To Precess or to Retrogress: Dynamics and Anomalous Sway Precession of Euler's Magnetic Pendulum

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The Euler’s Magnetic Pendulum system consists of a uniform cylindrical rod suspended within a magnetic potential field beneath a horizontal plane. Typically, when a relevant pendulum motion is in consideration, general assumption is that the pendulum exhibits a fixed unidirectional precession. However, this study delves into the dynamic of Euler's magnetic pendulum, focusing on the intriguing phenomenon of anomalous sway precession. This paper is the first to document the anomalous sway precession in this pendulum, the interesting characteristic this study named where the direction of its precession alternates. The study uses analytical mechanics and rotation equations to analyze the pendulum’s dynamics within ideal conservative system, quantitative experimentally confirming the theoretical model’s accuracy under conditions without dissipation. Revealing that dissipation of energy within the system is the primary mechanism behind the observed phenomenon. The study proposes two models – air viscosity and randomness collision – to elucidate this counterintuitive behavior. Experimental measurements highlight a quasi-periodic increase in sway frequency as the sway progresses. The study contributes to a deeper understanding of energy transfer within magnetically dissipative rotating system. Furthermore, the discovered phenomenon holds potential applications, in generation of alternating rotative mechanical waves induced by gravity and, separately, in behavioral psychology and physiology applications. Moreover, the experimental platform established demonstrates plausible scalability. This study not only sheds light on the complex dynamics of magnetic pendulums but also underscores its interdisciplinary relevance, spanning physics, engineering and behavioral studies.