9. Magnet in glass (12 points) — *Jaan Kalda, Eero Uustalu.*

Tools A transparent cylinder with a cylindrical permanent magnet inside and with foil caps covering its top and bottom; a solid cylinder made from a homogeneous material; a caliper; two boards (for building a slope on which the cylinders can roll down); two bricks (for fixing and adjusting the slope angles); a box for catching rolling cylinders; a ruler — can be also used to release the cylinders; a permanent marker — only for marking on the cylinders, ask an organizer if you need to clean the markings; a pencil — for marking on the boards. **NB! the glass cylinder with the magnet is brittle and expensive, handle it with care and avoid dropping it to the floor.**

In all the tasks, aim to obtain the best possible precision. You will get points both for the steps you take to improve the precision and for the accuracy of your results.

i) *(1 point)* Determine the height of the magnet as accurately as possible and estimate the uncertainty of your result.

ii) *(3 points)* The acceleration with which a cylinder rolls down a slope depends on the slope angle, and on the ratio $\kappa = I_0/MR^2$, where I_0 is its moment of inertia relative to the axis, M — its mass, and R — its radius. Determine the ratio κ for the glass cylinder with a magnet inside.

iii) *(2.5 points)*Determine the diameter of the magnet. *Hint:* find a way to determine it without knowing the coefficient of refraction of the glass.

iv) *(2.5 points)* Notice that the transparent part of the cylinder is actually made of two different materials: the coefficient of refraction of the central part n_c is slightly different from the coefficient of refraction of the outer part of the cylinder n_o (the central part has the same diameter as the permanent magnet). Determine the coefficient of refraction n_o and estimate the uncertainty of the result.

v) *(3 points)* Determine the coefficient of refraction n_c.