Experimental method of permanent magnet rotation

Weiming Tong (15193943275@139.com)
Suochi Schooling District, Cheng County https://orcid.org/0000-0003-0107-9526

Article

Keywords: Kinematic Relations, Spherical Magnet, Free Rotation

Posted Date: January 12th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-102538/v1

Abstract

Why does the earth rotate? In the 17th century, an accurate description of the earth's rotation was provided via Newtonian mechanics1. However, the driving force was not given a mechanistic treatment, was merely ascribed to a "push" by God. At present, All kinds of theories about the rotation of the planet are still hypotheses2,3. In this study, It provides experimental evidence for researching the relationship between planet (Earth) rotation and magnetic fields4. The proposed experimental devices and research methods are based on the characteristics of the kinematic relations between the sun and planet. A permanent magnet representing the sun is installed on the shaft of a DC motor, spherical magnet representing the planet is designed at the center of hollow sphere and can float on water, ensure free rotation. Based on the above device5, the method of permanent magnet rotation in magnetic field and the experimental procedure of rotation reason are introduced.

Introduction

All astronomical objects in the solar system are known to rotate[6], similar to the Earth[7]. At present, it is impossible to experimentally determine the force of planetary rotation[8,9]. Magnetic fields are among the fundamental fields of nature and exist in the space around satellites, planets, stars, galaxies, currents, moving charges, permanent magnets, and varying electric fields[10]. Although magnetic fields cannot be seen or touched, they can be studied based on their interactions with permanent magnets. The rapid development of modern electromagnetics has led to the emergence of electronic products, such as electric motor speed controllers[11], laser Doppler velocimeter[12], and Gauss meters, that measure magnetic induction[13]. Permanent magnets of various material, shapes, masses, and magnetic strength are also commonly used in everyday life[14,15,16,17]. With these developments, we now possess the necessary tools to study magnetic phenomena and the properties of magnetic fields using permanent.

This paper is structured as follows. In Section II, we list the conducted experiments and present our findings. In Section III, we conclude the paper and summarize the key points. In the Methods section, we detail the materials, design, and operation of the developed device and describe the experimental procedures followed for studying the rotation of the spherical permanent magnets for different parameters.

Experimental Results Of The Rotation Of Spherical Permanent Magnets In A Magnetic Field

The properties of the permanent magnets used in this study to represent the Sun and the planets are summarized in Table I.

A. Rotation effect of spherical magnet

The experimental setup for experiment A-I is illustrated in Fig. 1, and the experimental procedure followed in each experiment is detailed in the Methods section.

In experiment A, "planet"$m_{\square}$ started to rotation in the magnetic field because of the rotational torque of "sun"m_1[18]. Irrespective of where "planet"$m_{\square}$ was located around "sun"m_1, "planet"$m_{\square}$ always rotated around the axis passing through its core, similar to the rotation of the Earth[19,20]. Even when a 5-mm-thick iron plate was placed between them, "planet"$m_{\square}$ continued to rotate owing to the magnetic field. Therefore, we can place "planet"$m_{\square}$ anywhere around "sun"m_1 and observe its rotation behavior. For example, when "planet"$m_{\square}$ and "sun"m_1 are on the same horizontal plane, In each rotation cycle, "planet"$m_{\square}$ stopped for a moment and then continued to rotate. Furthermore, its rotational axis "wobble" once around its core during each cycle, and the wobble amplitude has obvious periodic frequency. This phenomenon is similar to the "Chandler wobble" and "polar wandering" exhibited by the Earth's rotation axis[21,22,23].

B. Magnet distance and speed

In experiment B, When the distance between "planet"$m_{\square}$ and "sun"m_1 was large, the initial speed of "sun"m_1 was decreased to allow "planet"$m_{\square}$ to rotate[24]. When the distance between "planet"$m_{\square}$ and "sun"m_1 was small, "planet"$m_{\square}$ rotated regardless of the speed of "sun"m_1.

C. Maximum rotation distance

In experiment C, With the "sun"m_1 on the motor as core. slowly move the "planet"$m_{\square}$ from near to far in any direction. □ When the static "planet"$m_{\square}$ is at every dot of the "sun"m_1, the maximum rotation distance from static to rotation between the "planet"$m_{\square}$ and the "sun"m_1 is measured. □ When the rotating "planet"$m_{\square}$ is located at every point of "sun"m_1, the maximum rotation distance between "planet"$m_{\square}$ and "sun"m_1 is measured. This experimental method demonstrated that maximum rotation distance between (from static to rotation and after rotation) magnets could be measured with spherical magnets of different masses and magnetic flux density in liquids of different viscosities. The spherical magnets could also be directly placed in air or vacuum to measure maximum rotation distance.

D. Distance and magnetic pole direction

In experiment D, "planet"$m_{\square}$ was placed in the surrounding space with "sun"m_1 as the core. Under the action of the rotation torque of "sun" m_1, "planet"$m_{\square}$ was in a rotation state in the magnetic field. When the distance between "planet"$m_{\square}$ and "sun"m_1 changed, we observed that the angle between the two ends of the magnetic pole of "planet"$m_{\square}$ and the horizontal plane changed with the centre of its own sphere as the vertex[25]. At every point from "planet"$m_{\square}$ to "sun"m_1, the angle between the polar direction of "planet"$m_{\square}$ and the floating horizontal plane was fixed. The angle between the direction of the magnetic pole of "planet"$m_{\square}$ and the horizontal plane depends on the distance between "planet"$m_{\square}$ and "sun"m_1. Therefore, when "sun"m_1 stopped rotating, we also observed the relationship between the distance between "planet"$m_{\square}$ and "sun"m_1 and the angle between the polar direction of the "planet"$m_{\square}$ and the horizontal plane.

E. Rotation of several spherical magnets

In experiment E, to observe the rotation behavior of the "planet" magnet, we can place not only one "planet" magnet in the space around the "sun" magnet but hundreds of "planet" magnet[26]. based on the minimum distance between "planet"$m_{\square}$ and "planet"$m_{\square}$ that does not affect the rotation and maximum rotation distance from "planet"$m_{\square}$ or "planet"$m_{\square}$ to "sun"m_1.

F. Synchronous rotation of magnet

In experiment F, It was observed that the rotation speed of "planet"$m_{\square}$ was the same as that of "sun"m_1. In each rotation period of "sun"m_1, the S and N poles of "planet"$m_{\square}$ corresponded to the N and S poles of "sun"m_1, respectively. Therefore, the rotations of "planet"$m_{\square}$ and "sun"m_1 were synchronous, and their velocities were the same[27]. When "sun"m_1 accelerated, decelerated, or stopped rotating, "planet"$m_{\square}$ accelerated, decelerated, or stopped rotating accordingly.

G. Feeling the rotational forces

In experiment G, The experimenter’s hands were used to feel the strength of the attractive force between "planet"$m_{\square}$ and "sun"m_1. Simultaneously, the rotational force between "sun"m_1 and "planet"$m_{\square}$ increased or decreased correspondingly, and the experimenter was able to feel the strength of the rotation force between "sun"m_1 and "planet"$m_{\square}$ by hand[28,29,30].

H. Rotation direction of spherical magnet

In experiment H, It was observed that the rotation direction of "planet"$m_{\square}$ was different at every angle and distance[31]. However, it was the same for any pair of angles with a difference of 180°. Assuming the distance "planet"$m_{\square}$ and "sun"m_1 was 30 cm. The rotation directions of "planet"$m_{\square}$ are the same at 0° and 180° (opposite to the rotation directions of "sun"m_1). The rotation directions of "planet"$m_{\square}$ are the same at 55° and 235° (perpendicular to the rotation directions of "sun"m_1). The rotation directions of "planet"$m_{\square}$ are the same at 90° and 270° (same as the rotation directions of "sun"m_1).

I. Magnet mass and flux density

In experiment I, we measured the magnetic flux density of three magnetic "sun" for different magnet masses[32]. when the masses of "sun"m_3 and "sun"m_4 increase, their magnetic flux density increase. As the mass and magnetic flux density of "sun"m_3 and "sun"m_4 increase, the maximum rotation distance (r) from each "planet" magnet to each "sun" magnet increase. The results are presented in Table □.

J. Cause of magnet rotation

Design of the instrument used to observation the causes of magnet rotation[5], experimental setup is illustrated in left side of Fig. 2. And the experimental procedure is detailed in the Methods K section. The main findings are as follows.

□ "planet"$m_{\square}$ did not rotate when the top of the motor's rotational shaft was aligned to a point between 0°–14°, from S to A or N to B. This occurred regardless of the orientation of "planet"$m_{\square}$ relative to "sun"m_5, rotational speed of "sun"m_5, and distance between "sun"m_5 and "planet"$m_{\square}$.

□ "planet"$m_{\square}$ rotated around its core in a large-amplitude oscillatory manner when the top of the motor's rotational shaft was aligned to a point between 15°–22°, from S to A or N to B. The rotational speed of "planet"$m_{\square}$ was slower than that of "sun"m_5, as "planet"$m_{\square}$ only completed one cycle for 3-5 cycles complete by "sun"m_5. The rotational motion of "planet"$m_{\square}$ was similar to the "astronomical nutation" exhibited by the Earth's rotational axis[33].

□ The rotational speed of "planet"$m_{\square}$ was equal to that of "sun"m_5 when the top of the motor's rotational shaft was aligned to a point between 23°–90°, from S to A or N to B, regardless of the orientation of "planet"$m_{\square}$ relative to "sun"m_5. Furthermore, the rotations of "planet"$m_{\square}$ and "sun"m_5 were synchronized[34].

Conclusion

Using the designed apparatus and the abovementioned experimental steps. □ The following relationships were initially established through experimental results: a relationship between the increasing magnetic mass and increasing magnetic flux density, a relationship between the maximum rotation distance of the magnets and the magnetic mass and flux density, a relationship between the synchronous speeds of the "planet" magnet and the "sun" magnet, and a relationship between the rotation of the "planet" magnet and the rotation speed of the "sun" magnet, the distance from the "sun" magnet, and the 0–90° angles on the "sun" magnet sphere. Finally, we observed a relationship between the torque energy transmitted by the magnetic field and the mass, flux density, magnet spacing, and mutual rotation speed of the permanent magnet. □ The experimenters felt and understood the different magnetic forces, namely, the attractive and rotating forces between the magnets. This contributed to the comprehension of the magnetic phenomena in physical electromagnetics discussed in textbooks. The study facilitates the production of apparatuses used to demonstrate the rotation between the sun and planet and provides the experimental methods for further research on the relationship between permanent magnet rotation and the magnetic field for different masses and magnetic flux densities. In addition, this work lays the foundation for further research on the relationship between the mass and the magnetic flux density and maximum rotation distance of permanent magnets, it provides experimental evidence for researching the relationship between planet rotation (e.g., the Earth) and magnetic fields.

References

1. NEWTON ISAAC. The Principia: The Authoritative Translation: Mathematical Principles of Natural Philosophy(2016) .
2. Lin Yuanzhang. Observational Study about the Influence of the Solar Wind on the Earth's Rotation. *Solar Physics.* **179**, 179-188(1998) .
3. Richard S. Gross. Ocean tidal effects on Earth rotation. *Journal of Geodynamics.* **48**, 219-225(2009) .
4. Sergei A. Klioner. On the Problem of post-Newtonian Rotational Motion. *Proceedings of the International Astronomical Union.* **165**, 383-390(1997) .
5. Tong, W. M., A device and method permanent magnet interaction movement[P]. *Chinese*: **CN**102055380A(2011-05-11) .
6. Mdzinarishvili T.G., et al. Determination of the solar rotation parameters via orthogonal polynomials. *Advances in Space Research.* **65**, 1843-1851(2020) .
7. Jean O. Dickey. Earth Rotation: Theory and Observation. EOS: *Earth & Space Science News.* **71**, 1791-1791(1990) .
8. V. Pashkevich. Some aspects of the mathematical modeling of the earth rotation. *Advances in Space Research.* **30**, 387-392(2002) .
9. Takeshi Imamura, et al. Superrotation in Planetary Atmospheres. *Space Science Reviews.* **216**, 263-277(2020) .
10. Ching-Ming Lai, Jean-Fu Kiang. Comparative Study on Planetary Magnetosphere in the Solar System. **20**, 6(2020) .
11. Ziwei Zhang, Shangtai Jin, Genfeng Liu, Zhongsheng Hou, Jianmin Zheng. Model-Free Adaptive Direct Torque Control for the Speed Regulation of Asynchronous Motors. **8**, 3(2020) .
12. Zhong Jianfeng, Zhong Shuncong, Zhang Qiukun , Peng Zhike. Measurement of instantaneous rotational speed using double-sine-varying-density fringe pattern. *Mechanical Systems and Signal Processing.* **103**, 117-130(2018) .
13. Katsuaki SATO. Tips for magnetic measurements. *Oyo Buturi.* **84**, 255-260(2015) .
14. Yutaka Matsuura. Recent development of Nd–Fe–B sintered magnets and their applications. *Journal of Magnetism and Magnetic Materials.* **303**, 344-347(2006) .
15. DEGAUQUE. Magnétisme et matériaux magnétiques : introduction. *The European Physical Journal Special Topics.* **2**, C3-1-C3-13(1992) .

16. M.D. Coey. Permanent magnet applications. *Journal of Magnetism and Magnetic Materials.* **248**, 441-456(2002) .
17. Lemaire. Matériaux durs pour aimants permanents. *The European Physical Journal - Applied Physics.* **9**, 819-836(1974) .
18. A. Kotov. Is the Earth's orbital motion linked to the spin rotation of the Sun? *Advances in Space Research.* **63***,* 3385-3389(2019) .
19. Chikara Sugawa, Chuichi Kakuta, Hideo Matsukura. On the Relation between the Rotation of the Earth and Solar Activity. *Proceedings of the International Astronomical Union.* **48**, 231-233(1972) .
20. Joël Sommeria. Foucault and the rotation of the Earth. *Comptes Rendus Physique.* **18**, 520-525(2017) .
21. Dennis D. McCarthy. Polar Motion — An Overview. *International Astronomical Union Colloquium.* **178**, 221-236(2000) .
22. Joachim Höpfner. Chandler and annual wobbles based on space-geodetic measurements. *Journal of Geodynamics.* **36**, 369-381(2003) .
23. Nandini Nagarajan. Earth's Magnetic Field and its Wandering Magnetic Poles. **25**, 363-379(2020) .
24. Li Jinbao. Physical Significance of the Distance Law of Planets and Reg-ular Satellites. *Astronomy and Astrophysics.* **1**, 20-31 (2013) .
25. HOSHI Hiroyuki, YAMAMOTO Yuhji, SHIBUYA Hidetoshi. Magnetic Poles and Geomagnetic Poles. *Education of Earth Science.* **68**, 197-203(2016) .
26. Cang Rongqin, Guo Jianpo, Hu Juanxiu, he Chaoqiong. The Angular Momentum of the Solar System. *Astronomy and Astrophysics.* **4**, 33-40 (2016) .
27. Alfvén H.. On the formation of celestial bodies. **3**, 57-62(1964) .
28. Chambers Charles. XXIII. On the nature of the sun's magnetic action upon the earthPhil. *R. Soc.* **153**, 503–516(1863) .
29. C. Ralph, M.D. Stiles. Spin transfer torques. *Journal of Magnetism and Magnetic Materials.* **320**, 1190-1216(2007) .
30. Koijam Manihar Singh, Kangujam Priyokumar Singh. The fifth force: An enigma in this Universe. *Modern Physics Letters A.* **34**, 24(2019) .
31. V. Savich. UNIVERSAL GRAVITATION AND MAGNETISM OF THE PLANETS. *Electrical Engineering & Electromechanics.* **5**, 13-14(2013) .
32. Vokoun, M. Beleggia. Forces between arrays of permanent magnets of basic geometric shapes. *Journal of Magnetism and Magnetic Materials.* **350**, 174-178(2014) .
33. A. Wilkins. Report of General Discussions at IAU Symposium No. 78 on Nutation and the Earth's Rotation. *Proceedings of the International Astronomical Union.* **78**, 247-250(1980) .
34. Zinovy Malkin, et al. On the eve of the 100th anniversary of IAU Commission 19/A2 "Rotation of the Earth". *Proceedings of the International Astronomical Union.* **13**, 325-331(2018) .

Tables

TABLE I "sun" and "planet" magnets of magnetic flux density and mass

"Sun" magnet	B/m (T/g)	“planet” magnet	B/m (T/g)
"sun"m_1	0.47/950	“planet”$m_{\square}$	0.572/8
"sun"m_2	0.117/100	“planet”$m_{\square}$	0.572/8
"sun"m_3	0.205/200	“planet”$m_{\square}$	0.172/8
"sun"m_4	0.334/400	“planet”$m_{\square}$	0.51/4
"sun"m_5	0.3/400		

TABLE II Maximum rotation distance between

"sun"m_2, m_3, m_4 and "planet"$m_{\square}$, $m_{\square}$, $m_{\square}$, $m_{\square}$

"sun"m_2/m_3/m_4	B/m (T/g)	n (r/S)	"planet"m□/m□/m□/m□	B/m (T/g)	r (cm)
"sun"m_2	0.117/100	1-3	"planet"m□	0.572/8	48
"sun"m_2	0.117/100	1-3	"planet"m□	0.572/8	48
"sun"m_2	0.117/100	1-3	"planet"m□	0.172/8	37
"sun"m_2	0.117/100	1-3	"planet"m□	0.51/4	35
"sun"m_3	0.205/200	1-3	"planet"m□	0.572/8	58
"sun"m_3	0.205/200	1-3	"planet"m□	0.572/8	58
"sun"m_3	0.205/200	1-3	"planet"m□	0.172/8	47
"sun"m_3	0.205/200	1-3	"planet"m□	0.51/4	45
"sun"m_4	0.334/400	1-3	"planet"m□	0.572/8	81
"sun"m_4	0.334/400	1-3	"planet"m□	0.572/8	81
"sun"m_4	0.334/400	1-3	"planet"m□	0.172/8	60
"sun"m_4	0.334/400	1-3	"planet"m□	0.51/4	58

Methods

I. MATERIAL REQUIREMENTS OF PERMANENT MAGNETS AND INSTRUMENT DESIGN

Design of permanent magnet representing the sun[1,2,3]. The permanent magnets representing the Sun all are NdFeB magnets(Nd2Fe14B)[4,5,6,7,8]; one cube magnet, triple cylindrical magnets, and one spherical magnet. Each permanent magnet was installed on the top of the shaft of a low-speed DC electric motor[9]. The centreline of the shaft passed through the centre of gravity of each permanent magnet. The electric motor base was round and made of non-magnetic materials. The round surface of the base was perpendicular to the rotation axis of the electric motor, making it stable when the base was placed on a horizontal surface. The electric motor speed controller was used to vary the electric motor speed (stop, slow, and fast) between1-25 r/S[10]. The permanent magnets were marked as "sun"m_1, "sun"m_2, "sun"m_3, "sun"m_4, and "sun"m_5 depending on the characteristic of magnetic flux density and mass. The north and south poles of the permanent magnets were marked with “N” and “S” respectively. The "sun"m_1 was a cube neodymium magnet of an edge length of 50 mm. Seven cylindrical NdFeB magnets of the same shape were used, the diameter and height of were 52 mm and 6.1 mm. Three "sun" magnets of different masses were are also designed; "sun"m_2 was a cylindrical magnet, "sun"m_3 comprised two cylindrical magnets, and "sun"m_4 comprised four cylindrical magnets. Finally, "sun"m_5 was a spherical neodymium magnet of a diameter of 63.2 mm. Since strong magnetic magnet will stick to each other at close distances, which could lead to unexpected outcomes during the experiment, the permanent magnets in the electric motor and the rotational shaft were placed in transparent spherical containers to prevent this outcome(See left side of Fig. 1).

Design of permanent magnets representing the planet[1]. The permanent magnets representing the planets were spherical[11]. Each spherical magnet was placed at the centre of a hollow spherical object floating on water to ensure free rotation. Alternatively, the spherical magnet could be directly placed in a round transparent container with a concave bottom or on the palm of the experimenter. For convenient observation and research, the north and south poles of each spherical permanent magnet were marked with dots in two different colours. A bisected circle perpendicular to the N-S pole axis (such as the equator of Earth) was then drawn on each spherical magnet. The two semi-circles of the bisected circle were marked with two different colours. The permanent magnets were marked as "planet"$m_{▯}$, "planet"$m_{▯}$, "planet"$m_{▯}$, and "planet"$m_{▯}$ depending on the characteristic of magnetic flux density and mass to distinguish them from each other and from the permanent magnets on the motor shaft. The diameters of the spheres of "planet"$m_{▯}$ and "planet"$m_{▯}$ are 12.5 mm, The diameter of "planet"$m_{▯}$ is 14 mm, The diameter of "planet"$m_{▯}$ is 9.6 mm, "planet"$m_{▯}$, "planet"$m_{▯}$ and "planet"$m_{▯}$ are all NdFeB spherical magnet (Nd2Fe14B)[12,13,14], "planet"$m_{▯}$ is ferrite spherical magnet(Fe2O3)[15,16,17]. During the experiment, each "planet" magnet is independent and cannot stick together(See right side of Fig. 1).

Method to measure magnetic flux density. When the Gauss meter was used to measure the magnetic flux density on the surface of the permanent magnet[18], the maximum magnetic flux density of the spherical magnet was observed at small areas around the N and S poles. However, the magnetic pole areas were large on the bar, square, rectangular, and cylindrical permanent magnets. The magnetic flux density of the magnetic poles was often distributed unevenly in the polar area. There was a united specific position, determined by the positional characteristics of the maximum magnetic flux density of spherical magnets, which helped measure the maximum magnetic flux density of permanent magnets of different shapes. In this study, the probe of the Gauss meter was placed on the centre of the N pole on the surface of the permanent magnet[18,19]. Then, the positive value displayed on the Gauss counter was used as the value of the magnetic flux density. When measuring the magnetic flux density of combined magnets (i.e., stuck together) of the same shape, mass, and magnetic flux density, we first aligned the N and S poles of the magnet on the same straight line. Then, we placed the Gauss meter probe in the N-pole centre of the first magnet surface and measured the magnetic flux density of increase magnets mass[18,19,20]. The results are presented in Table I.

II. EXPERIMENTAL SETUPS AND PROCEDURES

First, a cubical permanent magnet with a mass of 950 g and magnetic flux density of 0.47 T ("sun"m_1) was installed at the top of the rotational shaft of electric motor. The N and S poles of "sun"m_1 were directed perpendicularly to the rotational shaft. The speed of rotation of "sun"m_1 varied between 1-25 r/S using a motor speed controller[10,21]. Next, an 8-g spherical magnet with a magnetic flux density of 0.572 T[18,19], labelled "planet"m▯, was placed inside a hollow spherical object that floated on water. "planet"m▯ was then placed in a round transparent container filled with water with an opening of 1.5–2 times the diameter of "planet"m▯. During the experiment, "sun"m_1 and "planet"m▯ were kept away from ferromagnetic objects(See Fig. 1).

In experiment A, "planet"m▯ was placed at approximately 15–65 cm from the centre of "sun"m_1. Taking the horizontal plane in the round transparent container and the magnetic pole mark and the double-coloured circle on "planet"m▯ as reference system. Then, "sun"m_1 rotated at a speed of 1–3 r/S[10].

In experiment B, with "sun"m_1 as the core, move "planet"m▯ back and forth within a distance of 15-65 cm, keeping "planet"m▯ away from or near the "sun"m_1. Then, repeatedly adjust the speed of the "sun"m_1 from 1 r/S to maximum speed 25 r/S[10,21]. For example, in the same horizontal plane, when the distance "planet"m▯ and "sun"m_1 is 65cm, the initial speed of "sun"m_1 cannot exceed 1 r/S, otherwise, "planet"m▯ cannot rotate, the fastest speed cannot exceed 7.5 r/S, otherwise, "planet"m▯ cannot rotate. When the distance "planet"m▯ and "sun"m_1 is 30cm, the fastest speed of "sun"m_1 cannot exceed 23 r/S, otherwise, "planet"m▯ cannot rotate.

In experiment C, With "sun"m_1 the as core[22], slowly move the "planet"m▯ from near to far in any direction. ▯ When the "planet"m▯ is at every dot of the "sun"m_1, first, stop the rotation of "sun"m_1 and "planet"m▯, secondly, let the "sun"m_1 on the motor rotate at a speed of 1-3 r/S[10], finally, find out and measure the maximum rotation distance between "sun"m_1 and "planet"m▯. ▯ When the "planet"m▯ is at every dot of the "sun"m_1, first, let "sun"m_1 rotated at speed of 1-3 r/S[10], Secondly, slowly move the rotating "planet"m▯ from near to far, finally, find out and measure the maximum rotation distance between "sun"m_1 and "planet"m▯. For example, when "sun"m_1 and "planet"m▯ are in the same plane, the maximum rotation distance of "planet"m▯ and "sun"m_1 from static to rotation is 65 cm. The maximum rotation distance of "planet"m▯ and "sun"m_1 after rotation is 112cm(forbidden to use ferromagnetic ruler when measuring).

In experiment D, the rotation speed of "sun"m_1 was between 1-3r/S. On any half-line with "sun"m_1 as the core, we slowly moved "planet"m▯ and changed the distance between "planet"m▯ and "sun"m_1, taking the horizontal plane in the round transparent container and the magnetic pole mark on "planet"m▯ as reference system. The direction of the magnetic pole of "planet"m▯ was measured as follows. The rotation of "sun"m_1 was stopped when "planet"$m_{\square}$ rotated at a certain point. The centre of the protractor was then aligned with the centre of "planet"$m_{\square}$ to make the 0° line of the protractor parallel to the water surface. The magnetic pole above the horizontal plane was then rotated to one side of the 0° line. The angle corresponding to the magnetic pole of "planet"$m_{\square}$ could be measured above the horizontal plane[23].

In experiment E, with 1-3r/S rotated "sun"m_1 as the core, under the behavior of the rotation torque of "sun"m_1, the "planet"$m_{\square}$ and "planet"$m_{\square}$ was in a rotation state in the magnetic field. Be based on the mass and magnetic flux density of "planet"$m_{\square}$ and "planet"$m_{\square}$, the minimum distance between "planet"$m_{\square}$ and "planet"$m_{\square}$ without affecting each other's rotation is adjusted and measure[24]. Then, based on the minimum distance between "planet"$m_{\square}$ and "planet"$m_{\square}$ that does not affect the rotation and maximum rotation distance from "planet"$m_{\square}$ or "planet"$m_{\square}$ to "sun"m_1. Slowly move each "planet"$m_{\square}$ or "planet"$m_{\square}$ from near to far to the position of maximum rotation distance. According to the above method, many "planet"$m_{\square}$ and "planet"$m_{\square}$ Can placed in around "sun"m_1[25]. For example, the maximum rotation distance between "planet"$m_{\square}$ or "planet"$m_{\square}$ and "sun"m_1 is 112 cm, and the minimum rotation distance between "planet"$m_{\square}$ and "planet"$m_{\square}$ is 10 cm. Therefore, 10 "planet"$m_{\square}$ or "planet"$m_{\square}$ can be arranged on any horizontal line segment with "sun"m_1 as the core. By analogy, more "planet"$m_{\square}$ and "planet"$m_{\square}$ can be arranged around "sun"m_1.

In experiment F, "planet"$m_{\square}$ was placed at a distance of 15–65 cm from "sun"m_1. (1) When "sun"m_1 rotates at the speed of 1 r/S, the synchronous speed relation between "planet"$m_{\square}$ and "sun"m_1 can be observed[26,27]. (2) When the rotational speed of "sun"m_1 exceeded 2 r/S, the synchronous speed relation between "sun"m_1 and "planet"$m_{\square}$ was measured using a laser Doppler velocimeter[21].

In experiment G, "planet"$m_{\square}$ was placed on the palm of the hand, and "sun"m_1 was made to rotate at 1–25 r/S using the motor speed controller[10]. The motor to which "sun"m_1 was attached and the sphere containing "planet"$m_{\square}$ were held by the experimenter's left and right hands, respectively. Then, the distance between "sun"m_1 and "planet"$m_{\square}$ was varied between 5 and 30 cm, the experimenter's hands were used to feel the strength of the attractive force and rotation force between between "planet"$m_{\square}$ and "sun"m_1[28,29].

In experiment H, the distance between "planet"$m_{\square}$ and "sun"m_1 was set to 25–65 cm. Then, "sun"m_1 was made to rotate at 1-3 r/S using the electric motor speed controller[10]. under the behavior of the rotation torque of "sun"m_1, the "planet"$m_{\square}$ was in a rotation state in the magnetic field. The "planet"$m_{\square}$ move slowly at a 360° angle pass by the top and bottom of the electric motor with "sun"m_1 as the core and the double-coloured circle on "planet"$m_{\square}$ as the reference system[30]. The rotation direction of "planet"$m_{\square}$ is observed from different angles and compared with that of "sun"m_1.

In experiment I, the "sun" and "planet"magnet with different magnetic flux densities and the masses were used in the magnet rotation experiment. The observed phenomena are still the same, but the maximum rotation distance between the "sun" and "planet" magnet is different. Next, seven cylindrical magnets with the same material and shape were utilized, each with a mass of 100 g and a magnetic flux density of 0.117 T[18,19], and three "sun" magnet with different masses were designed. "sun"m_2 is a cylindrical magnet, "sun"m_3 is composed of two attract together cylindrical magnets, and "sun"m_4 is composed of four attract together cylindrical magnets. Each "sun" magnet installed on the electric motor shaft rotates at a speed of 1–3 r/S through the electric motor speed controller[10]. Then, the "planet"$m_{\square}$, $m_{\square}$, $m_{\square}$ and $m_{\square}$ are designed to float in each circular transparent container. Each "sun" magnet and each "planet" magnet are used for magnet rotation experiments. First, observe the change to magnetic flux density in case of any change to the mass of the "sun" magnet. Then observe the change to the maximum rotation distance from each "planet" magnet to the "sun" magnet (r) in case of any change to the mass and the magnetic flux density of the "sun" magnet. The results are shown in Table II.

In experiment J, the permanent magnet must be a spherical permanent magnet[11]. For example, a spherical magnet ("sun"m_5) was affixed on the top of the rotational shaft of a low-speed electric motor[1]. An arbitrary circle passing through the N and S poles of "sun"m_5 was drawn on the sphere. To divide these semicircles in half, two points, A and B, were selected on the NS and SN semicircles. Therefore, the central angles of the NA, NB, SA, and SB arcs were all 90°. Then, two arbitrary arcs were selected, such as NB and SA. The N and S points were denoted as 0°, while A and B were denoted as 90°. The subdivisions between 0° and 90° were then marked on the SA and NB arcs. The top of the motor's rotational shaft was aligned with any point between 0°–90° of "sun"m_5; therefore, the central axis of the electric motor rotational shaft also passed through the core of "sun"m_5(See left side of Fig. 2).

In experiment K, a spherical magnet with a mass of 400 g and magnetic flux density of 0.3 T ("sun"m_5) was installed at the top of the rotational shaft of the electric motor[11]. The "sun"m_5 speed of rotation was adjusted to 1-25 r/S using a electric motor speed controller[10]. Next, an 8-g spherical magnet with a magnetic flux density of 0.572 T, la belled "planet"$m_{\square}$, was placed inside a hollow spherical object that floated on water. "planet"$m_{\square}$ was then placed in a round transparent container filled with water with an opening of 1.5–2 times the diameter of "planet"$m_{\square}$ (See Fig. 2[1]).

(1) The distance between "planet"$m_{\square}$ and "sun"m_5 was set to 15–50 cm. The top of the motor's rotational shaft was aligned to each point between 0°–14°, from S to A or N to B, while "sun"m_5 was rotated at 1–25 r/S. The resulting rotation behavior of "planet"$m_{\square}$ were then recorded. (2) The distance between "sun"m_5 and "planet"$m_{\square}$ was set to 15–50 cm, and "sun"m_5 was rotated at 1 r/S. The top of the motor's rotational shaft was aligned to the points between 15°–22° from S to A or from N to B. The resulting rotation behavior of "planet"$m_{\square}$, as well as the relationship between "sun"m_5 and "planet"$m_{\square}$ rotational speeds, were then observe. (3) The distance between "sun"m_5 and "planet"$m_{\square}$ was set to 15–50 cm, and "sun"m_5 was rotated at 1–3 r/S. The top of the motor's rotational shaft was aligned with points between 23°–90° from S to A or from N to B. The resulting rotation behavior of "planet"$m_{\square}$ were then observed.

References

1. Tong, W. M., A device and method permanent magnet interaction movement[P]. *Chinese*: CN102055380A(2011-05-11) .
2. Gold T.. Magnetic field in the solar system. *Il Nuovo Cimento Series.* **13**, 318-323(1959) .
3. A. Kotov, S.V. Kotov, V.V. Setyaev. Towards Calibration of the Mean Magnetic Field of the sun. *Solar Physics.* **209**, 233-245(2002) .
4. Li Xiangbin, et al. Effects of terbium sulfide addition on magnetic properties,microstructure and thermal stability of sintered Nd-Fe–B magnets. *Chinese Physics B.* **25**, 427-430(2016) .
5. Nikolaus Urban, Alexander Meyer, Vitalij Keller, Jörg Franke. Contribution of Additive Manufacturing of Rare Earth Material to the Increase in Performance and Resource Efficiency of Permanent Magnets. *Applied Mechanics and Materials.* **4742***,* 135-141(2018) .
6. Hono, H. Sepehri-Amin. Prospect for HRE-free high coercivity Nd-Fe-B permanent magnets. *Scripta Materialia.* **151**, 6-13(2018) .
7. Wei Li. Editorial for the Special Issue on Rare Earth Permanent Magnets. **6**, 101-101(2020) .
8. Liu W.F., Zhang M.G., Li M.J. Classification and application process of NdFeB Permanent Magnetic Material. *Shanxi Metallurgy.* **36**, 1–3(2013) .
9. Bonfiglioli Riduttori S.p.A.. Gear Motor Handbook(1995) .
10. Lotfy, M. Kaveh, M. R. Mosavi, A. R. Rahmati. An enhanced fuzzy controller based on improved genetic algorithm for speed control of DC motors. *Analog Integr Circ Sig Process*(2020) .
11. Zhang Yuyang, Leng Yonggang, Tan Dan, et al. Study on Magnetic Force Calculation of Spherical Permanent Magnets. *Journal of Magnetics.* **23**, 654-658(2018) .
12. Deng Zhiwei, Yan Runpu, Chen Jie. Study on Methods for Improving the Milling Process of Sintered NdFeB. *Material chemistry frontier.* **6**, 20-25(2018) .
13. Homma Motofumi, Sugimoto Satoshi. Advances in Magnetic Materials Over the Last Decade. *Materia Japan.* **36**, 946-949(1997) .
14. P. Haberer, H. Lemaire. The physics and the technology of rare earth permanent magnets. *The European Physical Journal Special Topics.* **40**, C5-273-C5-273(1979) .
15. Yutaka Matsuura. Recent development of Nd–Fe–B sintered magnets and their applications. *Journal of Magnetism and Magnetic Materials.* **303**, 344-347(2006) .
16. ZHajime Nakamura. The current and future status of rare earth permanent magnets. *Scripta Materialia.* **154**, 273-276(2018) .
17. Y. Chin. New Magnetic Alloys. *Science.* **208**, 888-894(1980) .
18. Siya Lozanova, Avgust Ivanov, Chavdar Roumenin. A Hall Effect Device with Enhanced Sensitivity. *Procedia Engineering.* **25**, 543-546(2011) .

19. Cabassi. Singular Point Detection for characterization of polycrystalline permanent magnets. *Measurement.* **160**, 107830(2020) .
20. Katsuaki SATO. Tips for magnetic measurements. *Oyo Buturi.* **84**, 255-260(2015) .
21. Zhong Jianfeng, Zhong Shuncong, Zhang Qiukun , Peng Zhike. Measurement of instantaneous rotational speed using double-sine-varying-density fringe pattern. *Mechanical Systems and Signal Processing.* **103**, 117-130(2018) .
22. D. DO NASCIMENTO. THE PAST, PRESENT AND FUTURE OF THE SUN'S MAGNETISM. *International Journal of Modern Physics: Conference Series.* **18**, 130-135(2012) .
23. Dennis D. McCarthy. Polar motion and Earth rotation. *Reviews of Geophysics.* **17**, 1397-1403(1979) .
24. Luiz A. G. Boldrin, Rosana A. N. Araujo, Othon C. Winter. On the rotational motion of NEAs during close encounters with the Earth. *The European Physical Journal Special Topics.* **229**, 1391-1403(2020) .
25. Y.Ukhorskiy, et al. Rotationally driven 'zebra stripes' in Earth's inner radiation belt. *Nature***507**, 338-40(2014) .
26. Li ZhiXiong, Huang Runqian, Wang Shumin. On the non-synchronous rotation of binary systems?. *Science China(Physics, Mechanics & Astronomy).* **57**, 1194-1200(2014) .
27. Djurović, P. Pâquet. The common oscillations of solar activity, the geomagnetic field, and the Earth's rotation. *Solar Physics.* **167**, 427-439(1996) .
28. Aurel Bejancu, Hani Reda Farran. A new point of view on the fifth force in

$$4D$$

physics. *General Relativity and Gravitation.* **45**, 449-463(2013) .
29. C. Ralph, M.D. Stiles. Spin transfer torques. *Journal of Magnetism and Magnetic Materials.* **320**, 1190-1216(2007) .
30. Sungmin Ryu. Quadrant analysis on vortex-induced autorotation of a rigid square cylinder. *J Mech Sci Technol.* **32**, 2629–2635 (2018) .

Acknowledgments: I would like to thank Mr. Zhongping Jia and Mr. Guojun Wei from the Longnan Electric Power Bureau of Gansu Province, China, and Ms. Liping Liu and Mr. Qiang Liu from Cheng County, Gansu Province, China. Thank them for their financial support to this research work during the last decade.

Author Contributions Weiming Tong designed and made the instrument, and he wrote the paper according to its experimental procedure and methodology. He named the permanent magnet and distinguished it according to the characteristics of its quality and magnetic flux density. And he made measurement to the data using non-ferromagnetic centimeter ruler, laser Doppler velocimeter, gauss meter and microelectronic balance, and he also reviewed and commented on the paper.

Ethics declarations: This manuscript has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal including the Internet. We have read and understood nature journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

Author information: Affiliations, Suochi Schooling District, Cheng County, Gansu Province, China, 742509

Correspondence and requests for materials should be addressed to Weiming Tong at 15193943275@139.com

Figures

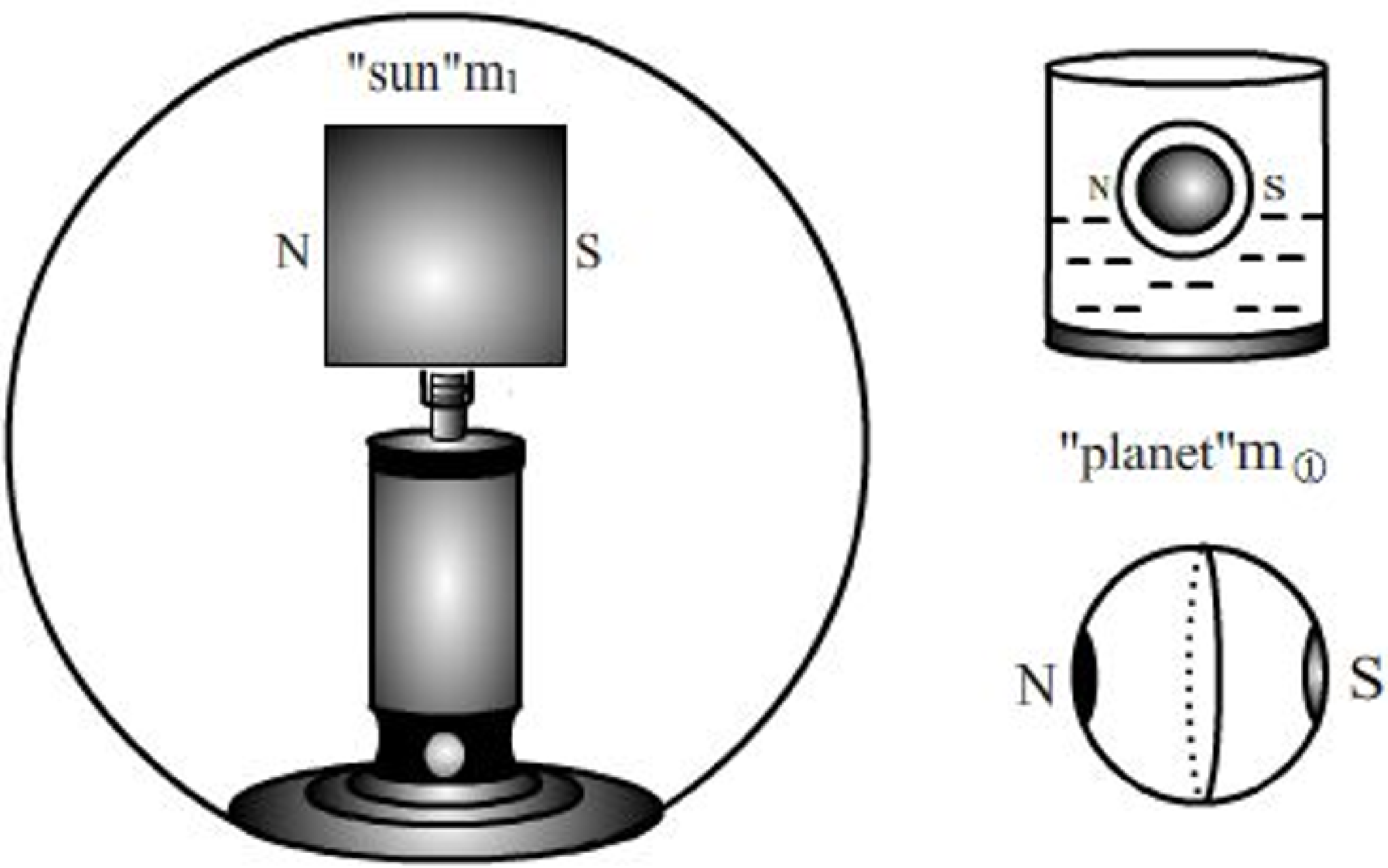

Figure 1

Instrument design for studying the rotation of the spherical magnet

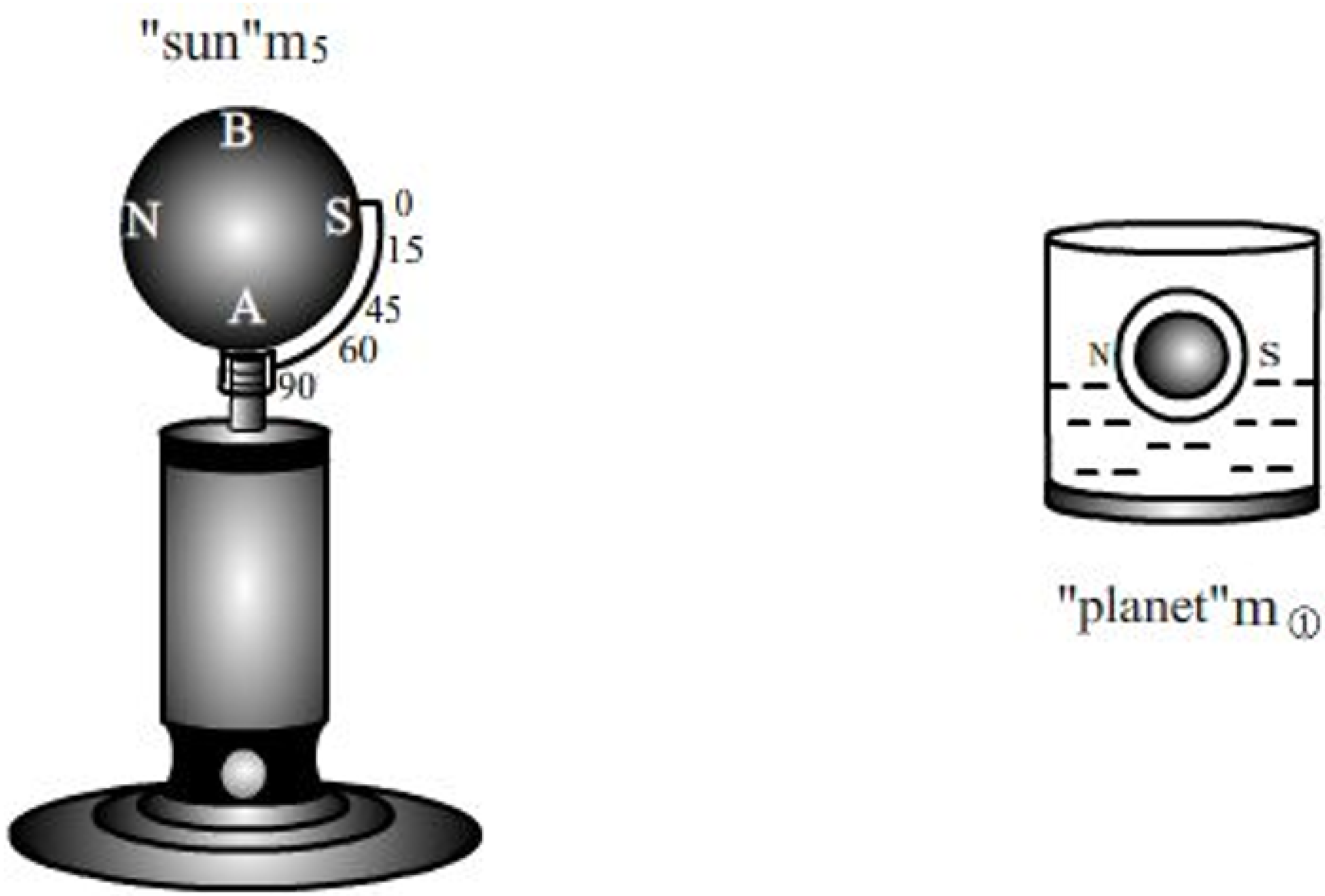

Figure 2

Design of the instrument used to observation the causes of magnet rotation