MuMaX3 Workshop | Exercises

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Standard problem 1

https://www.ctcms.nist.gov/~rdm/mumag.org.html

Standard problem 2

Fully solve Std Problem 2

https://www.ctcms.nist.gov/~rdm/std2/results.html

Standard problem 5

Fully solve Std Problem 5 based on the vortex movement with STT:

https://www.ctcms.nist.gov/~rdm/mumag.org.html

You can check MuMax3 repository:

Std Prob 5

FMR of a skyrmion

The following exercise consists in simulating a Neél skyrmion in a thin disk and then finding its resonance modes.

Geometry:

```
Disk 16 nm radius

Magnetic parameters for: PdFe on Ir(111) [PRL, 114(17):1-5, 2015]
Ms = 1.1e6  A/m
A = 2e-12   J/m
Ku = 2.5e6 - uniaxial out of plane anisotropy
DMI interfacial of D = 3.9 mJ / m^2
Do not consider demag
```

FMR of a skyrmion

Instructions:

- ☐ Relax a Neel skyrmion structure with the core in the $-z$ direction and the boundaries at $+z$
- ☐ Apply a weak `sinc` pulse in the $+z$ direction with the following parameters

```
fc := 50e9              // cutoff-freq -> simulate modes up to 50 GHz
t0 := 49.99 * 1e-12     // Delay time of the sinc pulse -> 50 ps
h0 := 0.01              // Pulse strength in Tesla
alpha = 0.01            // LLG damping
```

You can use the following function: $h_0 \text{sinc}\left(2\pi f_c(t - t_0)\right)$

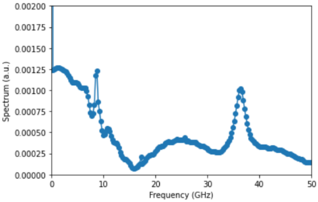
In MuMax3 you can use the `t` parameter when defining a vector field for the external field, for example:

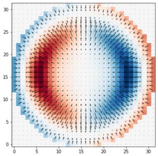
```
B_ext.set(vector(0, cos(2 * pi * t), 0))
```

For the exercise can use MuMax's `sinc(x) = sin(x) / x` function or use `sin(x)`

FMR of a skyrmion

- Run the simulation for `4 ns` and save both the magnetisation and average magnetisation (table) every `1e-11 s`
- To obtain the spectrum from the average magnetisation:
  - Take the `mz` from the table and substract `mz` at time `t=0`
  - Perform a 1D Fast Fourier Transform on the `mz` data and then take the absolute values (FFT gives imaginary numbers). Now you have the spectrum as a function of frequency.
  - When plotting you can obtain something like (to the right is the relaxed state)

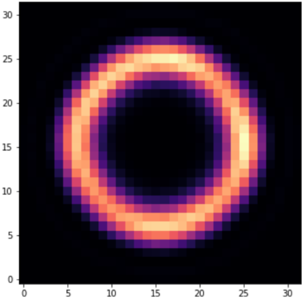




FMR of a skyrmion

Advanced: If you want to observe the resonane modes:

- ☐ In a single matrix stack the `mz` components of every node for every time
- ☐ For every node, perform a FFT and then ake the absolute values
- ☐ From the spectrum of the previous slide, estimate where the peak is and plot the `mz` components at the corresponding frequency. One of the resonance modes:



Spin waves DMI

Solve the problem of spin waves without DMI from

https://iopscience.iop.org/article/10.1088/1367-2630/aaea1c

You can base your results from the scripts in the public repository:

Standard problem DMI MuMax3 script