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Torsion of Shafts

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1 Introduction

This project looks at how the material used in a torsion test affects the twisting of circular shafts. Using the ES5 kit, data will be collected applied to the theory to determine the modulus of rigidity (the shear modulus), (G) for different materials by rearranging the standard torsion equation. The results will be compared with published values to check accuracy and discuss possible sources of error, with relevance to real-world components like drive shafts and torsion bars in machinery.

2 Experimental Procedure

The aim of this experiment is to demonstrate how a material is affected under torsion. To start the experiment the equipment must be set up and established. Within the kit you get a few pieces which need to be assembled as seen in the photos below:

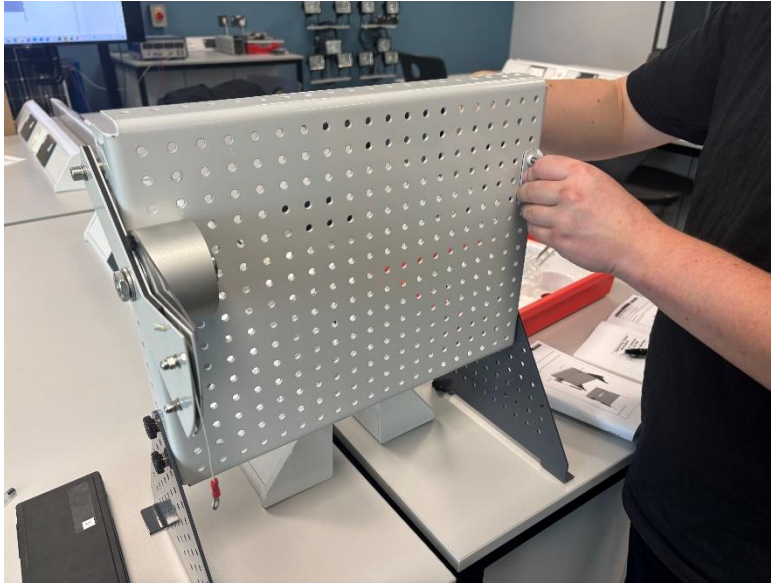


Figure 1 Experiment Set up 1

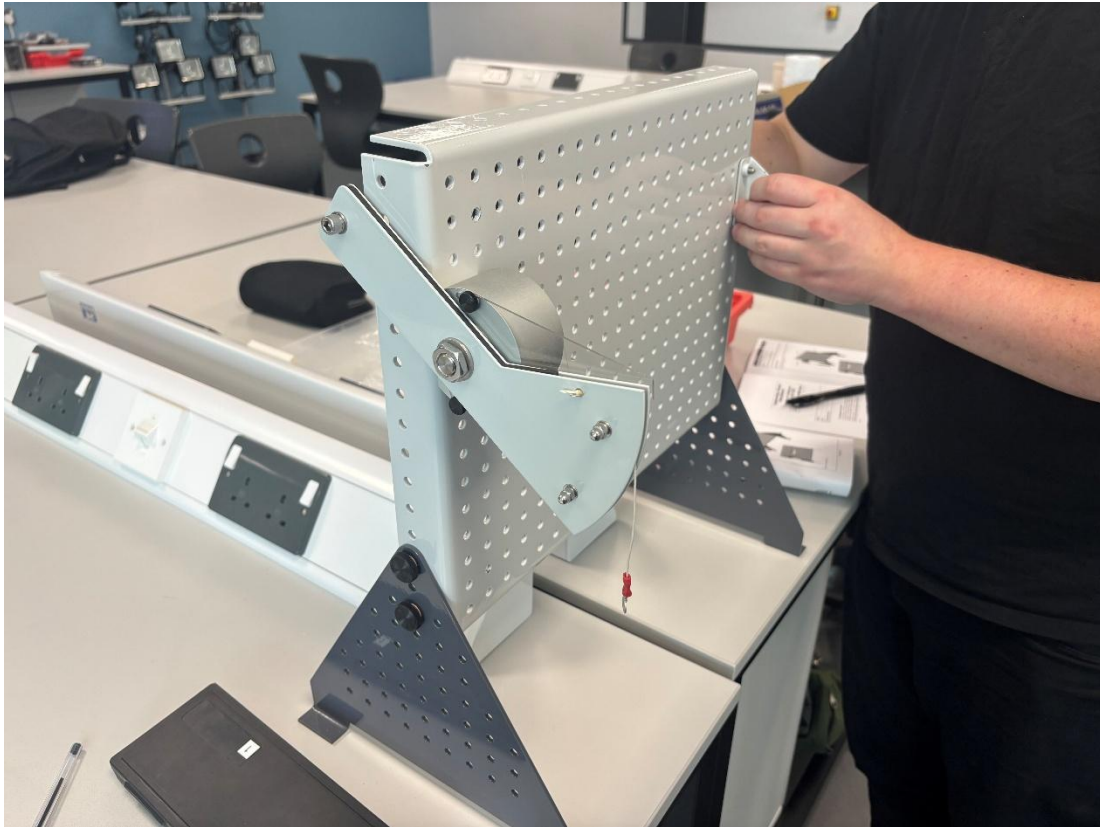


Figure 2 Experiment Set up 2

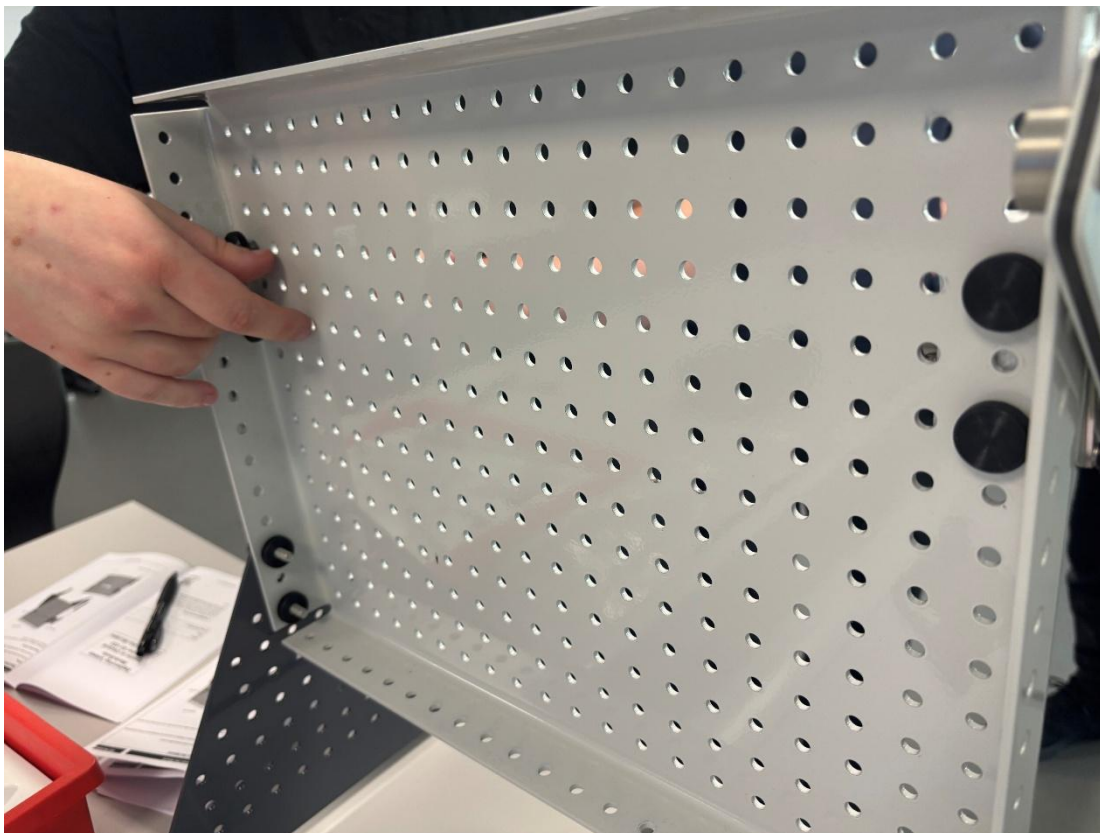


Figure 3 Experiment Set up 3

Once done the setup of the first specimen can begin use the hexagonal tool (Allen key) supplied to loosen the grub screws and slide the specimen into the fixed chuck. Push it fully through the fixed chuck and into the rotating chuck as far as it will go, then tighten down the grub screws of the fixed chuck. As can be seen in the image below:

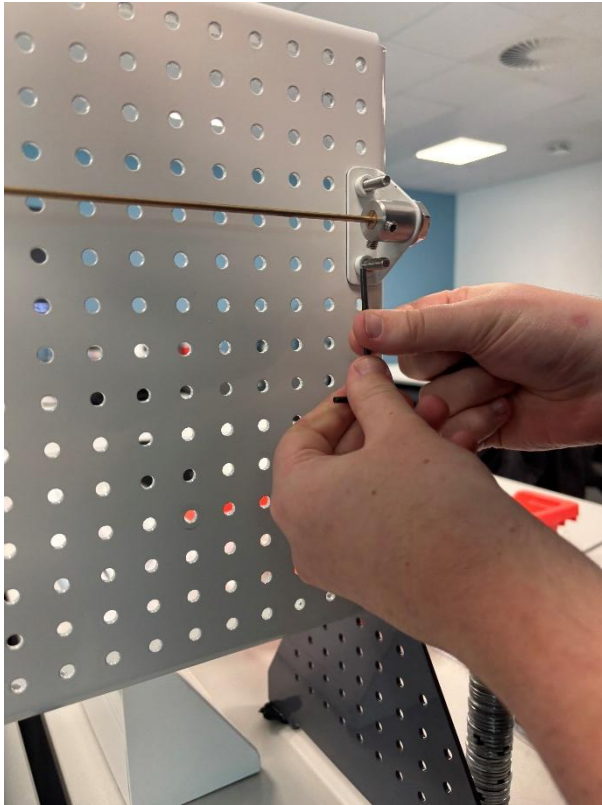


Figure 4 Experiment Set up 4

Now that the specimen is in you need to zero the rotating chuck, loosen the grubscrews on the rotating chuck so that the torque arm can move without affecting the specimen. Next carefully align the torque arm so that the 0-degree mark is visible through the

transparent cursor as can be seen in the image below:

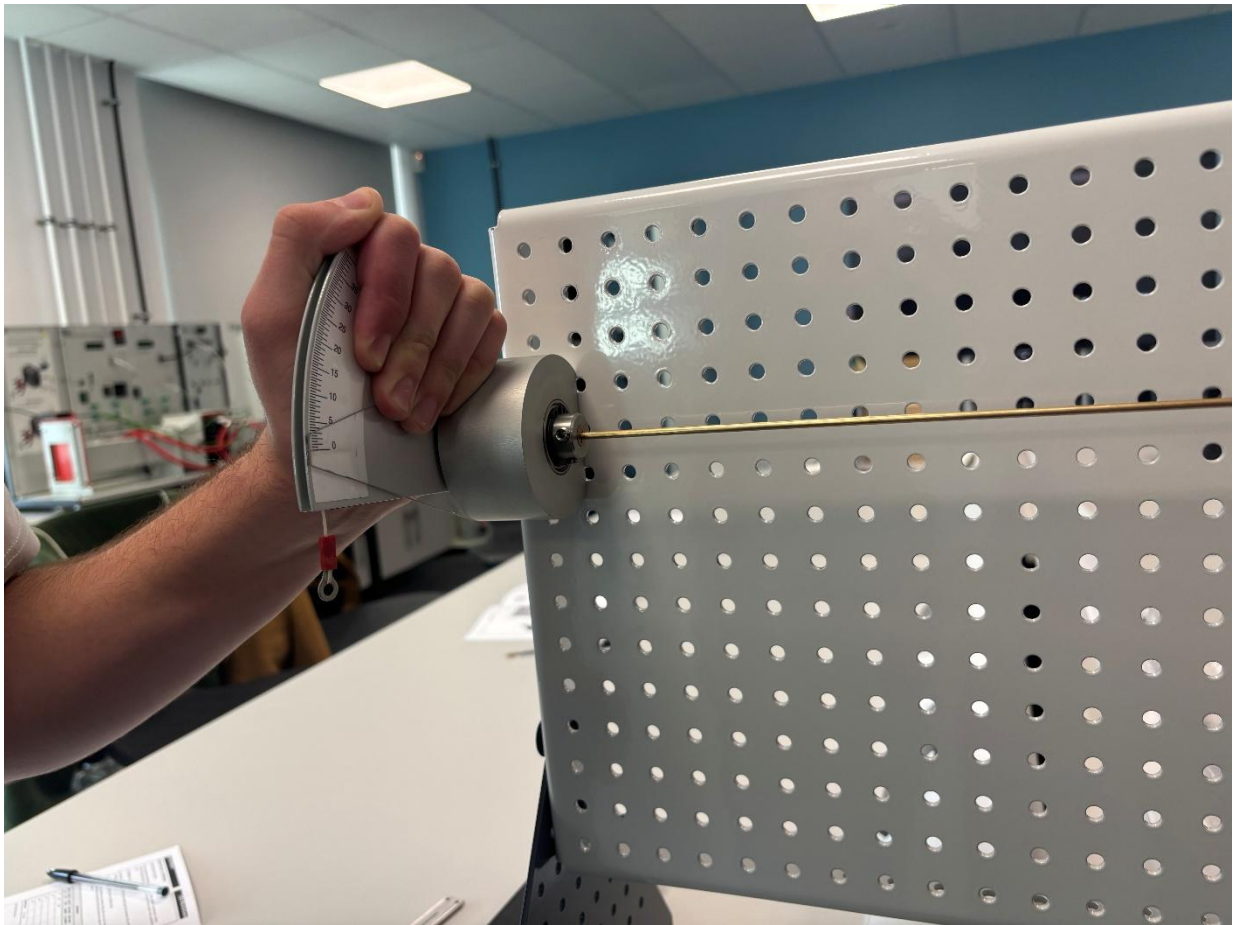


Figure 5 Experiment Set up 5

Then tighten the grub screws and add the weight and record the rotation angle.

The progression of the experiment is to then repeat for all the specimens adding 100 grams of weight each time and tapping the set up to reduce friction, however, make sure that you zero the rotating chuck every time you add weight to ensure accurate measurements.

Below are some images that were recorded as the experiment proceeded:

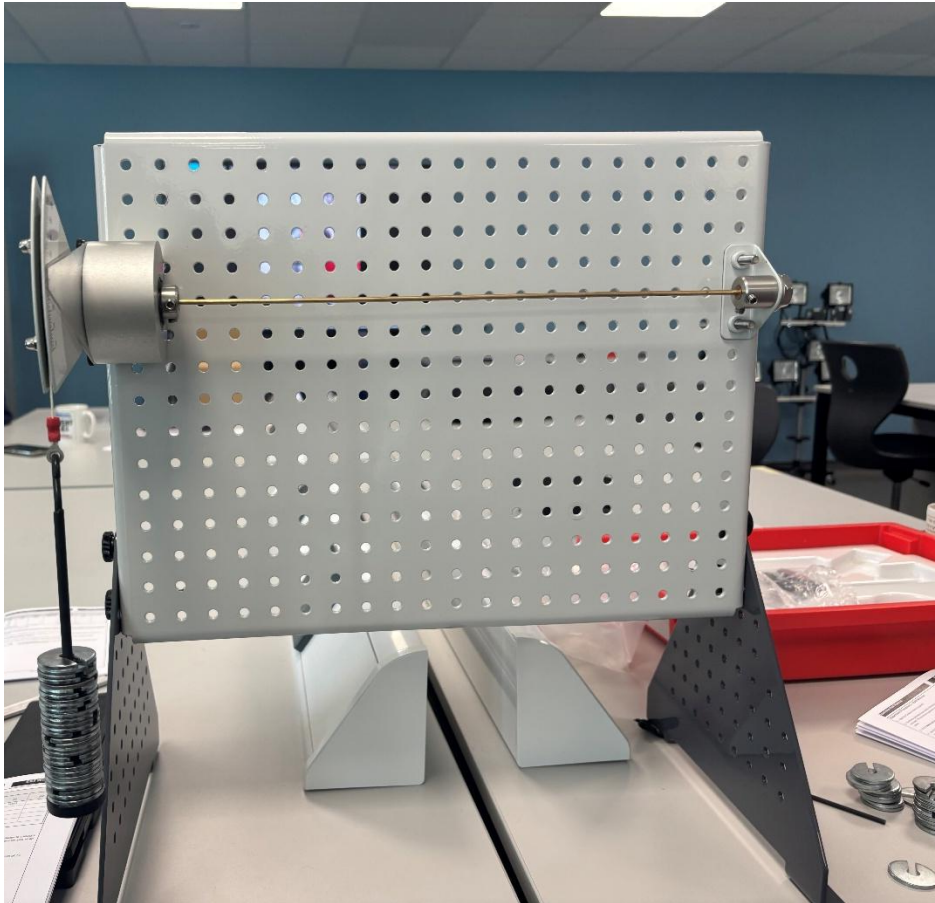


Figure 6 Experiment 1

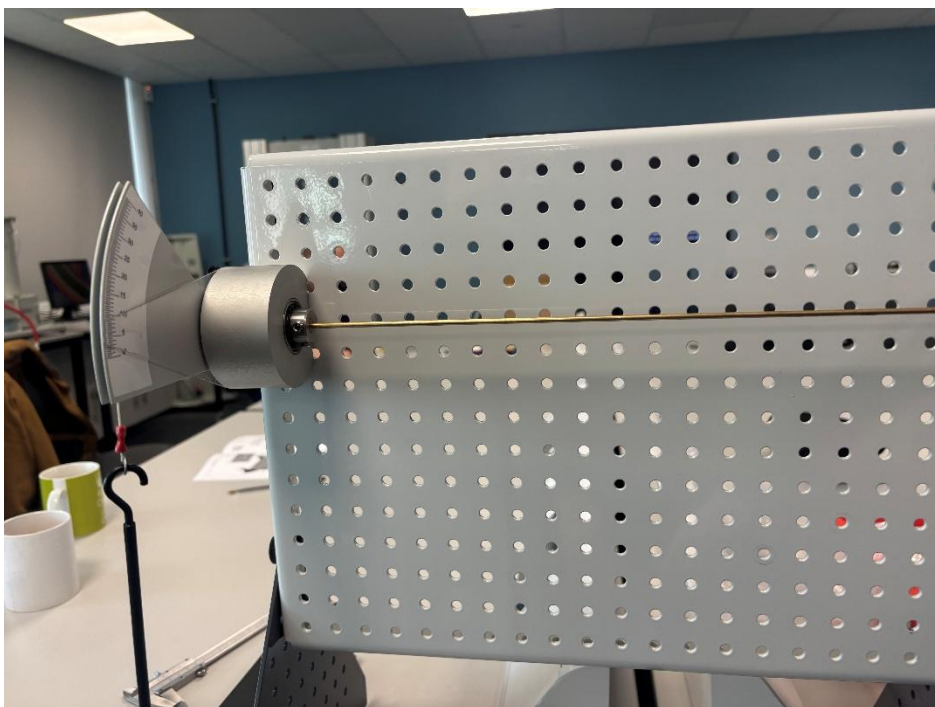


Figure 7 Experiment 2

3 Results

The results from the experiment are as follows, these are the straight results recorded at the time of the experiment moved to an excel spreadsheet for ease:

Shaft Modulus					
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (Radians)	TL
100	0.98	0.098	6	0.033	J8
200			11.75		
300			17.75		
400			23.75		
500			29.5		
Material: Brass					
	0.34	D=	0.0031	J=	
Shaft Modulus					
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (Radians)	TL
100	0.98	0.098	7.75		0.033
200			15.25		
300			22.75		
400			30.5		
Material: Aluminium					
	0.34	D=	0.0031	J=	
Shaft Modulus					
Load (m) (g)	Load (W) (N)	Torque (T) (Nm)	Twist Angle (Degrees)	Twist Angle (Radians)	TL
100	0.98	0.098	2.5		0.033
200			5		
300			7.5		
400			10		
500			12.5		
Material: Steel					
	0.34	D=	0.0033	J=	

Figure 8 Spreadsheet for Results

In the results you can see the twist angle the diameter of the specimen and the length of the specimen as well.

4 Analysis

Below are the analysed results from the results gathered from the experiment outlining the shear modulus for each of the outlined specimens.

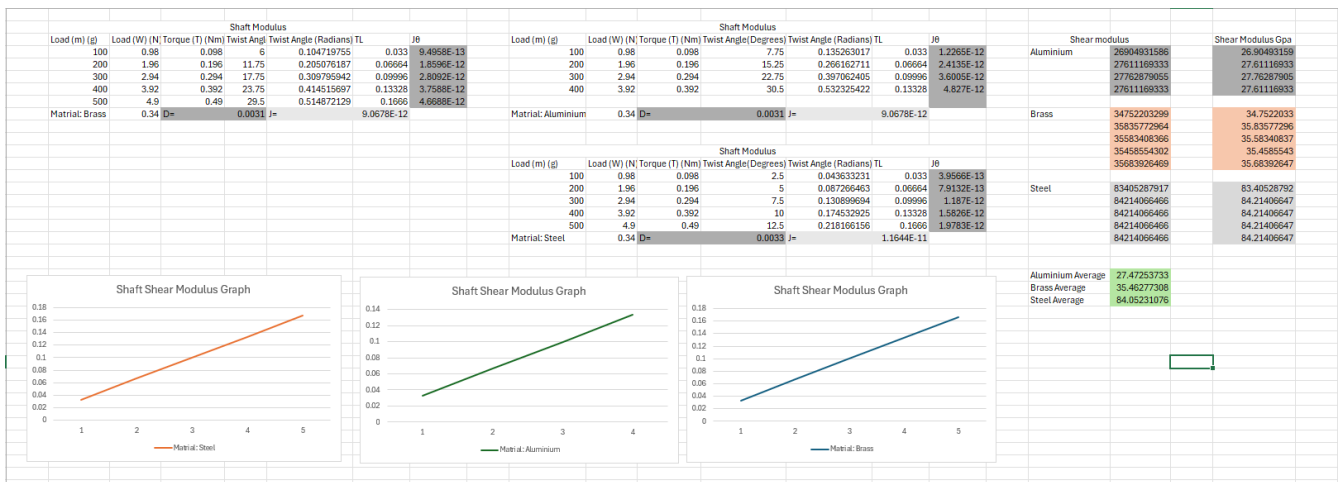


Figure 9 Analysis Results

From the analysis there are clear linear lines between the TL and J0 showing an evident elastic quality within the range measured, you can also see the calculated average of the shear modulus for each of the materials/specimens.

5 Conclusion

The point of this experiment was to measure the torsional response of circular shafts using the ES5 kit and determined the shear modulus (G) for aluminium, brass and steel. The measured shear modulus was, aluminium 27.47 GPa, brass 35.46 GPa, and steel 84.05 GPa. These values compare with researched values of approximately 24 GPa for aluminium, ≈ 38.0 GPa for brass and ≈ 86 GPa for steel (*Metals/Alloys - Elastic and Shear Modulus*, n.d.). The θ vs T relation/response was linear which indicates that there is elastic behaviour within the tested range, and the measured ordering of stiffness (steel then brass followed by aluminium) matches what would be expected. Any differences are likely caused mainly by angle-reading resolution and the uncertainty of the measurement of the diameter, as if the error is present, it will be magnified because of the equation $J \propto D^4$, meaning that the value is multiplied to the power of 4 making the error or incorrect measurement larger. To improve the accuracy of measurements they could be taken with a micrometre. Overall, the experimental values are reasonably close to the published values, validating the experimental method.

6 Evaluation

To eliminate as many errors as possible during the experiment, every time more weight was added to the rotating chuck the chuck was checked that it was at zero or zeroed before continuing, or the chuck would be adjusted accordingly to ensure that the value was zero before moving onto the next stage of the experiment. The fixed chuck was also checked to ensure that the specimen was fixed and hadn't rotated at all between the phases of the experiment.

7 Further Work

For further work, it would be good to use a digital angle sensor or video analysis for more accurate twist readings and to measure the rod diameter several times with a micrometer across the length and then averaging this value. Each load could be repeated to average out random errors and then the chucks checked in case they slip and try different diameters/lengths so the D^4 and L effects can be tested properly. Friction could also be either minimised by lubricating parts or by calculating it separately and then integrating it with the experiment.

8 Bibliography

Metals/Alloys - Elastic and Shear Modulus. (n.d.). Retrieved December 20, 2025, from https://www.structx.com/Material_Properties_003b.html