Experiment No. 4

Aim:

To obtain the magnetic signature of a Naval Vessel (ship/submarine) under the influence of Earth's magnetic field using FEM-based EM Simulation Software.

What will you learn by performing this experiment?

This experiment develops an understanding of the degaussing problem in naval vessels. A 3-D model of either ship or submarine under the influence of Earth's magnetic field is simulated as a magnetostatic problem in a FEM solver (COMSOL Multiphysics). The result obtained is the induced magnetism in the vessel observed at a line below the hull.

Software Required:

1. COMSOL Multiphysics (Magnetostatics, Magnetic Fields no currents) or any FEM based 3D EM Simulation Software.

Theory:

Magnetic Signature and Degaussing

The term "signature" describes the spatial and temporal distribution of a ship's electromagnetic fields. The most important signature source of magnetic field is the magnetization of the ferromagnetic steel used in the construction of a naval vessel's hull, internal structure, machinery, and equipment. This signature can be detected by the underwater mines and cause damage to the ship. A degaussing system comprises several loops of cable placed throughout the vessel, which, when energized with the proper amount of current, produce a magnetic flux distribution equal to the un-degaussed signature but of opposite polarity. It could be said that degaussing, correctly done, makes a ship "invisible" to the sensors of magnetic mines. Still, the ship remains visible to the human eye, radar, and underwater listening devices.

Fig. 4.1 Threats to a Naval Vessel

Earth's Magnetic Field

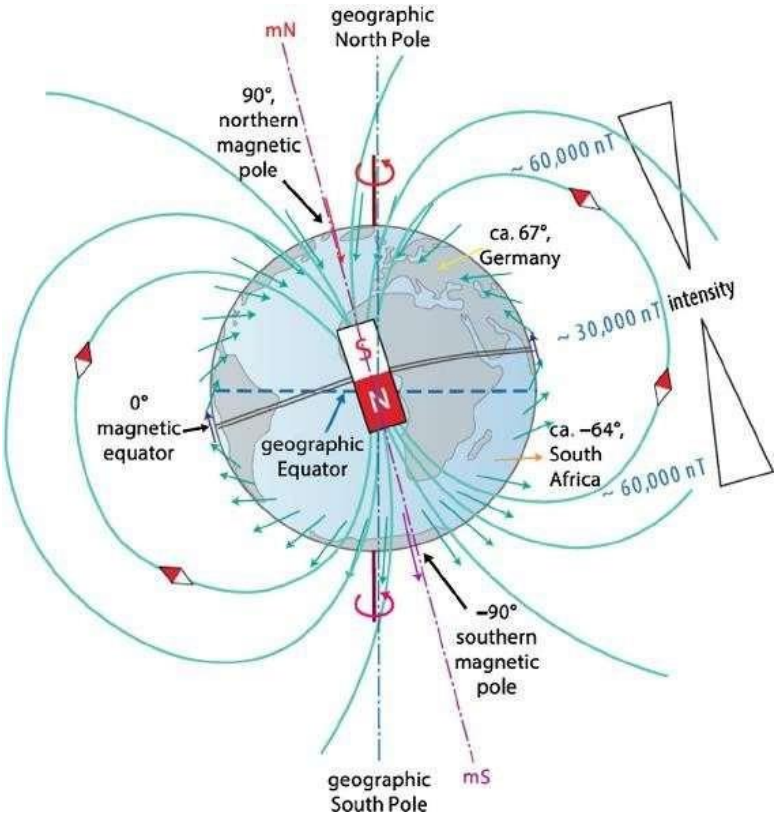
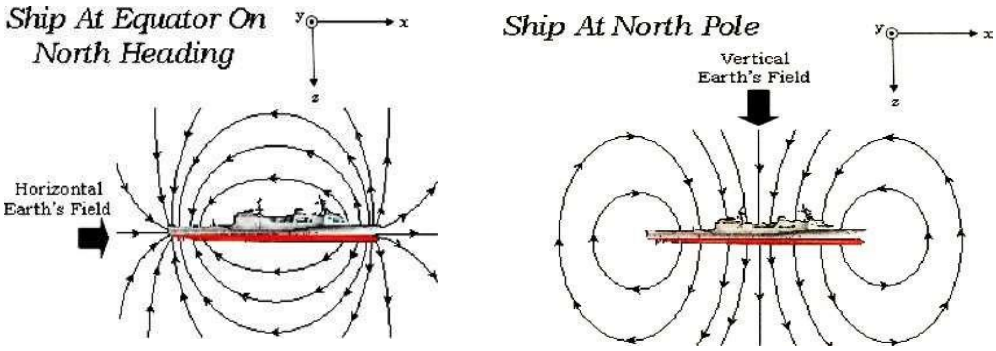


Fig. 4.2 Earth as a magnetic

The strength of Earth's magnetic field at the surface varies from approx. 30000 nT near the equator to 60000 nT near the poles. The accepted model for Earth's magnetic field is the International Geomagnetic Reference Field (IGRF), put forth by the International Association of Geomagnetism and Aeronomy (IAGA). Online IGRF data: Taj Mahal, Agra (47359 nT).

Based upon the location and heading of a vessel different components of Earth's magnetic field become dominant. For example, vertical component of magnetic field **B** is more dominant at the north pole.



Simulation:

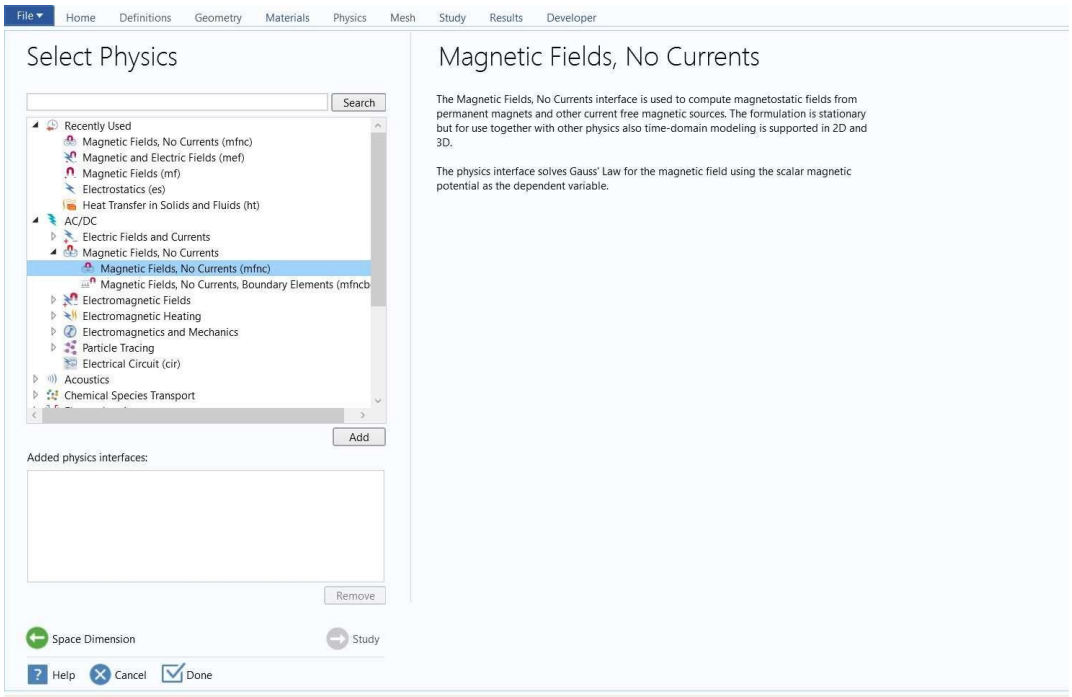
Simulation Geometry:

The CAD models of scaled-down versions of ship hull (7:36) and submarine(1:6) with units in mm can be referred to here: https://drive.google.com/drive/folders/19-oRicQZrBicDE1crnr3uJGqWPzoAgPW?usp=sharing. Students can choose any arbitrary dimensions and design for the same.

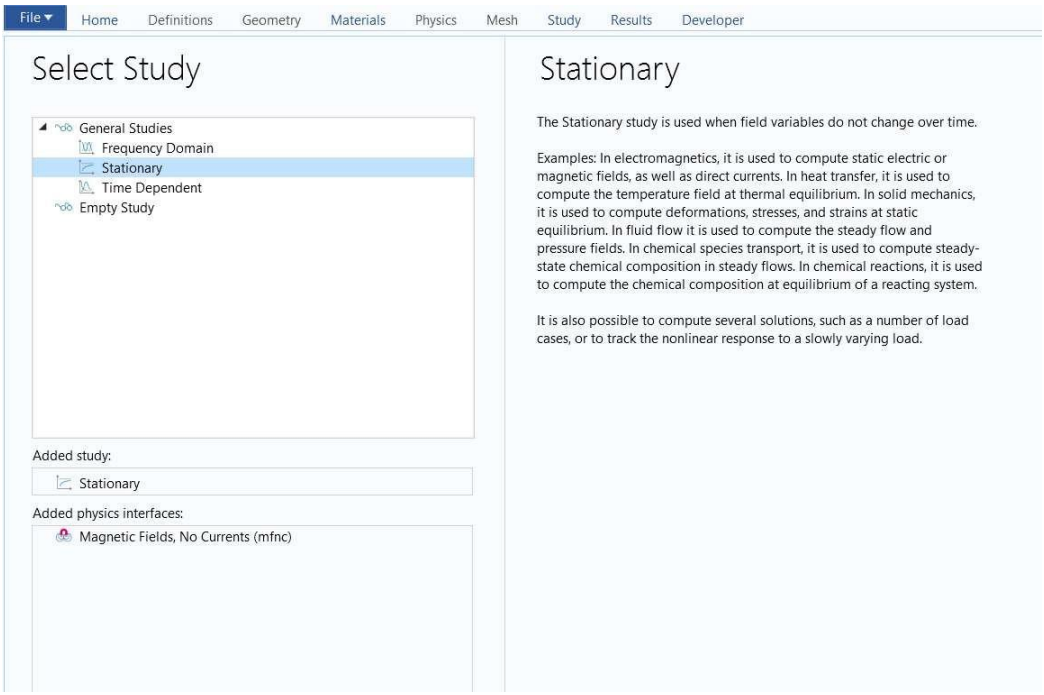
Procedure:

1. Install the EM Simulation Software.

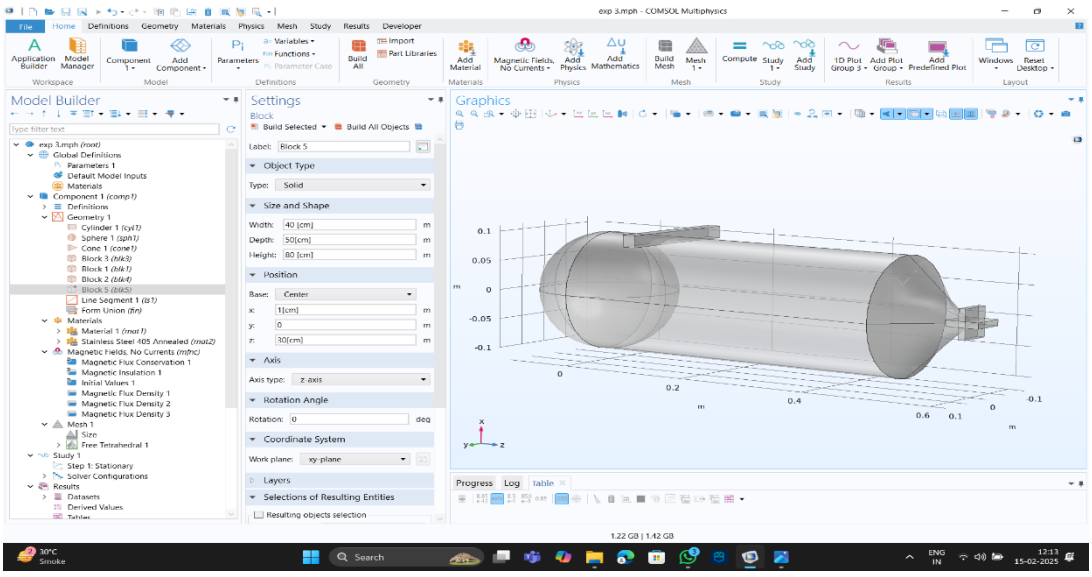
2. Select 3D Modeling-> AC/DC Module-> Magnetic Fields no Currents->Magnetostatics



3. Choose Stationary Solver.

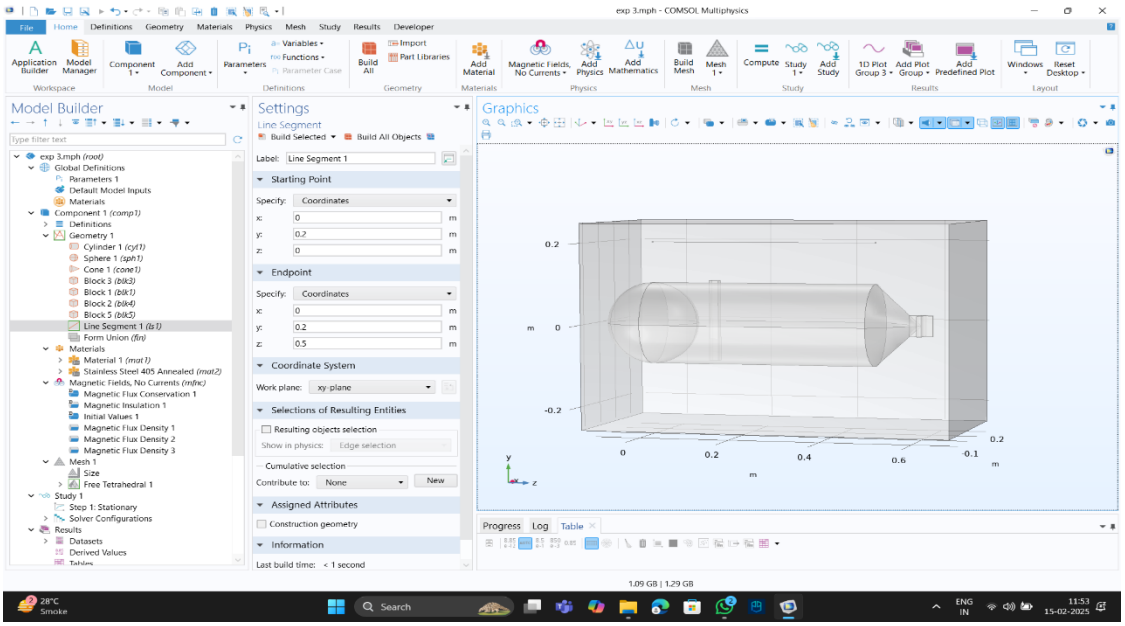


4. Create Model Geometry.

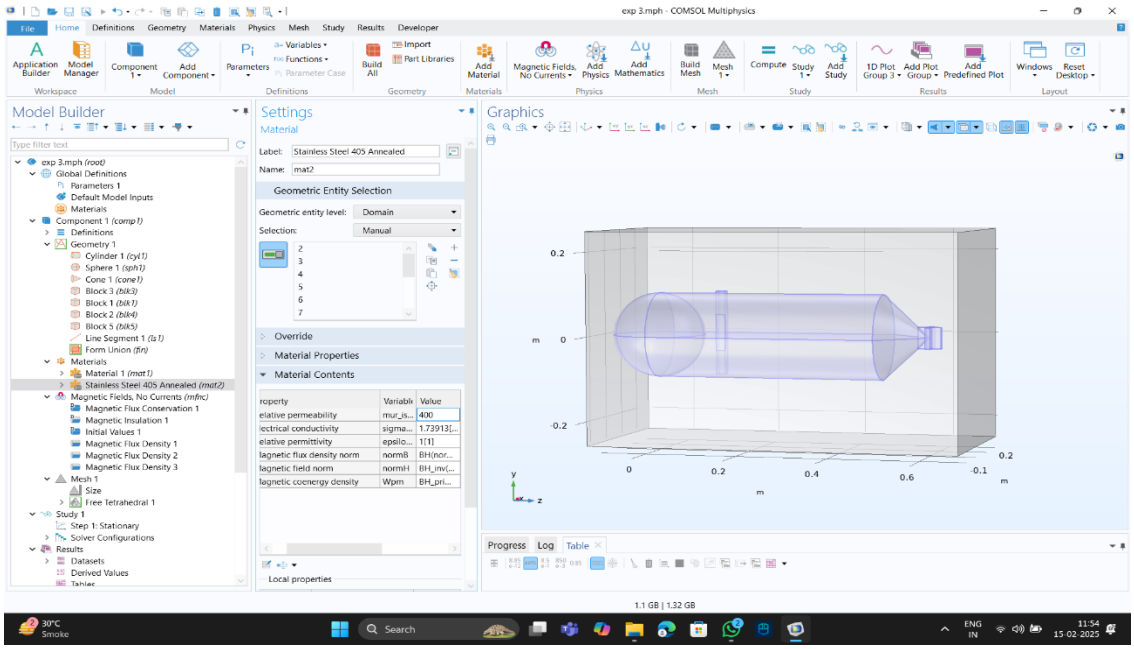


Right click on Geometry-> in Boolean Partitions select Union and Union all objects in the geometry.

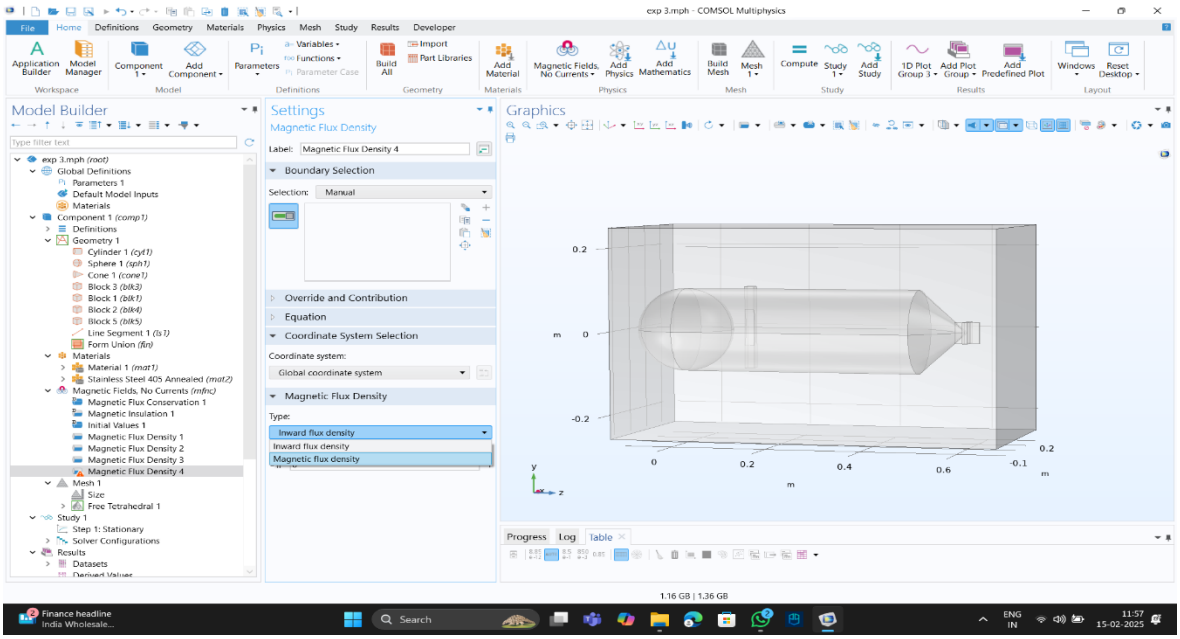
5. Create a surrounding block and an observation line at some distance below the hull.



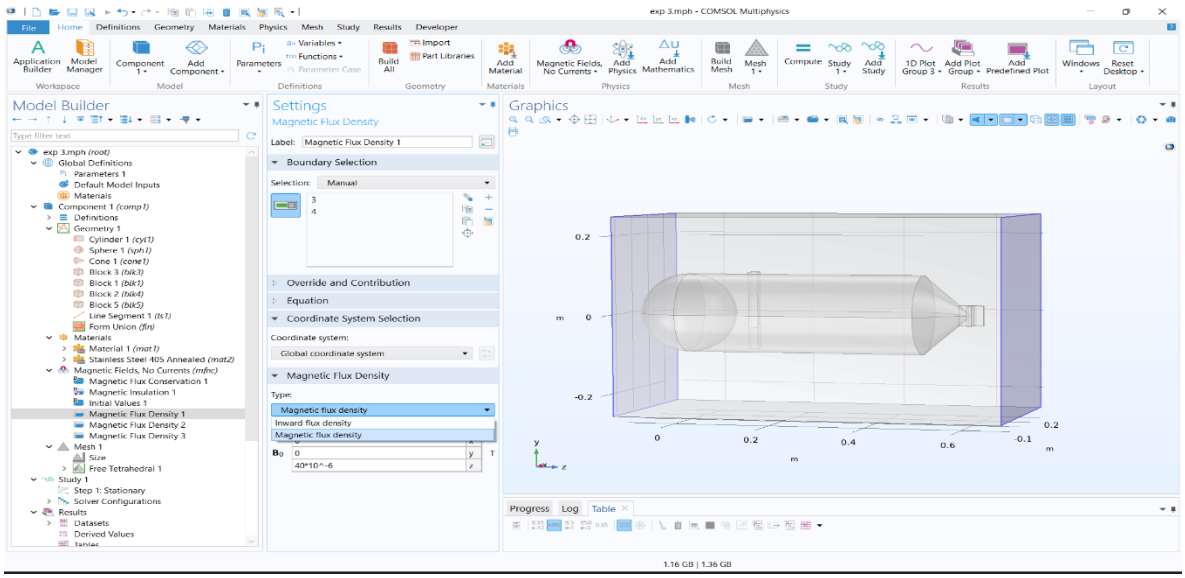
6. Assign blank material with permeability 1 for the outer block and choose Stainless steel from the material library with permeability 400.



7. Choose magnetic flux density boundary condition with type magnetic flux density.



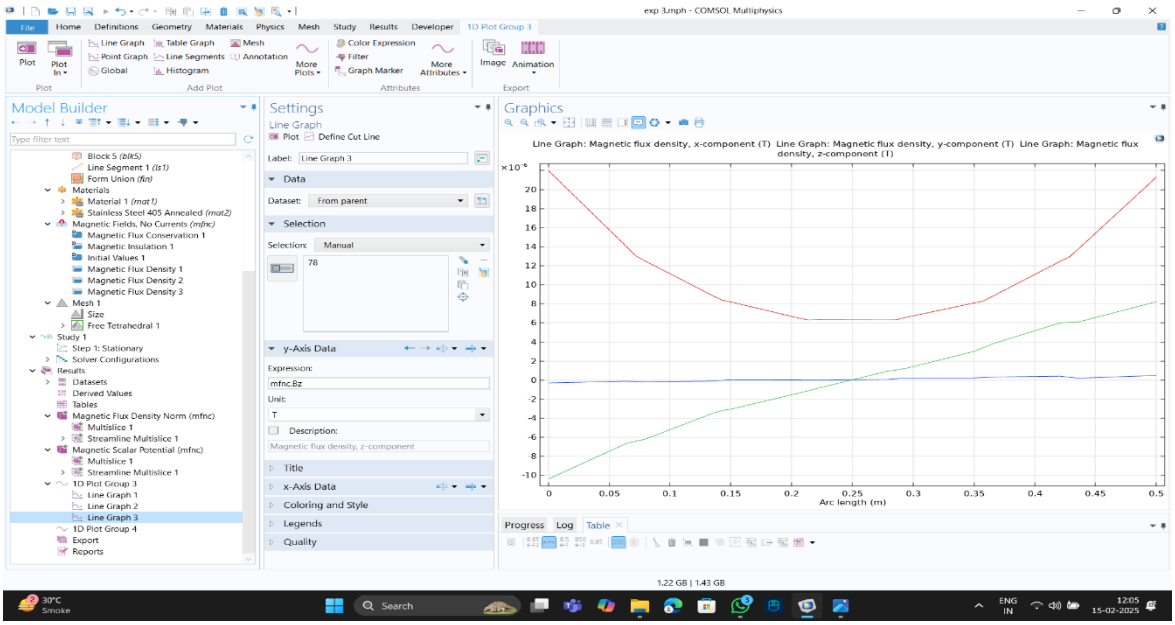
8. Set three boundary conditions for each pair of faces in the three directions.



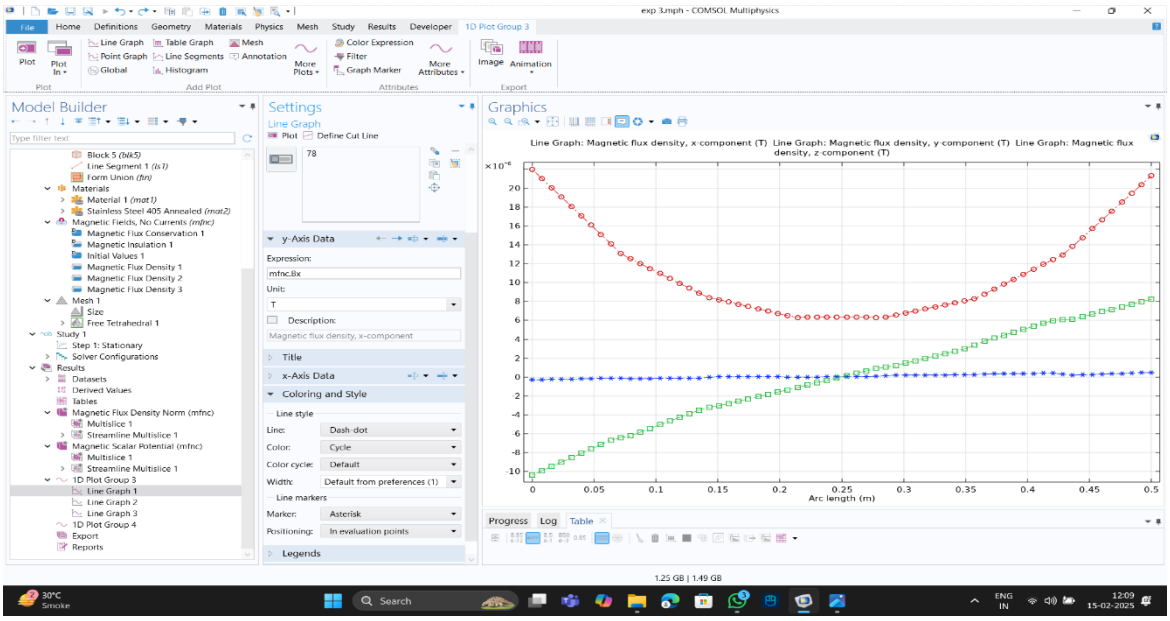
9. Observe the Results/Plots.

Results:

The magnetic signature plot choosing 1D Plot group->Line graph (1 each for mfnc.Bx, mfnc.By, mfnc.Bz) will be as follows:



Subtract the external field in each direction to get the actual magnitudes of the signature.



Conclusion & Discussion:

By performing this experiment, we learned the nature of the magnetic signature of a Naval Vessel (ship/submarine) under the influence of Earth's magnetic field and obtained it using the COMSOL Multiphysics Simulation Software.