**Experiment 18**

# Elastic Modulus of Rubber

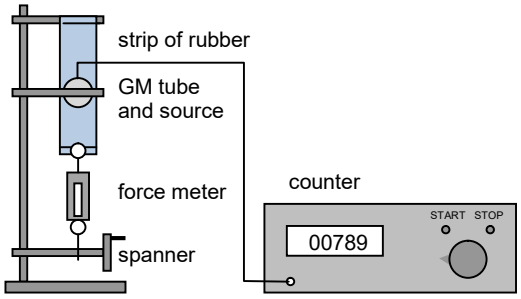
First read the introduction at experiment 18 in the booklet *ISP Experiments* about the way to measure the elastic modulus of a material.

**Aim**

To measure the elastic modulus of rubber.

**Set-up**

The set-up consists of a strip of rubber, clamped to a force meter and a spanner (for stretching the strip of rubber). The force applied to the strip of rubber should not exceed a value of 20 N.
A source of strontium-90 ($^{90}$Sr) and a Geiger-Müller tube are mounted on opposite sides of the strip of rubber. The GM tube is connected to a pulse counter. The counter can be set to an automatic measuring time of 10 s or to 'continuous'. In the latter case, after starting the counter will continue counting until the stop button is pressed. For measuring time, then use a stopwatch.
In this set-up it is not possible to measure (and thus to correct for) the background radiation, because both the source and the GM tube are stuck together in the equipment set-up.




With the equipment set-up the elastic modulus $E$ of rubber can be determined by measuring the force $F$ on and the elongation $\Delta\ell$ of the strip of rubber, in combination with the cross-section area $A$ and the original length $\ell_0$ of the strip. Determining the cross-section area $A$ requires measuring the width $w$ and thickness $d$ of the strip of rubber. This thickness $d$ is measured through the absorption of β radiation in the strip of rubber. The measured intensity $I$ of the transmitted radiation and the calibration graph (see *Instructions* on the other side of this worksheet) allow the reading of the thickness $d$. All other quantities can be measured directly by means of a force meter and a ruler.

**Research question**

- Draw up a research question fitting the aim and equipment set-up of this experiment.

**Hypothesis**

- Draw up an argued hypothesis about the relation between the force $F$ applied to the strip of rubber and the product $A{\cdot}\Delta\ell$ (the product of cross-section area $A$ and elongation $\Delta\ell$ of the strip).
- Give this hypothesis also in the form of a sketch of the relation between these quantities in an $F$,$A{\cdot}\Delta\ell$-graph.
- Also draw up a hypothesis about the order of magnitude of the elastic modulus $E$ of rubber.

**Plan of Work**

- Draw up a plan of work for the investigation with the given equipment set-up.
- In this plan of work, indicate how you will vary which quantities in order to be able to check your hypothesis.
- Indicate how you will determine the elastic modulus $E$ of rubber from your measurements.
- Prepare an (empty) table for recording your measurements.
- Indicate whether the experiment will contribute to the radiation dose you receive during the laboratory session. And, if so: how you can take care that this radiation dose stays as low as possible.
- Discuss your research question, hypothesis and corresponding plan of work with your teacher or the school's laboratory technician.
- If necessary, review your research question, hypothesis and/or plan of work.

**Investigation**

- Carry out the investigation according to your plan of work. During the laboratory session, take care of an adequate radiation protection.

**Data Processing**

● Process your measurements in order to check your hypothesis, and to answer your research question. The box below gives some instructions for such data processing.

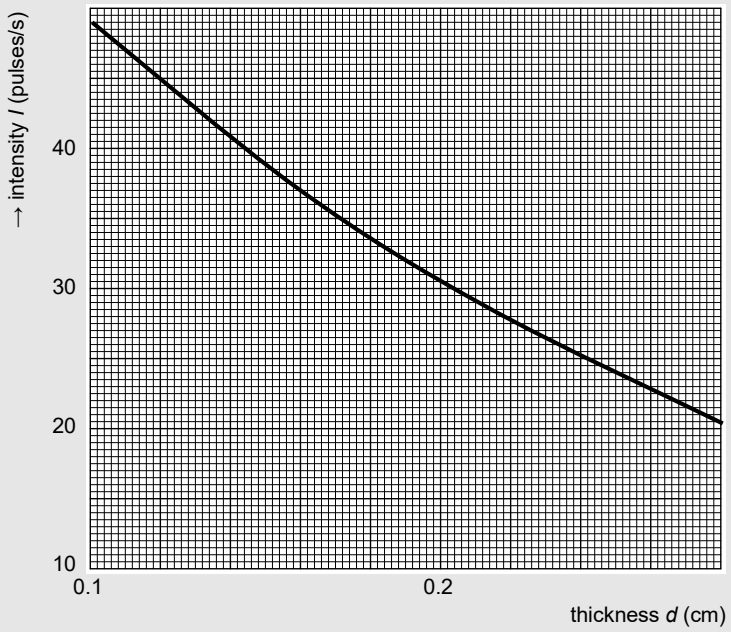
**Instructions**

● Plot your measurements in a $F,A\cdot\Delta\ell$-graph. For doing this, determine the thickness $d$ of the strip of rubber from the measured intensity $I$ of the transmitted β radiation and the calibration graph below.

● From the $F,A\cdot\Delta\ell$-graph of your measurements it appears that the relation between the quantities $F$ and $A\cdot\Delta\ell$ probably is *inversely proportional*. Or, in other words: that the value of $F/(A\cdot\Delta\ell)$ is a constant.

> From the graph, determine the value of this constant, and thus the value of the elastic modulus $E$ of rubber.

The calibration graph below gives the intensity $I$ of the transmitted β radiation as a function of the thickness $d$ of the strip of rubber.




**Extra question**

In industrial applications thicknesses of metal, paper and carpeting is often determined by using radiation. Explain for each of these materials which type of radiation will be used.

**Report**

● Write a report about this investigation. This report presents your *research question*, *hypothesis*, (processed) *measurements* and *conclusion* about the hypothesis being confirmed or not.