Precession, Nutation and Dynamic Trajectory of a Magnetic Rod in an Axisymmetric Magnetic Field

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Precession and nutation in dynamical systems have been of long-standing research interest. Manifesting in systems as diverse as spinning tops to celestial bodies like planets, understanding these motions offer a window into the intricate dance of forces governing such systems. One example of a previously unexplored system exhibiting precession and nutation is that of a magnetic rod in an axisymmetric magnetic field. This project aims to study this system through qualitative, quantitative, and experimental means. A theoretical model was formulated using Newton’s Second Law and the torque equation, accounting for energy dissipation. One unique aspect of this system compared to other systems exhibiting precession and nutation is the presence of the non-linear magnetic force and torque, which were modelled by considering both magnets as current carrying cylinders. Experimentally, the dynamic trajectory and relevant degrees of freedom of the rod were measured using image binarization and ellipse fitting. This was used for a systematic investigation into how the nutation, precession and petaloid-like trajectories are affected by number of magnets, initial angular velocity and other relevant parameters. Theoretical predictions and experimental results show a good agreement. This work has various engineering applications such as centrifuge design, and could be used to introduce students to the concepts of precession, nutation and the magnetic force.