Young's Modulus

This experiment should be completed in 1 Week.

Key Physics in Experiment
In this experiment you will investigate the behaviour of a long thin wire when it is placed under a tensile stress. The experiment is designed to illustrate the following physics:

- Hooke's law – you will see that the extension is proportional to the load applied to the wire.
- Elastic properties of materials – you will see that as the wire remains inside its elastic limit the wire returns to its original length when the load is removed.
- Young's modulus – you will find that the Young's modulus of a material is related to the ratio.

Background reading
University Physics, Benson Chapter 14.

Transferable skills development
In this experiment you will learn

- how to measure small changes in length by use of a digital caliper.
- How to use graphical data to determine key parameters associated with the wire.

Reference Source for accepted value of Young's Modulus
Kaye and Laby Online
http://www.kayelaby.npl.co.uk/general_physics/2_2/2_2_2.html

Theory: One end of a uniform thin wire of cross-sectional area A and length L is attached to a support. A mass, M, is attached to the other end as shown in figure 1. The resulting force on the wire induces a small change in the length of the wire, ΔL. Provided that the elastic limit of the wire is not exceeded the extension will be proportional to the applied force. This is known as Hooke's law

$$F = k\Delta L. \qquad (1)$$

Photograph of experimental arrangement will go here

Figure 1. The experimental arrangement.

The constant of proportionality k, is the "spring constant" for the wire. Young extended Hooke's law to say that the tensile stress in a body was proportional to the tensile strain in the body. The constant of proportionality is Young's modulus E.

$$E = \frac{tensile\ stress}{tensile\ strain} \qquad (2)$$

The tensile stress and tensile strain are given by

$$tensile\ stress = \frac{Mg}{A} \quad tensile stress = \frac{F}{A} = \frac{Mg}{A} \qquad (3)$$

and

$$tensile\ strain = \frac{\Delta L}{L} \qquad (4)$$

with g the acceleration due to gravity. Thus using equations (1), (3) and (4) we find

$$E = \frac{kL}{A}. \qquad (5)$$

So plotting a straight line graph of weight (y-axis) against change in length (x-axis) and determining the gradient, of the best-fit straight line will allow E to be estimated

Procedure: Gently place a 1 kg load onto the carrying pan attached to one of the two wires and set the digital calliper to zero If in doubt, ask the demonstrator for help. Measure the length of the wire from the support to the flat edge of the top jaw of the digital calliper scale. This length will be L. Repeat this measurement several times. Measure the diameter of the wire at several points along the wire between the support and the top of the digital calliper. Increase the load on the carrying pan and record the reading from the digital calliper, ΔL. Do this until a load of 10 kg has been added to the carrying pan. Systematically reduce the load on the wire and record the digital calliper reading each time. Repeat the last two steps five times.

Analysis and uncertainty analysis: On separate graphs plot the change in length (x axis) against additional weight added (y axis) for both increasing and decreasing weight. Determine the gradients of the best-fit lines for each graph, you may use Excel but ensure that when you add the equation of the trendline to the graph you display the equation in scientific notation with 3 decimal places. The gradient for each graph corresponds to k. Calculate the average diameter and length of the wire and use equation (5) to evaluate Young's modulus for steel for both increasing and decreasing load. Compare your answers with that quoted in Kaye and Laby. Determine the uncertainty in your measurement.

Questions:

1. Why is a long length thin length of wire used in the experiment?
2. Why are two wires of the same material and dimensions used in the experiment?

3. Does the wire remain within its elastic limit? Justify your answer.
4. Does the diameter of the wire change as the load on the wire is increased? Justify your answer.