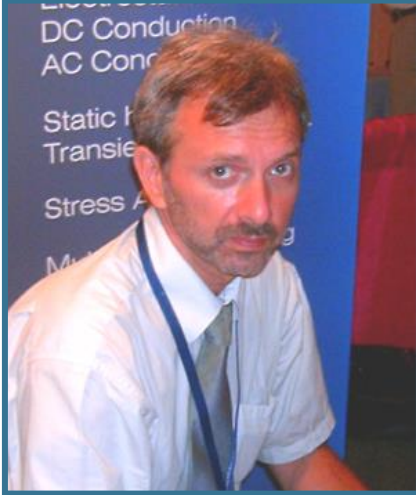


DC Magnetic simulation with QuickField



Vladimir Podnos

**Director of Marketing and Support
Tera Analysis Ltd.**



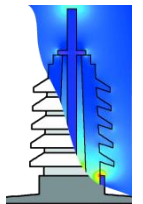
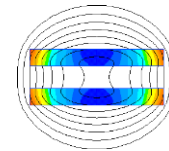
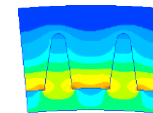
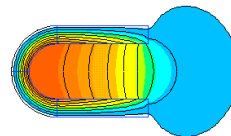
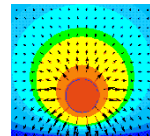
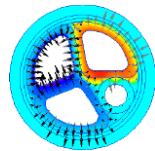
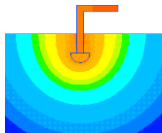
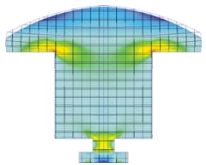
Alexander Lyubimtsev

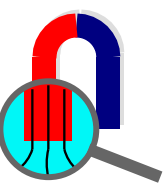
**Support Engineer
Tera Analysis Ltd.**



QuickField Analysis Options

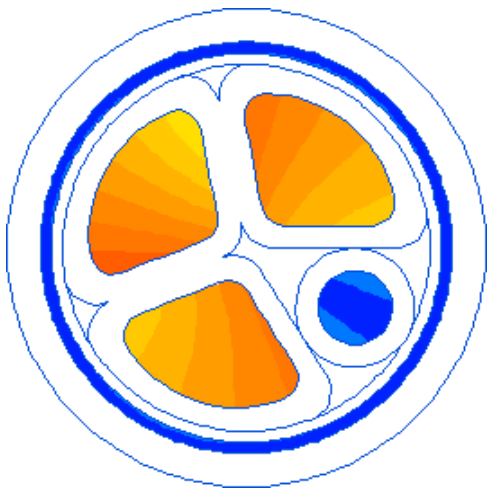
Magnetic analysis suite	Magnetostatics
	AC Magnetics
	Transient Magnetic
Electric analysis suite	Electrostatics (2D,3D) and DC Conduction (2D,3D)
	AC Conduction
	Transient Electric field
Thermostructural analysis suite	Steady-State Heat transfer (2D,3D)
	Transient Heat transfer
	Stress analysis





MultiPhysics (2D)

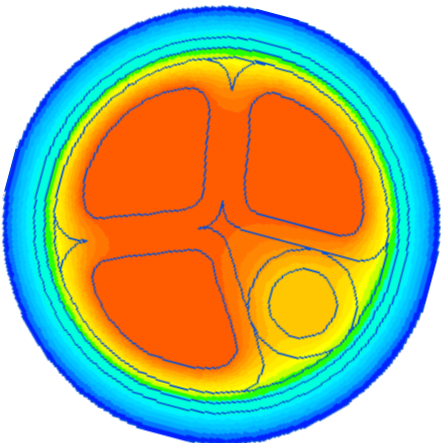
Electromagnetic
fields



Losses

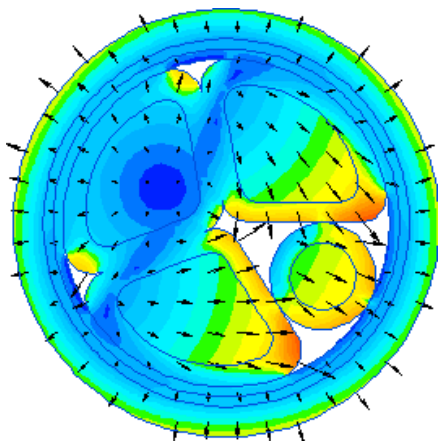


Temperature field



Temperature
field import

**Thermal
Stresses**



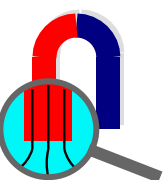
Forces



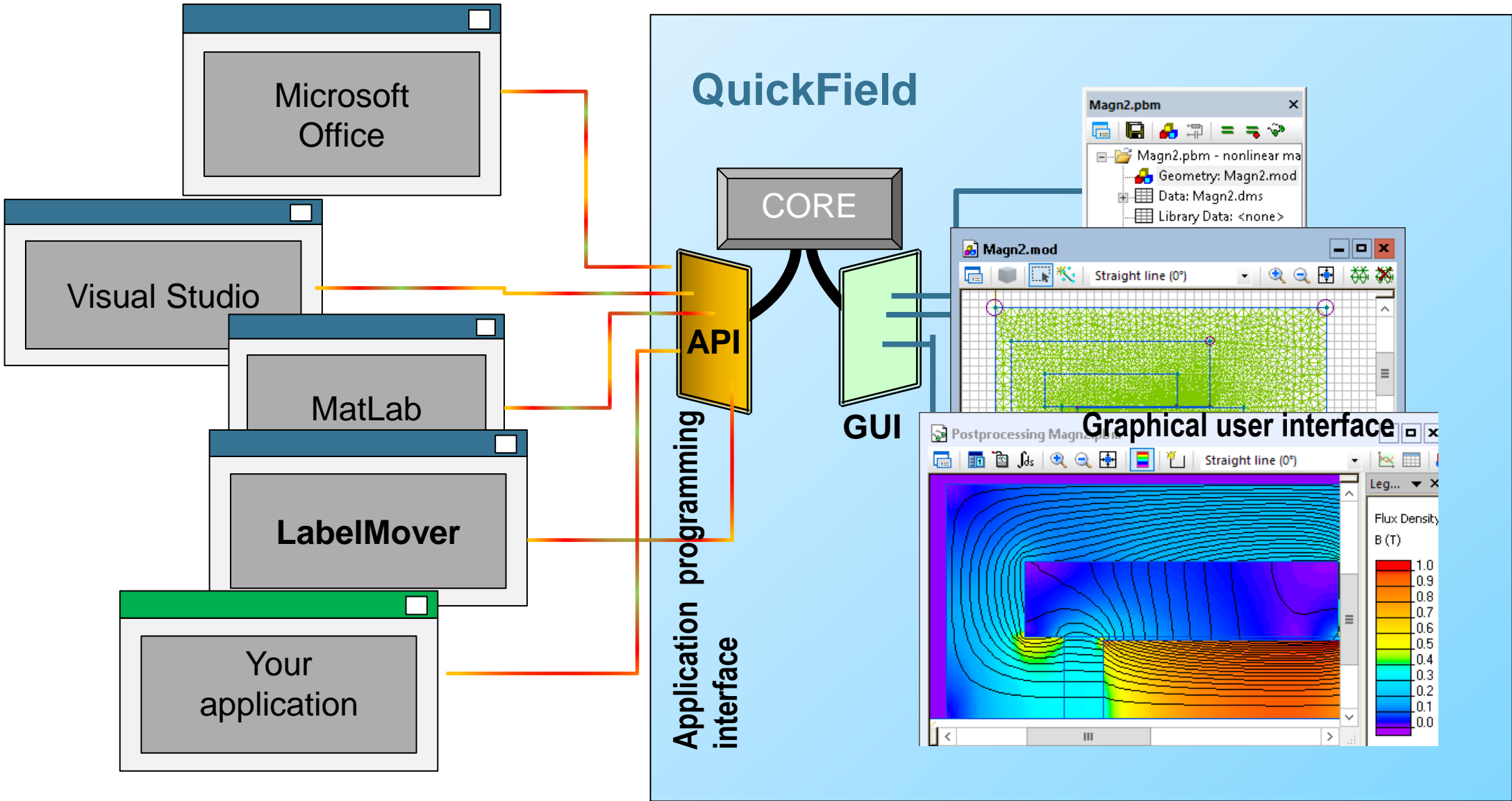
Stresses & Deformations

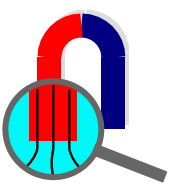
Magnetic state
import





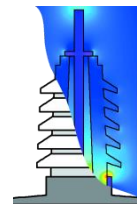
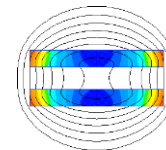
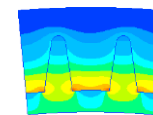
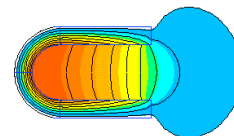
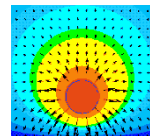
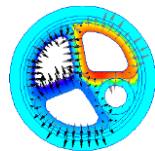
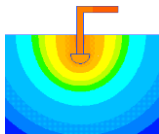
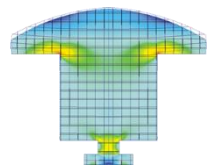
QuickField API

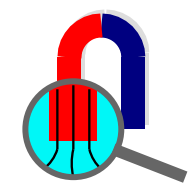




QuickField Magnetostatics

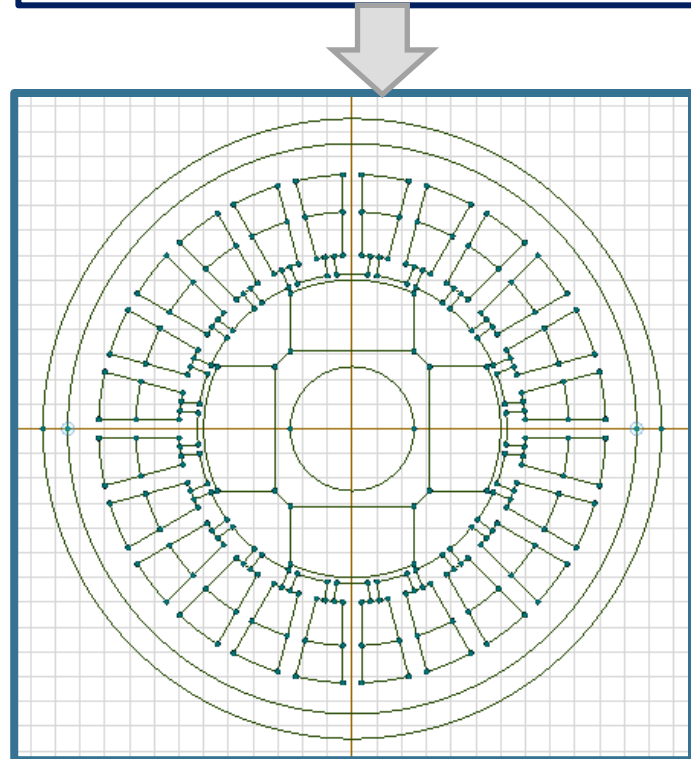
Magnetic analysis suite	Magnetostatics
	AC Magnetics
	Transient Magnetic
Electric analysis suite	Electrostatics (2D,3D) and DC Conduction (2D,3D)
	AC Conduction
	Transient Electric field
Thermostructural analysis suite	Steady-State Heat transfer (2D,3D)
	Transient Heat transfer
	Stress analysis



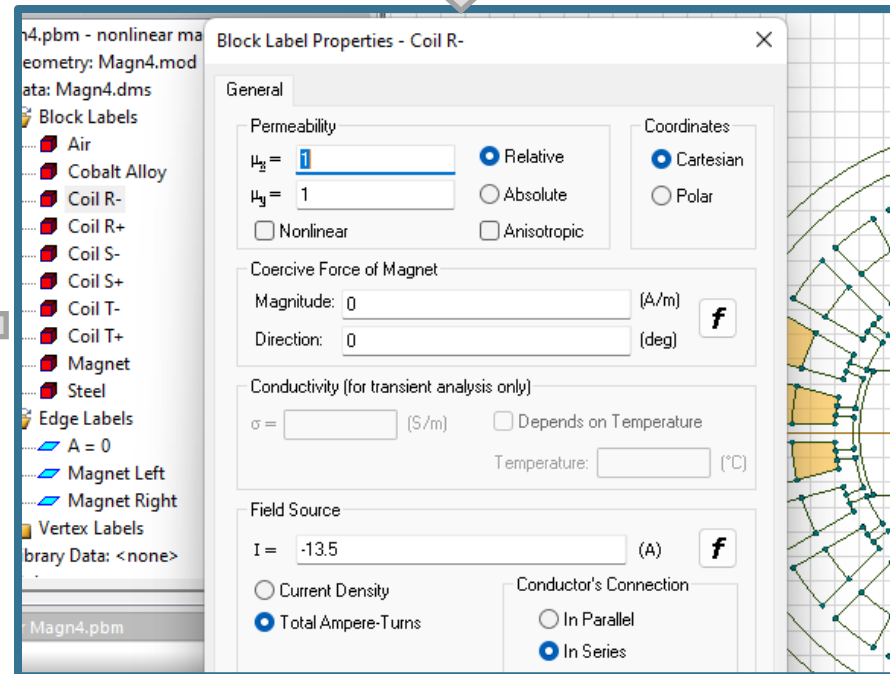


QuickField Workflow

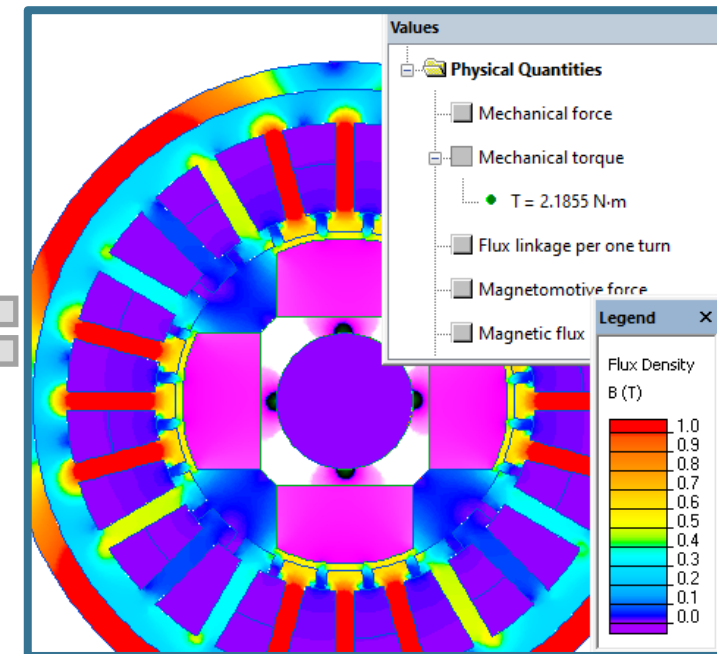
Problem setup



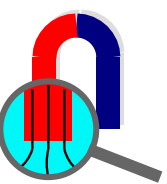
**Geometry definition
using the Model editor**



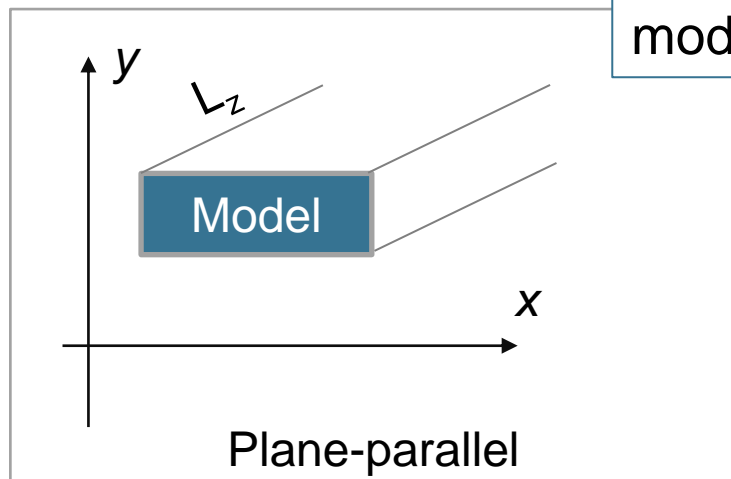
**Specifying the material properties,
field sources and boundary conditions
Using the Data Editor**



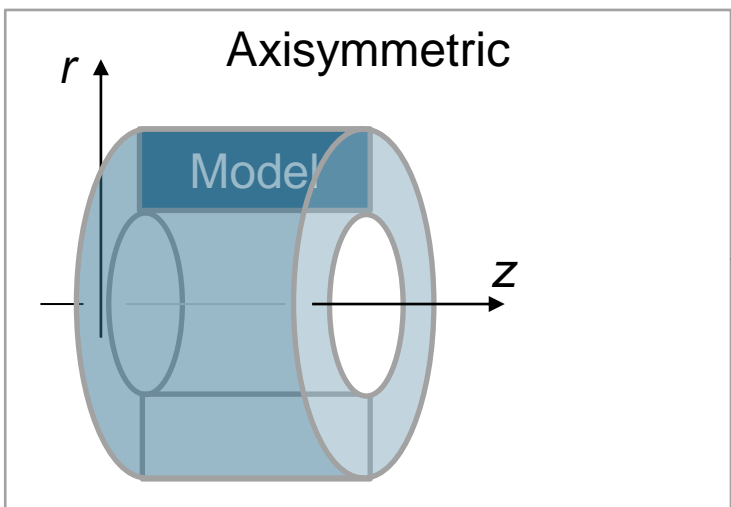
**Results analysis
using the Postprocessor**



QuickField Magnetostatics. Problem setup



Plane-parallel



Axisymmetric

2. Choose the model class

1. Choose the problem type: Magnetostatics

Problem Properties - Magn5_base.pbm

General Links

Problem Type: Magnetostatics

Length Units: Meters

Coordinate System: Cartesian

Precision: Normal

Model Class

Plane-parallel

Plane-parallel

Axisymmetric

$L_z = 1$ m

Files

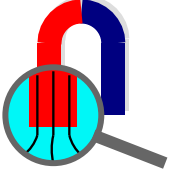
Geometry: Magn5.mod

Data: Magn5_base.dms

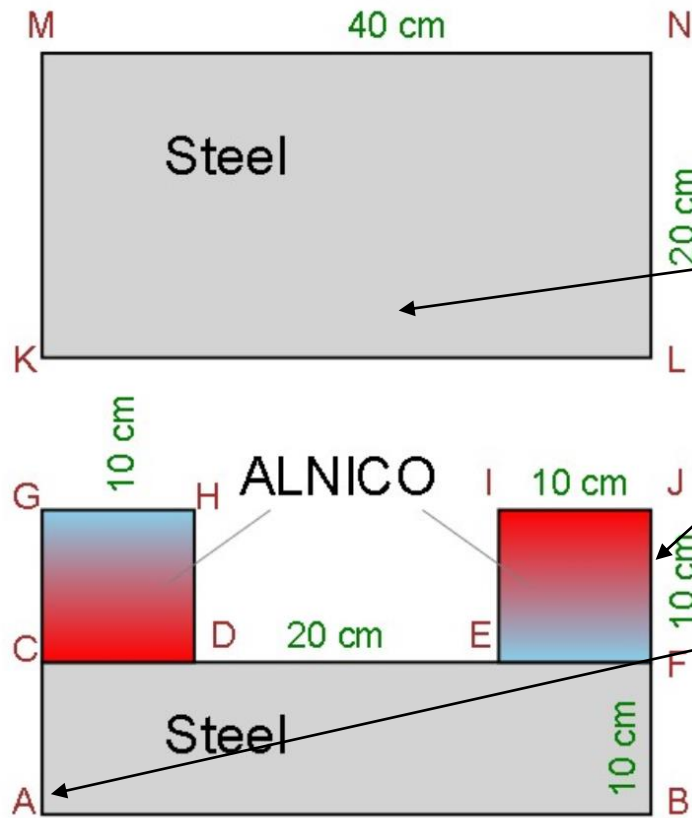
Library Data:

Location: D:\gdrive\websites\quickfield.com\seminar\dc_magn\magn5

OK Cancel Help



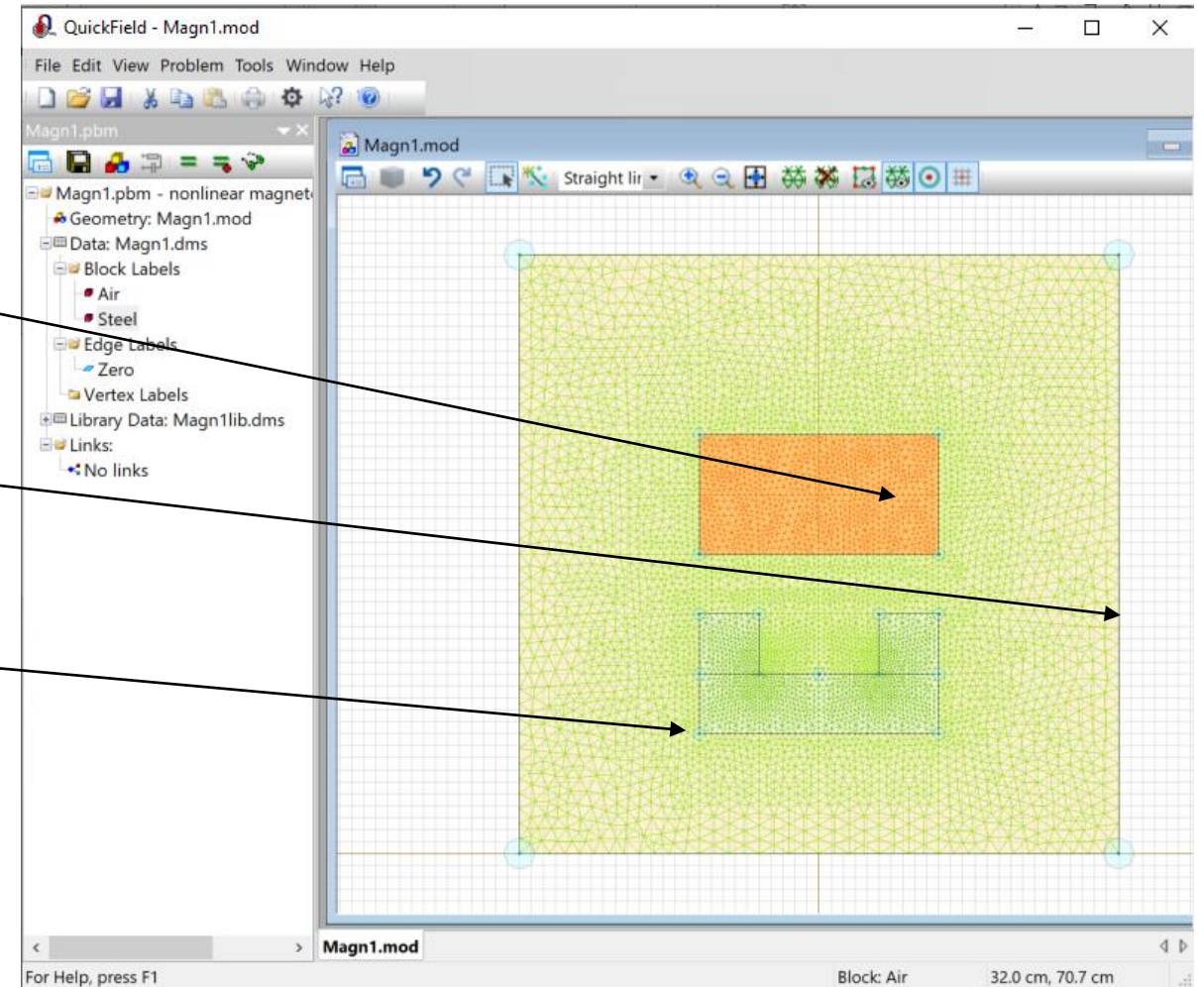
QuickField Magnetostatics. Geometry

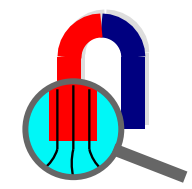


Block

Edge

Vertex

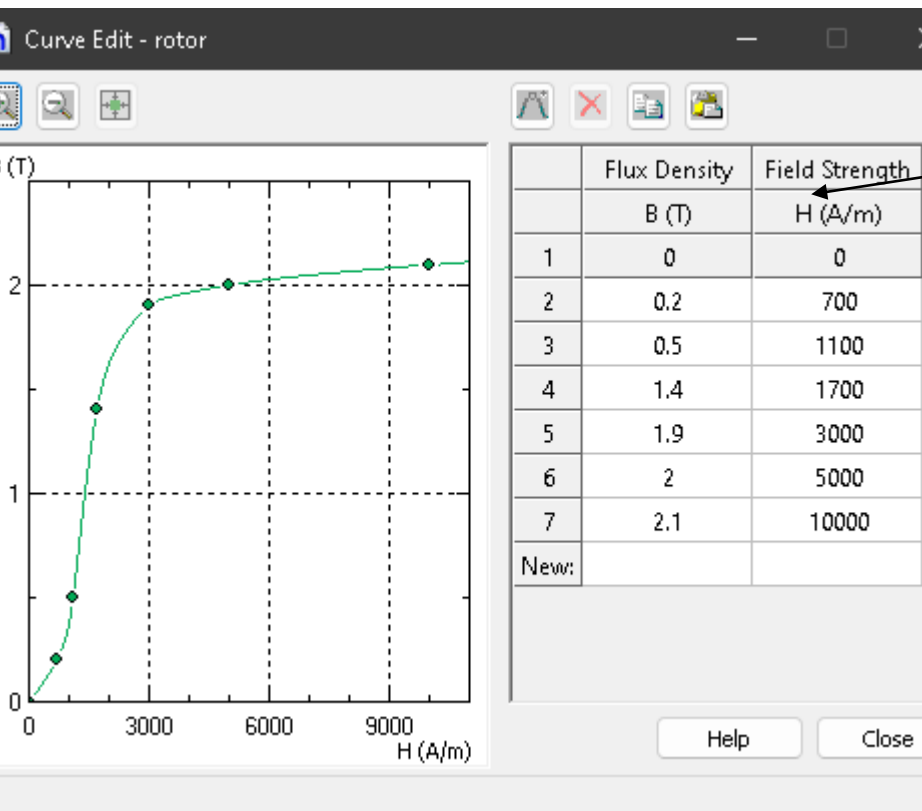




QuickField Magnetostatics. Label properties

Edge

Block



Block Label Properties - magnet E

General

Permeability

$\mu_x = 1$ $\mu_y = 1$

☒ Relative ☐ Absolute

☐ Nonlinear ☐ Anisotropic

Coordinates

☒ Cartesian ☐ Polar

Coercive Force of Magnet

Magnitude: 800000 (A/m)

Direction: 90 (deg)

Conductivity (for transient analysis only)

$\sigma =$ (S/m)

Field Source

$j =$ (A/m²)

☒ Current Density ☐ Total Ampere-Turns

Conductor's Connection

☒ In Parallel ☐ In Series

Formulas are supported

OK Cancel Help

Edge Label Properties - symmetry

General

☒ Magnetic Potential: $A = A_0$

$A_0 = 0$ (Wb/m)

☐ Tangential Field: $H_t = \sigma$ ($\Delta H_t = \sigma$)

$\sigma = 0$ (A/m)

☐ Zero Normal Flux: $B_n = 0$

☐ Even Periodic: $A_1 = A_2$

☐ Odd Periodic: $A_1 = -A_2$

Vertex

Vertex Label Properties - current

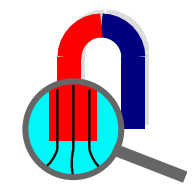
General

☐ Magnetic Potential: $A = A_0$

$A_0 = 0$ (Wb/m)

☒ Linear Current

$I = 5 * \text{sqrt}(2)$ (A)



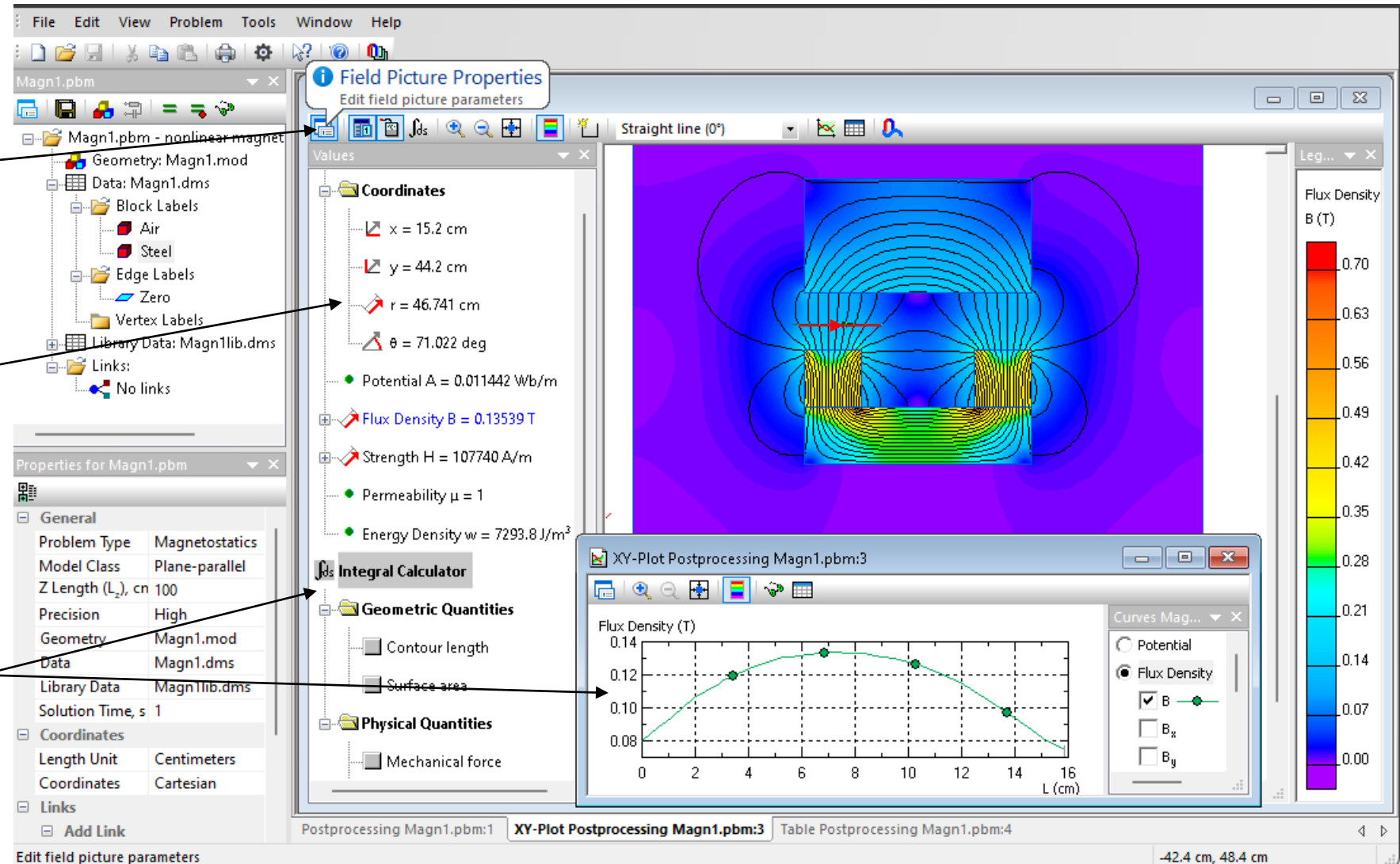
QuickField Magnetostatics. Results

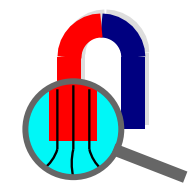
Results analysis is the most complicated part, having more options. Generally the following types of result analysis are available:

Field maps showing the space distribution of different field parameters

Field parameters in arbitrary point

Contour analysis, including field parameters distribution and integral calculations





QuickField Magnetostatics. Results

Field maps

Field Picture Properties

☒ Equilines of Potential Interval: 0.001 Wb
Base: 0 Wb

☒ Vectors of: Scale: 1
☒ Flux Density B Cell: 0.02 m
☐ Strength H

☒ Color Map of:
☐ Potential
☒ Flux Density
☐ Strength
☐ Misc. Quantities

Color Grades: 20
Maximum: 1.2 T
Minimum: 0 T

☐ Show Mesh

OK Apply Cancel Help Suggest

Local field data

Values

Local Values

Coordinates

- $x = -0.0408$ m
- $y = 0.0136$ m
- $r = 0.043007$ m
- $\theta = 161.57$ deg

Potential $A = -0.0047433$ Wb/m

Flux Density $B = 0.3382$ T

- Flux Density $B_x = -0.33805$ T
- Flux Density $B_y = 0.010048$ T

Strength $H = 51613$ A/m

- Strength $H_x = 50990$ A/m
- Strength $H_y = 7996.3$ A/m

Permeability $\mu = 1$

Energy Density $w = 1673.8$ J/m³

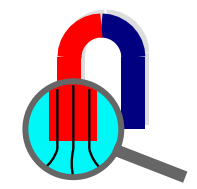
Integrals

Integral Calculator

Geometric Quantities

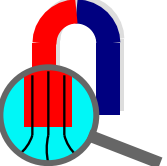
Physical Quantities

- Mechanical force
- Mechanical torque
- Flux linkage per one turn
- Magnetomotive force
- Magnetic flux
- Magnetic field energy
- Magnetic field co-energy
- Linearized field energy
- Surface energy
- Average surface potential
- Average volume potential
- Average volume flux density
- Average volume strength
- Mean square flux density

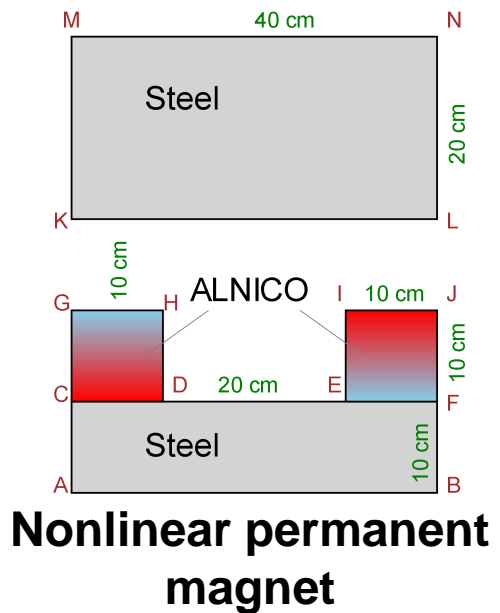


QuickField Difference

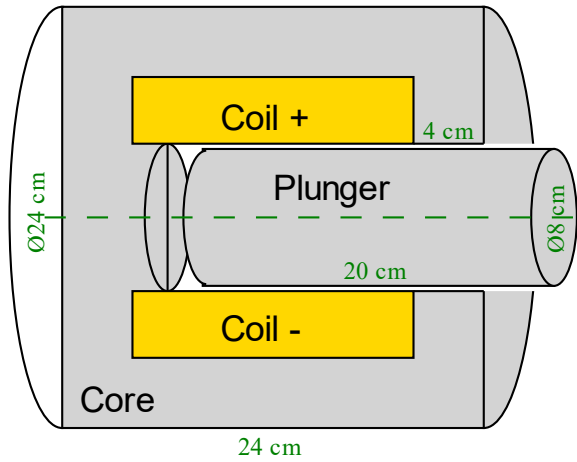




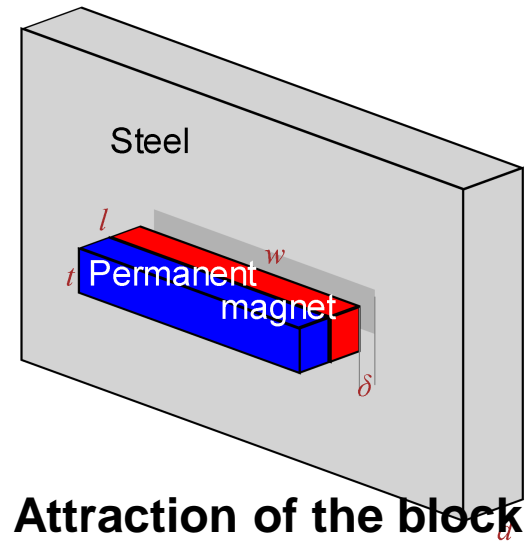
Magnetostatics simulation with QuickField



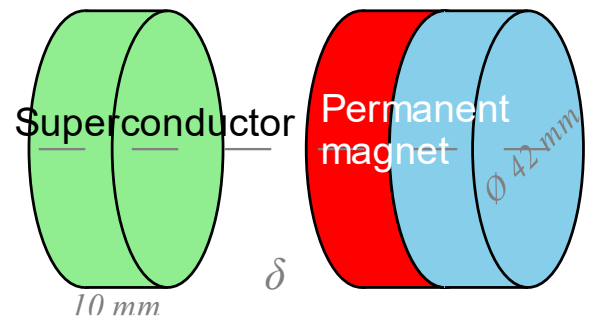
Nonlinear permanent magnet



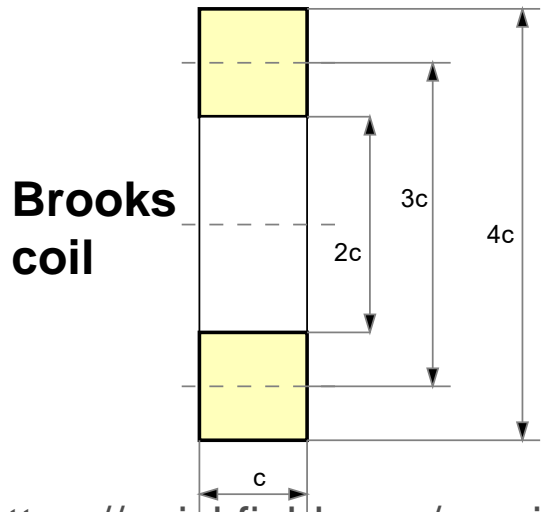
Solenoid actuator force



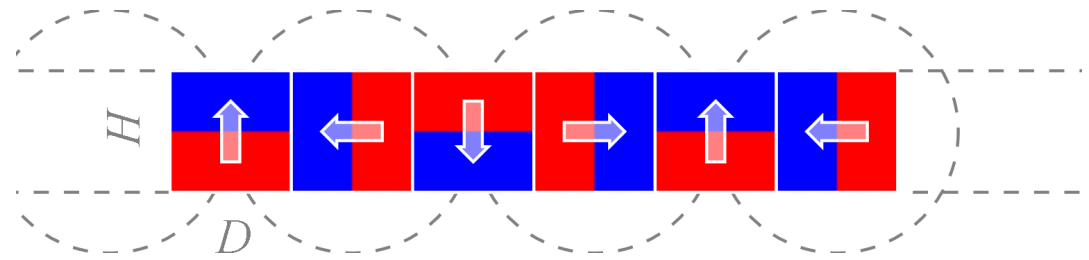
Attraction of the block magnet to the steel plate



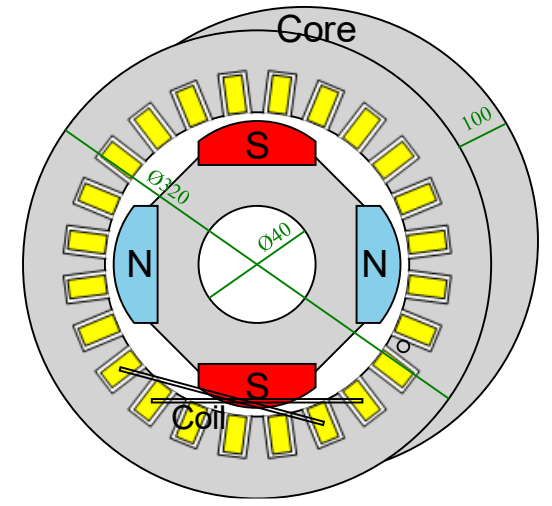
Superconductor levitation



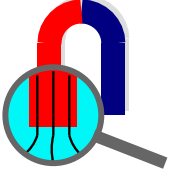
Brooks coil



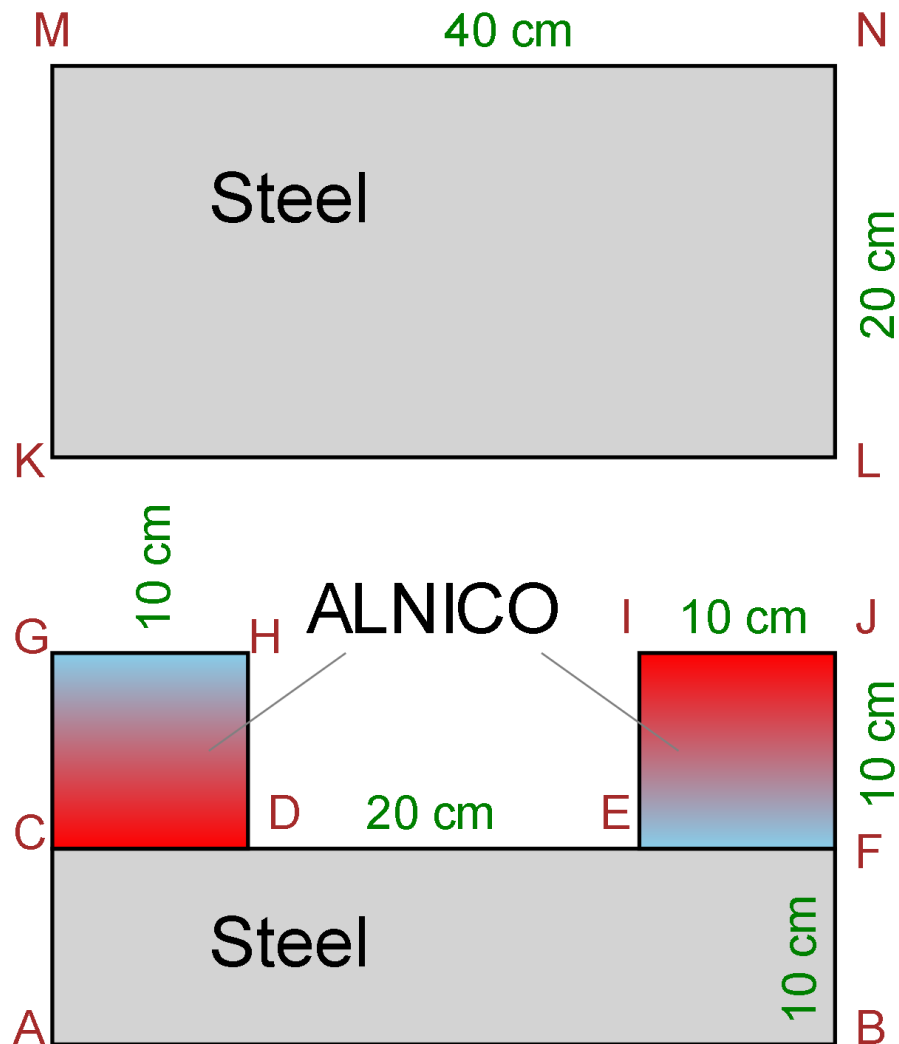
Halbach array



Armature winding inductance



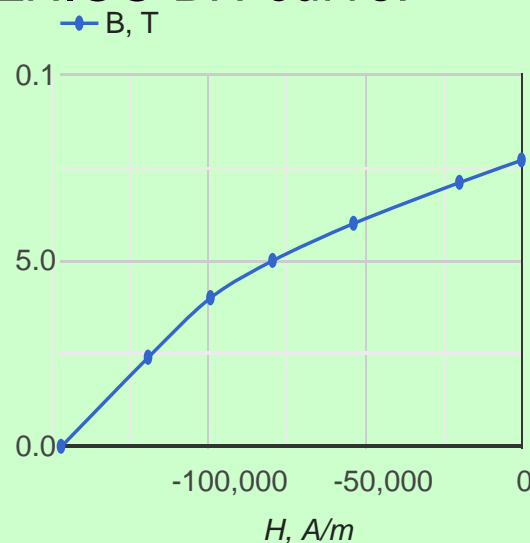
Nonlinear permanent magnet



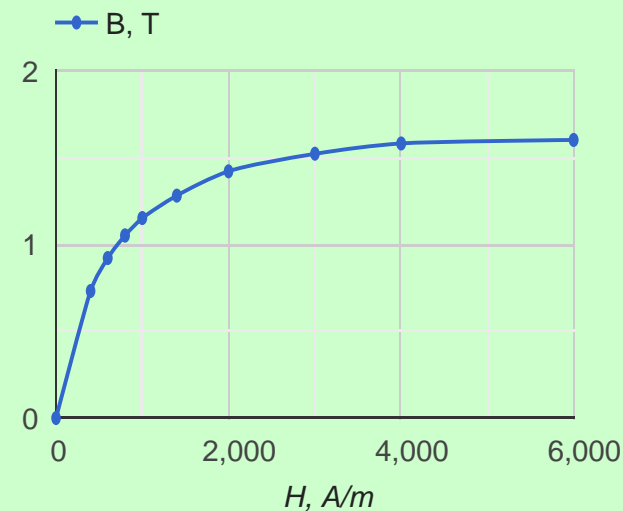
Problem specification:

The permanent magnets coercive force is 147 kA/m,

ALNICO BH-curve:

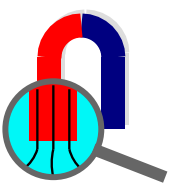


Steel BH-curve:

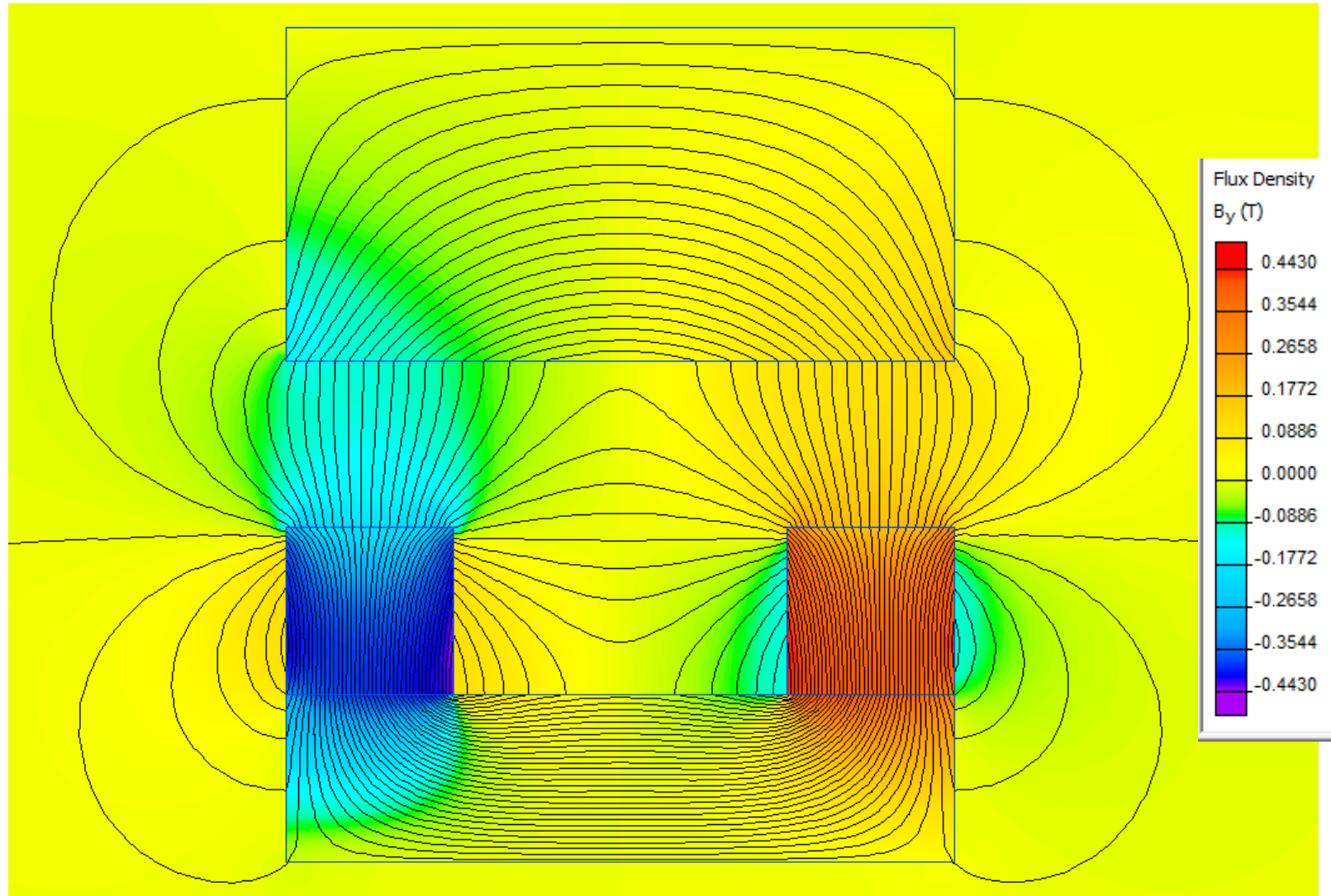


Task:

Calculate the force as a function of the yoke position.

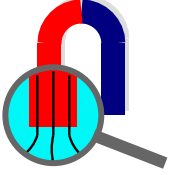


Nonlinear permanent magnet

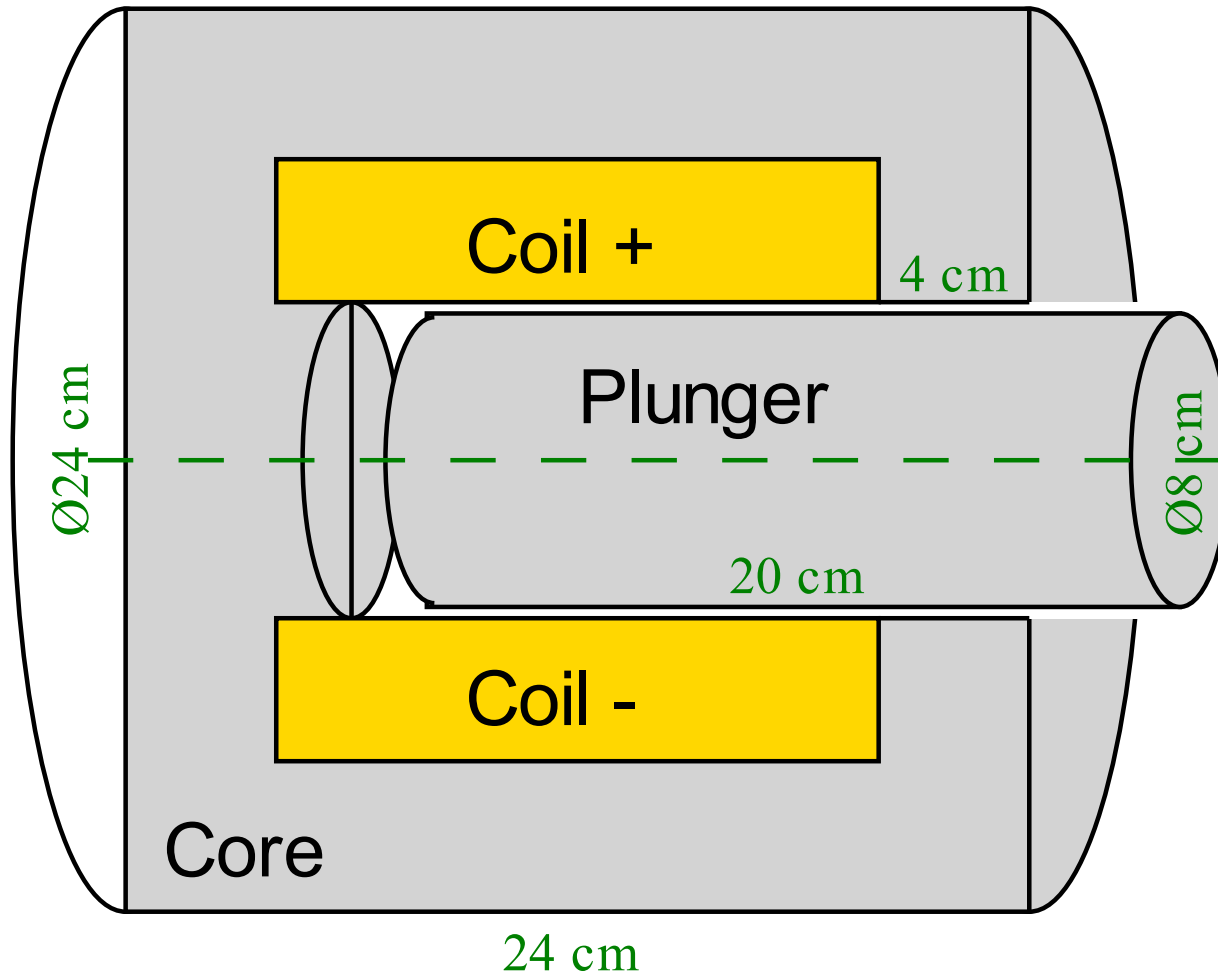


Values	
Physical Quantities	
Mechanical force	
f	$f = 1304.3 \text{ N}$
ϕ	$\phi = -89.897^\circ$
f_x	$f_x = 2.3342 \text{ N}$
f_y	$f_y = -1304.3 \text{ N}$

General	
Problem Type	Magnetostatics
Model Class	Plane-parallel
Z Length (L_z), cm	100

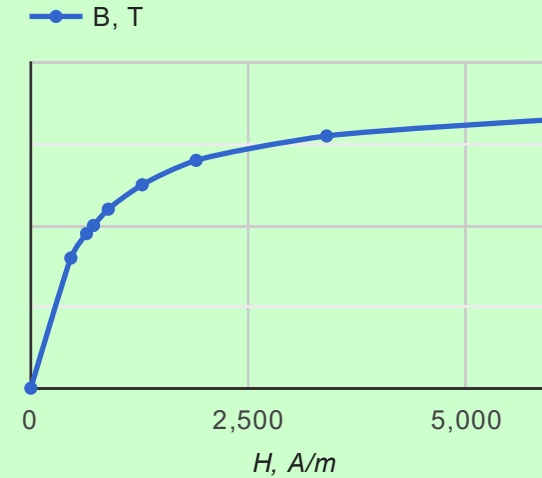


Solenoid actuator force



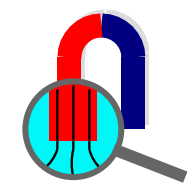
Problem specification:

Current density in the coil $j = 1 \text{ A/mm}^2$;
The BH-curve for the core and the plunger:

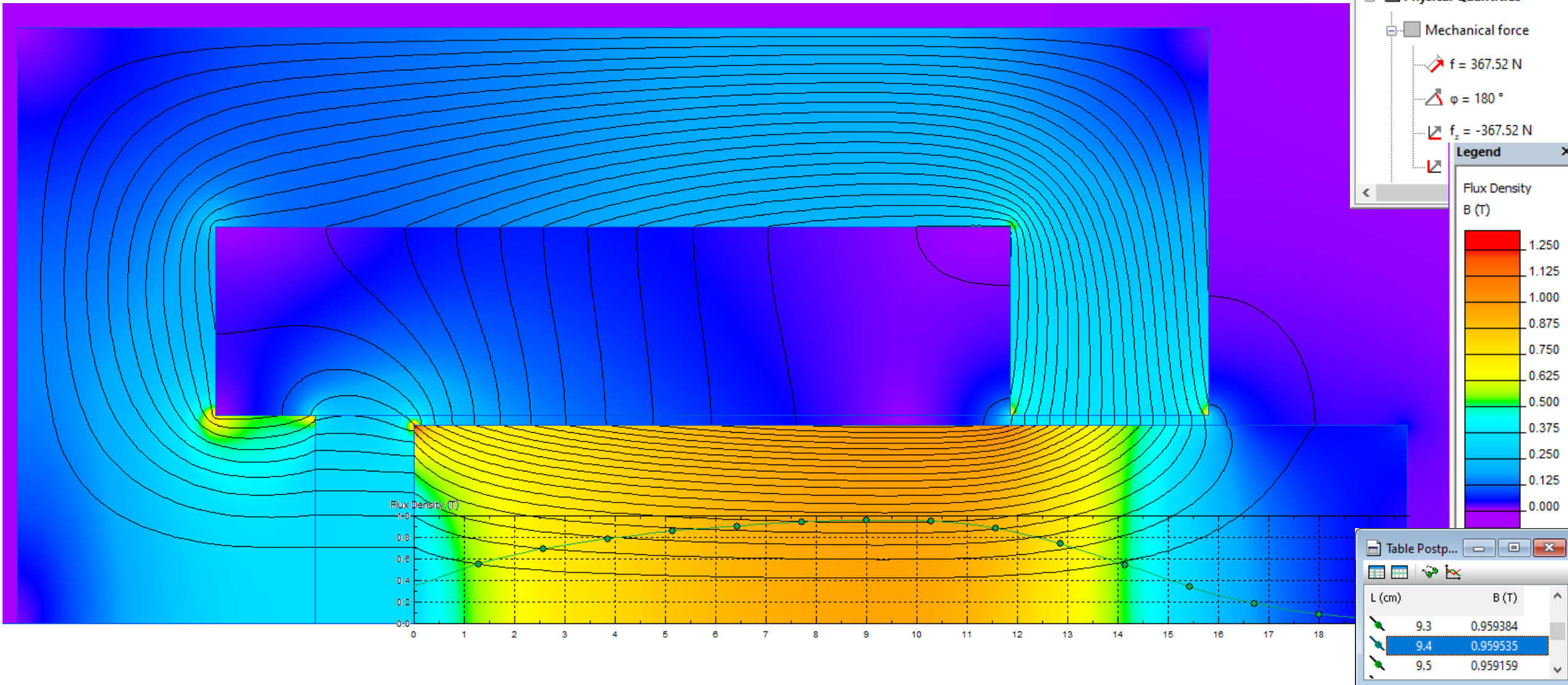


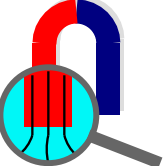
Task:

Calculate the force as a function of the plunger position.

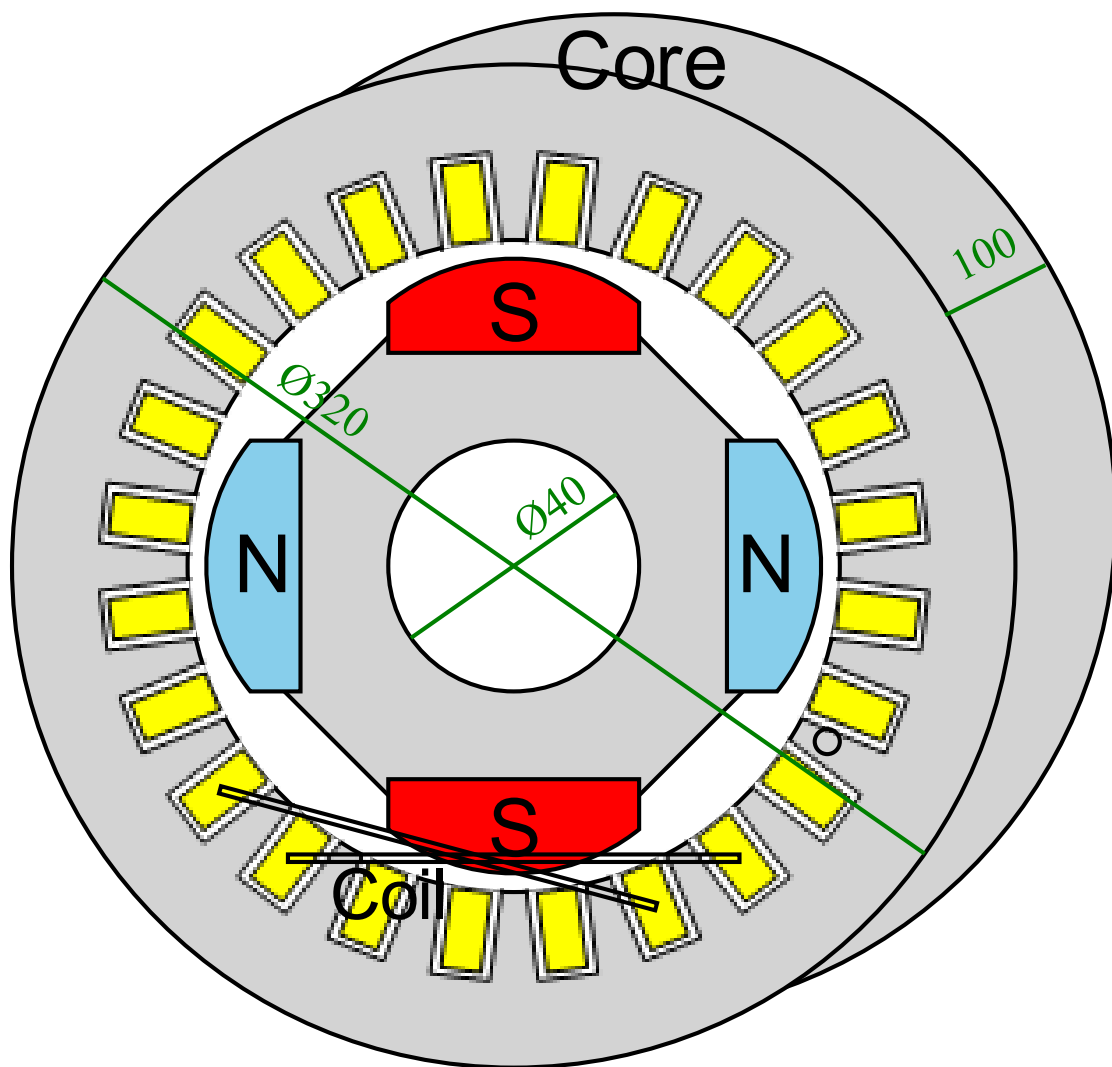


Solenoid actuator force





Armature winding inductance

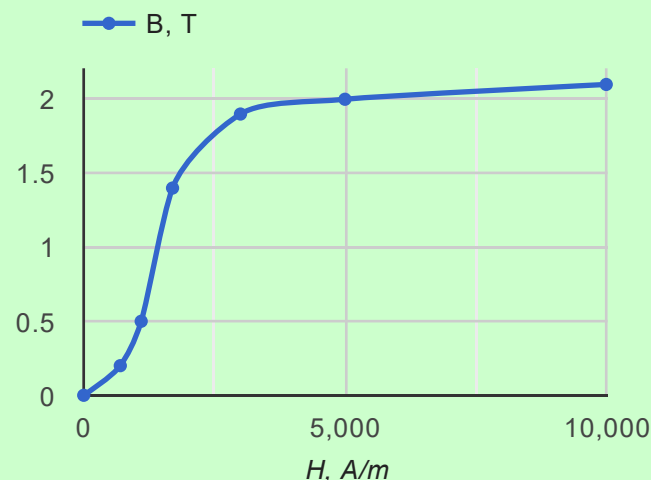


Problem specification:

3-phase stator winding scheme: A-A, Z-Z, B-B, X-X, C-C, Y-Y, slot current 200 A, number of turns 100,

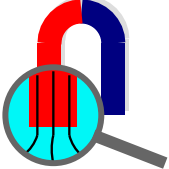
Permanent magnet coercive force $H_c = 820$ kA/m, remanence $B_r = 1.1$ T;

Steel core B-H curve:

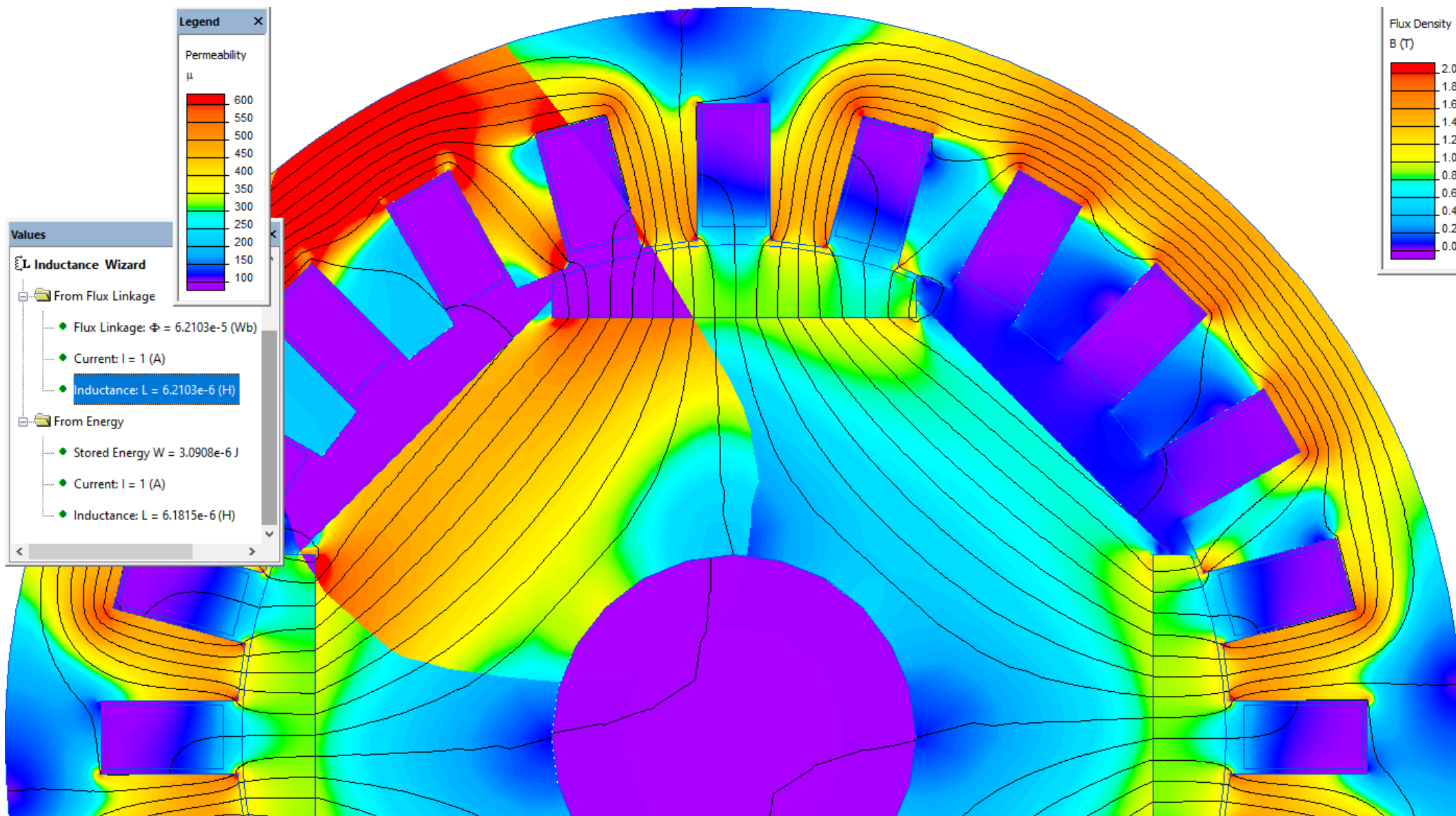


Task:

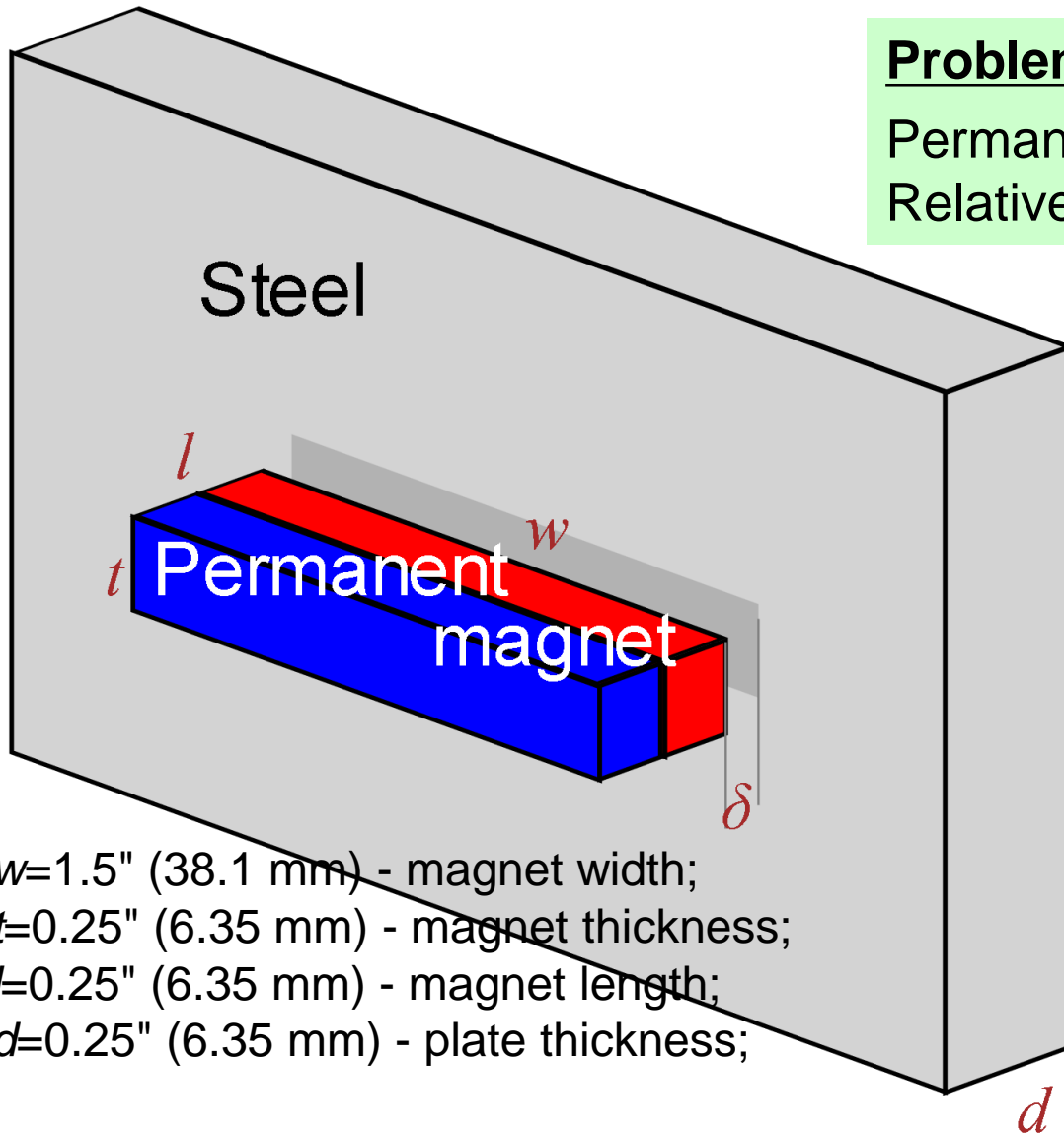
Calculate the phase coil inductance for the normal operating conditions.



Armature winding inductance



Attraction of the block magnet to the steel plate



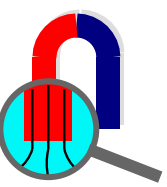
Problem specification:

Permanent magnet grade N35: $H_c = 954930 \text{ A/m}$, $B_r = 1.26 \text{ T}$;
Relative magnetic permeability of steel $\mu_{\text{steel}} = 1000$.

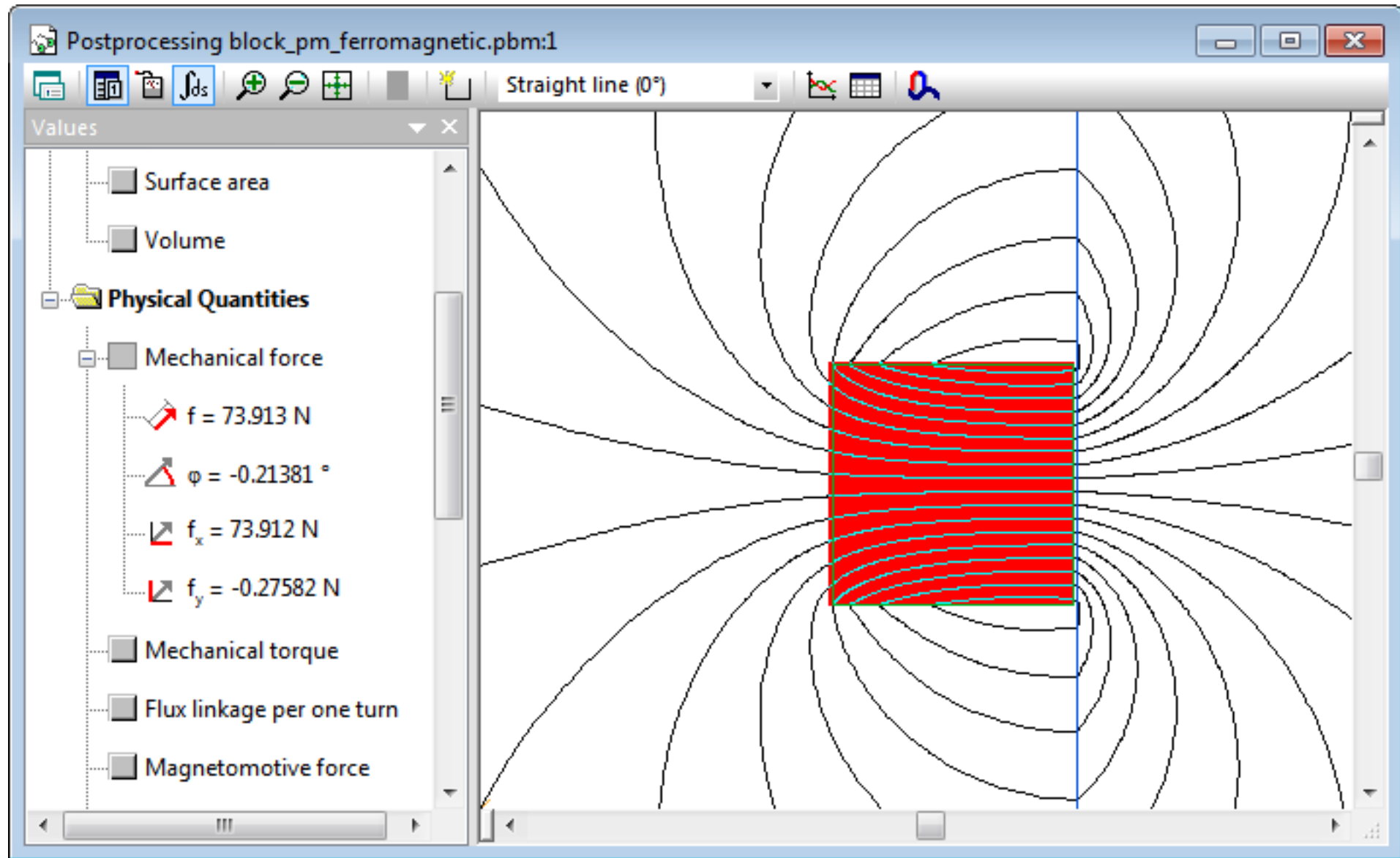
Task:

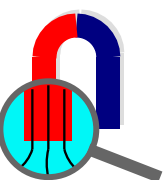
Calculate the pulling force of the magnet attraction to the steel plate.

$w=1.5''$ (38.1 mm) - magnet width;
 $t=0.25''$ (6.35 mm) - magnet thickness;
 $l=0.25''$ (6.35 mm) - magnet length;
 $d=0.25''$ (6.35 mm) - plate thickness;

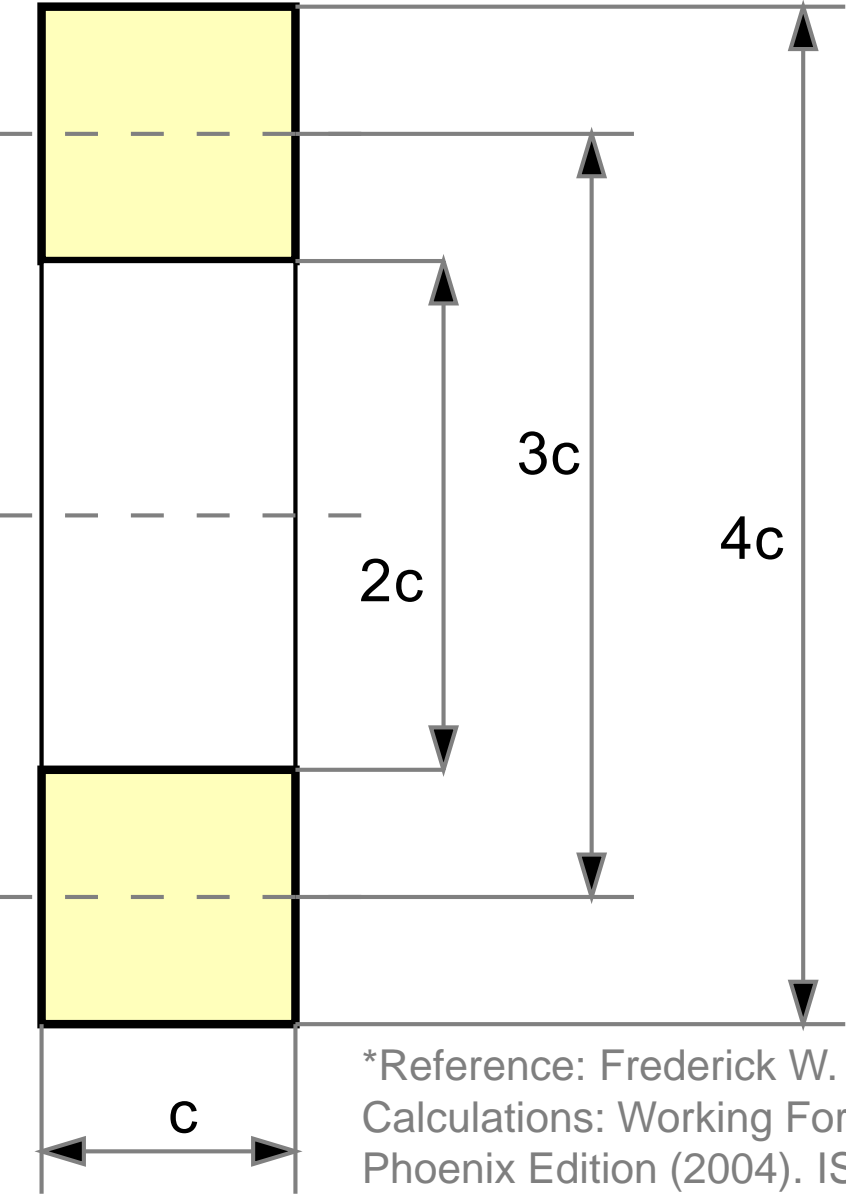


Attraction of the block magnet to the steel plate





Brooks coil



Problem specification:

Current $I = 1$ A, number of turns $N = 200$,
 $c = 20$ mm.

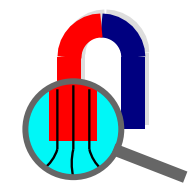
Task:

Calculate the inductance

Brooks coil inductance can be
calculated using equation*:

$$L = 1.6994 \cdot 10^{-6} \cdot (3/2 \cdot c) \cdot N^2$$

*Reference: Frederick W. Grover, Inductance
Calculations: Working Formulas and Tables, Dover
Phoenix Edition (2004). ISBN 0486495779. Page 98.



Brooks coil

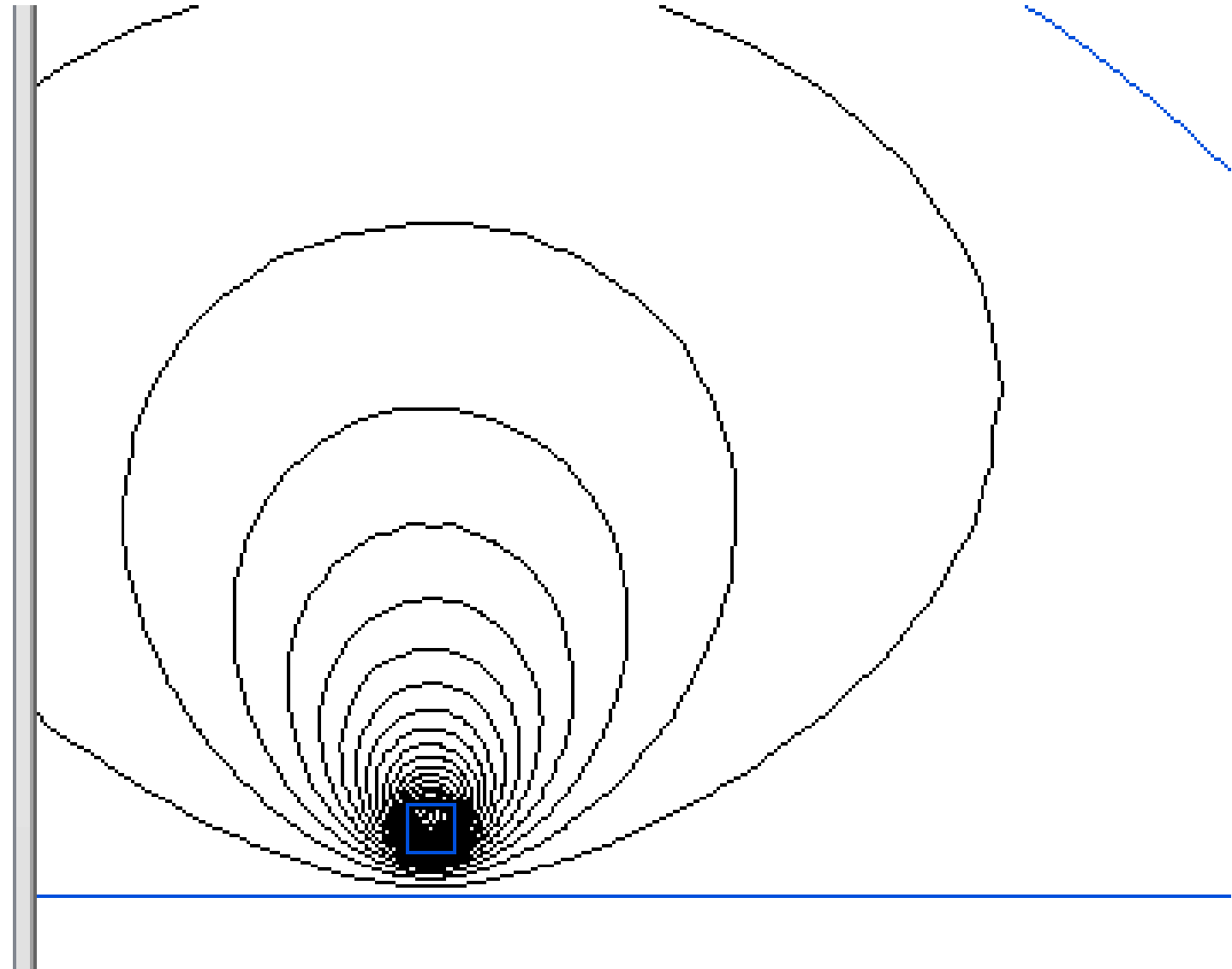
L Inductance Wizard

From Flux Linkage

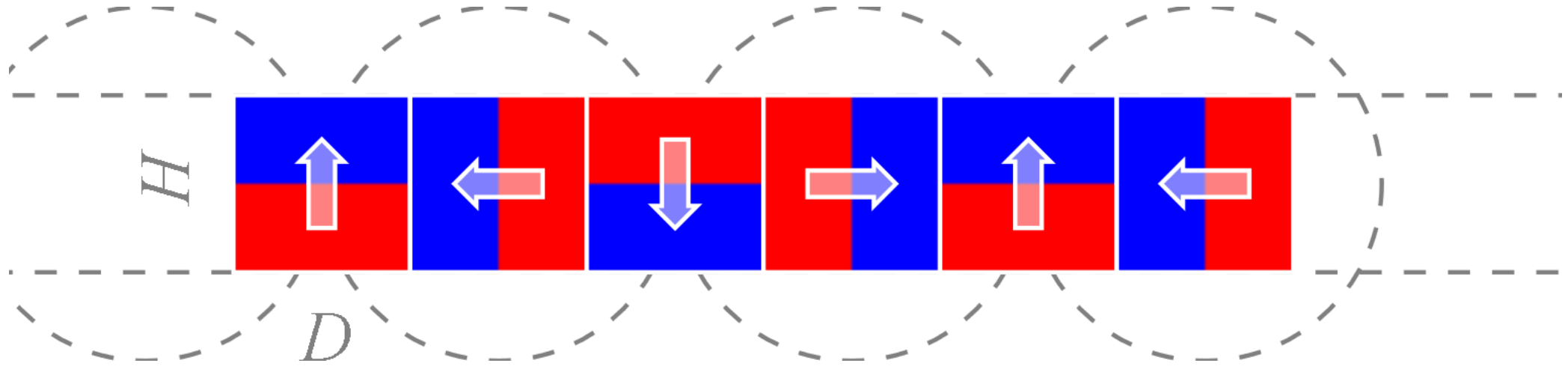
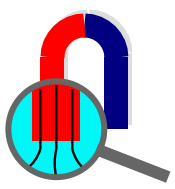
- Flux Linkage: $\Phi = 0.0020334$ (Wb)
- Current: $I = 1$ (A)
- Inductance: $L = 0.002033$ (H)

From Energy

- Stored Energy $W = 0.0010164$ J
- Current: $I = 1$ (A)
- Inductance: $L = 0.002033$ (H)



Halbach array



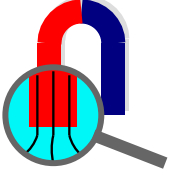
$D = 0.5$ inch, $H = 0.5$ inch,

Problem specification:

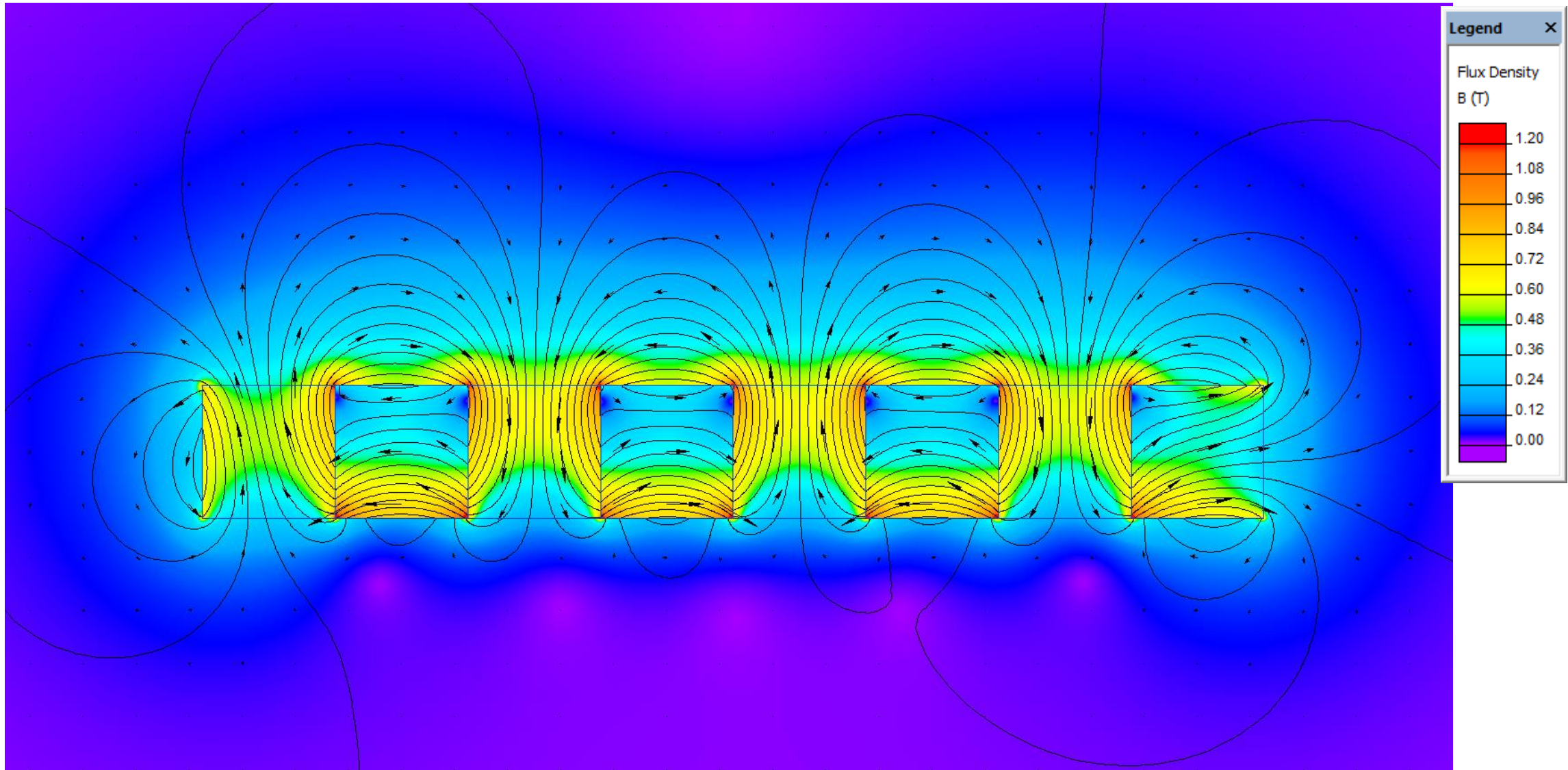
Permanent magnet coercive
force $H_c = 750$ kA/m;
remanence $B_r = 1.1$ T

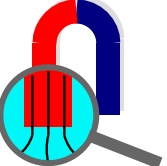
Task:

Calculate the magnetic
field distribution.

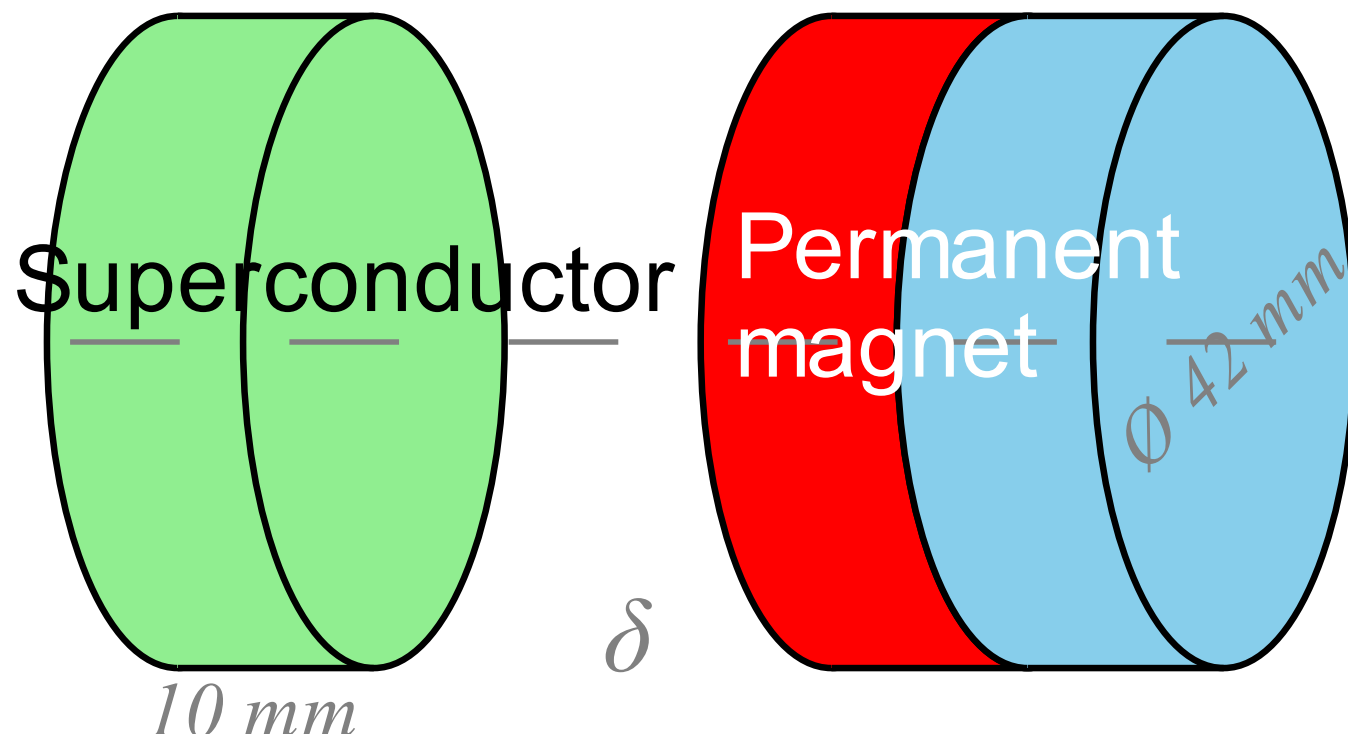


Halbach array





Superconductor levitation



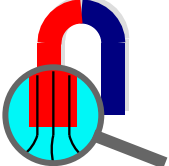
Problem specification:

Permanent magnet coercive force $H_c = 575 \text{ kA/m}$

Task:

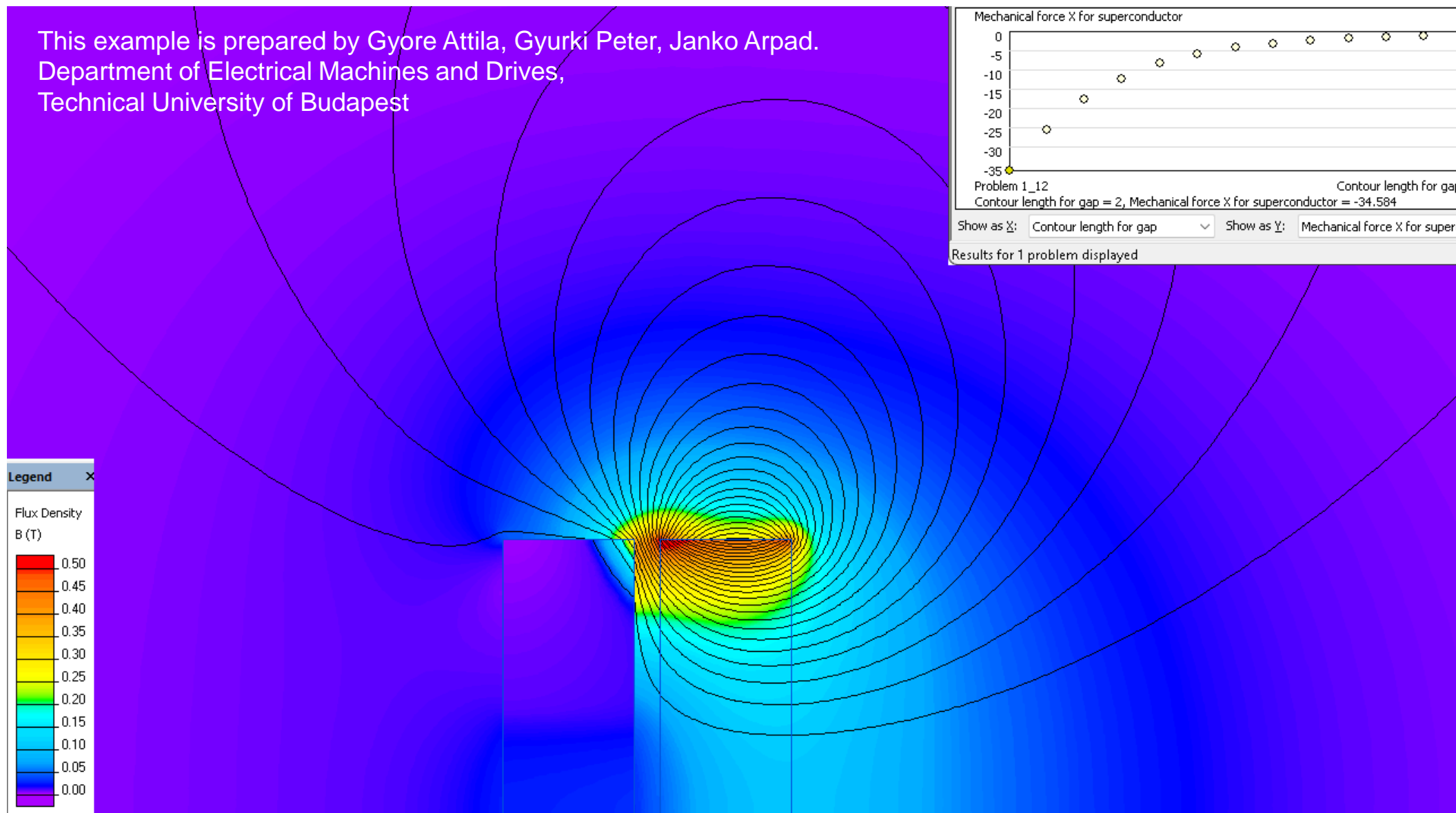
Calculate the magnetic force acting on a superconductor.

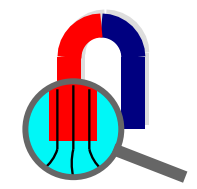
This example is prepared by Gyore Attila, Gyurki Peter, Janko Arpad.
Department of Electrical Machines and Drives,
Technical University of Budapest



Superconductor levitation

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This recording is over

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