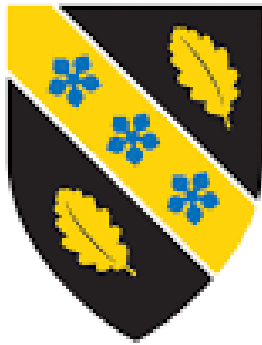


University of Wales Trinity Saint David

Wales Institute of Science & Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Torsion of Shafts

Mechanics and dynamics (ACHA4026)

Word Count: 1,557

James Smith

2404832

January 2026

Contents

1	Introduction	1
2	Methodology	2
3	Results	4
4	Analysis	6
5	Conclusion	9
6	Evaluation	10
7	Further Work	11
	References	12
	Figure 1: Measuring Scale	2
	Figure 2: Experiment Equipment	3
	Figure 3: Lab Data	4
	Figure 4: Graph to Show Aluminium	6
	Figure 5: Graph to Show Brass	7
	Figure 6: Graph to Show Steel	7
	Figure 7: Graph to Show Torsional Stiffness	8
	Equation 1: Torsion Equation	5
	Equation 2: Torsion Equation For $J\theta$	5
	Equation 3: Torsion Equation For TL	5

1 Introduction

This report talks about an experiment investigating torsional stiffness in a specimen (rod) when a torque is applied. To gather the necessary data an experiment has been conducted. The values in the data set can be used to solve these aims set out in the experiment. There are two aims for this experiment, to show how the torsion stiffness is affected by the material and to find the modulus of rigidity.

2 Methodology

The first thing to do is set up the equipment as figure one shows, leaving sufficient space for the specimen to be fitted. A rotating chuck is fitted at one side of the backplate, and weight can be added to the rotating chuck via a string. When the chuck rotates under the applied load, the bar will twist and could potentially permanently deform. The specimen slides through the fixed chuck into the rotating chuck.

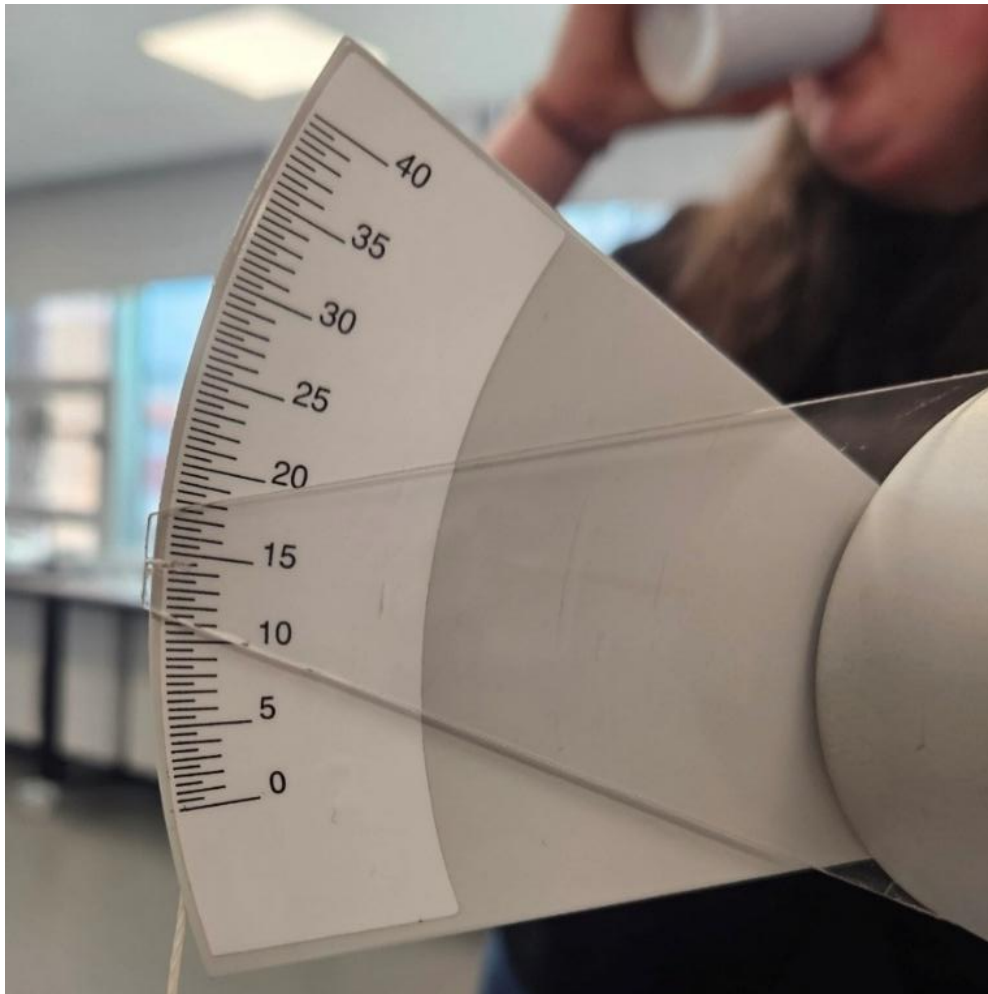


Figure 1: Measuring Scale

The rotating chuck has a scale of numbers that range from zero to forty degrees. When fitting the specimen in place, zero the rotating chuck and tighten the grub screw. There were grub screws on both the rotating chuck and fixed chuck in order to stop the specimen from spinning with the rotating chuck. Janowiak (1992) states that this experiment requires the scale the measurements are taken from to be at an appropriate length from the loading point. The scale attached to the rotating chuck would be considered to be in an appropriate place in this set up and because the scale is fixed to the chuck it means that there won't be any requirement to refit the scale with each specimen.

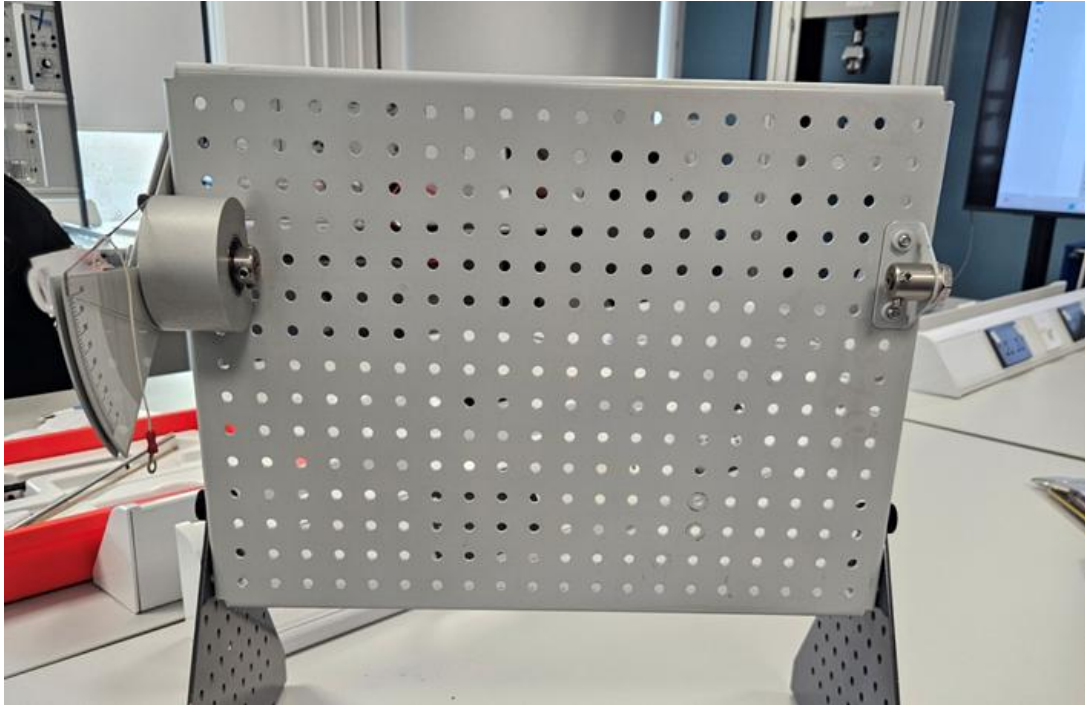


Figure 2: Experiment Equipment

The length of the specimen is 340 millimetres long and the length between the rotating chuck and fixed chuck should be sufficient to hold the specimen in place. Each specimen will have different torsional properties, so to build a reliable data range the experiment was repeated through increments of 100g load applied, starting at 100g. For the brass and steel specimen, weight was added until 500g but (because the aluminium is softer), to prevent permanent deformation of the aluminium specimen the weight did not exceed 400g.

3 Results

The results were recorded and excel was used to create graphs and easily view the data shown in the figure below. During the experiment the twist angle was recorded in degrees. However, to calculate anything needing the twist angle they have to be in international standard. To convert from degrees to radians the data is multiplied by $\frac{2\pi}{60}$.

Shaft Modulus						
Load (g)	Load (n)	Torque (Nm)	Twist Angle °	Twist Angle Radian	TL	J theta
100	0.98	0.098	5.1	0.534	0.033	0.00088
200	0.98	0.196	11.2	1.173	0.067	0.00175
300	0.98	0.294	17.5	1.833	0.100	0.00263
400	0.98	0.392	23	2.409	0.133	0.00351
500	0.98	0.49	29.5	3.089	0.167	0.00438
Material: Brass		L = 0.34		D = 3.1m	J = 9.07 x 10^-12	
Shaft Modulus						
Load (g)	Load (n)	Torque (Nm)	Twist Angle °	Twist Angle Radian	TL	J theta
100	0.98	0.098	7.5	0.785	0.033	0.00131
200	0.98	0.196	15.5	1.623	0.067	0.00261
300	0.98	0.294	23	2.409	0.100	0.00392
400	0.98	0.392	31	3.246	0.133	0.00523
Material: Aluminium		L = 0.34		D = 3.1m	J = 9.07 x 10^-12	
Shaft Modulus						
Load (g)	Load (n)	Torque (Nm)	Twist Angle °	Twist Angle Radian	TL	J theta
100	0.98	0.098	3	0.314	0.033	0.00042
200	0.98	0.196	4.5	0.471	0.067	0.00084
300	0.98	0.294	7.5	0.785	0.100	0.00127
400	0.98	0.392	10	1.047	0.133	0.00169
500	0.98	0.49	13	1.36	0.167	0.00211
Material: Steel		L = 0.34		D = 3.1m	J = 9.07 x 10^-12	

Figure 3: Lab Data

From the results the load and torque can be calculated. It was calculated by first converting the load (g) to kilograms and then multiplying it by the load (n). The second value for load measured in newtons is the universal value of gravity. All of the specimens will have the same load and therefore torque applied at each interval because that is the controlled variable. The independent variable is the specimen that allows the properties of each material to be seen. Measuring the twist angle makes that the dependent variable. The first aim of this experiment is to show the torsional stiffness of the specimen. To do this, key values needed to be calculated.

To calculate the values of TL and $J\theta$ shown in the lab data, the torsion equation was used:

$$\frac{T}{J} = \frac{G\theta}{L}$$

Equation 1: Torsion Equation

This is then rearranged to find the value of $J\theta$:

$$J\theta = \frac{TL}{G}$$

Equation 2: Torsion Equation For $J\theta$

TL can be worked out by multiplying Torque by Length, however in this case the torsion equation rearranged to find TL:

$$TL = G\theta J$$

Equation 3: Torsion Equation For TL

4 Analysis

To show the Torsional stiffness the following graphs were created. The gradient of the graph gives the value for the modulus of rigidity. Using the equation $y = mx + c$ the modulus of rigidity can be found. All of the graphs are linear which indicates that the gradient is accurate as torsional stiffness is a constant. The length and size of the specimen would affect the torsional stiffness.

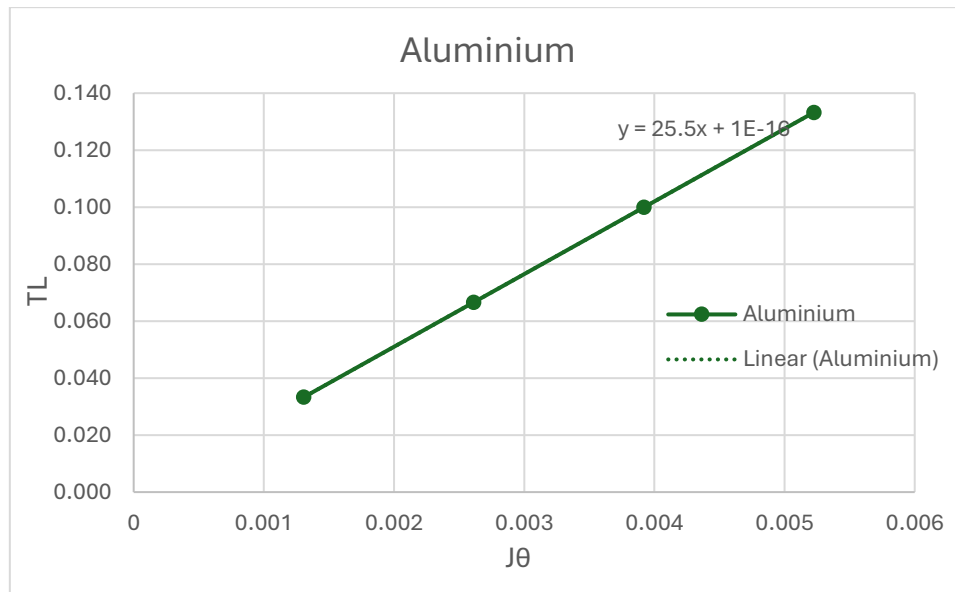


Figure 4: Graph to Show Aluminium

From the graph showing the torsional stiffness of the specimen, the gradient shows that the aluminium specimen has a modulus of rigidity of 25.5 N/m^2 . It also shows that aluminium has quite a low resistance to torsional load and is quite a soft and malleable material.

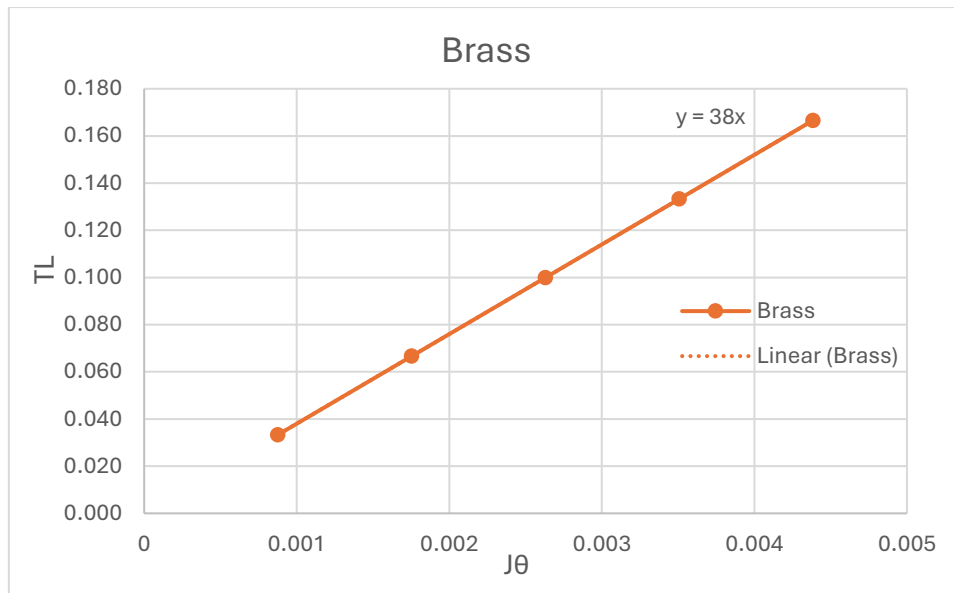


Figure 5: Graph to Show Brass

The graph showing torsional stiffness of the brass specimen shows from the gradient that it has a modulus of rigidity of 38 N/m^2 . This means that the brass specimen has a more resistance to the load applied than the aluminium specimen.

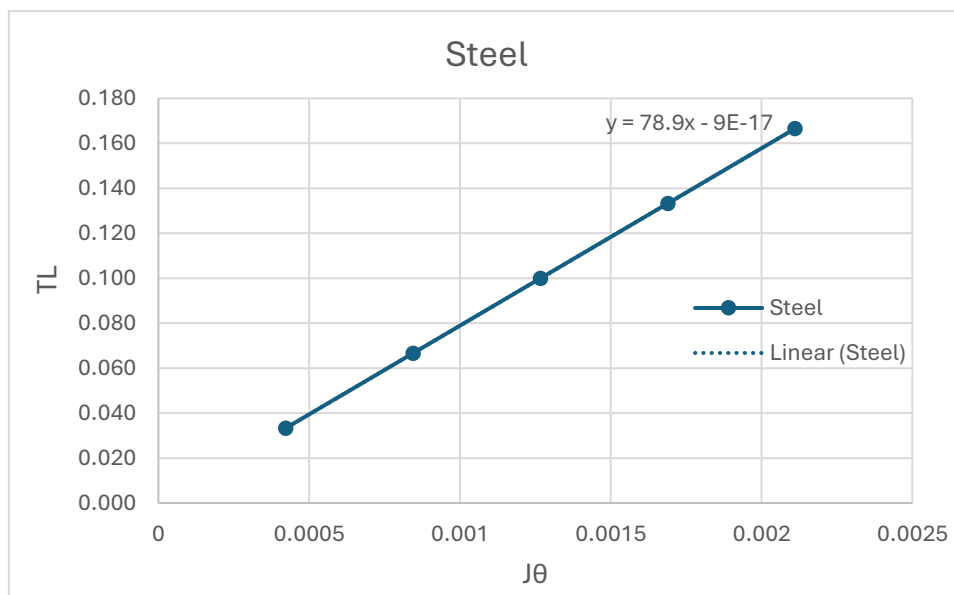


Figure 6: Graph to Show Steel

The graph showing torsional stiffness through a steel specimen shows from the gradient that the modulus of rigidity is 78.9 N/m^2 . This is the highest value for shear modulus out of all the materials tested.

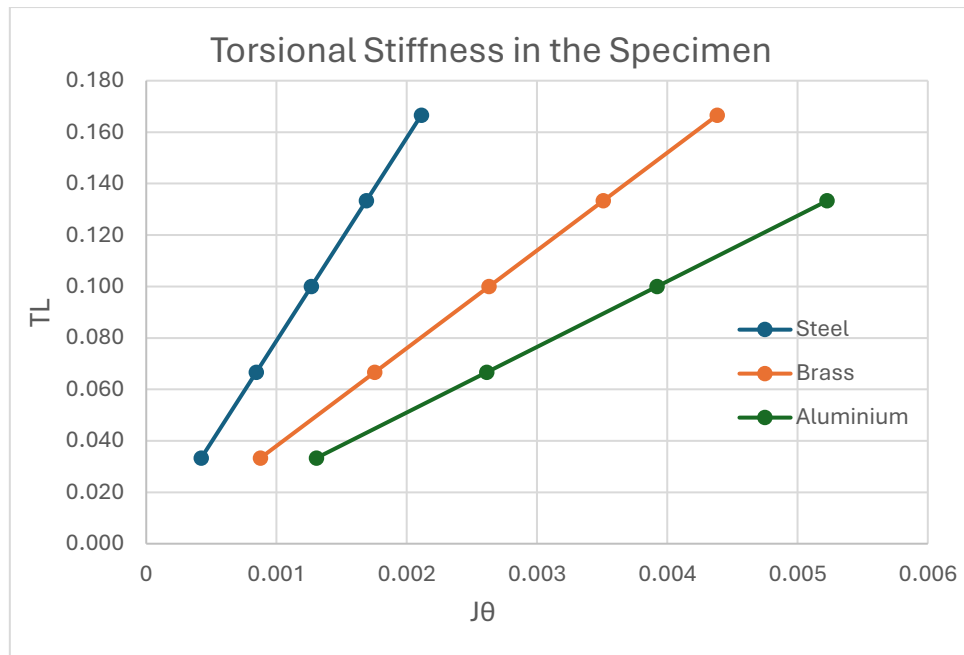


Figure 7: Graph to Show Torsional Stiffness

Figure 7 shows that all the specimens are the same length. Changing the length as spoken about at the start of this section would cause the properties of the material to change. Increasing or decreasing the torsional stiffness of the material. This therefore is another control variable. Interestingly the ratio between stiffness and mass can be used to optimize vehicle chassis (Krzikalla et al., 2019). This is evident in the graph because the heaviest material (steel) has the highest tolerance to torsional loads. Automotive vehicle's chassis are made from steel and not aluminium because of these torsional loads. Aluminium is however a lot lighter than steel. This is why composites are used because they give the same lightweight advantages of aluminium while maintaining the strength of steel.

5 Conclusion

In conclusion this experiment has shown that torsional stiffness is constant throughout the material. Each of the graphs show the trend is linear confirming that the torsional stiffness of the property remains the same. Comparing the values of the modulus of rigidity calculated from the experiment to the textbook ("ES5 Guidance 1012 - Torsion Experiment Documentation - Studocu," n.d.) means any error can be easily identified. The aluminium and brass values for modulus of rigidity are exactly the same as the values provided. The aluminium value comes out at 25.5 N/m^2 and the value for brass comes out as 38.0 N/m^2 . However, the value for the steel has a slight discrepancy of 0.7 N/m^2 . The textbook value is provided as 79.6 N/m^2 whereas the value calculated in the experiment was calculated to be 78.9 N/m^2 . There must have been error caused by the specimen slipping out of the Rotating chuck during the last few increments being measured. This meant that the scale had to be zeroed again. This would have caused the discrepancy. However, in the graph showing the torsional stiffness in the steel specimen spoken about in the analysis section, showed the trend was still linear. If there was error in the results due to something being changed slightly the trendline wouldn't have been expected to be linear. This explains how the error has gone unnoticed until comparing with the textbook values. Modulus of rigidity is different to torsional stiffness so that could explain why the trendline was still linear. The brass specimen also slipped out of the chuck on the last load being applied. However, this didn't cause any discrepancy in the values from the textbook and the experimental data.

6 Evaluation

In the experiment each person was given a job to do. This ensured consistency with the amount of error possible. If someone else had taken over, then they might do things slightly different causing there to be a difference in the results. Effective communication is required to uphold the highest standards and precision of the experiment. Ineffective communication could cause arguments and distract from the task at hand. Distraction, even to get the attention of the teacher can cause error to be unseen or a mistake to be made (Viechnicki and Kuipers, 2006).

The same specimen was recorded throughout the whole range of load before changing to remove the error that would have been caused by the removal and refitting. Although there was error with needing to refit the steel and brass specimen as spoken about in the conclusion, the amount of error was reduced by zeroing the chuck as precisely as possible. The load was applied in the same manner ever time to give consistency to the way the specimen reacted. If the load was slowly lowered on the hanger the first time and the next time the load was dropped on the hanger, then the specimen may have had different response to the load being applied. When something is hit with a hammer the material may deform. Now say the load could be recorded and applied slowly in the same position, the material wouldn't deform as much because the pressure is being spread across the specimen.

7 Further Work

Given unlimited time and money the experiment could be improved by using a more effective way of securing the specimen in place because during the experiment the specimen slipped from the rotating chuck. This could have caused slight error when refitting and zeroing the gauge. Alternatively, an electronic measuring device could have been used. The experiment could have also been repeated for each specimen to build a set of data that should make any errors obvious.

This experiment is a good way of demonstrating the torsional stiffness of different materials. It could be changed and adapted to test larger much heavier bars and structural frames in construction. A better way of securing the chuck would be needed as the loads would be greater. There have been designs that can secure the specimens up to 2000N without it slipping and causing any error (Grolleau et al., 2022).

References

- ES5 Guidance 1012 - Torsion Experiment Documentation - Studocu [WWW Document], n.d. URL <https://www.studocu.com/en-us/document/jamestown-community-college/mechanics-of-materials/es5-guidance-1012-equipment-documents/37904897> (accessed 12.24.25).
- Grolleau, V., Roth, C.C., Mohr, D., 2022. Design of in-plane torsion experiment to characterize anisotropic plasticity and fracture under simple shear. *Int J Solids Struct* 236–237, 111341. <https://doi.org/10.1016/J.IJSOLSTR.2021.111341>
- Janowiak, J.J., Pellerin, R.F., 1992. Shear Moduli Determination Using Torsional Stiffness Measurements. *Wood and Fiber Science* 392–400.
- Krzikalla, D., Mesicek, J., Petru, J., Smiraus, J., 2019. Analysis of Torsional Stiffness of the Frame of a Formula Student Vehicle. *J Appl Mech Eng* 8, 315. <https://doi.org/10.35248/2168-9873.19.8.315>
- Viechnicki, G.B., Kuipers, J., 2006. “It’s all human error!”: When a school science experiment fails. *Linguistics and Education* 17, 107–130. <https://doi.org/10.1016/J.LINGED.2006.09.002>