

AC Magnetic simulation with QuickField



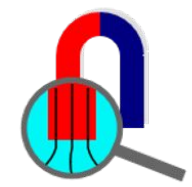
Vladimir Podnos

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



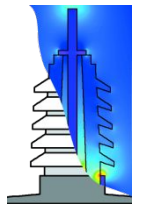
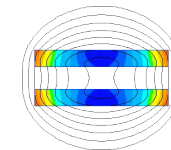
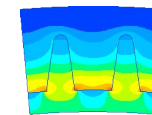
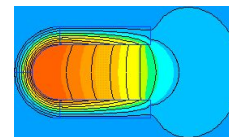
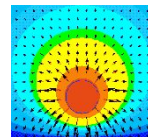
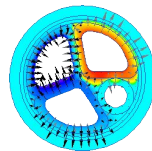
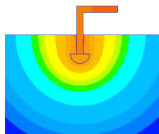
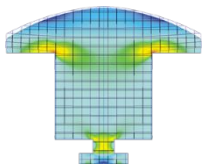
Alexander Lyubimtsev

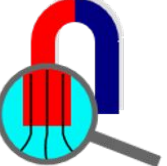
**Support Engineer
Tera Analysis Ltd.**



QuickField Analysis Options

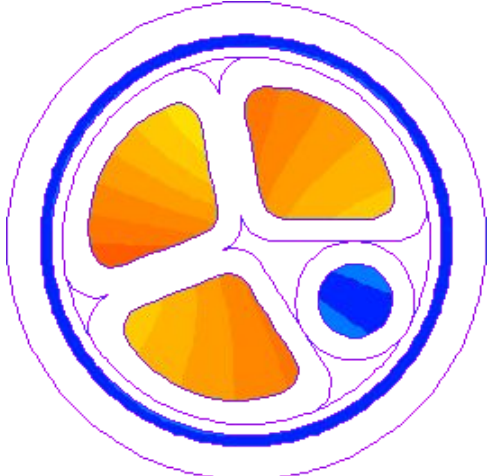
Magnetic analysis suite	Magnetostatics
	AC Magnetics
	Transient Magnetic
Electric analysis suite	Electrostatics (2D,3D) and DC Conduction (2D,3D)
	AC Conduction
	Transient Electric field
Thermostructural analysis suite	Steady-State Heat transfer (2D,3D)
	Transient Heat transfer
	Stress analysis





MultiPhysics (2D)

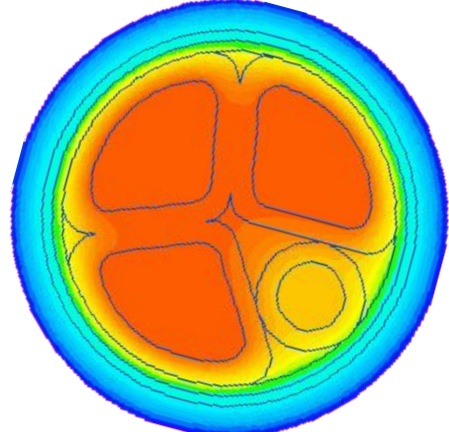
Electromagnetic fields



Losses

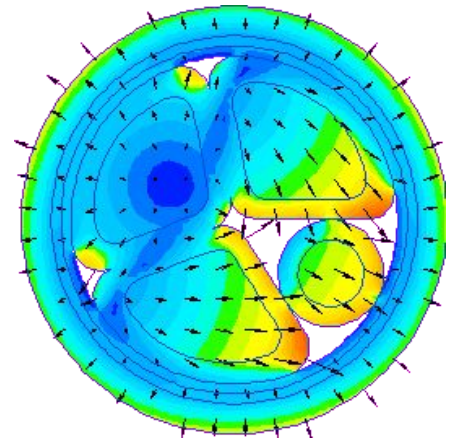


Temperature field



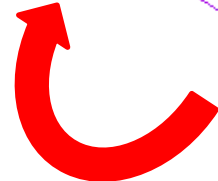
Temperature field import

Thermal Stresses

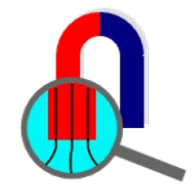


Stresses & Deformations

Forces

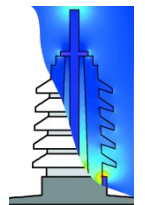
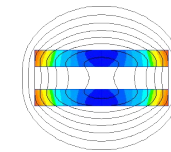
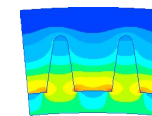
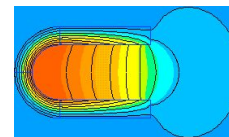
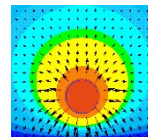
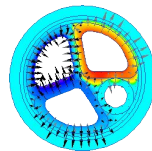
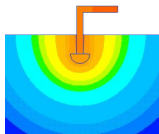
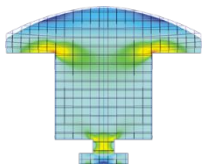


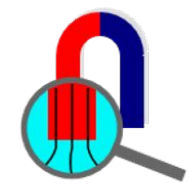
Magnetic state import



QuickField AC Magnetics

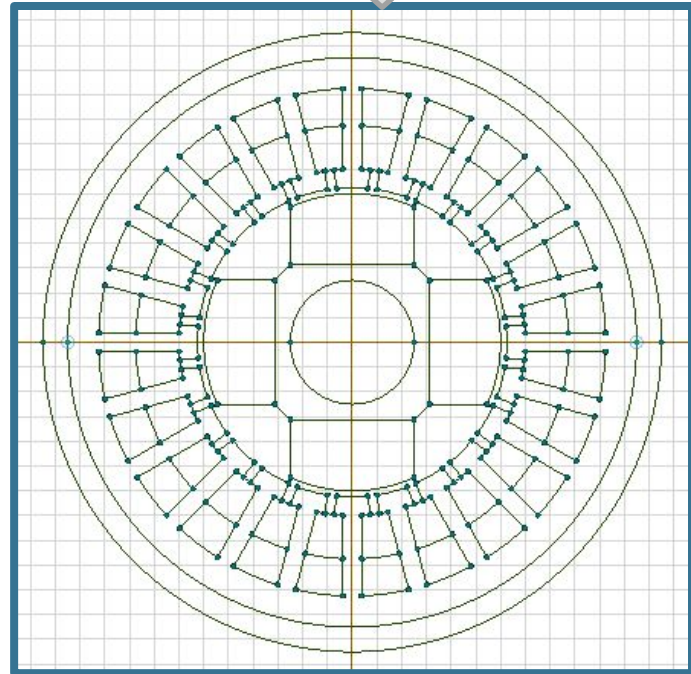
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	Stress analysis



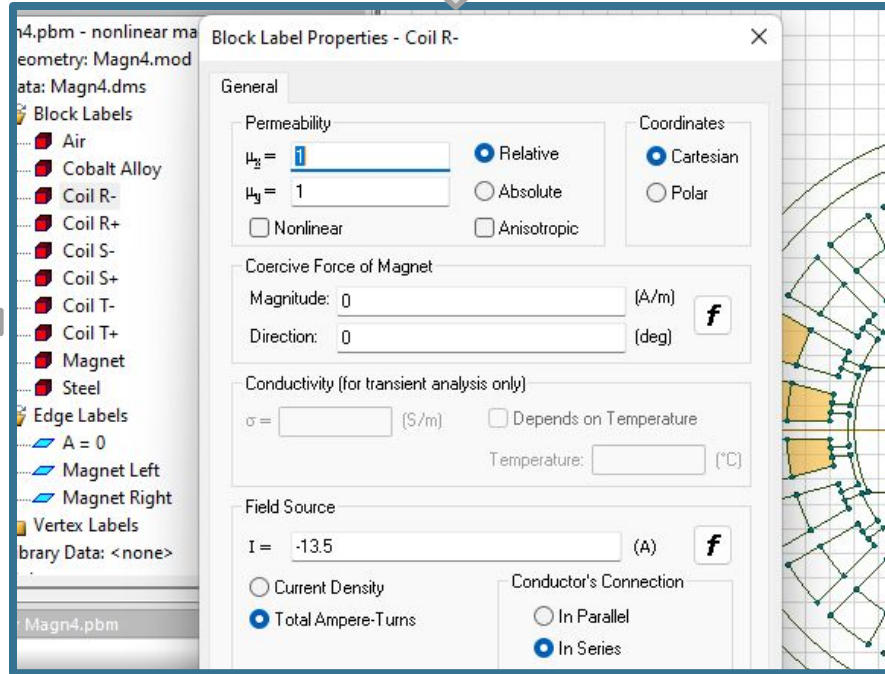


QuickField Workflow

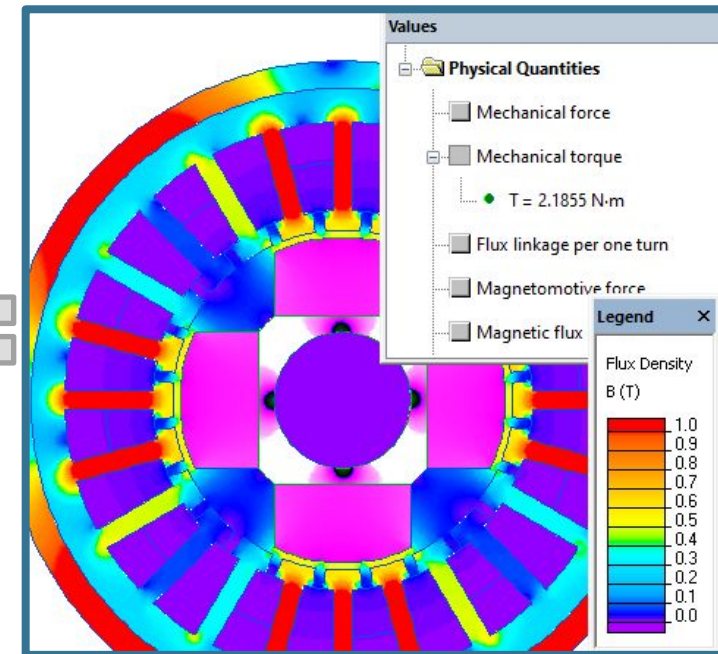
Problem setup



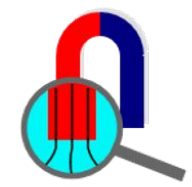
Model editor



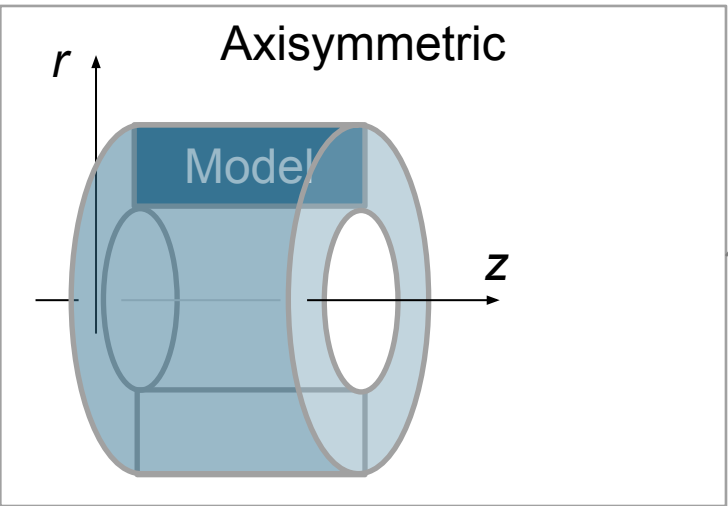
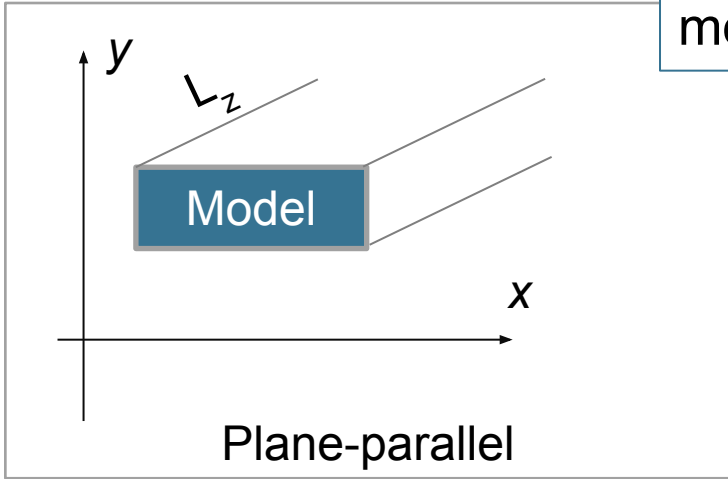
**Material physical properties,
field sources and
boundary conditions**



Results analysis



QuickField AC Magnetics. Problem setup



2. Choose model class

1. Choose problem type: AC magnetics

3. Enter frequency value

4. Optional: define circuit file name

Problem Properties - Motor_c.pbm

General Links

Problem Type: AC Magnetics

Length Units: Millimeters

Model Class: Plane-parallel (selected), Plane-parallel, Axisymmetric

Frequency: f = 50 Hz

Coordinate System: Polar

Files

Geometry: Acmotor_c.mod

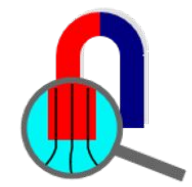
Data: Motor_c.dhe

Library Data:

Circuit: motor_c.qcr

Location: D:\gdrive\websites\quickfield.com\seminar\ac_magn\8. ac_motor_ca

OK Cancel Help



QuickField AC Magnetics. Label properties

Block

Edge

Vertex

Block Label Properties - Copper Bar

General Core Loss

Permeability

$\mu_x =$ Relative Absolute

$\mu_y =$

Nonlinear Anisotropic

Coordinates

Cartesian Polar

Electrical Conductivity

$\sigma =$ (S/m) Depends on Temperature

Temperature: (°C)

Field Source

$I_o =$ (A) **f**

$\varphi =$ (deg)

Source Mode

Voltage Total Current

Conductor's Connection

In Parallel In Series

OK Cancel Help

Edge Label Properties - A=0

General

Magnetic Potential: $A = A_o$

$A_o =$ (Wb/m)

$\varphi =$ (deg) **f**

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

$\sigma =$ (A/m)

$\varphi =$ (deg)

Zero Normal Flux: $B_n = 0$

Even Periodic: $A_1 = A_2$

Odd Periodic: $A_1 = -A_2$

OK Cancel Help

Vertex Label Properties - current

General

Magnetic Potential: $A = A_o$

$A_o =$ (Wb/m)

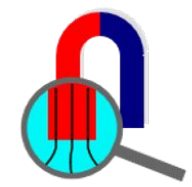
$\varphi =$ (deg) **f**

Linear Current

$I =$ (A)

$\varphi =$ (deg)

OK Cancel Help



QuickField AC Magnetics. Circuit

AC magnetic problems in QuickField may be defined with the **electric circuits** connected to blocks of the field model. These formulations are suitable to model electromagnetic devices, like motors with complex winding scheme, or transformers with combined load.

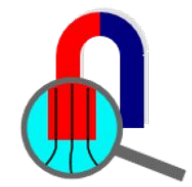
Features

- Passive elements (R,L,C) and sources (U,I)
- Loads: constant, sinusoidal and complex pulse shape sources (you can use formulas to describe the electric source parameters)
- Results: voltage, current and impedance for each element. Current and voltage time plot.

The screenshot displays the QuickField software interface for an AC magnetics problem. The main window shows a 2D magnetic field model with a green mesh and two orange rectangular regions representing windings. The interface includes a menu bar (File, Edit, View, Insert, Problem, Tools, Window, Help), a toolbar, and a file explorer on the left. The file explorer shows the project structure for 'Circuit2.pbm', including 'Geometry: Circuit2.mod', 'Data: Circuit2.dhe', 'Block Labels' (Air, core, Primary-, Primary+, Secondary-, Secondary+), 'Edge Labels', 'Vertex Labels', 'Library Data: <none>', 'Circuit: Circuit2.qcr', and 'Links: No links'. The bottom panel shows the 'Properties for Circuit2.pbm' window with a 'QuickField Block' table:

Label	Secondary-

The bottom right panel shows the 'Circuit2.qcr' window, which displays an electrical circuit diagram. The circuit includes a voltage source labeled 'Secondary-' and a current source labeled 'Secondary+'. It also features a resistor labeled 'R1' with a value of 2, and a capacitor labeled 'C1' with a value of 1e-9. The circuit is connected to the magnetic field model.



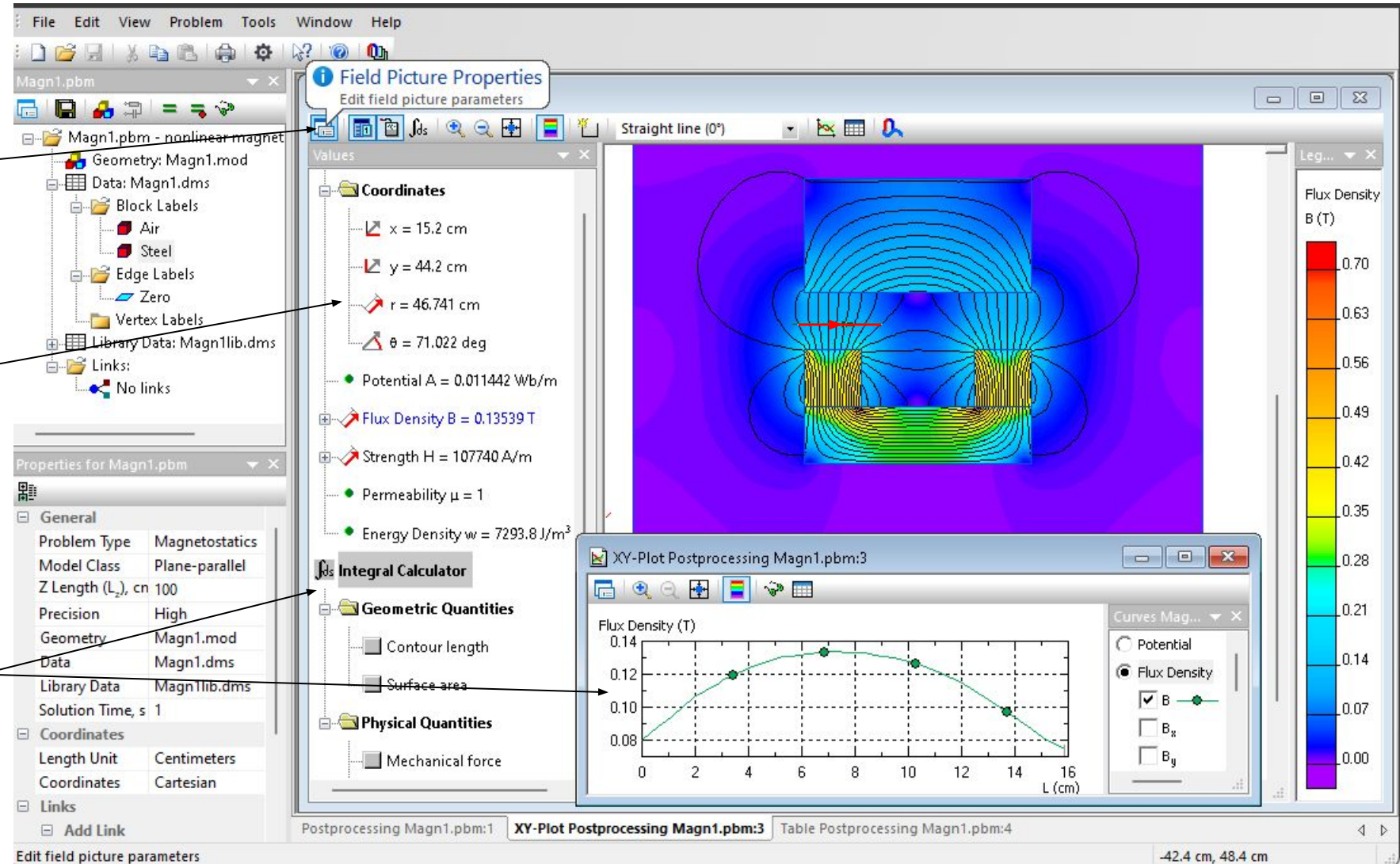
QuickField AC Magnetics. Results

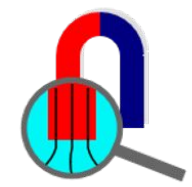
Results analysis is the most complicated part, having more options. Generally the following types of result analysis are available:

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 AC Magnetics. Results

Field maps

Field Picture Properties

Phase for Momentary Values: 0 deg

Field Lines
 Snapshot at given phase Interval: 9.e-8 Wb/m
 Snapshot at phase + 90°

Vector Plot
 Snapshot at given phase
 Snapshot at phase + 90°
Cell: 2 mm
Scale: 10000

Zone Plot
 Momentary Value
 Color Map of: RMS Value Peak Value
Color Grades: 20
Maximum: 11400 A/m²
Minimum: 2350 A/m²

Flux Density B
Strength H
Poynting Vector S
Lorentz Force F

Strength H_y
Current Density j_{total}
Current Density j_{external}
Current Density j_{eddies}
Power Loss Q
Energy Density w
Poynting Vector S
Poynting Vector S_x

Show Mesh

Local field data

Values

Local Values

Coordinates
x = 0.4 mm
y = 8.7 mm
r = 8.7092 mm
θ = 87.368 deg

RMS Values

Average Values
Power Loss Q = 0.23741 W/m³
Energy Density w = 0.00090748 J/m³

Peak Values
Potential A = 1.6937e-6 Wb/m
Flux Density B = 6.7538e-5 T
Strength H = 53.745 A/m
Current Density j_{total} = 5248 A/m²
Power Loss Q = 0.47482 W/m³
Energy Density w = 0.0018149 J/m³

Momentary Values at phase φ

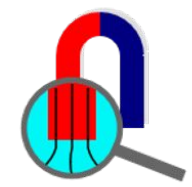
Integrals

Values

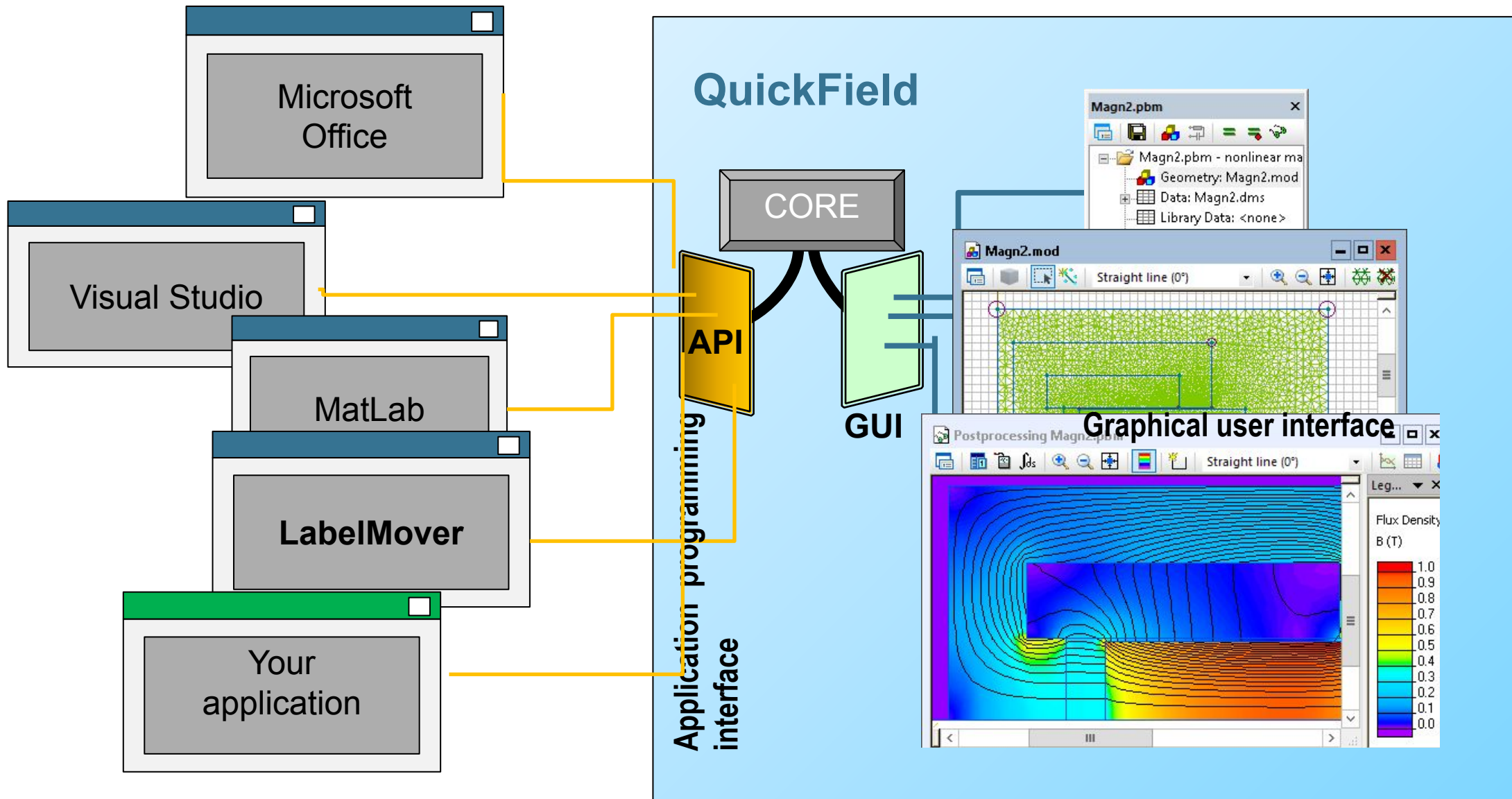
Integral Calculator

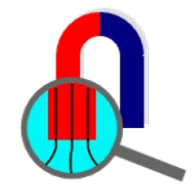
Geometric Quantities

Physical Quantities
Total current
External current
Eddy current
Joule heat
Core Loss
Power flow
Maxwell force
Maxwell torque
Lorentz force
Lorentz torque
Electrical Conductance
Magnetic field energy
Flux linkage per one turn
Magnetomotive force
Magnetic flux



QuickField API

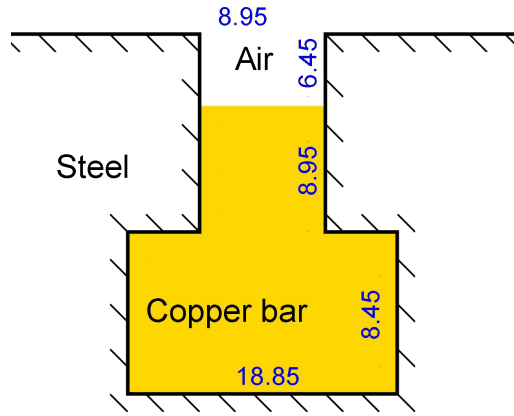
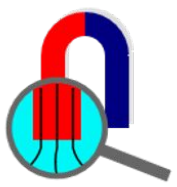




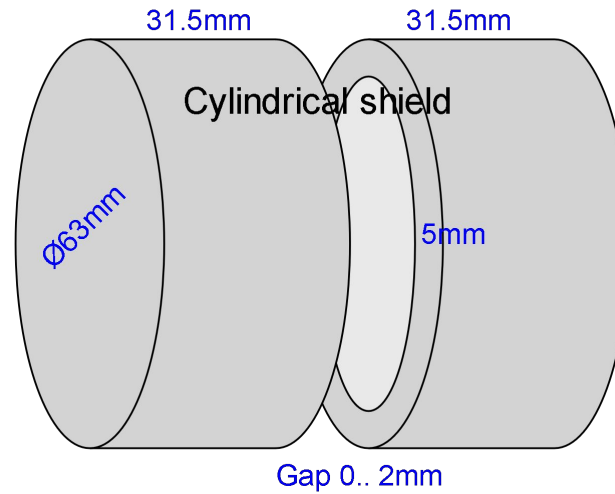
QuickField Difference



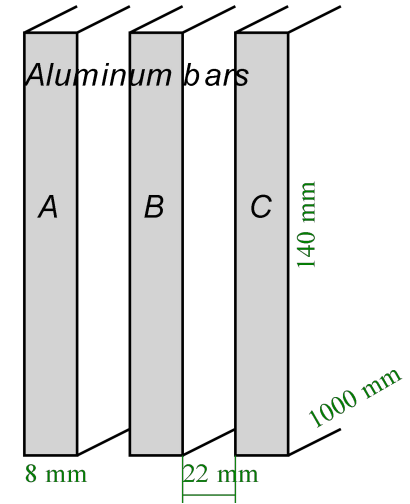
AC Magnetic simulation with QuickField



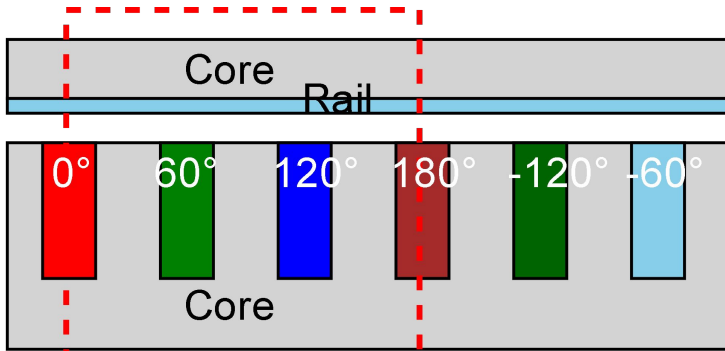
Slot embedded conductor skin effect



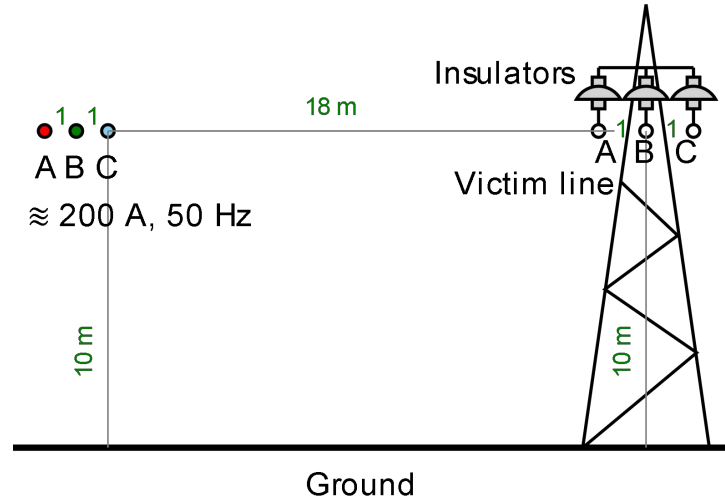
Electromagnetic shielding



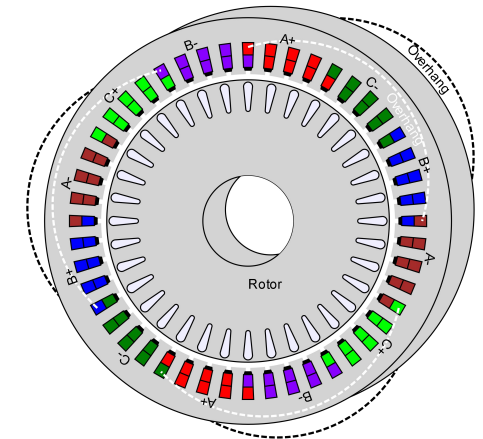
Three-phase busbar losses



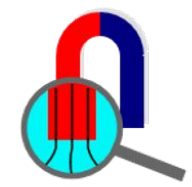
Linear electric motor



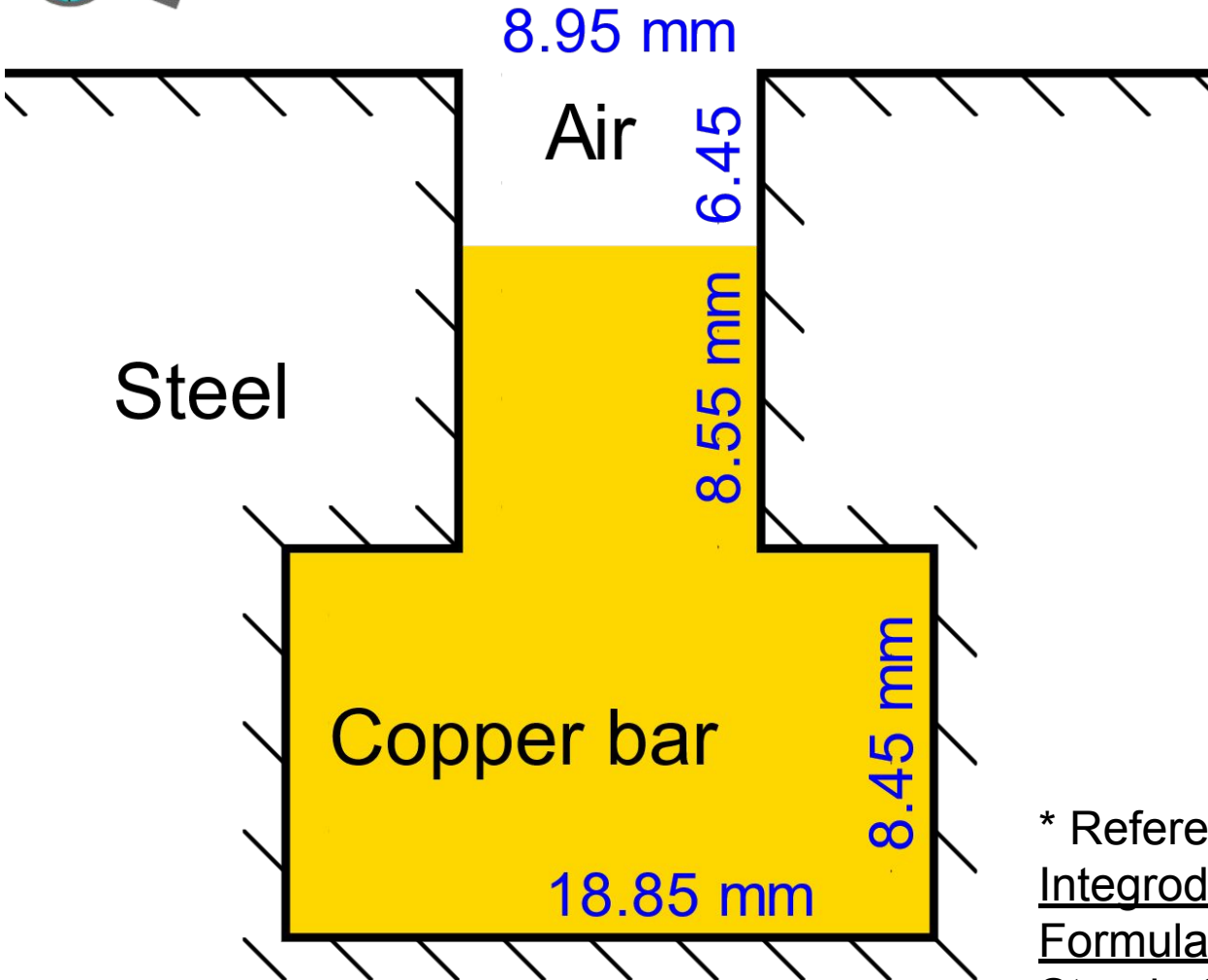
Transmission line magnetic coupling



Induction motor



Slot embedded conductor skin effect



All dimensions are in millimeters

Problem specification:

Conductivity of copper $\sigma = 58 \text{ MS/m}$

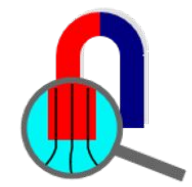
Current in the conductor $I = 1 \text{ A}$

Frequency $f = 45 \text{ Hz}$

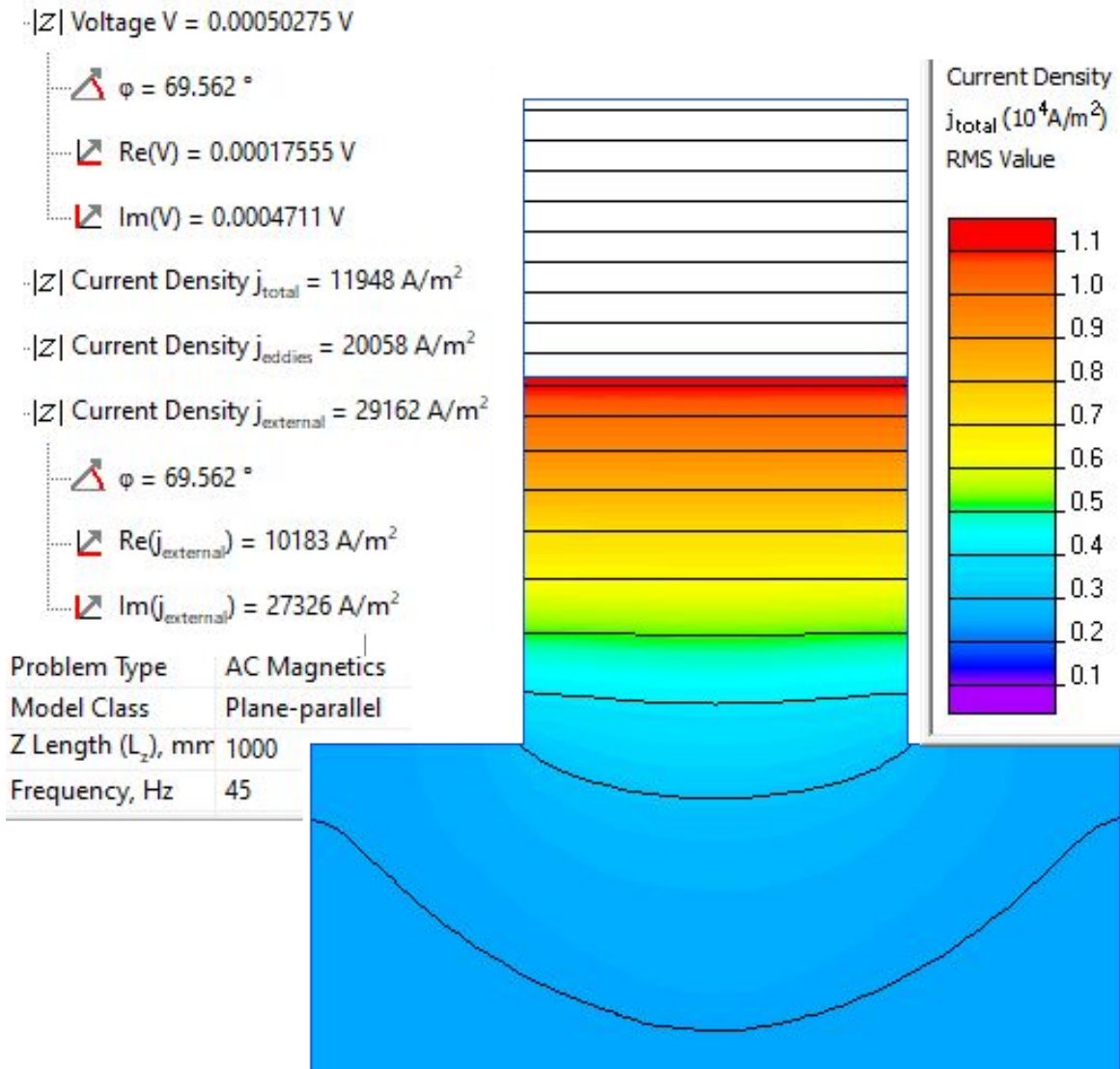
Task:

Determine current distribution within the conductor and complex impedance of the conductor.

* Reference: A. Konrad,
Integrodifferential Finite Element
Formulation of Two-Dimensional
Steady-State Skin Effect Problems,
IEEE Trans. Magnetics,
Vol MAG-18, # 1, January 1982.



Slot embedded conductor skin effect



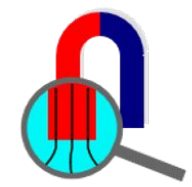
	External current density, A/m ²
QuickField	10183 + j27326
Reference*	10182.7 + j27327.9

* Reference: A. Konrad, Integrodifferential Finite Element Formulation of Two-Dimensional Steady-State Skin Effect Problems, IEEE Trans. Magnetics, Vol MAG-18, # 1, January 1982.

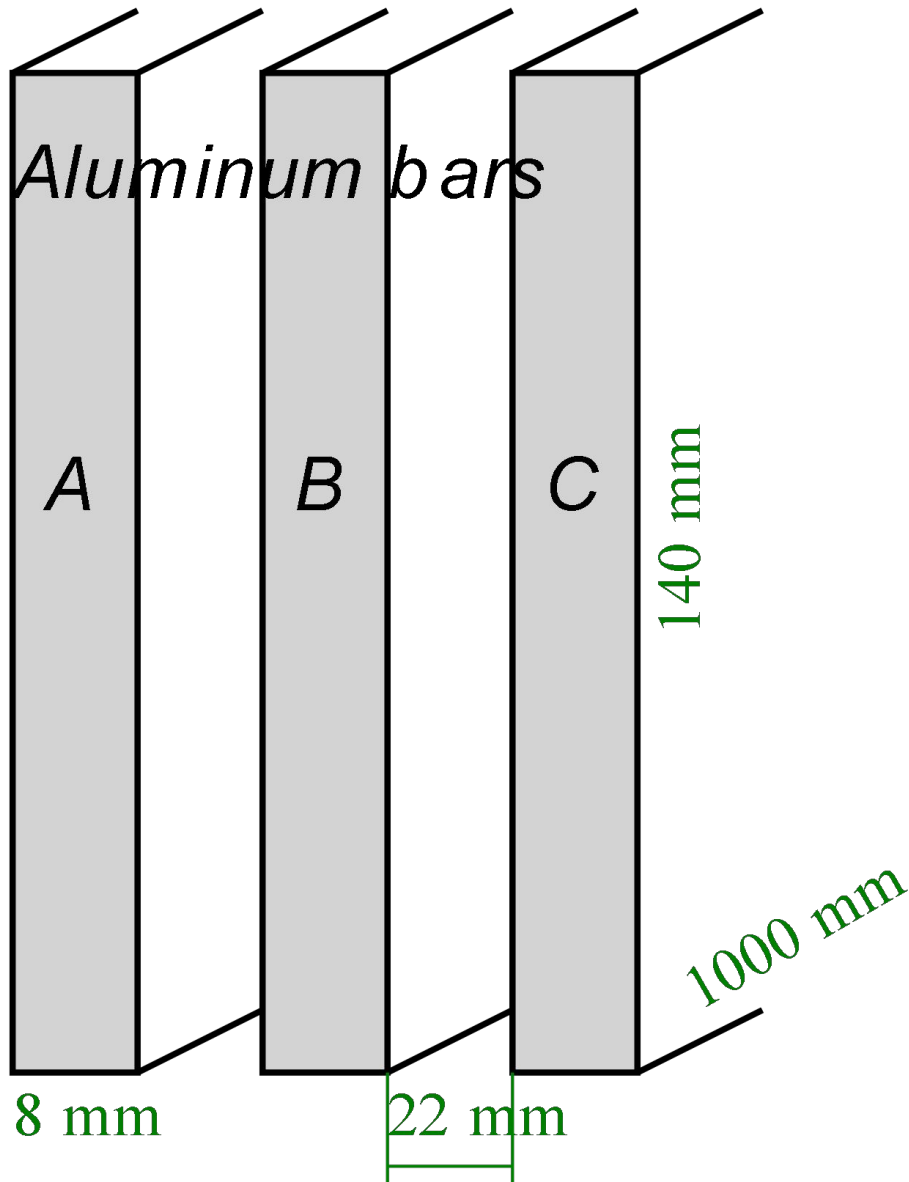
Values

Z Impedance Wizard

- $|Z|$ Impedance: $Z = 0.00050275$ (Ω)
 - Resistance: $R = 0.00017555$ (Ω)
 - Reactance: $X_L = 0.0004711$ (Ω)
- Inductance: $L = 1.6662e-6$ (H)



Three-phase busbar losses



Problem specification:

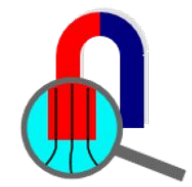
Conductivity of aluminum $\sigma = 37 \text{ MS/m}$

AC current $I = 1000 \text{ A}$ (R.M.S. value)

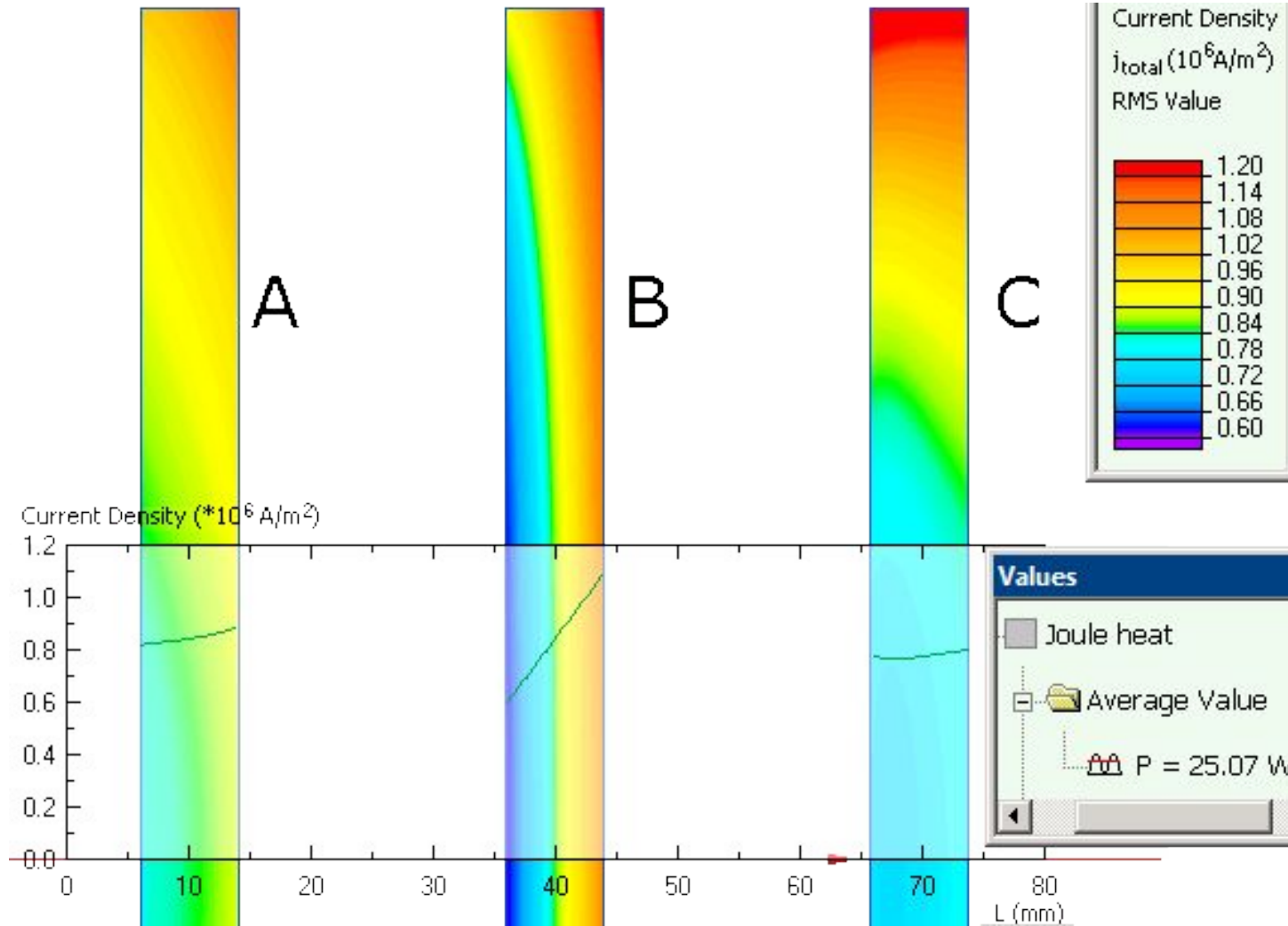
Frequency f : 50 Hz, 400 Hz, 1 kHz, 3 kHz

Task:

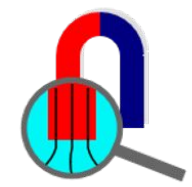
Calculate the dependence of the busbar losses on the alternating current frequency.



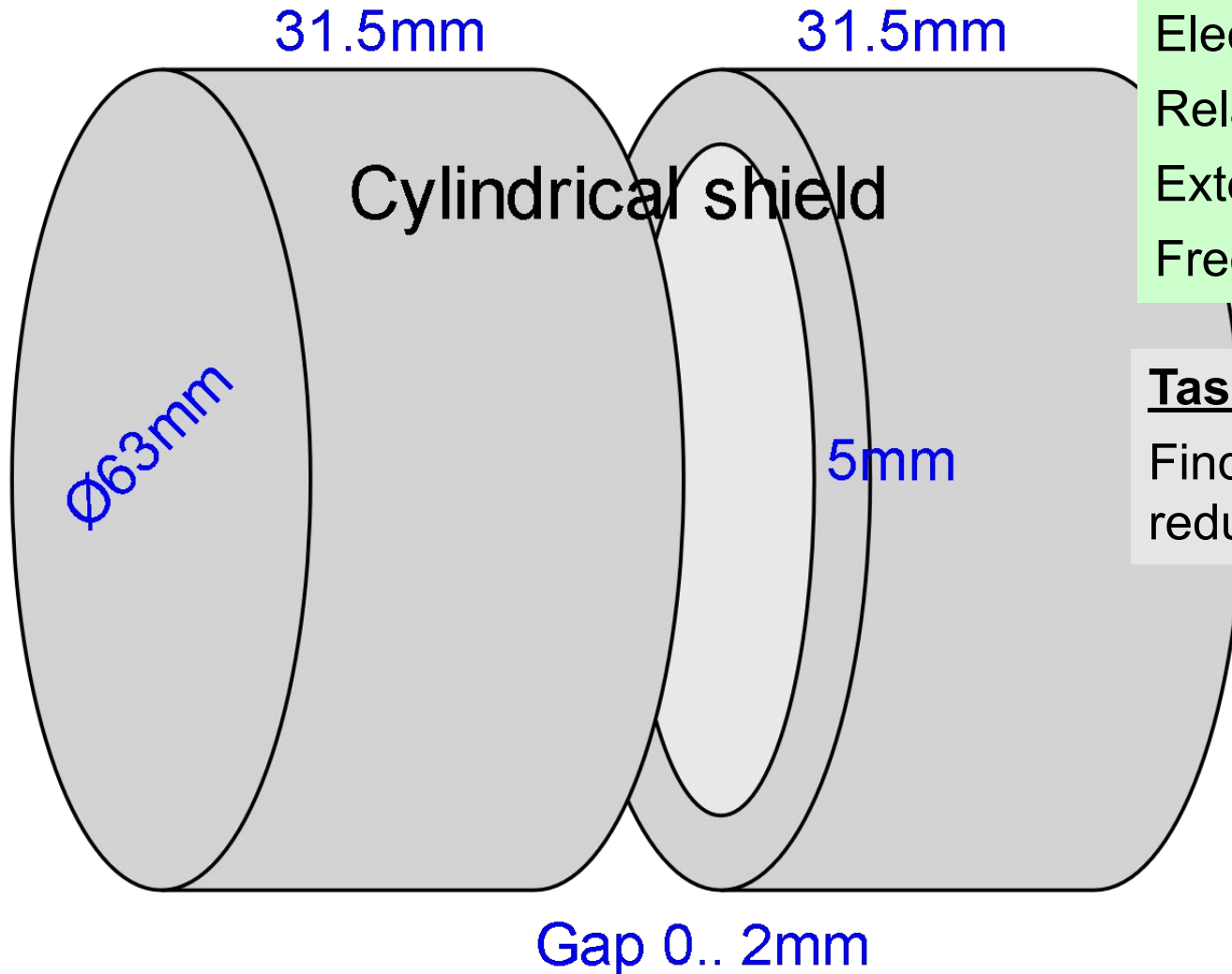
Three-phase busbar losses



	Joule heat losses, W per 1 m of busbar length		
Frequency, Hz	A	B	C
0	24	24	24
50	25.3	25.0	25.0
400	37.6	50.7	37.3
1000	56	90	56
3000	98	155	98



Electromagnetic shielding



Problem specification:

Electrical conductivity of steel 10 MS/m

Relative magnetic permeability of steel $\mu=1000$

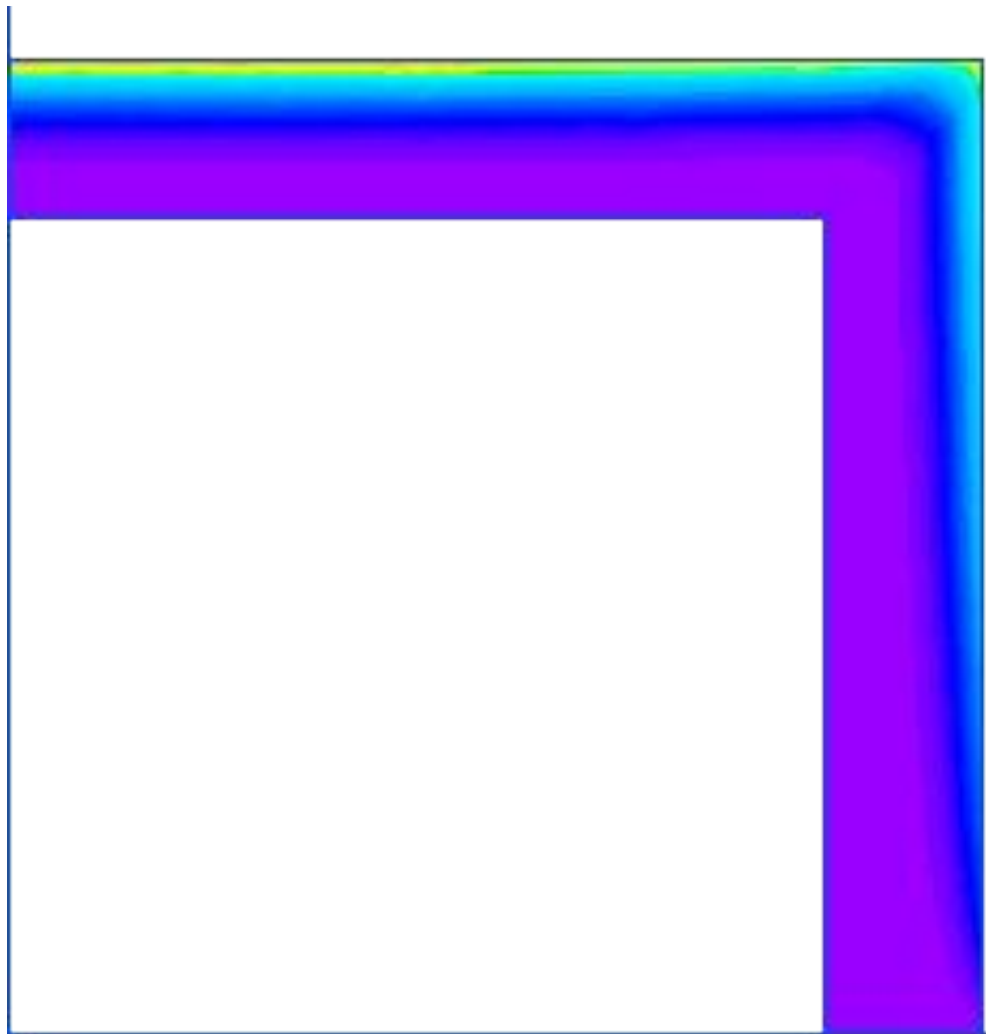
External magnetic field flux density $B = 0.139$ T

Frequency $f = 50$ Hz

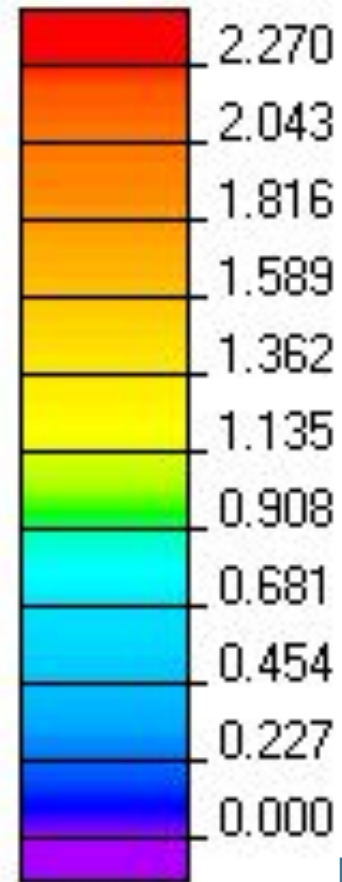
Task:

Find the level of magnetic field reduction inside the shield

Electromagnetic shielding

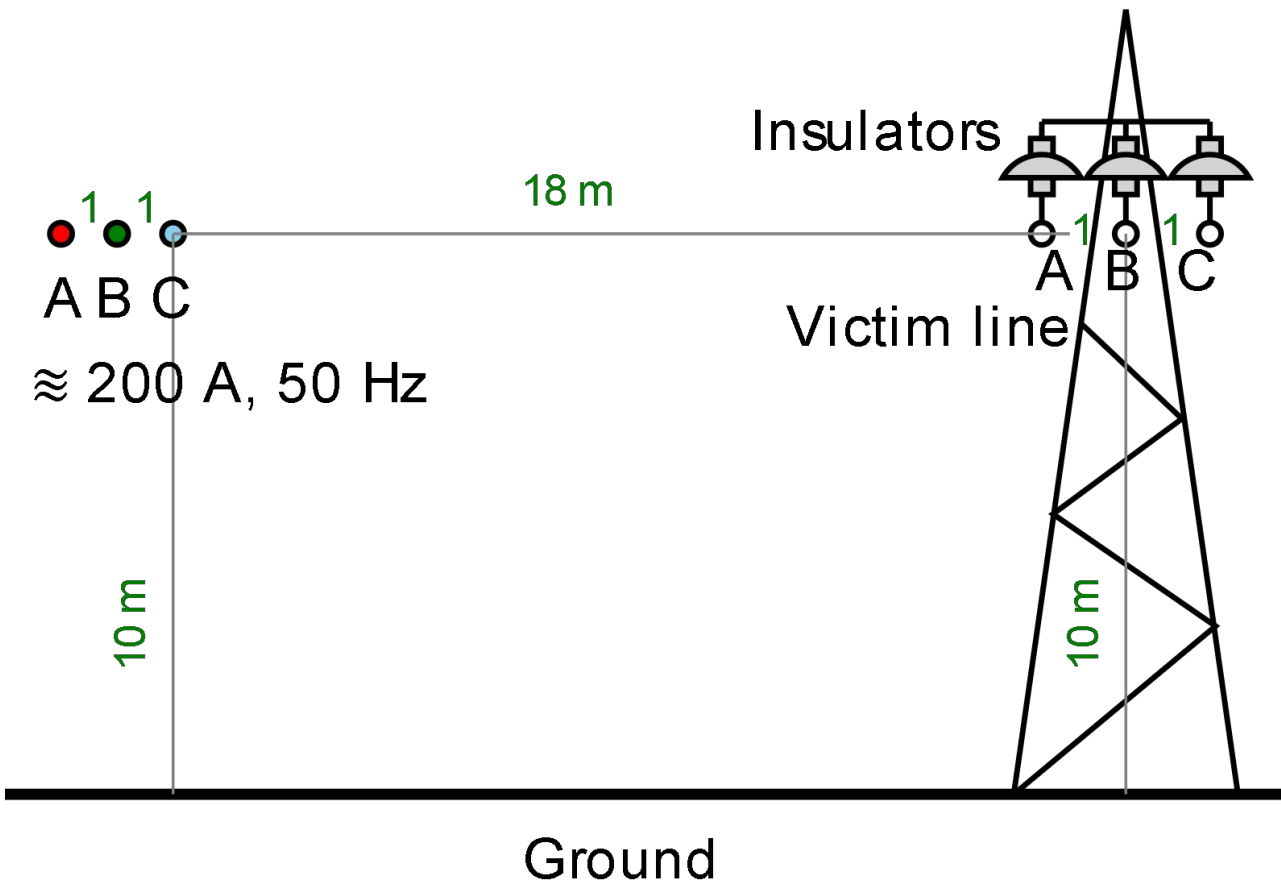
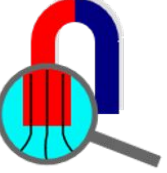


Current Density
 i_{total} ($10^7 A/m^2$)
RMS Value



Shield type	Peak value of flux density in the center, mT
Steel cylinder with slot 1 mm	30
Steel cylinder with slot 2 mm	40

Transmission line magnetic coupling



Problem specification:

Left line current: 200 A (r.m.s)

Frequency $f = 50$ Hz

Ground electrical conductivity $\sigma = 0.1$ S/m

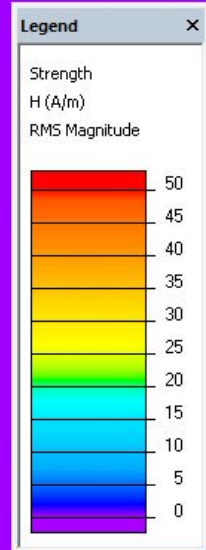
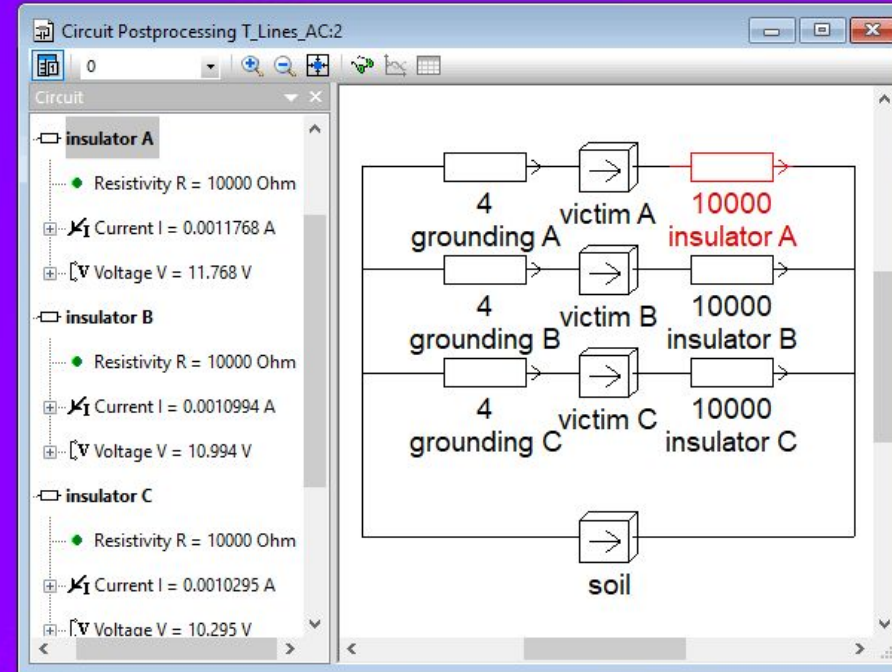
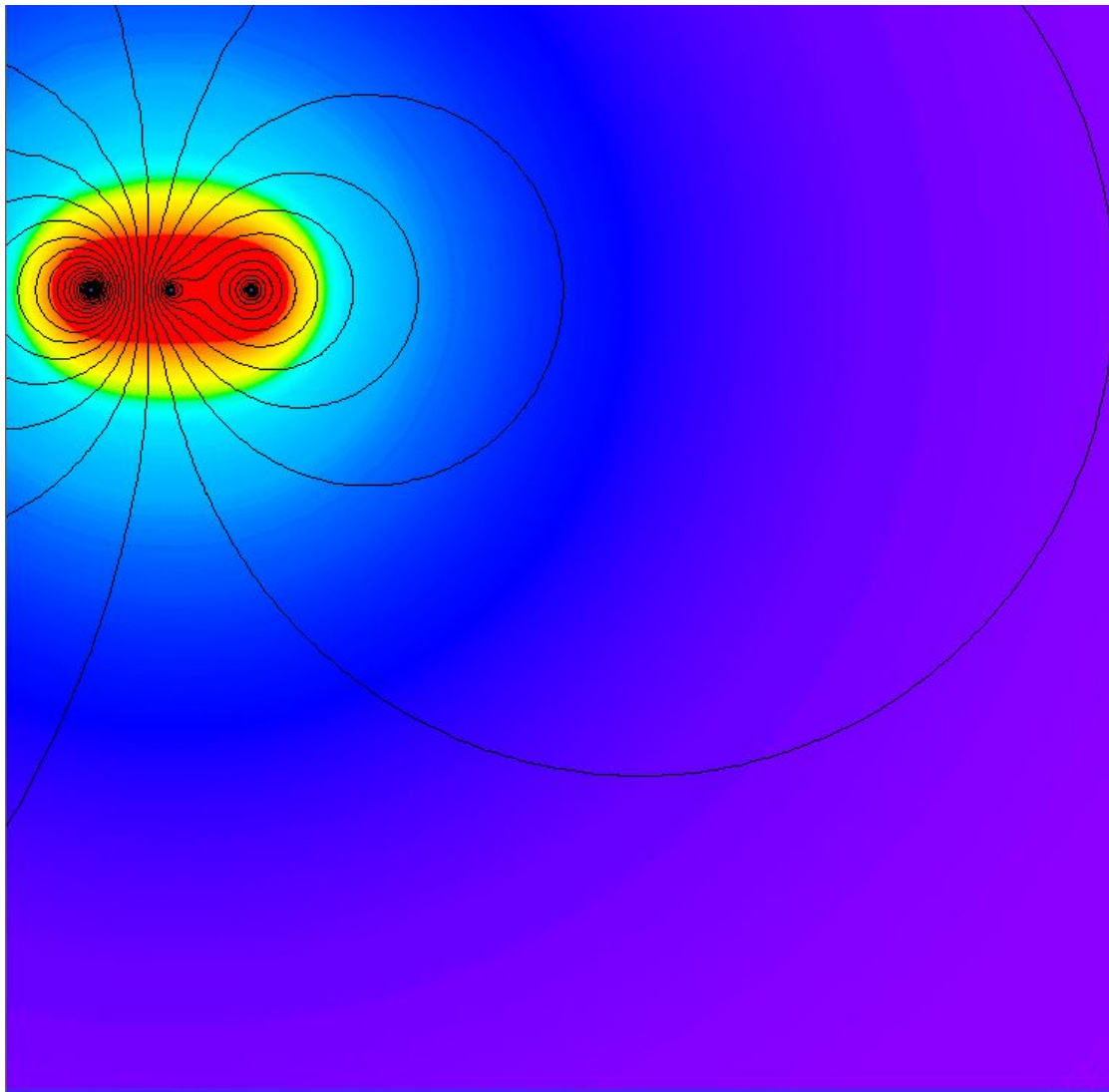
Transmission line length $L_z = 10$ km

Victim line grounding resistance $R = 4$ Ohm

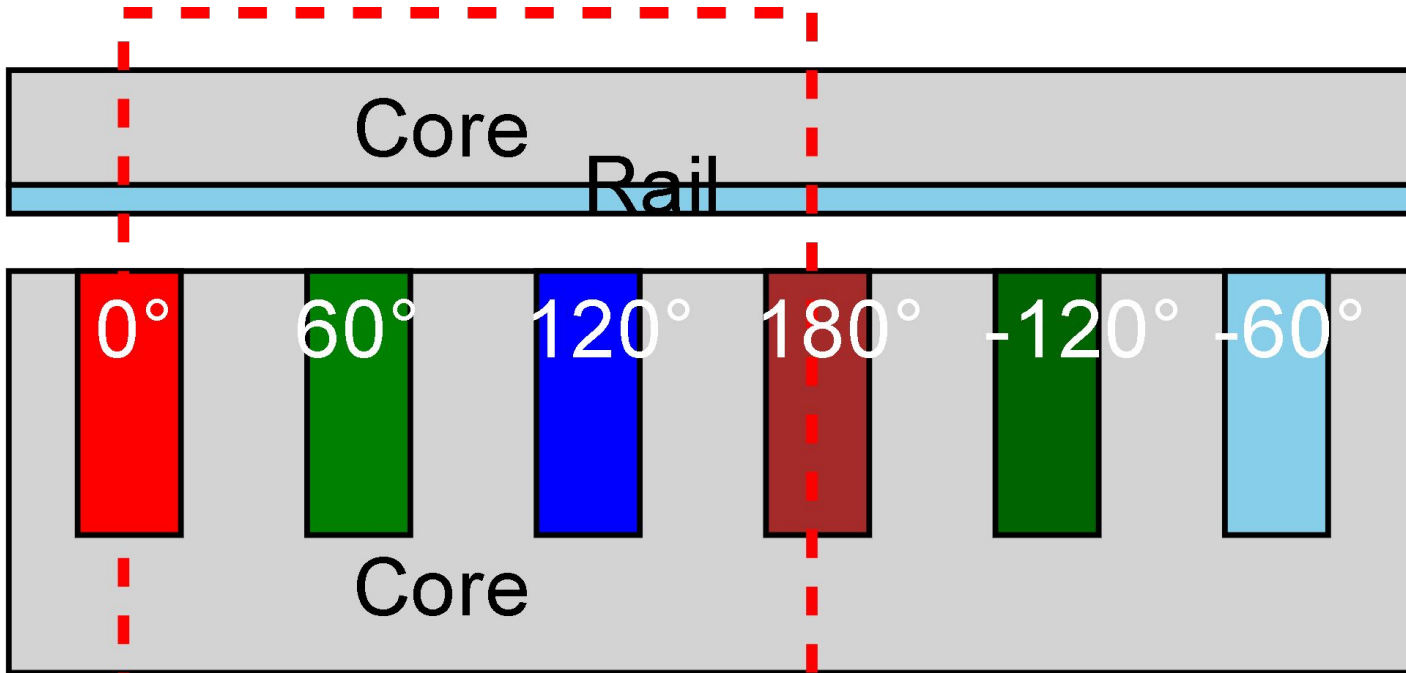
Task:

Find the electromagnetically induced voltages in the right (victim) transmission line at the ungrounded end of the 10 km segment.

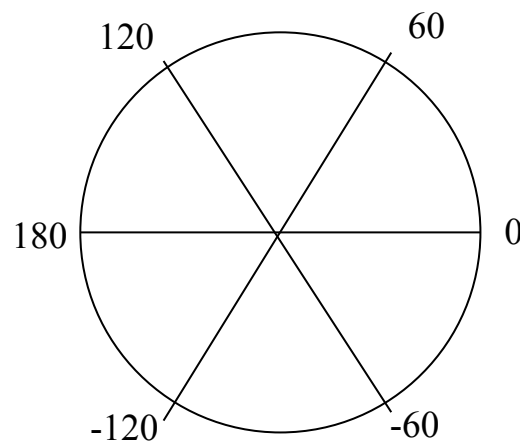
Transmission line magnetic coupling



Linear electric motor



Model



Problem specification:

Core permeability $\mu = 1000$;

Rail conductivity $\sigma = 37 \text{ MS/m}$;

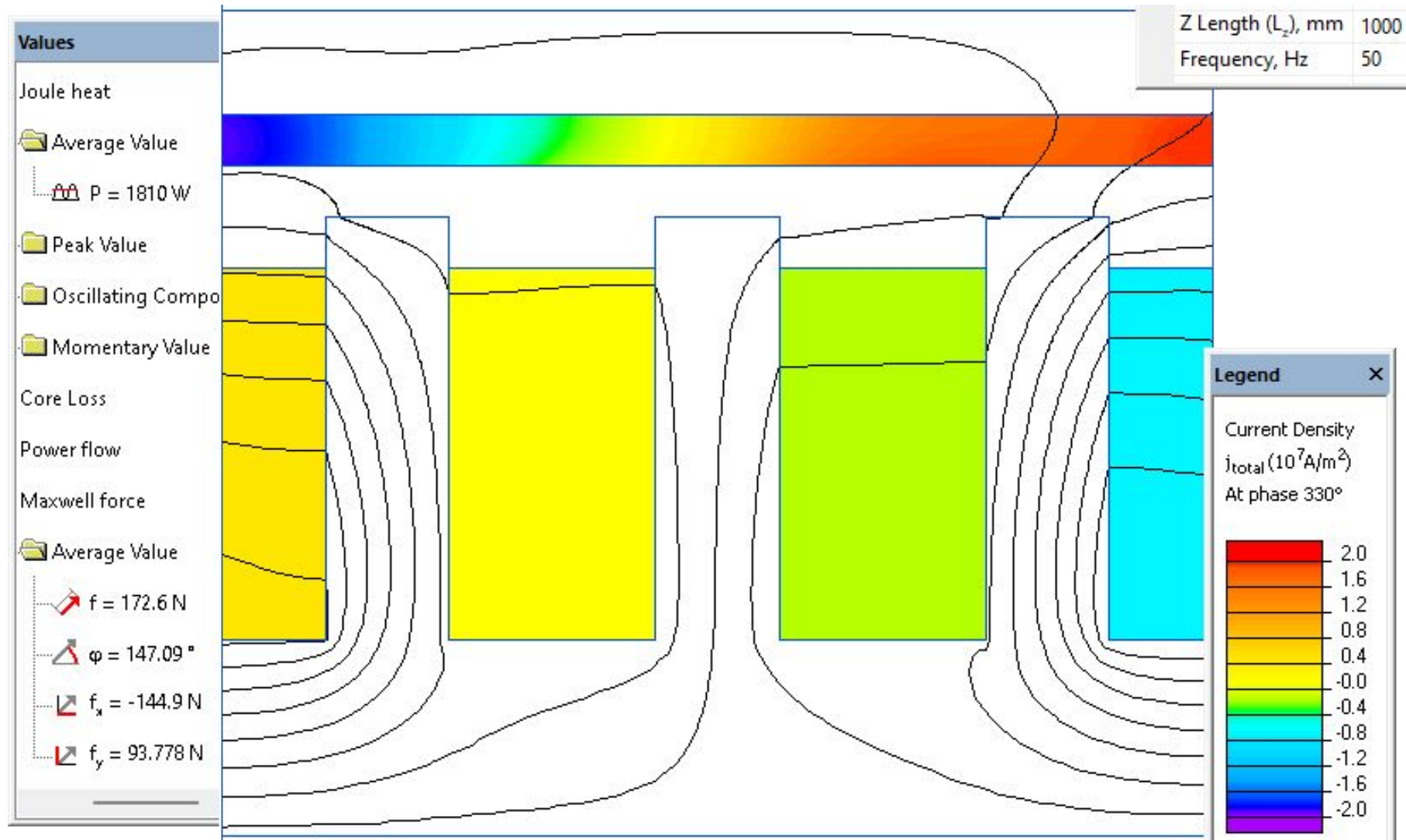
Frequency $f = 50 \text{ Hz}$.

Slot total current $I = 1844 \text{ A (r.m.s)}$

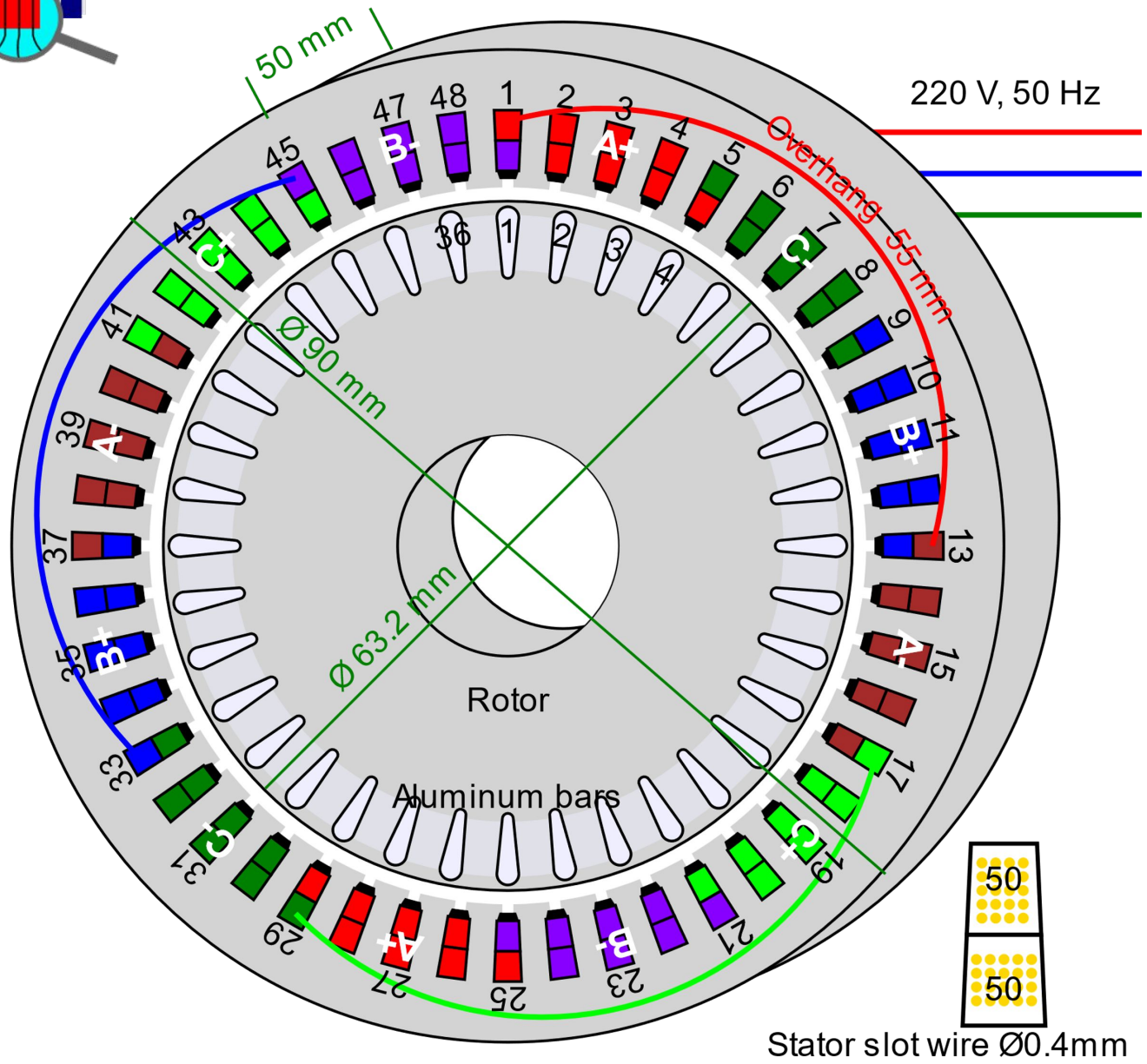
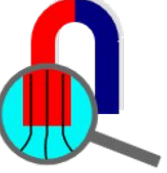
Task:

Calculate propulsion force acting on the rail and Joule heat loss.

Linear electric motor



Induction motor



Problem specification:

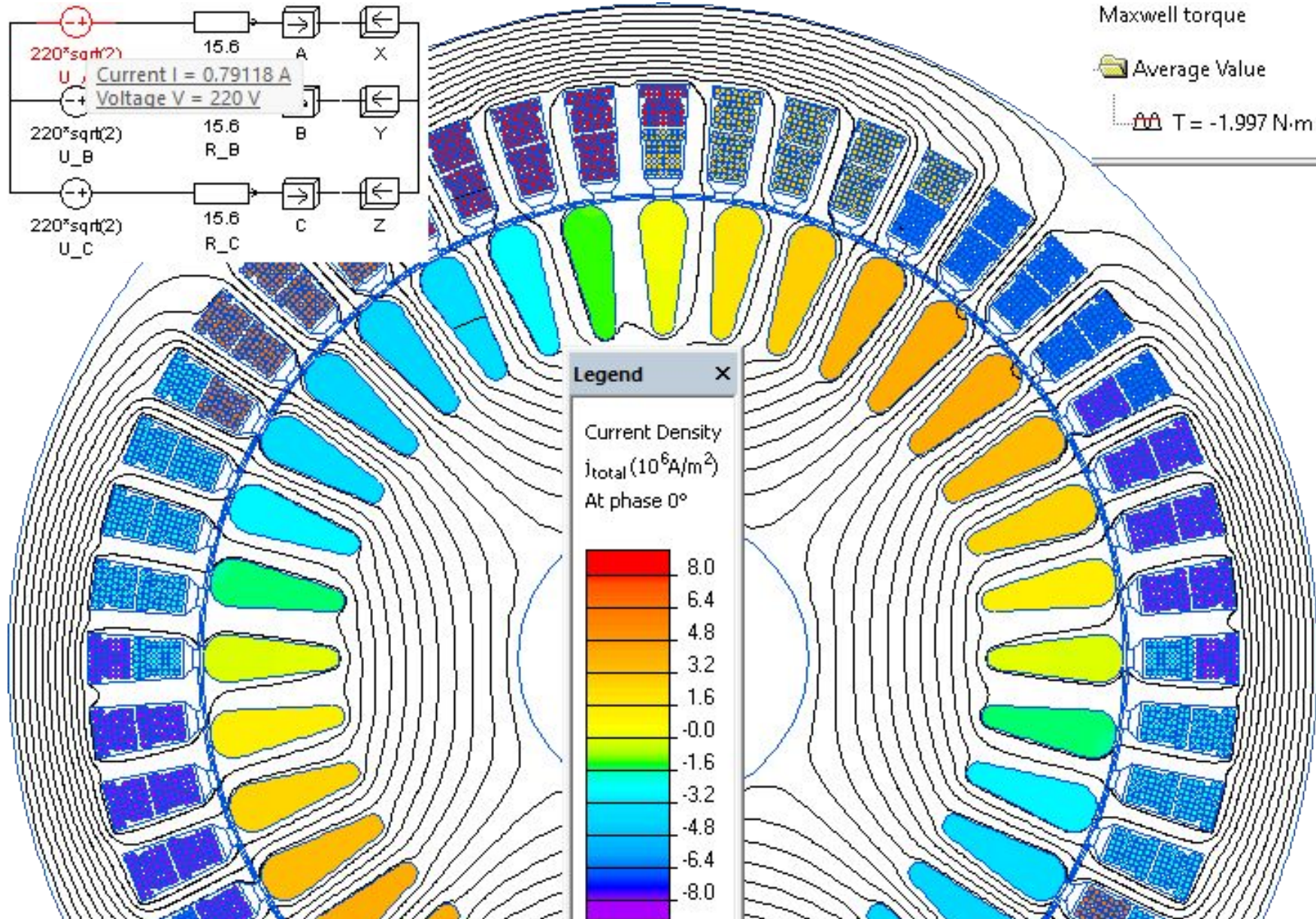
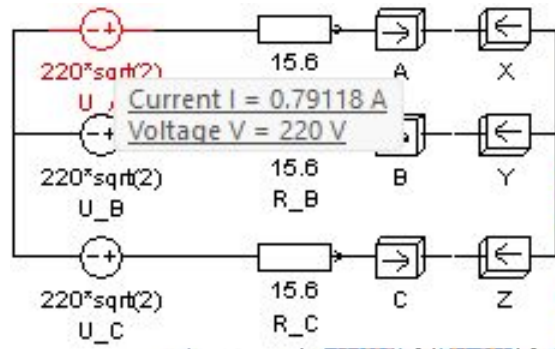
Conductivity of copper $\sigma_1 = 46.8 \text{ MS/m}$;
 Conductivity of aluminum $\sigma_2 = 31.1 \text{ MS/m}$;

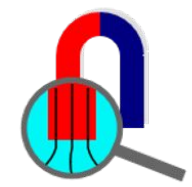
Task:

Calculate torque, current, Joule heat losses in the rotor at various rotation speeds

Rotation velocity	Rotor currents	Bar conductivity in the model
0 - stall		σ_2
Slip: $0 < n < n_0$		$\sigma_2 * (1 - n / n_0)$
Synchronous	0	0

Induction motor





This recording is over

**More recordings and simulation
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Your feedback is welcome: support@quickfield.com