



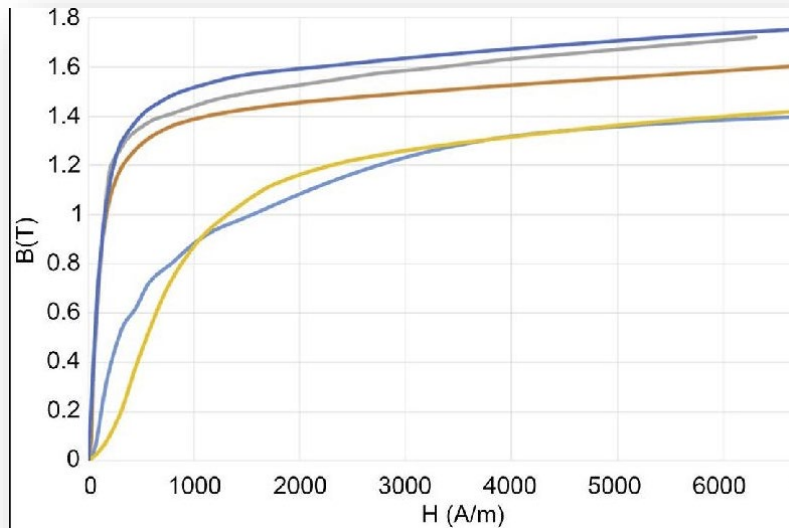
A Highschool Dissertation - Physics
A floating train

The project was carried out for two years at Idan Technology by two local high school students

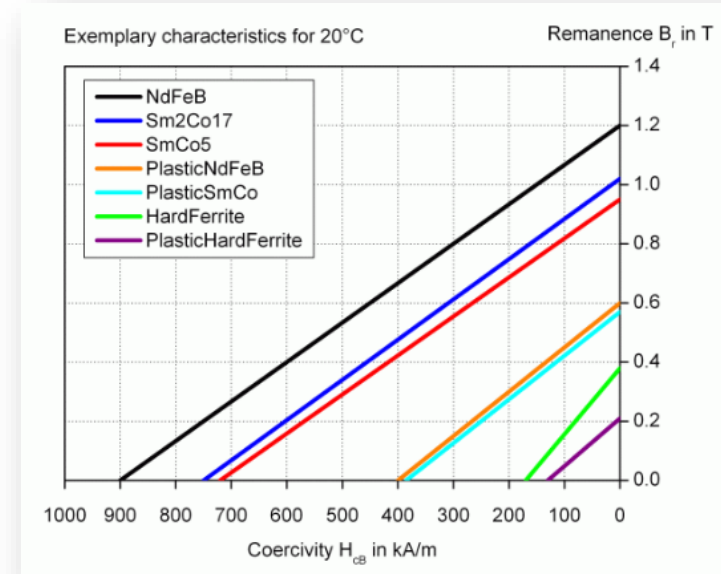
Advised by **Zvika Raviv**, lead engineer at Gevasol Group



Magnetic steels and Permanent Magnets basics



Magnetic characteristic of magnetic steels



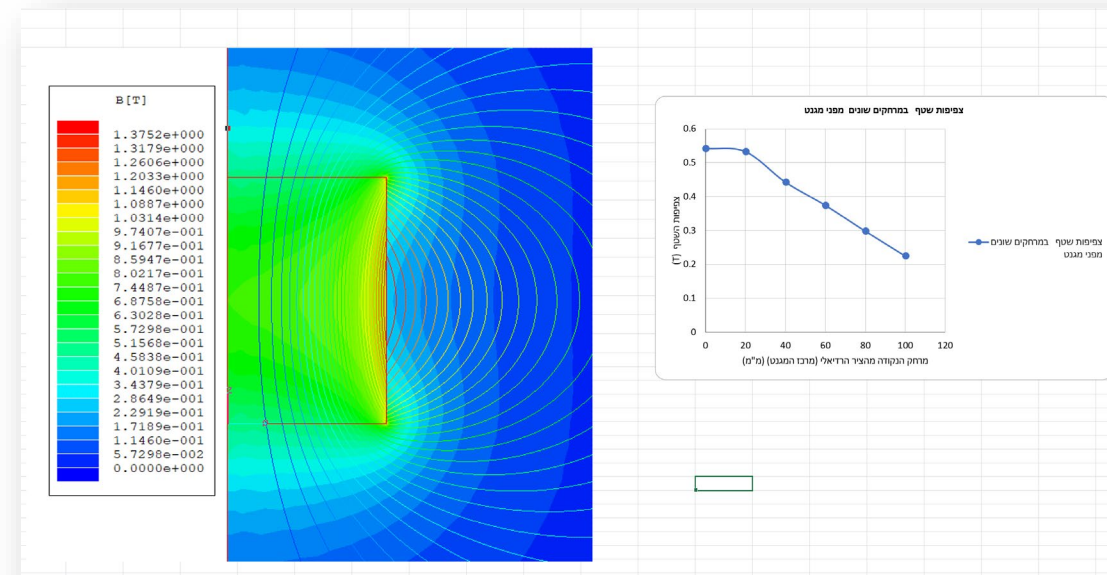
Magnetic characteristics of permanent magnets

Permanent magnets - learning with the help of magnetic software

Learning two-dimensional analysis software

Studying and understanding the meaning of the various magnetic parameters

- Magnetic flux
- Magnetic flux density
- Magnetic field strength



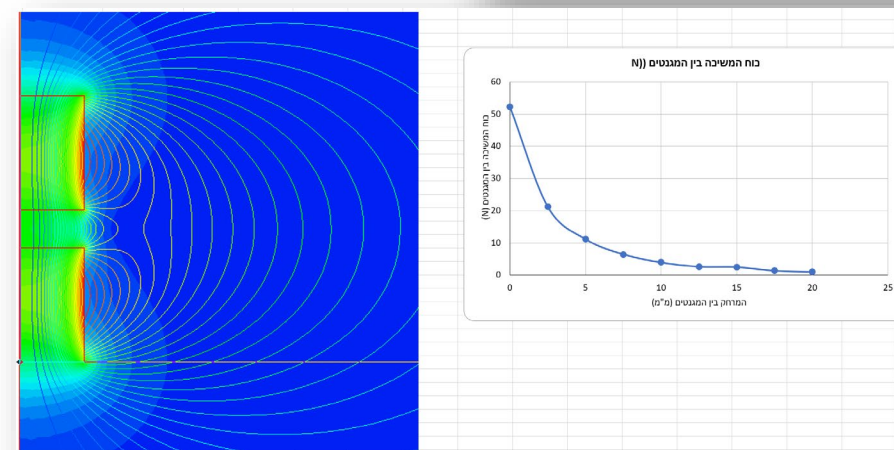
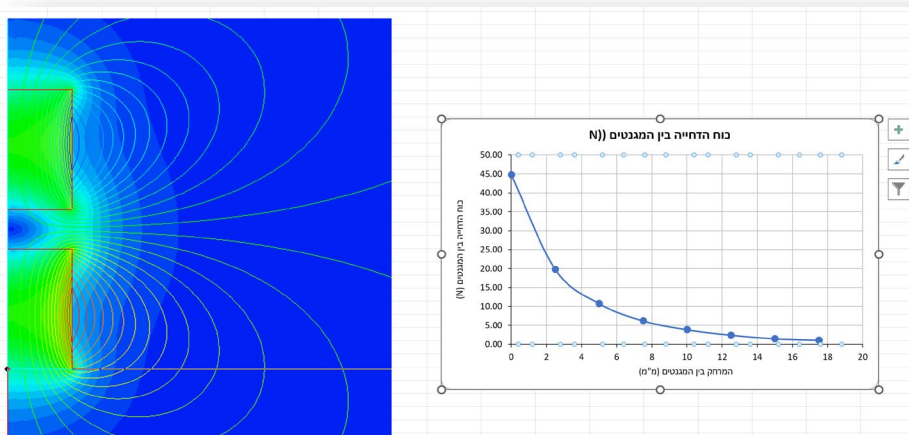
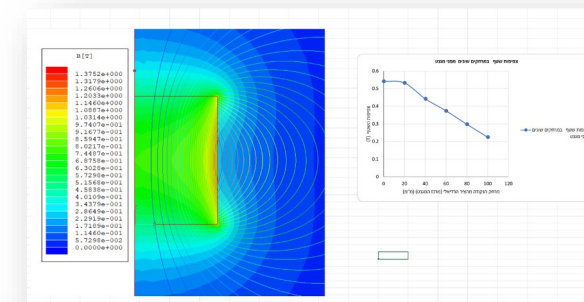
Flux density map of permanent magnet

Permanent magnets - learning with the help of magnetic software

Learning two-dimensional analysis software

Studying and understanding the meaning of the various magnetic parameters

- Magnetic flux
- Magnetic flux density
- Magnetic field strength
- Forces between permanent magnets

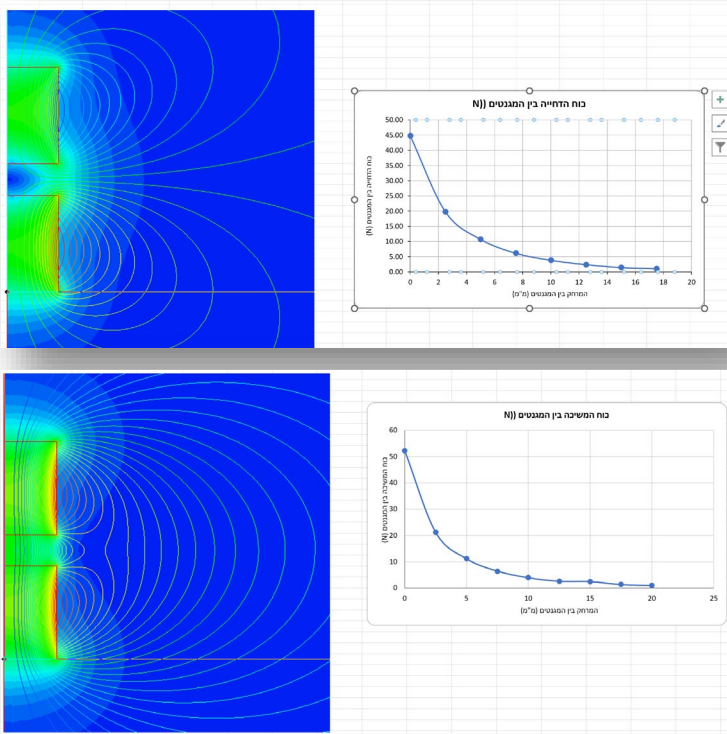


Repulsion force between two permanent magnets

Attraction force between two permanent magnets

Permanent magnets - learning with the help of magnetic software and practical verification

- Forces between magnets - attraction/repulsion

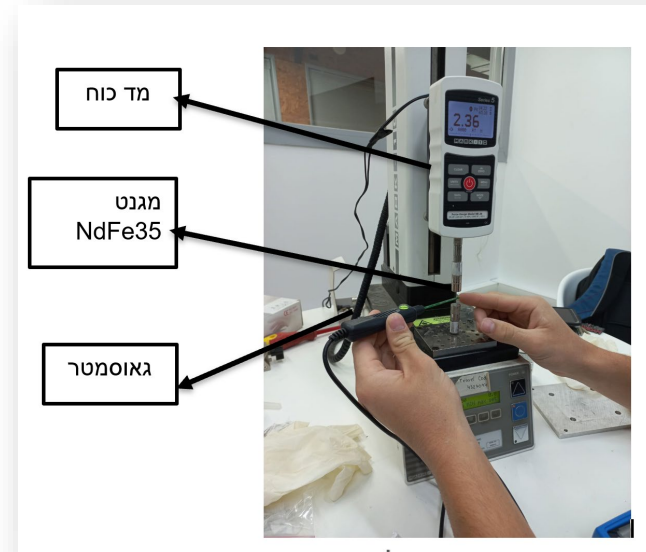


מרחק בין המגנטים (mm)	כוח המשיכה בין המגנטים (N)
20	0.99
17.5	1.35
15	2.5
12.5	2.64
10	3.93
7.5	6.47
5	11.16
2.5	21.21
0	52.23

As calculated

מרחק בין המגנטים (mm)	כוח המשיכה בין המגנטים (N)
20	1.1
17.5	1.5
15	2.1
12.5	3.1
10	4.9
7.5	7.7
5	12.8
2.5	24.1
1	38.2
0.5	45.8
0	56.9

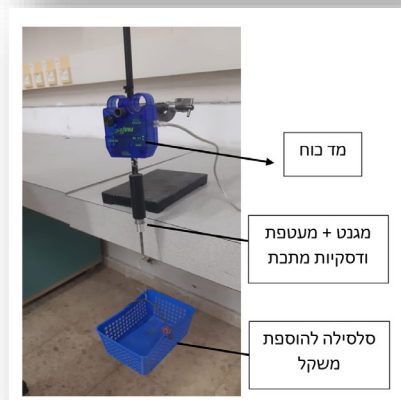
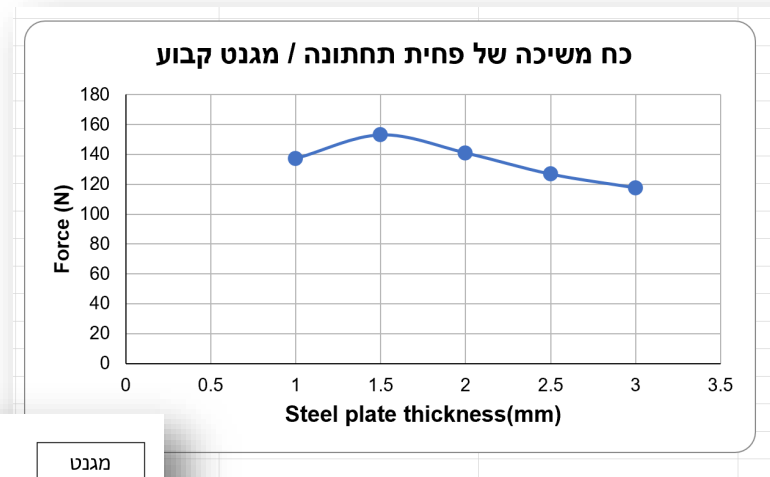
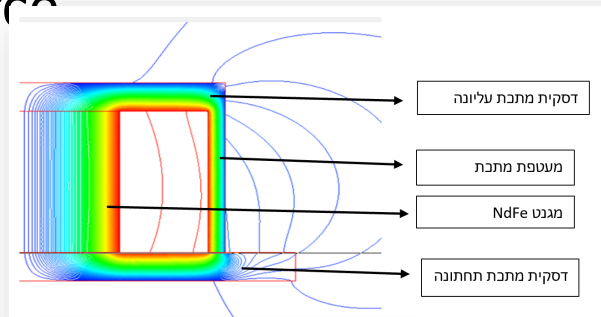
As measured



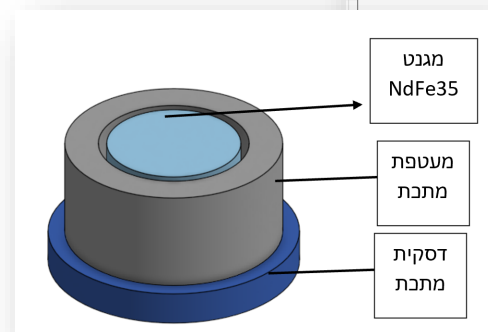
Attraction force between permanent magnets

Permanent magnets - learning with the help of magnetic software and practical verification

Magnetic forces - use of iron to concentrate flux that increases the force



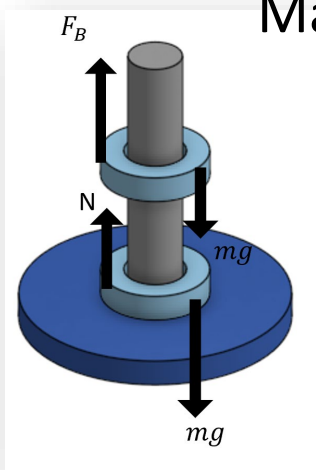
The setup of the experiment



Attraction force of the lower steel plate

Permanent magnets and electric current - summary

Magnetic Forces



Repulsive force testing array

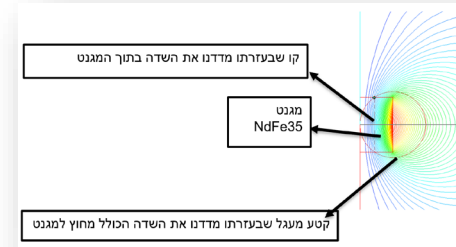
$$F \simeq \left[\frac{B_0^2 A^2 (L^2 + R^2)}{\pi \mu_0 L^2} \right] \left[\frac{1}{x^2} + \frac{1}{(x+2L)^2} - \frac{2}{(x+L)^2} \right]$$

- B_0 - צפיפות השטף קרוב מאוד לקטבים [T]
- A - השטח של הקטבים [m^2]
- L - האורך של כל אחד מהמגנטים [m]
- R - הרדיוס של כל אחד מהמגנטים [m]
- x - המרחק בין מגנטים [m]
- μ_0 - קבוע פרמאביליות הריק $1.257 \cdot 10^{-6} [H \cdot m^{-1}]$

$$F = -\frac{q*q}{4\pi r^2} - \frac{q*q}{4\pi(r+2d)^2} + 2 * \frac{q*q}{4\pi(r+d)^2} -$$

Approximate formulas in terms of dipoles
in terms of distances and magnet size
when $X \gg L$

$$\oint H * dl = I$$



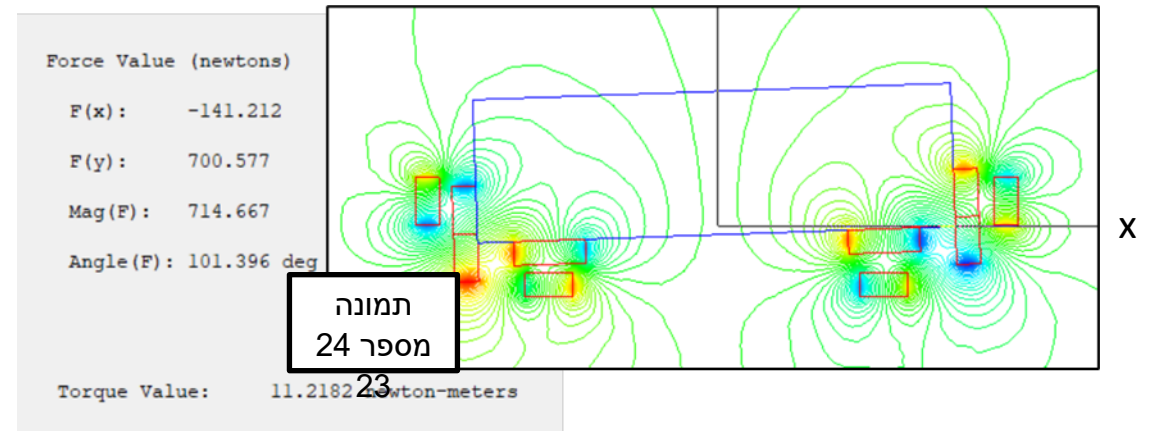
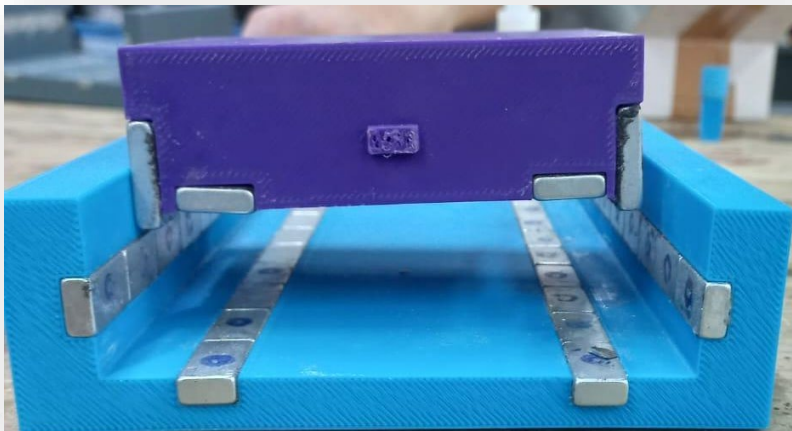
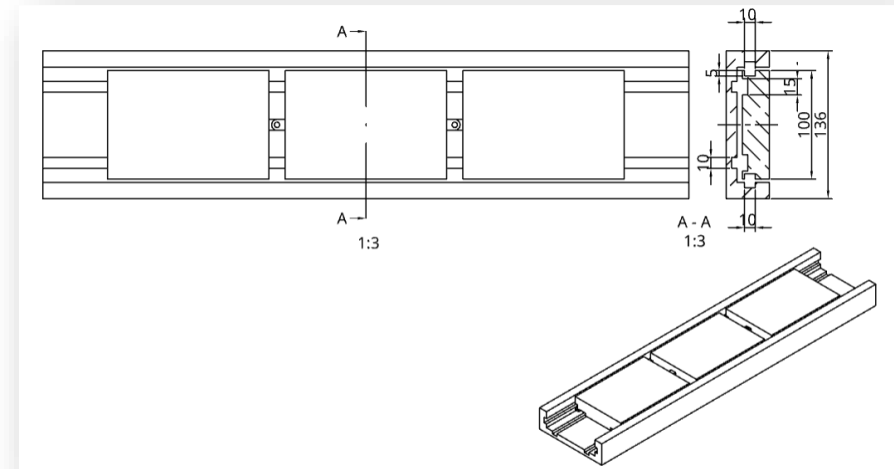
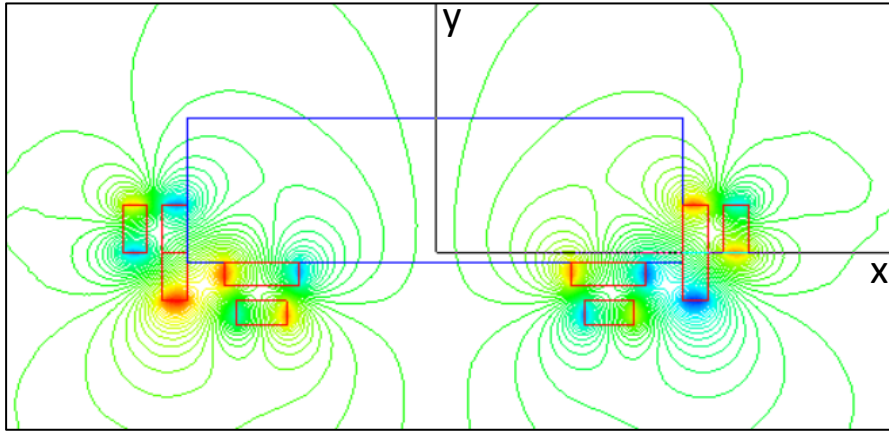
Ampere's law

For a permanent magnet $I=0$, a calculation was made using the software

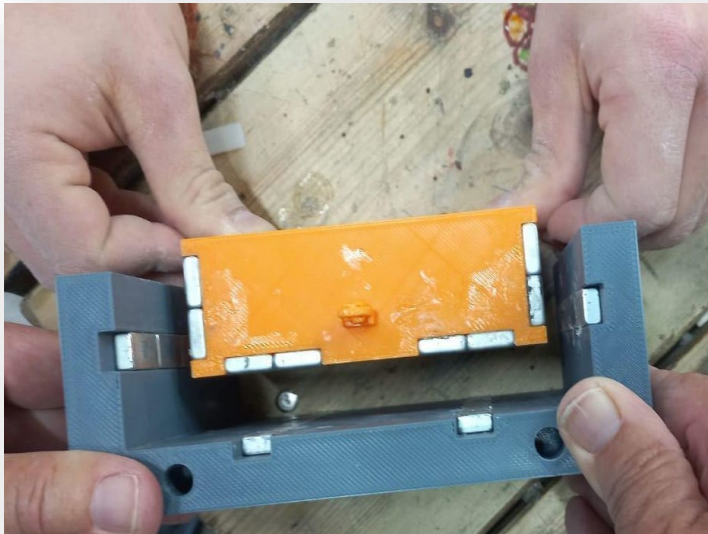
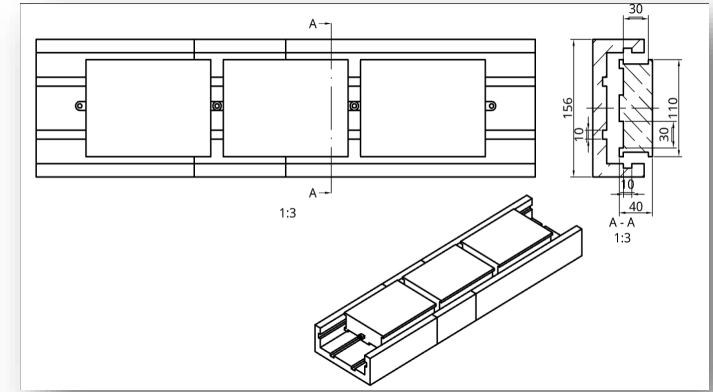
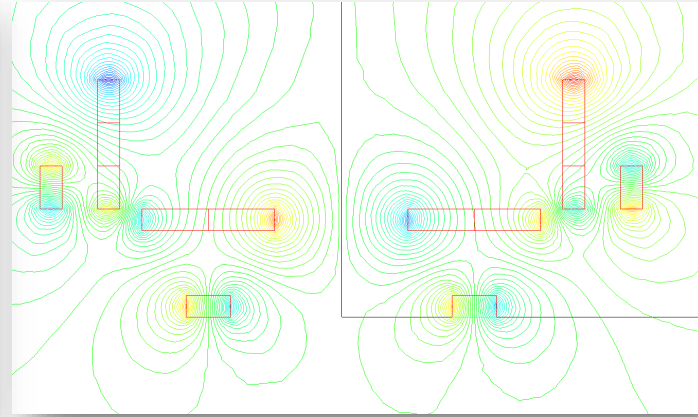
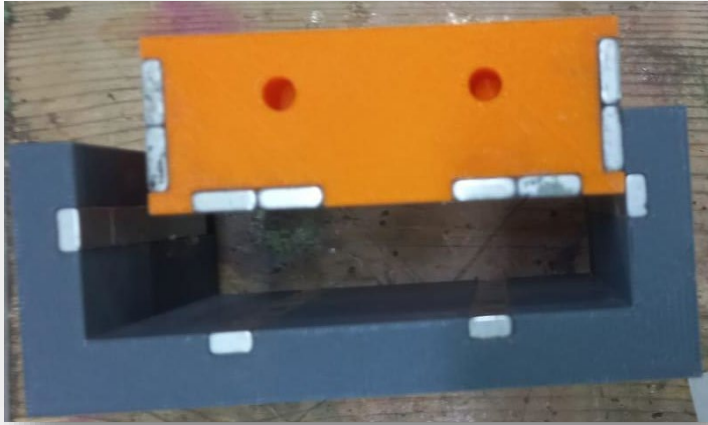
Magnetic levitation design and execution

- Using magnetic simulation software, each planned design was modeled to test its actual execution before being executed.
- As the various structures were being designed, forces and rotational moments were studied to provide answers to the conduct of the various structures.
- As a result, the students applied judgment, thought about how to improve, and made progress.
- Using the software, they checked positional changes of the "car" in front of the rail and got appropriate or opposite forces and torques.

Magnetic levitation - design and execution of a first model

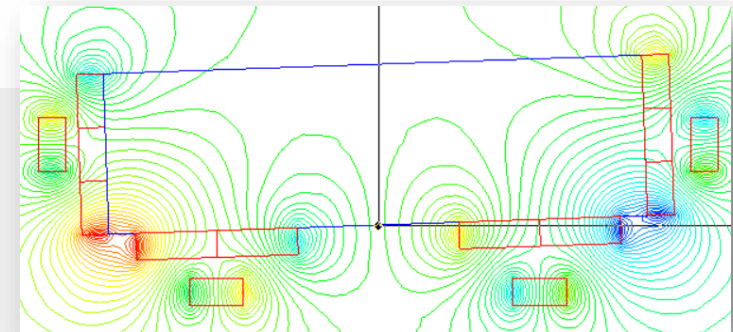


Magnetic levitation - design and execution of a second model

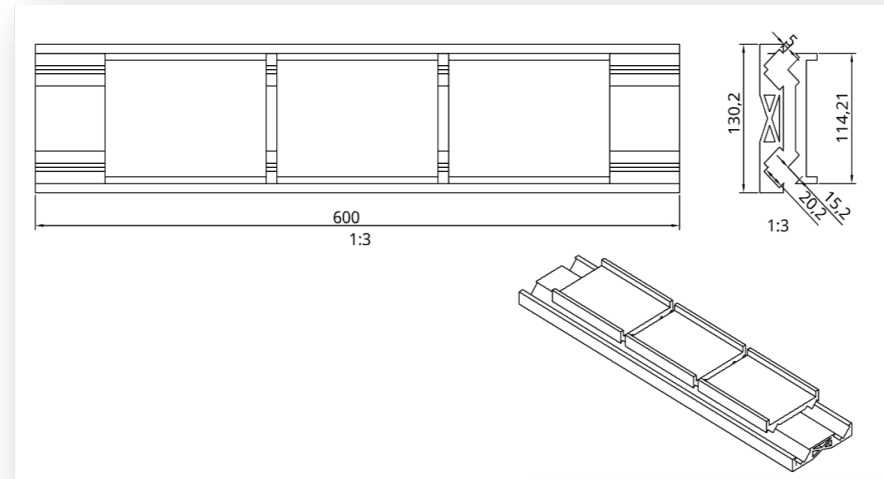
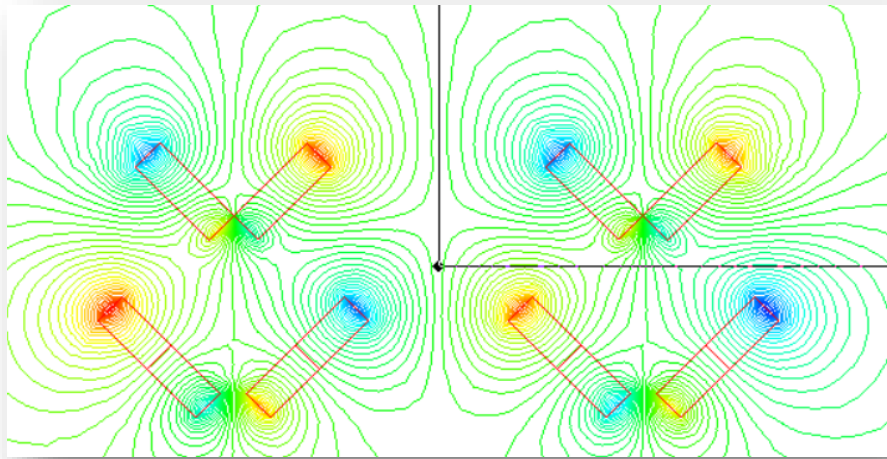


Force Value (newtons)
F(x): -76.4678
F(y): 498.548
Mag(F): 504.379
Angle(F): 98.7201 deg

Torque Value: -2.98795 newton-meters

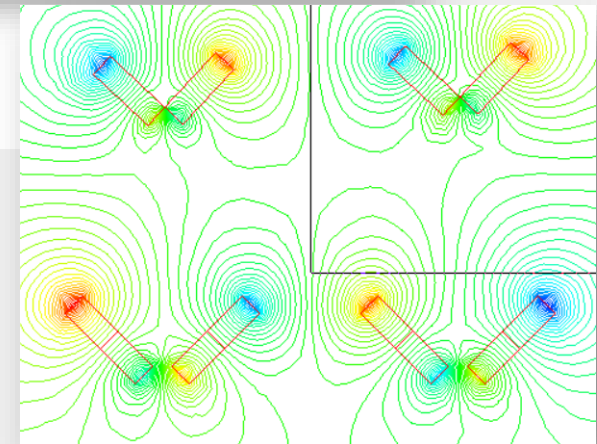


A third model for magnetic levitation is designed and executed / a stable model is achieved



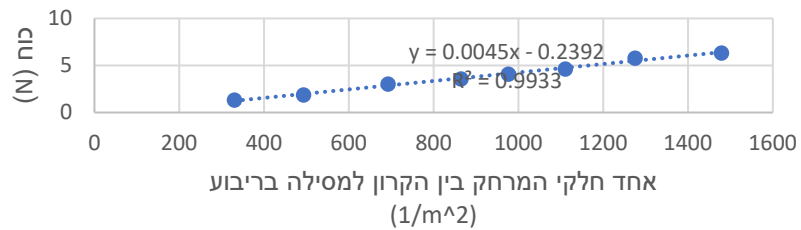
Force Value (newtons)
F(x): 20.276
F(y): 256.08
Mag(F): 256.881
Angle(F): 85.4729 deg

Torque Value: -2.1205 newton-meters

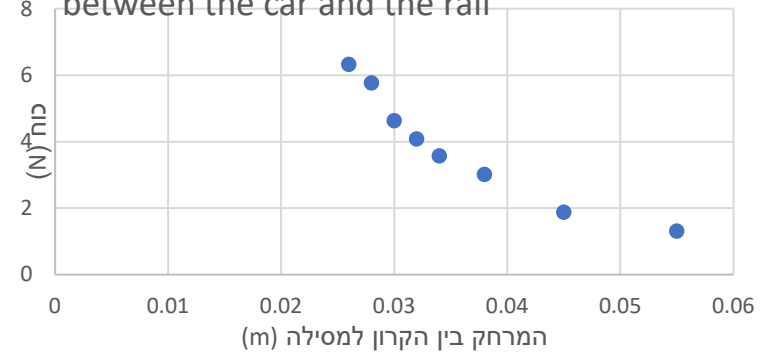


Magnetic levitation - design and execution of a third model / weight loading

The force as a function of one divided by the distance between the car and the rail squared



Force as a function of the distance between the car and the rail



To sum up:

"The project lasted for two school years. It was a fascinating experience and sheer pleasure meeting the students' curiosity, learning, creativity, and results. Even though the results were not what we had hoped for, we still have a working product that could be improved.

"Many thanks to Miki, the accompanying teacher, and Omer and Tal, the students who played a crucial role in making the experience enjoyable." Zvika Raviv

