Phys460 Solid State project - Maxwell Rizzo - 4/28/23

1.

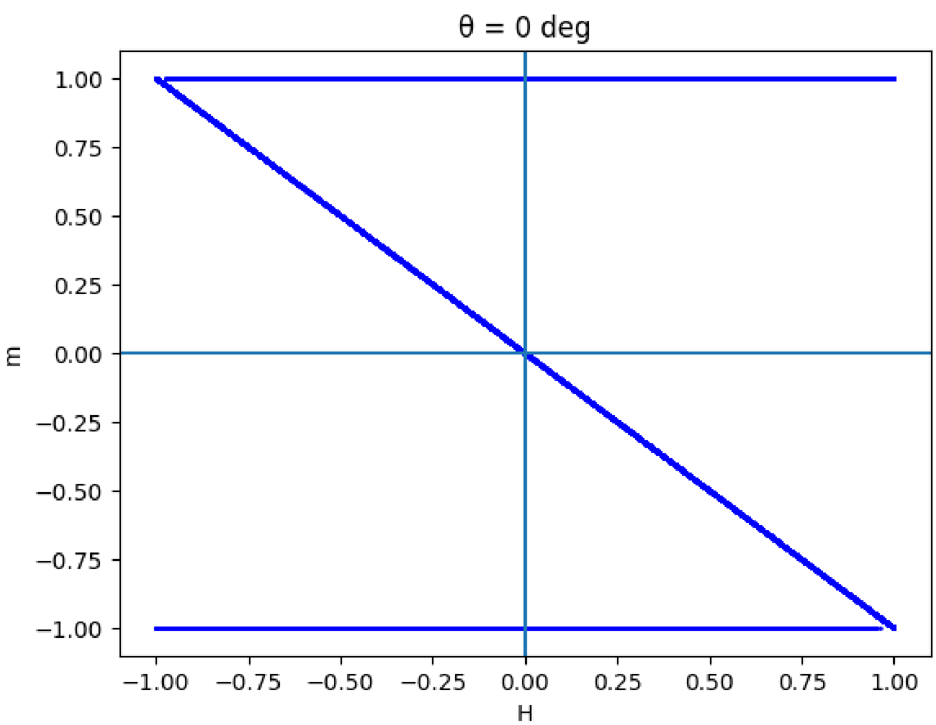
Ellipsoidal nanomagnet/ single magnetic domain. Magnetic field is applied at an angle Θ with respect to the long axis. Find the plot of how m depends on H for a few discrete values of Θ (0, 18, 30, 45, 60,90) degrees. Describe how the plots are generated.

The formula for the reduced energy
$\eta = E/((D_b - D_a)M) = \text{constants} - (1/4)\cos(2(\phi-\Theta)) - b\cos(\phi)$. The equilibrium position is when the energy is minimized, or $d\eta/d\phi = 0$ for a given value of Θ. $b = H/((D_b - D_a)M)$.

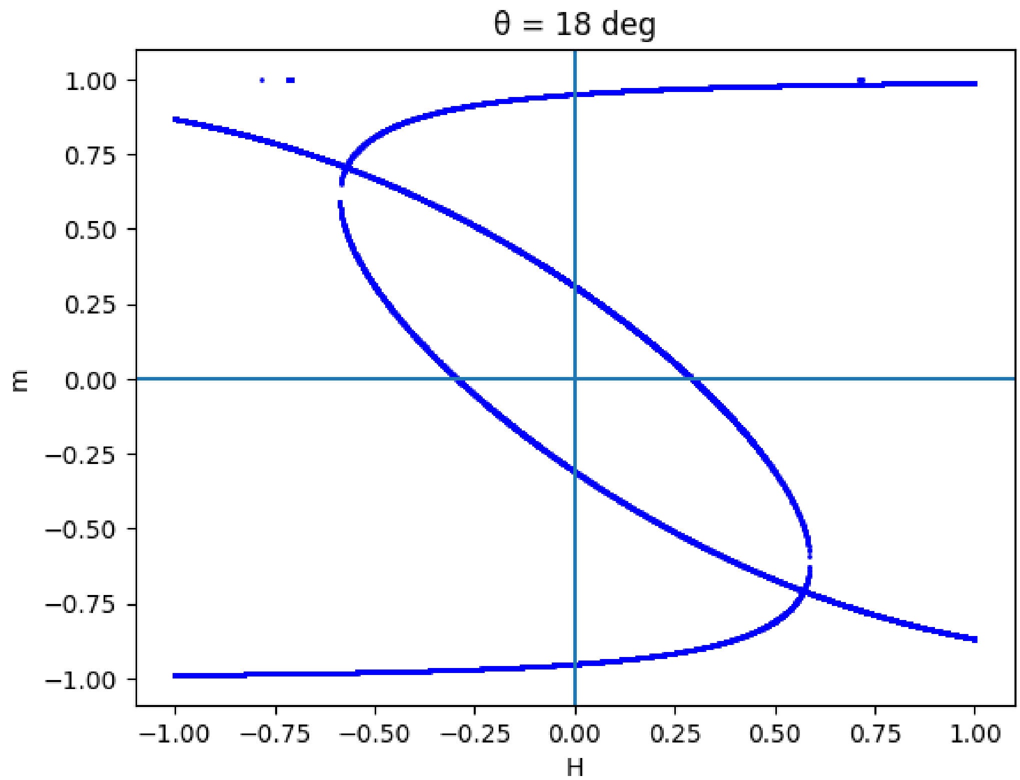
$d\eta/d\phi = (1/2)\sin(2(\phi-\Theta)) + b\sin(\phi) = 0$. The procedure for solving this equation is to pick a value of Θ, then loop through values of b = (-1,1). For each value of b, the equation can be solved numerically to determine values of ϕ that solve the equation. So, this step produces $\phi(b)$, as the process is solving for ϕ. Then, the projection $m = M\cos(\phi)$, and $\phi(b)$ is known, so
$m(b) = M\cos(\phi(b))$, which produces a plot of the projected magnetization m as a function of b, which is essentially H.

A.

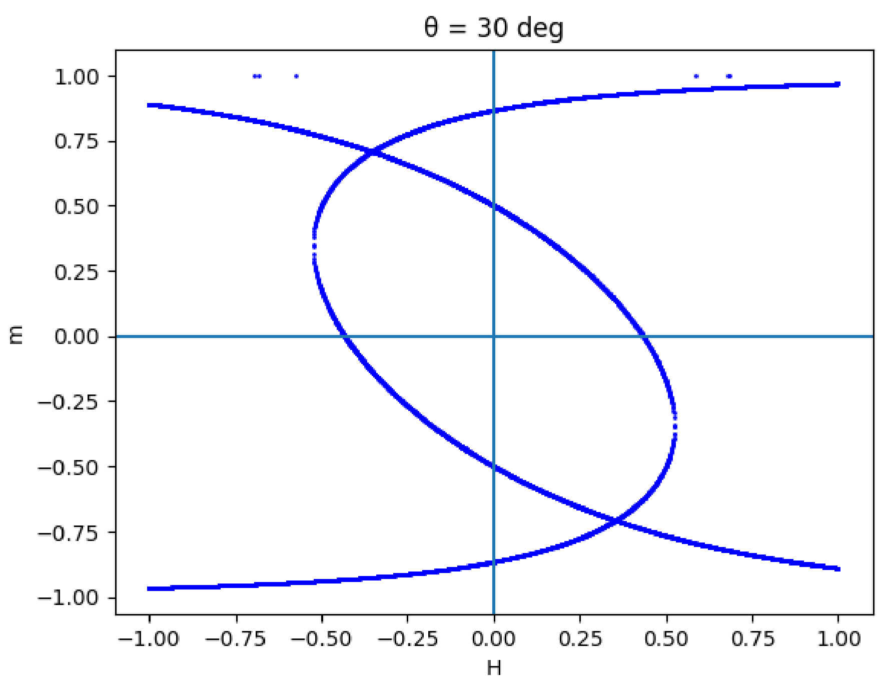
For Θ = 0 deg , here is the generated plot. The x-axis is b(H).



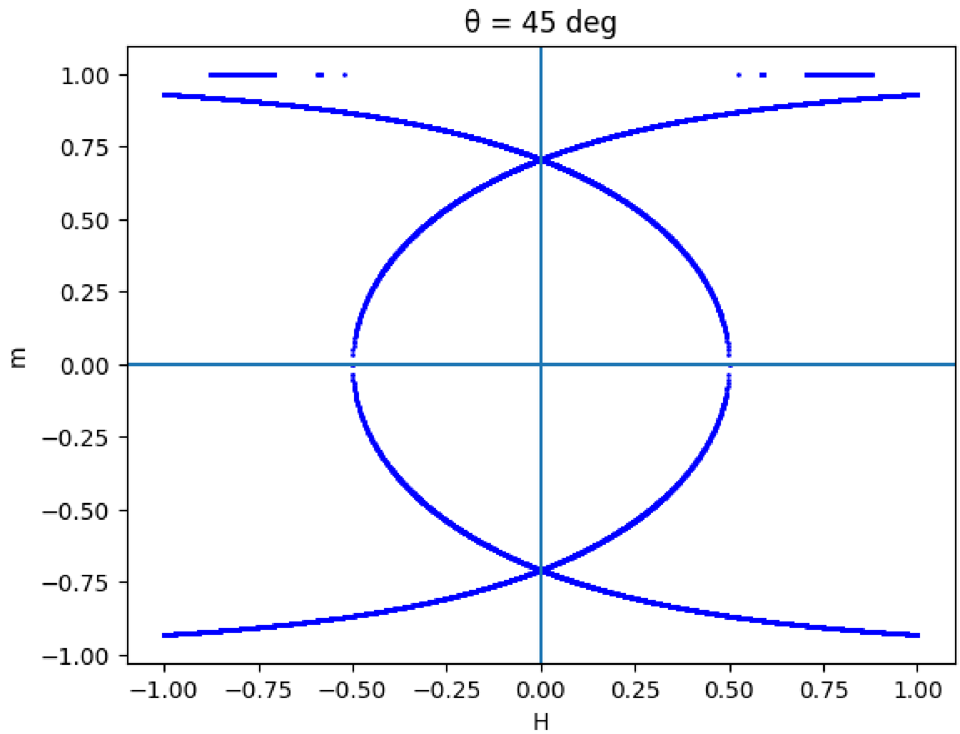
For Θ = 18 deg,



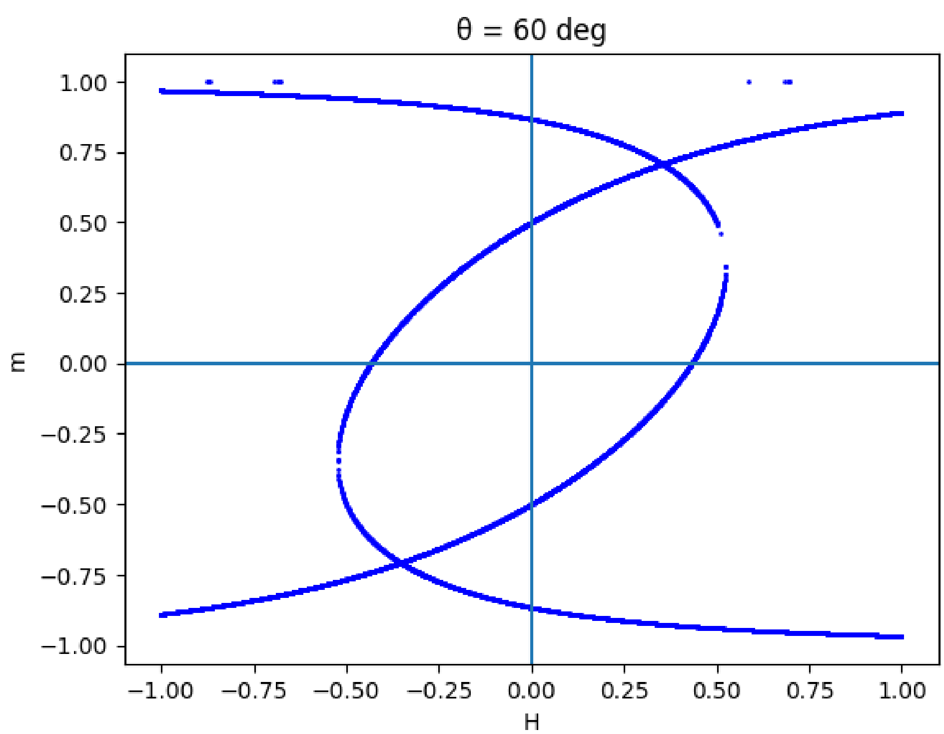
For Θ = 30 deg,



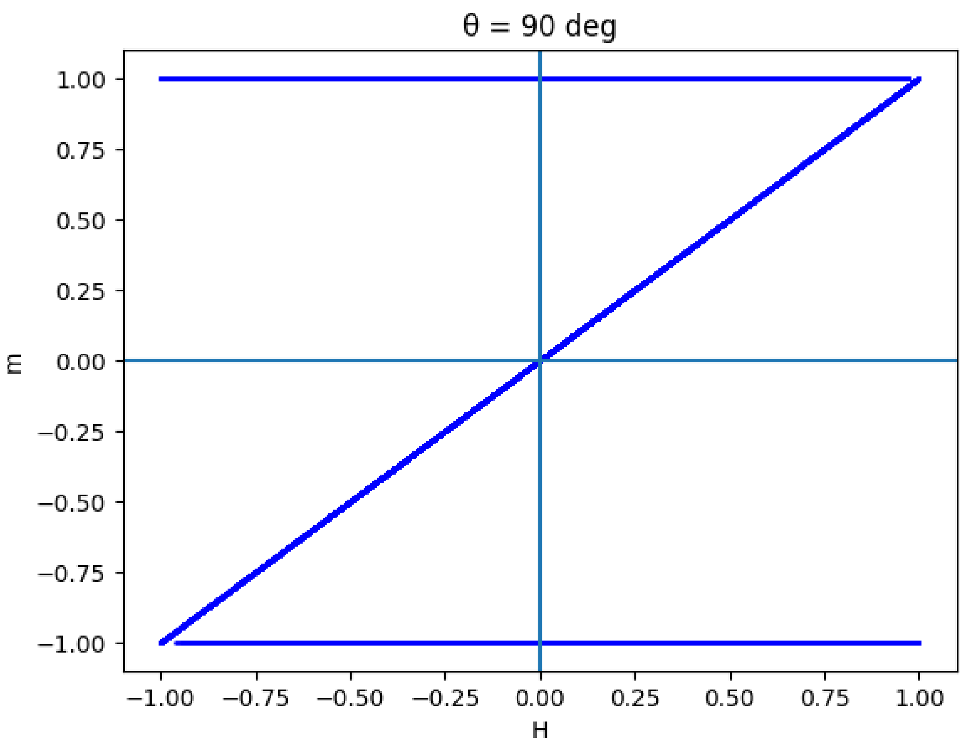
For Θ = 45 deg,



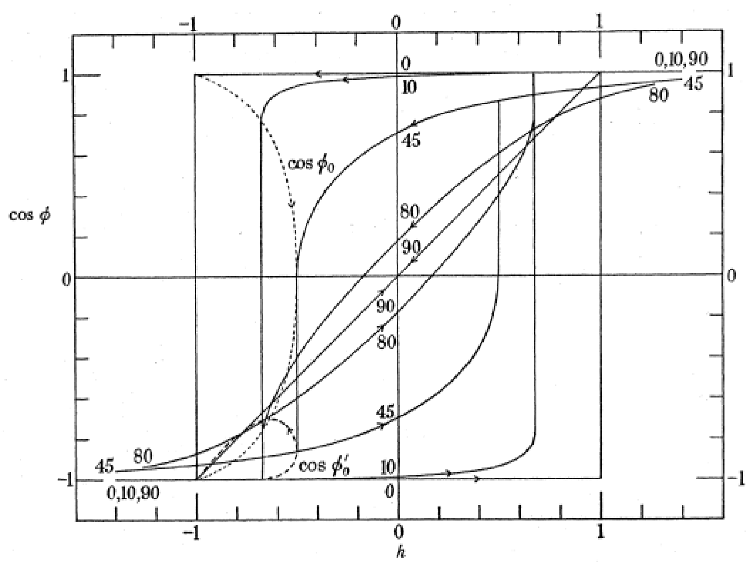
For Θ = 60 deg



For Θ = 90 deg



What they should look like (credit: Stoner 1947 Fig6)

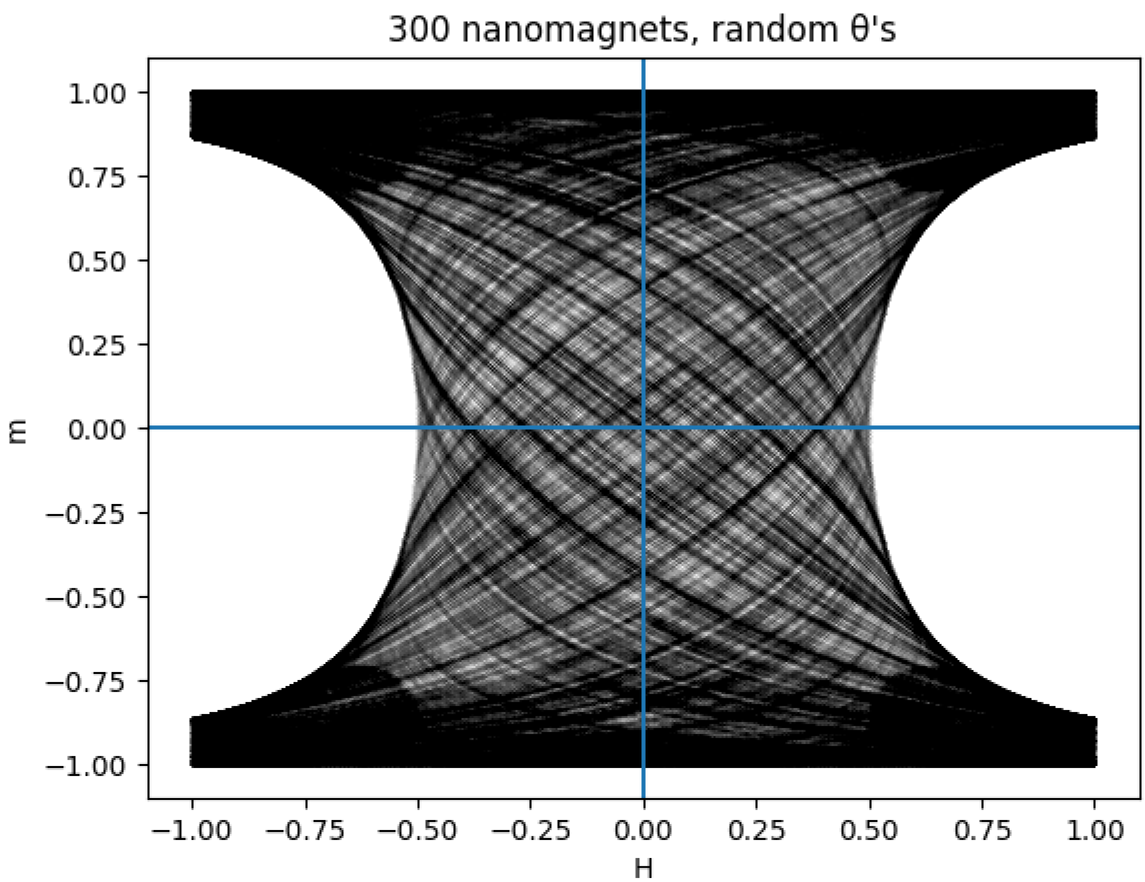


The plots are close to correct. The horizontal branches approximately match the figure from the Stoner paper, but the vertical/ transitions or discontinuities do not match. For Θ = 0 degrees, the top and bottom branches are recovered, but for some reason there is a linear branch connecting them instead of a instantaneous jump. I am not sure why this is occurring, but I believe it may have something to do with the multiple solutions in ϕ, and the correct mapping between ϕ(b) and m(ϕ).

The plots look approximately correct, but there are some major differences. I am not sure if my code is fully functional, I spent a significant amount of time coding this up and could not get it to fully function. I would like to spend more time to figure out the issue with my code, but with time constraints that is not an option. My code does recover multiple branches, and it appears that the plots could be reflected/translated to produce the expected result. It seems that it is a mapping issue between the recovered solutions. I believe my code recovers the solutions, it is just an issue of plotting the correct points in the right spots given the branches and degeneracies.

The main python code can be viewed Here, on my Github.

B. Running the code and plotting the figures for 300 different values of Θ.



Definitely an interesting plot. It appears to just be many different lissajous figures, overlaid on top of one another. I don't believe this is correct, overall the solutions should average and converge to a single hysteresis loop. Still this is an interesting result, and possibly indicates the total phase space possibilities of m vs H(b), given an arbitrary value of Θ. It shows what the maximum memory or field that exists for 0 applied field can be, and the range of values in between.

These results, while most likely incorrect, are interesting and require further analysis. I would like to refine my code to understand what is happening, but there is a lack of time so I must move on. I enjoyed the project, although it was significantly more difficult than I anticipated.