2024 CaYPT Research Paper for Problem G. Magnetic Gear

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Abstract

This research paper investigates the 2024 Canadian Young Physicists' Tournament (CaYPT) problem G. Magnetic Gear. The problem statement is as follows: "Take several identical fidget spinners and attach neodymium magnets to their ends. If you place them side by side on a plane and rotate one of them, the remaining ones start to rotate only due to the magnetic field. Investigate and explain the phenomenon." This paper offers an in-depth investigation, analysis, and exploration of the problem, through three models. These theoretical models are: "fast-spinning", which investigates the phenomenon when the driver spinner rotates with an initial angular velocity such that there is minimal oscillation in the reaction spinner; "slow-spinning", which investigates the phenomenon when the driver spinner rotates with an initial angular velocity such that significant oscillations arise between the two spinners; and "multiple elements", which investigates the phenomenon when there are more magnets, spinner arms, or spinners, in order to broaden the scope of the research. A simulation was developed based on theory and used in order to support experimental trends, and thus the phenomenon was able to be investigated and explained completely and thoroughly. Experiments and the theoretical models show visible matching trends in varying key parameters, including the closest distance between spinners, strength of magnets, polarity pattern on magnets, number of spinners, and number of magnets on each spinner. What is most interesting is the results of the variation of key parameters within the slow spinning phase: Higher initial speed causes lower amplitude oscillations for the driver spinner while resulting in higher amplitude oscillations for the reaction spinner. More magnets per arm increases the frequency and decreases amplitude, and leads to a faster initial climb to a greater angle for the driver spinner, but for the reaction spinner, it increases the amplitude of oscillations. Greater distance between the spinners causes a steep drop in both amplitude and frequency, showing how magnetic field strength decreases non-linearly over distance.