Annotated lab report

Structural features

Communication features

Abstract

A small steel beam was placed on an aluminium extrusion frame and mass was applied incrementally to one end, whilst the other end remained fixed. The deflection of the beam was measured with both a dial gauge and a potentiometer. The experimental data was then compared with a theoretical model to provide an experimental value of Young's modulus for the beam. The potentiometer was found to contain an unacceptable level of systematic error when compared to the theory, and was discounted. Least squares analysis of the data, combined with the calculation of standard error, produced a value of 231GPa as the Young's modulus (E) of the steel beam, with a standard error of 1.06 GPa. These results are outside of the range supplied for the sample; E should fall within 190–210 GPa. Nevertheless, the standard error is very low, suggesting that random error within the repeated measurements can be discounted, and there is either a systematic error remaining that has not been identified, or that one of the control measurements is incorrect.

Abstract:
The last thing you write – usually a single paragraph, but is sometimes headed paragraphs, and may include bullets.

Use past tenses to talk about the experiment.
Use present tense to discuss theories, and to discuss conclusions about the area. under investigation.

A summary of the whole experiment, i.e. Aims, Method, Results, and Conclusion. See 'Chapter 2, Getting started on your lab report.

Introduction

Classical beam theory, (a simplification of the linear theory of elasticity) can be used to calculate the load-carrying and deflection characteristics of beams[2].

The objective of the experiment was to use classical beam theory to determine an experimental value for E of the supplied steel beam through a simple cantilever experiment. This could be achieved by comparing the theory of a simple steel beam equation to the measurements made, using both the theory and statistical methods to identify sources of error within the data and to reduce uncertainty.

To simplify the theoretical model to a beam cantilever problem, several assumptions had to be made. Firstly, the frame that the beam was attached to was assumed to be fixed, and that the weight attached to the beam was applied at a single point, acting vertically downwards. Secondly, any lateral forces or movement were discounted to allow the problem to be reduced to two

Introduction:
Important background for understanding experiment. About 100–200 words.

Use present tenses for theories and facts.

See Chapter 5, Writing with accuracy.

Identify the problem under investigation.

Summary of background information and the objective which you hope to achieve. Include references to previous published studies where necessary (e.g. if you are trying to build on or replicate someone else's results).

dimensions. Given these assumptions, we can take the deflection of the beam to be:

$$\delta_x = \frac{Fx^2}{6EI}(3L-X)$$

where δ_χ is the beam's deflection, F is the applied load, χ is the distance between the fixed point at the beam's end and the deflection measuring point, E is the Young's modulus of the beam, I is the second moment of area of the beam, and L the distance between the fixed point of the beam and the load application. I can be calculated from the beam dimensions as follows:

$$I = \frac{bh^3}{12}$$

where *b* is the width of the beam and *h* the thickness. By measuring the applied load, F, and the deflection, δ_χ , we can then calculate Young's modulus, E for the beam.

Use of correct formatting for equations (space above and below, and indented, and numbered). See Chapter 2, Getting started on your lab report.

Do not refer to the results you obtained in the study you are reporting.

Procedure/Method

The dimensions for the beam **were measured** with a combination of vernier callipers and a ruler; the width, length and thickness, as well as the distance for which the deflection **was to be measured** from, **were** all **recorded** together with the uncertainties of the measuring equipment. Next, both the dial gauge and potentiometer **were calibrated** to zero whilst the beam remained unloaded within the frame.

Nine masses **were** then **added** to the end of the beam incrementally, and the deflection from both devices recorded. The masses **were** then **removed**, and the experiment repeated a further five times to obtain repeat readings. The data collected **was** then **compared** to the theory model. The model predicted a linear increase in deflection directly proportional to the mass applied. One set of data for both the potentiometer and dial gauge **were scatter plotted**; deflection against applied load.

A linear line of best fit **was** then **drawn** by hand for both graphs. The dial gauge matched the linear predictions of the model closely, whereas the potentiometer's data 'curved away' from the line. This seemed to indicate a systematic error present within the potentiometer, so its data **was discounted.**

Method: a description of what was done. Do not write in the style of instructions to someone else.

Use **passive**. Do not use personal pronouns.

See 'Writing in academic style', Chapter 7.

Provide sufficient information of the steps performed (to enable exact replication of experiment).

Use sequencing words to show the steps (first, next, then).

Provide diagrams of experimental set-up, flow-charts, etc., if appropriate. (Not shown here.)

Logical organisation of known and new information to improve flow of ideas.

See 'Writing with clarity, Chapter 4.

Results

As shown in Figures 1 and 2 below, the potentiometer clearly does not follow a linear relationship in the same way that the dial gauge does. Also apparent is that despite using the maximum estimate of E as 210 GPa, the estimate line does not match the dial gauge data as closely as it could do.

Further analysis on the dial gauge data, using the least squares method for each data set, then combining the data sets to reduce uncertainty, provides an experimental value of E as 231 GPa, with a standard error of 1.06 Gpa. Figure 3 shows that this value of E matches the data set much more closely.

Table 1 gives a comparison of the relative uncertainties, showing the percentage change in the value of E obtained if each variable used in the equation were to increase by 1%.

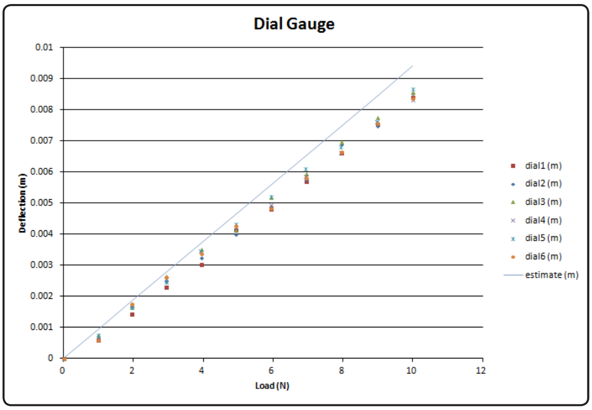

Figure 1: All 6 data sets compared to a theoretical prediction, using the closest estimate of E within the 190–210 GPa range specified.

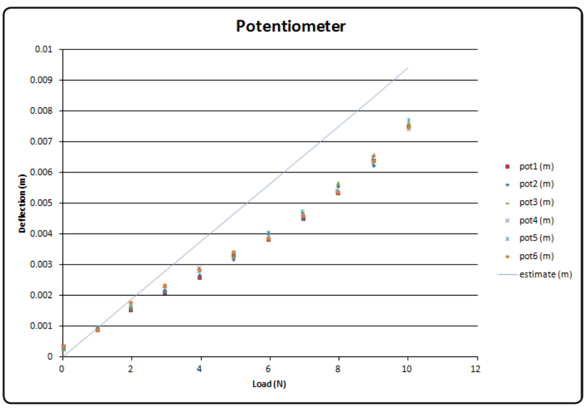

Figure 2: All 6 data sets compared to a theoretical prediction, using the closest estimate of E within the 190–210 GPa range specified.

Results: a description of what was found. Do not discuss the significance here.

Organise into separate paragraphs for different results.

Provide text before figures and tables. **Make reference to figures and tables in the text**. Select most relevant details to describe.

Use present tense to talk about what the figures and tables show. However, you can use the past tense to describe your findings in some circumstances.

e.g. 'The subjects all showed similar responses.'

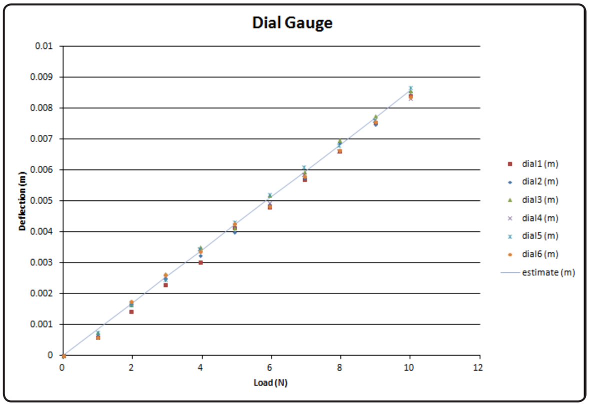

Figure 3: All 6 data sets compared to the experimental prediction, using the value of E obtained through least squares analysis.

Caption for figure below the figure (and above for a table).

Table 1: Uncertainties Table

1% change in	% change in E
F	1.00
x	1.58
b	– 0.99
h	– 2.94
L	1.42

Discussion

The results obtained are not as expected; the value of E obtained falls outside the range originally specified of 190–210 GPa by a significant margin. However, random error within the measurements of deflection and applied load can be safely discounted as an explanation, as the calculated standard error of 1.06 GPa means that the chance the mean value of E would fall inside the range is negligible. However, the critical dimensions of the beam were only measured once. It is possible that, due to human error, one of the measurements of the beam was taken incorrectly. As Table 1 shows, an incorrect measurement of the thickness of the beam or its length could create an error in E of

Discussion relates findings to each other, to theory and to published literature. A critical attitude to your work is needed.

Suitable use of hedging, see 'Writing in academic style', Chapter 7.

nearly three times the magnitude of the initial error. Potentially, cumulative errors in measurement, such as not placing the ruler exactly parallel to the beam when measuring, could explain **this discrepancy.**

Use of **'this' + summarising words** to avoid repetition See Chapter 4, Writing with clarity.

This seems to be the most likely source of error. Given that the dial gauge data matches the linear trend predicted, and correctly displayed no deflection when the load was removed for each repeat without further calibration, further systematic error within the measuring equipment seems unlikely. The only remaining explanation would be an incorrect application of the theory, or an inaccurate range supplied for the beam's value of E; both of which are beyond the scope of this report to investigate.

Suitable use of formality.

See 'Writing in academic style', Chapter 7.

Have you achieved your aims?

Therefore, the theoretical prediction and experimental results do not agree quantitatively. The value of E obtained falls outside the range provided. Nonetheless, qualitatively the results match the theory closely. A linear relationship between applied load and deflection was predicted, and this is reflected in the experimental data with a very low degree of standard error. The measurement of the dimensions of the beam and the position of the dial gauge created the highest uncertainties within this experiment. Whilst the Vernier callipers used to measure b and h had a high degree of precision, the size and location of L and x precluded their use, with a standard ruler used instead. Obviously, this is much less precise, with a ruler accurate to only 1 mm when used correctly.

What has been achieved and what are the significance of your findings and discussion?

Discuss possible errors in measurements and make suggestions for improvements (e.g. in method).

Furthermore, the lack of repeat readings for each of these dimensions makes it hard to rule out the introduction of significant random error. The results obtained in this case could be easily improved through the use of more precise measuring equipment, or by taking repeat readings from different members of the group to rule out human error.

Use present tense to show significance of your findings.

Conclusion

An experimental value of E **was found** through the use of least squares analysis in Microsoft Excel. At 231 GPa, it falls outside of the range supplied for the steel the sample **was made** from. This presents two conclusions; either an error in measuring the critical dimensions in the beam **occurred**, or that the range supplied is simply wrong. As **stated** before, the data matches the linear trend predicted by the theory, so is at least qualitatively correct.

Conclusion is a concise statement of quantitative and/or qualitative outcomes.

Mix of **past** and present forms to show significance of your findings.

As the main purpose of this lab was the application of least squares analysis to obtain a value of E with the smallest

Do not introduce any new material in your conclusion.

uncertainty possible (represented in this case as standard error), this has been successful. The datasets were combined to produce a value of E with the low standard error of 1.06 GPa. However, the discrepancy between the range provided and the Young's modulus obtained demonstrates that there has likely been some kind of procedural error during the experiment itself. The measurement of the beam, particularly dimensions L and x have been identified as likely sources of this error, especially as they contribute heavily to any change in E, as seen in Table 1.

References

1. Gere, J.M. and Timoshenko, S.P., (1991). Mechanics of Materials Third SI Edition, Cengage, Stamford.

2. Timoshenko, S., (1953), History of Strength of Materials, McGraw-Hill, New York.

References: Citing and list style depend on reference system used. In scientific writing it is often a Numeric style (shown here). It could be: Alphabetical / Harvard / APA / Numeric.