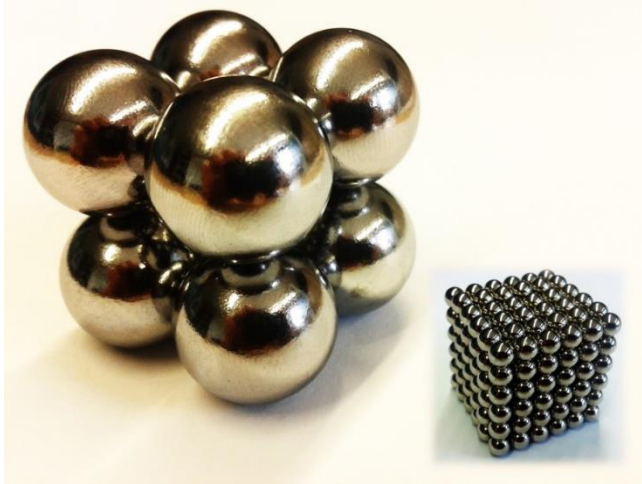


Cubic 2×2×2 Dipole Cluster – Ground state and interaction

Python animation [10.5281/zenodo.6484441](https://zenodo.org/record/6484441), Version 1.2.1 (2024)

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Experimental realizations of two different cuboidal dipole clusters formed from magnetic spheres. The 2×2×2-cluster is animated in with the software provided here.

The ground state of a **2×2×2-cuboidal dipole cluster** is animated with this Python program named `dipole_cube_main`. For details of the physics see: [Phys. Rev. B 98, 214424 \(2018\)](#), or <https://doi.org/10.48550/arXiv.1809.08081> and Refs. cited therein. Note that the [interactive gallery of the dipole cube](#) listed there moved to https://formaldesign.net/archive/cube_gallery/index.html.

Note that larger cubes can be animated with the code provided in [10.5281/zenodo.10084573](https://zenodo.org/record/10084573).

In version 1.2.1, some additional layout features were added and some flaws in the code corrected.

In Version 1.2, some errors of Version 1.1 were corrected and the layout is slightly changed. The inner structure of the program is adapted to the dipole cluster relaxation code described in T. Friedrich, I. Rehberg, R. Richter, Comment on "Self-assembly of magnetic balls: From chains to tubes", [Phys. Rev. E 91 \(2015\) 057201](#), and provided within the module “`dipole_cube_tools.py`” in the package “`dipole_cube_animation_1_2.zip`”.

The code is tested with Python 3.11.7, as downloaded from:

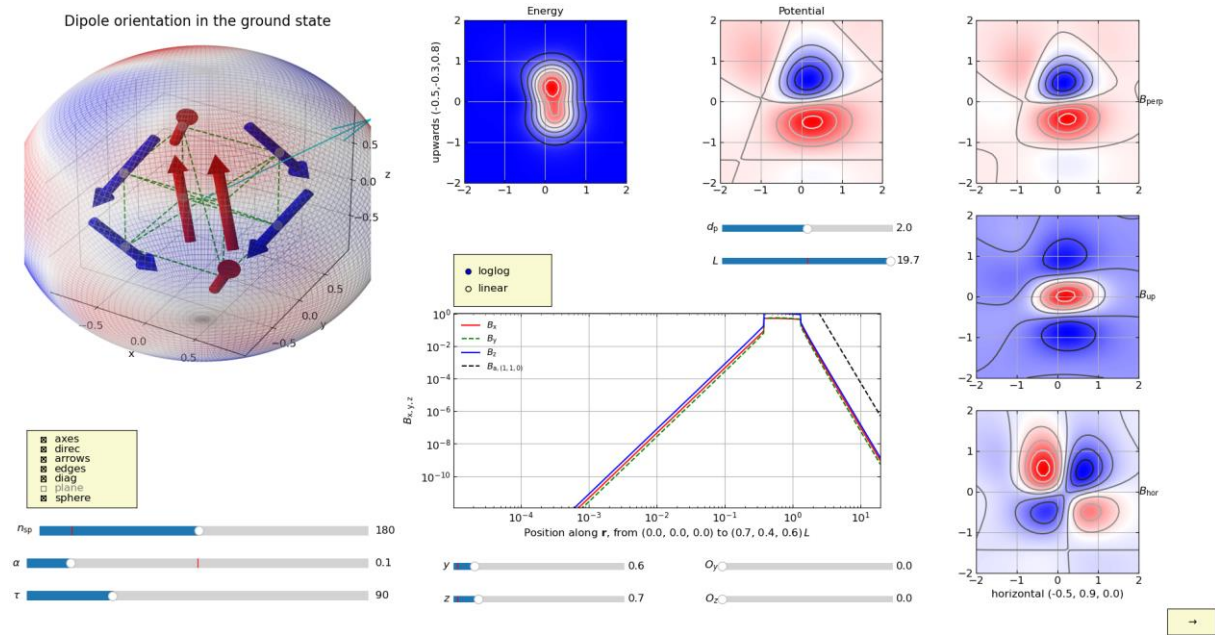
<https://www.anaconda.com/download/#windows>.

I gratefully acknowledge - and highly recommend - the use of Spyder IDE! (Spyder version: 5.5.1 (conda), Python version: 3.11.7 64-bit, Qt version: 5.15.2, PyQt5 version: 5.15.10, Operating System: Windows-10-10.0.19045-SP0)



*An experimental realization
of the continuous ground state
animated in the python script provided here.*

To get started, unzip the files and run “dipol_cube_main.py” on the upper directory. The animation comes with 2 figures, below is a screenshot from the first one:



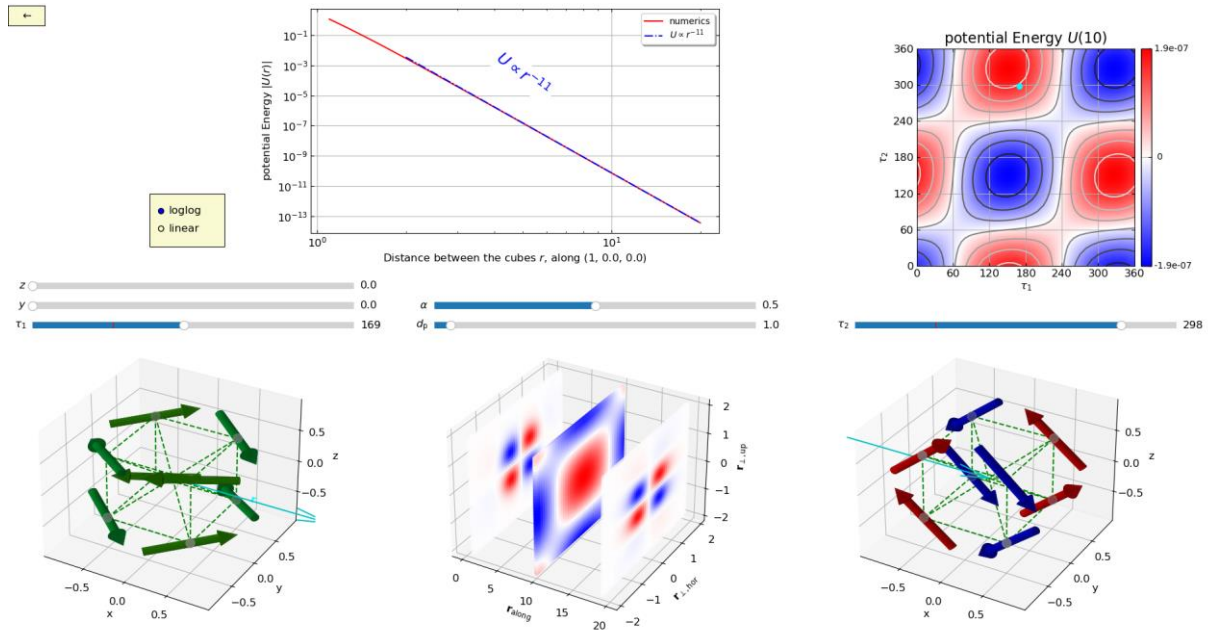
- The 3d-figure on the left hand side shows the orientation of the dipoles in the continuous ground state. The color of the arrows indicate the direction (as in [10.5281/zenodo.10084573](https://zenodo.org/record/10084573)). The slider τ varies that state. The edges and space diagonals of the cube can be added as guides to the eye with the “edges, diag” CheckButtons. The axes, the direction arrow, and the dipole vectors can be turned on/off with the “axes, direc, arrows” CheckButtons.

Additionally, a component of the magnetic induction is shown on a plane or spherical surface (as determined by the “plane, sphere” Checkbuttons), precisely the field component perpendicular to that surface. The α -slider determines the transparency of both surfaces.

Sphere: Its spatial resolution of the can be adjusted with the nsp-Slider at discrete values within the range 10 to 360 (180 in this screenshot). This number has to be chosen as a compromise between the artistic impression and the speed of the calculation.

Surface: It is chosen perpendicular to the cyan arrow shown inside the cube. Its direction and origin is changed with the four sliders in the lower middle part.

- The figure in the middle shows the three \mathbf{B} -field components along the direction \mathbf{r} as indicated by the cyan arrow. They are shown on either a linear or a loglog-scale, switchable with the “loglog, linear radio button”. The absolute value B_a along the (1, 1, 0) direction is shown as a reference.
- The remaining Figs. 3-7 show aspects of the magnetic field within the plane perpendicular to that direction, at a finite distance d_p as determined by the d_p -slider.
- The button \rightarrow on the lower hand side leads to the second figure, shown on a second page.



A screenshot from the second figure. Here two cubes are manipulated individually with the corresponding τ sliders. The coordinate systems of the 2 cubes are parallel to each other. For the animation, the center of the second cube is located at a fixed distance of 20 along the r -direction indicated in cyan color. r can be manipulated with the y, z -sliders. The remarkable feature of the interaction between both cubes is the decay of the interaction potential with the 11th power. The upper plot illustrates this on a semi-logarithmic or linear scale as chosen by the “loglog, lin”-Radiobuttons. While that power is robust for all combinations of τ_1 and τ_2 , both the sign and the prefactor are a function of τ_1 and τ_2 as indicated by the plot on the upper right hand side.

The lower middle plot illustrates that interaction further for a fixed distance of 20 between the cubes centers, measured along the direction of the cyan arrow r . Here the coordinate system is chosen such that the x-axis is parallel to the cyan arrow r shown in the center of the left cube. The 3 planes from the left (right) cube. The plane in the middle denotes the component of the Maxwell stress tensor, such that the integral over this plane (extended to infinity) gives the strength of the force component F_{along} between the cubes.

The d_p -slider indicates the distance of the planes showing the potential from their corresponding cube, and thus determines the distance between the planes. The transparency of both planes is set with the α -slider, while the middle “Maxwell”-plane is fixed to $\alpha=1$.

The \leftarrow button on the upper left hand side leads back to the first figure.

Cite as: Rehberg, Ingo. (2024). Python code for the animation of a cubic dipole cluster (Version 1.2.1). Zenodo. <https://doi.org/10.5281/zenodo.8387225>

An experimental realization to study the interaction of two cuboidal clusters formed by magnetic spheres with a diameter of 5 mm.

