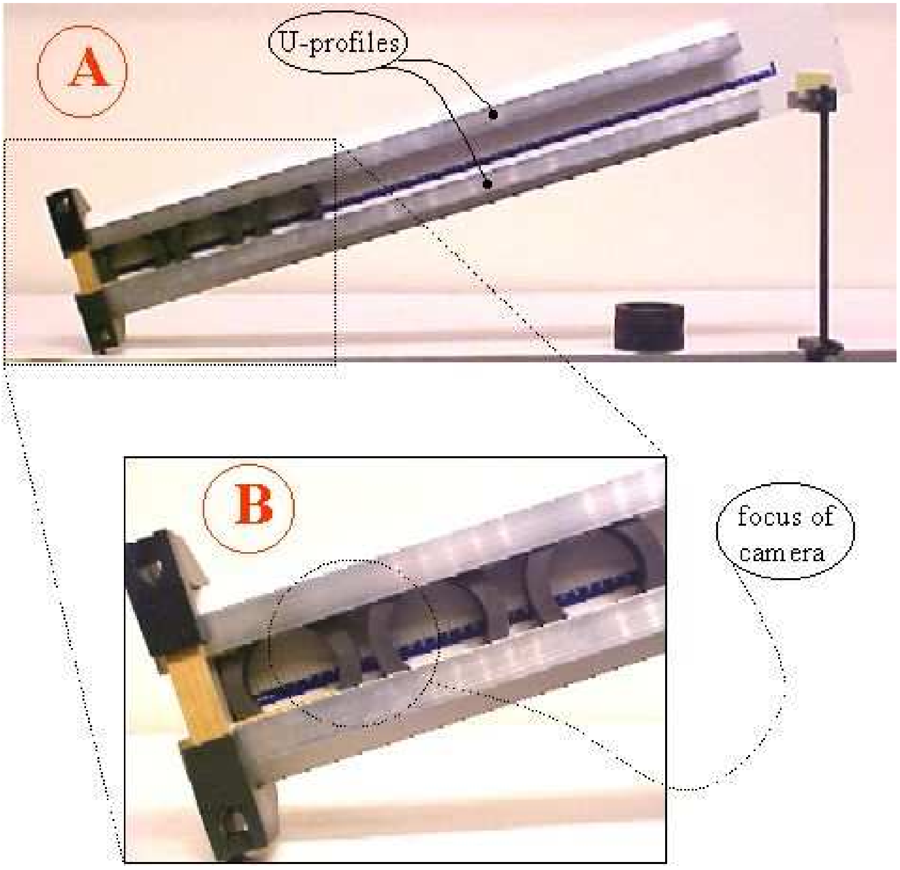
force between magnets (1)

Aim: To show how the force between two magnets depends on the distance between these two magnets. (An investigation.)

Subjects: 5H20 (Forces on Magnets)

Diagram:



Equipment:

- 6 Hardferrite magnets, 100x70x20 mm (ring).
- Smooth shelf.
- 2 Aluminum U-sections, 30x30x30x2 mm, clamped to shelf.
- Clamping material.
- Paper ruler, stuck to shelf.
- Camera and beamer focussed on the first two magnets (see DiagramB).

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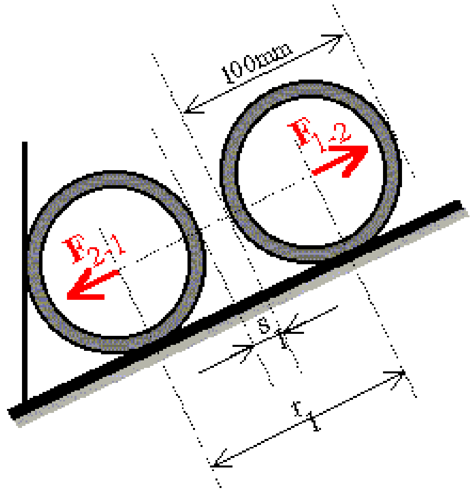
Presentation: The U-sections and shelf are set up as shown in Diagram. The magnets can roll freely in the U-profiles.
The first magnet is placed in the shelf, stopped by a clamp (see Diagram). Then the second magnet is placed in the U-section. It rolls towards the first magnet, then stops due to repulsion. The set up is bumped gently by hand, in order to reduce the influence of friction on the setting of the distance between the repelling magnets. Then the seperation *s*, between the magnets can be read (the audience can do so thanks to the projection by the beamer) and the center to center distance (*d*) is determined by adding 100mm to *s* (see Figure 1).



	Number of magnets	s (mm)	r (mm)
1	2	3.3	13.3
2	3	2.2	12.2
3	4	1.4	11.4
4	5	1.2	11.2
5	6	1.0	11.0

Figure 1

The third magnet is placed. It rolls towards the second magnet until it stops. Again the set up is bumped gently by hand until the three magnets have set themselves due to magnetic forces alone. The separation between the two first magnets has become smaller. Again this distance is read.
A fourth magnet is added and the procedure repeated. Also a fifth - and sixth magnet follow.
The table in Figure 1 shows a typical result of our measurements.

Explanation: Supposing that the force between magnetic (mono)poles is like Coulomb's law for electric charges, then we can write: $F_{poles} = k\frac{p_1 p_2}{r^n}$ (p_1 and p_2 are the "magnetic pole strength" of pole 1 and pole 2).
Between real magnets, being dipoles, the force between them will be of a higher power then the foregoing "Coulomb's law for magnets" indicates. So, we write: $F_{magnets} = c\frac{R_1 R_2}{r^m}$.
The first measurement (with two magnets) gives: $F_1 r_1^m = cR_1R_2$.
The second measurement (with three magnets) gives: $F_2 r_2^m = cR_1R_2$.

force between magnets (1)

Since $F_2=2F_1$ (see Figure 2), we find: $\frac{r_1}{r_2}=\sqrt[m]{2}$

So measuring r_1 and r_2, we can determine *m*!

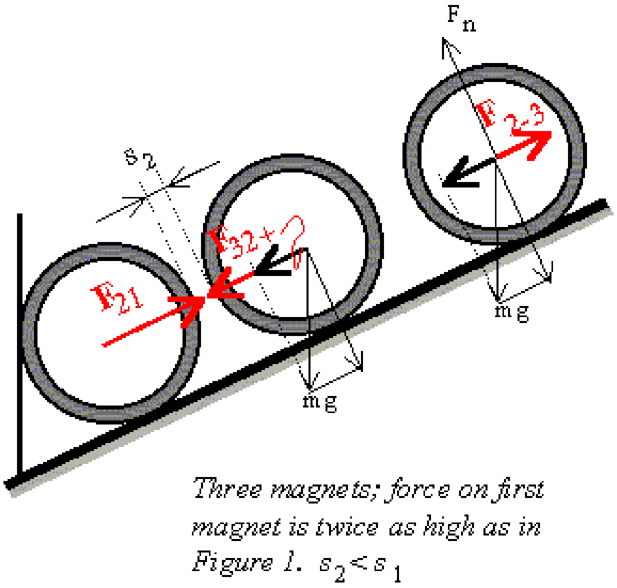


Figure 2

The result in Figure1 making $F_2=2F_1$, gives us 13.3/12.2=1.09, making *m*=7 ($2^{1/7}$=1.10).
The next measurement, with four magnets in total, making $F_3=3F_1$, gives us 13.3/11.4=1.17, making *m*=7 ($3^{1/7}$=1.17).
Next measurement, with five magnets in total, making $F_4=4F_1$, gives us: 13.3/11.2=1.19, making *m*=8 ($4^{1/8}$=1.19).
Our last measurement with six magnets, making $F_5=5F_1$, gives us: 13,3/11.0=1.21, making *m*=8 ($5^{1/8}$=1.22).

This demonstration shows that *r* has a high power (*m* = 7, 8), and, as the results slightly suggest, that this power increases as *r* increases.
The Explanation in the next demonstration in this database ("Force between magnets (2)") shows that when dipoles are far enough away from each other that the theoretical *m*-value = 4. In our demonstration with ring magnets so close to each other, this is not the situation.
A second objection can be that these ring magnets cannot be considered as simple dipoles.

Remarks:

- As an extra result we can also easily compare F_2 (= $2F_1$) and F_4 (= $4F_1$). Comparing these numbers gives: 12.2/11.2=1.09, so again: *m*=7.
- When all magnets are placed the increasing separation between them suggests that comparing these mutual separations will give the same result as we collected in Figure1 while looking at the changing separation between the first two magnets only. This other method can be used only when all magnets have the same strength (which usually is not so).

Sources:

- Mansfield, M and O'Sullivan, C., Understanding physics, pag. 474-475 and 484-486