# Project Overview: Analytical Study of the non-ideal superconducting sphere trapped in Quadrupole magnetic field

This project involves detailed analytical calculations for the non-ideal superconducting sphere (non-ideal sphere described as spheroid) trapped in a quadrupole magnetic field.

In this summary, we first define the surface of a spheroid using a summation of spherical harmonic vectors. We then derive the normal vector to the surface of the spheroid. Following this, we analytically calculate the magnetic field at the surface of the spheroid, considering the applied quadrupole magnetic field for a single translational degree of freedom. Finally, we generalize this calculation to contain all three translational degrees of freedom aligned with the force calculations.

## Structure:

* All the files submitted on 15th Aug 2024 are given in folder - **20240815 current results**.
* This folder is divided into several subfolders stated as **20240815\_P1, 20240815\_P2, 20240815\_P3, 20240815\_P4, 20240815\_P** whose detailed description is given below.
* Each pdf file is accompanied with a corresponding Mathematica file which includes the lengthy equations referenced in the handwritten notes. Mathematica files may also be used from verification of the calculations.

## 20240815\_P1 : Defining the Spheroid

This subfolder contains files which focus on defining the analytical equation of the non-ideal sphere, which will be used throughout the project. The non-ideal sphere is modeled as a spheroid. This section provides a detailed derivation of the equation for the spheroid in spherical co-ordinates.

Link to the Folder: [20240815\_P1](https://uofwaterloo.sharepoint.com/:f:/r/sites/tm-iqc-sqdmisc2-DarshKhandelwalS24/Shared%20Documents/DarshKhandelwalS24/20240815_current%20results/20240815_P1?csf=1&web=1&e=ammbp3)

Contents:

***Section A - Defining the spheroid.pdf*** : Handwritten notes involving detailed calculations for the derivation of equation of spheroid in spherical coordinates. The equation derived is expressed as a summation of two spherical harmonics namely, Y00 and Y20.

***Defining the spheroid.nb***: Mathematica file including references of equations given in the handwritten notes. This file can be used for verifying the calculation and referencing the lengthy equations.

## 20240815\_P2 : Normal Vector to surface of Spheroid

This subfolder focuses on deriving the normal vector to the surface of the spheroid using the equation of the spheroid.

Link to the Folder: [20240815\_P2](https://uofwaterloo.sharepoint.com/:f:/r/sites/tm-iqc-sqdmisc2-DarshKhandelwalS24/Shared%20Documents/DarshKhandelwalS24/20240815_current%20results/20240815_P2?csf=1&web=1&e=gXcgIf)

Contents:

***Section B - Normal Vector to surface of Spheroid.pdf*** : Handwritten notes which involves detailed calculations for deriving the normal vector to the surface of the spheroid.

***Normal Vector to Surface of Spheroid.nb*** : Corresponding Mathematica file for reference of the equations.

## 20240815\_P3 : General procedure

This subfolder contains the handwritten notes file which describes the general procedure to calculate the Magnetic field for different configurations or orientations of spheroid with respect to the applied magnetic field.

**Note** - This section is completely theoretical and does not involve any Mathematica file for the reference. The procedure described in this file is used throughout the project.

Link to the Folder: [20240815\_P3](https://uofwaterloo.sharepoint.com/:f:/r/sites/tm-iqc-sqdmisc2-DarshKhandelwalS24/Shared%20Documents/DarshKhandelwalS24/20240815_current%20results/20240815_P3?csf=1&web=1&e=ABNhkI)

Content:

***Section C - General Procedure Bout.pdf*** : Handwritten notes describing the general procedure performed throughout the project for the calculation of Magnetic field at the surface of spheroid (B).

## 20240815\_P4 : Displacement (dz )

This subfolder describes the calculation for the case of translation of applied magnetic field in (z) direction. This folder involves the calculation for Magnetic field and force acting on the spheroid for the configuration of applied magnetic field.

Link to the Folder: [20240815\_P4](https://uofwaterloo.sharepoint.com/:f:/r/sites/tm-iqc-sqdmisc2-DarshKhandelwalS24/Shared%20Documents/DarshKhandelwalS24/20240815_current%20results/20240815_P4?csf=1&web=1&e=t4DV7M)

Content:

B:

***Section D - Displacement dz.pdf*** : Handwritten notes for B calculation for the defined configuration.

***Displacement dz.nb*** : Corresponding Mathematica file for B calculation.

Force:

***Section E - Force Displacement dz.pdf*** : Handwritten notes for force acting on the spheroid.

***Force displacement dz.nb*** : Corresponding Mathematica file for force.

## 20240815\_P5 : General Displacement

This subfolder describes the calculation for the case of general translation of applied magnetic field in (x,y,z) directions. This folder involves the calculation for Magnetic field and force acting on the spheroid for the configuration of applied magnetic field.

Link to the Folder: [20240815\_P5](https://uofwaterloo.sharepoint.com/:f:/r/sites/tm-iqc-sqdmisc2-DarshKhandelwalS24/Shared%20Documents/DarshKhandelwalS24/20240815_current%20results/20240815_P5?csf=1&web=1&e=0MhfLZ)

Content:

B:

***Section F - General Translation.pdf*** : Handwritten notes for B calculation for defined configuration.

***General Translation.nb*** : Corresponding Mathematica file for B calculation.

Force:

***Section G - Force General Translation.pdf***: Handwritten notes for force calculation.

***Force General Translation.nb*** : Corresponding Mathematica file for force.

Next Steps and Future work:

Upcoming Additions to the Above Calculations:

* Extending the work of analytical calculations by encountering the three rotational degrees of freedom on the spheroid accompanied with three translational degrees of freedom (There are some issues in calculation on which I am working on right now. I will upload the notes as soon as I resolve the issues).

The above extension includes the calculation of -

1. Magnetic field at the surface of spheroid (B)
2. Force acting on the Spheroid
3. Torque acting on the Spheroid

* Calculation of the Energy of the system.