EXPERIMENTAL EXAMINATION

Experimental problem

The flight of a paper cup (paper filter).

The drag force on a body moving through a fluid acts opposite to its motion and depends on its velocity. One model for this dependence is

$$F=cv^{\gamma},$$

where c and γ are constants depending on the body shape and the fluid properties.

Study the fall through air of one or more paper cups stacked together, released with their openings upward (opposite to a falling parachute). Their speed is approximately constant throughout the fall whenever it lasts more than one second.

Determine the exponent in the expression experimentally. Your workstation provides:

- 3 cups of equal mass
- a stopwatch
- adhesive tape to mark the height
- graph paper and log-log paper

The cups shape strongly affects their fall. Handle them carefully to avoid deformation. If one is damaged, ask the supervisor for a replacement.

Measuring magnetic moments with rulers

A cylindrical permanent magnet can be represented by a solenoid carrying a closed steady current. Its magnetic moment, expressed in Am^2, characterises it. Magnetic moments are usually measured with magnetometers, whose principles range from induction in a pickup coil to superconducting quantum interference and which usually require sophisticated electronics.

Here you will measure the magnetic moment of a commercial permanent magnet using only simple rulers-and a second identical magnet. Your workstation contains:

1. Two identical permanent magnets, each of the stated mass
2. Rulers
3. Adhesive tape
4. Paper
5. A laboratory stand with clamps (the magnets are attached to it)

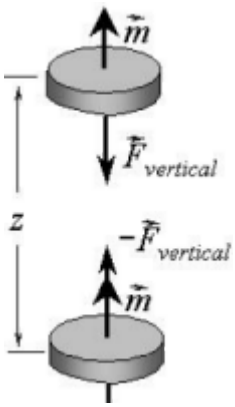
Determine the magnitude of the magnets magnetic moment by two different methods using only the items listed.

Develop one method fully: describe it, measure the magnetic moment and calculate its error.

For the other method, describe it and make at least one measurement of the magnetic moment, without calculating errors.

The following expressions and data may be useful. Assume they hold for our magnets:

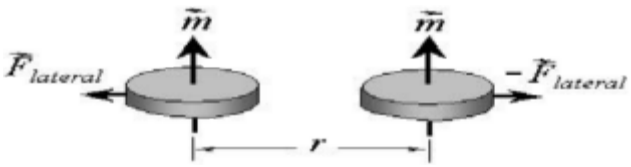
1. The force magnitude exerted by a magnet of magnetic moment m on an identical magnet a distance z away along the system symmetry axis (figure at right):



$$F_{vertical} = \frac{3\mu_0}{2\pi}\frac{m^2}{z^4}$$ (E1.1) The figure shows attraction. The force is repulsive if the magnetic moments point in opposite directions.

2. The force magnitude exerted by a magnet of magnetic moment m on an identical magnet a lateral distance r away (figure at right):

$$F_{lateral} = \frac{3\mu_0}{4\pi}\frac{m^2}{r^4}$$ (E1.2) The figure shows repulsion. The force is attractive if the magnetic moments point in opposite directions.



3. The coefficient of static friction between a magnet flat face and the rulers and set squares is
$\mu_{estatica} = 0.58 \pm 0.08$
4. $g \approx 9.80 \frac{\text{m}}{\text{s}^2}$, $\mu_0 \approx 1.26 \times 10^{-6} \frac{\text{m kg}}{\text{s}^2\, A^2}$