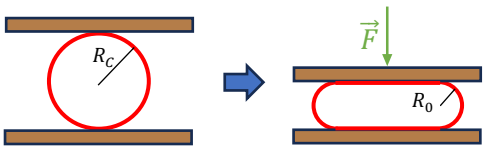
Final of the Luxembourg Physics Olympiad 2024

PRACTICAL TASK

On the elasticity properties of a plastic film

Introduction

In this practical round, we will investigate the elastic properties of a rolled-up sheet. If this sheet is compressed perpendicularly to its axis of symmetry, the shape of the film can be approximated geometrically with that of a **stadium**, which consists of two semicircles connected by straight line segments.



Theory:

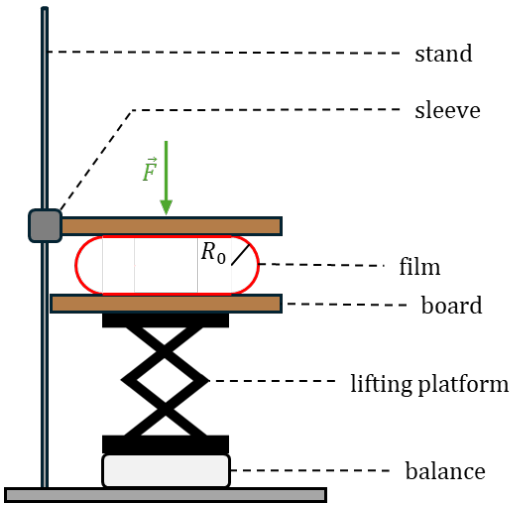
In the stadium approximation, the following power law gives the relation between the applied force and radius:

$$\boldsymbol{F = \kappa \cdot R_0^{\alpha}}$$

- R_0 is the curve radius.
- The constants κ und α must be determined experimentally!

Materials and experimental setup

- laboratory scales
- lab jack + boards
- tripod and right angle screw clamps
- plastic sheet
- adhesive tape
- ruler with stand and sliders
- scissors
- graphing paper



Experiment instructions and evaluation

1. Roll up the plastic sheet lengthwise to form a cylinder. Connect the ends of the film using a strip of adhesive tape. The ends may partially overlap (1 cm to 2 cm).
2. Place the roll on the body as shown in the sketch. Raise the lifting platform until the cylinder just touches both wooden boards and fits tightly.
3. Calibrate the scale and determine the initial radius R_c of the cylinder. Make sure to check the scale regularly. The scale display will switch off after a few minutes if there are no changes in measurement. Tap it occasionally with your finger or a pen to keep it active.
4. Now lift the platform step by step and measure the mass corresponding to the force F acting on the cylinder and the respective radius R_0. Take care not to kink the sheet.
5. Make a note the measured values in a table and calculate the values: $\ln(R_0)$ and $\ln(F)$.
6. Draw $\ln(F)$ against $\ln(R_0)$.
7. Draw a trendline and clearly mark the region where the stadium approximation holds.
8. Use the diagram to determine the parameters κ and α in the power law.
9. Estimate the absolute measurement uncertainty $\Delta\alpha$ for the parameter α from the diagram.

   Tip: $\Delta\alpha = \frac{\alpha_{max} - \alpha_{min}}{2}$ Calculate the the relative error $\frac{\Delta\alpha}{\alpha}$.
10. Discuss which test parameters the value κ could depend on. Which series of experiments would be needed to find these relationships? You can qualitatively test your assumptions in two ways:

    - experimental approach (only with the available material): use a measurement to test your reasoning without a full investigation.

    - theoretical approach:
      Justify and discuss your suggestions mathematically or using physical arguments.

Appendix

Logarithm rules

- $\ln(x) + \ln(y) = \ln(x \cdot y)$
- $\ln(x) - \ln(x) = \ln(x/y)$
- $\ln(x^y) = y \cdot \ln(x)$
- $\ln\left(\sqrt[n]{x}\right) = n^{-1} \cdot \ln(x)$

Evaluation

1.	0,5 pts	6.	6 pts
2.	0,5 pts	7.	2 pts
3.	0,5 pts	8.	5 pts
4.	0,5 pts	9.	3 pts
5.	3 pts	10.	4 pts

TOTAL: **25 pts.**