equations:

Equation of Deflection: $\delta = \frac{F \cdot L^3}{48 \cdot E \cdot I}$

Derivation to find Force from Equation of Deflection: $F = \frac{48 \cdot \delta \cdot E \cdot I}{L^3}$

$F \propto I$

$F \propto \frac{b \cdot t^3}{12}$ $\quad (\because I = \frac{b \cdot t^3}{12})$

$\therefore F \propto t^3$ & $F \propto b$

Force vs Displacement (slope of graph) for Sample 3 = 4762.13 N/m
Force vs Displacement (slope of graph) for Sample 6 = 38989.08 N/m

Our answers confirm the theoretical equations as the force required to displace Sample 6 by 3mm was more than 7 times the force required to displace Sample 3. This shows that force is directly proportional to the thickness cubed.

d. **Which material that you tested would produce the lightest tie rod, that has the highest value of $\frac{E}{\rho}$? Use the following values of density and show your calculation:**

Material	**Density, ρ (Mg/m^3)**
Stainless Steel	7.7
Aluminum	2.7
Brass	8.9

A. Sample 6 has the highest value for specific modulus (E/ρ). Since thickness cubed is directly proportional to the force applied, the material with higher thickness would need greater force to deform the material, hence making Sample 6 the most suitable material to use to make a light tie rod with highest value of specific modulus ($^{E}/_{\rho}$).

$$\frac{E}{\rho}_{(\text{Sample 6})} = \frac{70.51\times10^{9}\ Pa}{2.7\ ^{mg}/_{m^3}}$$

$$= 26.11\times10^{9}\ \frac{Pa}{^{mg}/_{m^3}}$$

∴ Sample 6 has the highest value for specific modulus.

e. **A mobile phone manufacturing company is looking to create a high-end mobile phone for that purpose they have hired your team, their idea is to create a phone that is Aesthetically pleasing, Mechanical rigid and Resistant to scratches (deformation), based on your understanding of materials and experimental result, which of the three materials would you recommend to the company to use on their phone?**

A. Steel is the best material to use to make a high-end mobile phone as it is one of the stiffest materials. Steel is also less prone to permanent deformities such as scratches as it has a high Elastic Modulus. Steel is easier to paint, giving more aesthetically pleasing designs and varieties for end-consumers.

f. **3D printing is an evolutionary manufacturing method that allowed us to make complex geometries with minimal cost and time. 3D printing is commonly achieved through thermoplastic polymers (PLA, ABS), although metals are also possible to 3D print. In this lab, a 3D printing parameter (infill density) was introduced and tested through PLA samples. From the 3D printed samples, explain how the infill density influences the structural stiffness of the sample? What other parameters influence the stiffness as well?**

A. A 3D printed part's stiffness is impacted by infill density. The part becomes denser as the infill density value rises. A part that is denser is more resistant to changing shape. As a result, a part's stiffness increases as its infill density increases. Because a stiffer material has a higher elastic modulus, the modulus of elasticity will increase as the infill density increases.

Some of the factors that influence stiffness are mentioned in the table below:

Parameter	Reasoning
Material type	Different types of materials have different effect on stiffness. For example, PLA is relatively rigid, while ABS is more flexible.
Print pattern	Some 3D printing patterns, such as honeycomb or gyroid infill, can provide better stiffness compared to simple grid or linear infill patterns, thus improving structural integrity.
Print temperature	The temperature at which the material is extruded can affect the bonding between layers and, consequently, the stiffness of the final print.
Print speed	Slower print speeds can sometimes result in better layer adhesion and, therefore, increased stiffness.
Layer height	The layer height determines the thickness of each layer in the 3D printed object. Smaller layer heights can result in finer and smoother prints, potentially increasing stiffness.
Wall thickness	The thickness of the outer shell or walls of the object can impact stiffness. Thicker walls generally provide more structural rigidity.