An Experimental Study to Examine the Curved Spacetime Using Magnetic Fields

ABSTRACT

The curvature of spacetime represented by Einstein field equation has many physical implications, including gravity. As light is deflected by the curvature of spacetime, a magnetic field will also be influenced by the curved spacetime. A permanent magnet is generally known to maintain its persistent magnetic field on the ground as long as there is no external magnetic interference. However, a series of experiments find that there are noticeable changes in the magnetic fields distribution while the permanent magnet rotates. The magnetic field lines of the permanent magnet are deflected towards Earth's centre, implying a possibility that we can use magnetic field, a more efficient tool than a satellite, to measure the curvature of spacetime. However, comparing the experimental results of this study with theoretically obtained values of the curvature of spacetime remains a vast area of research for future studies.

1. INTRODUCTION

The Einstein field equation [1,2] that mass warps spacetime was announced in 1916. Yet, the theory of general relativity was not known to all until Arthur Eddington observed the deflection of starlight around the Sun in 1919 [3, 4]. Besides the Arthur Eddington's discovery, several experimental studies have verified the Einstein field equation through recession of Mercury's orbit, a gravitational redshift in the Pound–Rebka [5], gravitational lensing [6-9] around the galaxies, and so on. Despite many studies confirming the Einstein field equation, however, not many have directly measured the curvature, which is key for the Einstein field equation. To verify the geodetic effect or the frame-dragging effect predicted in Einstein field equation, it is critical to measure the curvature of spacetime around us. Given that the deflection of solar light by the local space time of Earth is not more than 40 micro arcseconds [10], examining the curvature of spacetime remains challenging. NASA has been trying to measure Earth's curvature of spacetime with a precise gyroscope since 1964. Recently, NASA has successfully detected the precession caused by the geodetic effect with four gyroscopes in Gravity Probe B (GP-B) experiments [11-13]. However, it is hard to say that the experiment was efficient, because it required (1) expensive satellites and (2) perfect gyroscopes to measure the minuscule angle.

Here, an alternative and more efficient method has been suggested to measure the curvature of spacetime – that is, using magnetic fields on the ground. As light, a type of electromagnetic wave, is deflected by the curvature of spacetime, a magnetic field is influenced by the curved spacetime [14-17]. Maxwell's equations are generally used on the assumption that the space time is flat. However, it is necessary to use Maxwell's equations in curved spacetime in order to observe the magnetic fields on the ground more precisely [17]. Thus, any noticeable changes are found in the magnetic fields due to the curvature of spacetime on the ground, a magnetic field will be a good tool to measure the curvature of spacetime.

2. EXPERIMENTAL APPROACH TO EXAMINE THE CURVED SPACETIME USING MAGNETIC FIELDS

This study conducts a series of experiments using a permanent magnet attached on a rotating table, to test the above ideas on the effect of curvature in spacetime on magnetic field,. A permanent magnet is used, because it maintains its persistent magnetic field as long as there is no external magnetic interference. A disc-type neodymium permanent magnet having a hole in the center is used for the experiments, because a neodymium permanent magnet has a very strong magnetic field among the permanent magnets. The neodymium magnet has 30mm of outer diameter, 3mm of thickness and 7mm of the inner diameter (Fig. 1). The magnetic field measurement instrument is a gauss meter made by Keuwlsoft. The permanent magnet and the magnetic field sensor are fastened to the rotating table (Fig. 2). The magnetic field sensor is located 4mm away from the center line of the permanent magnet, facing the S pole for type-A and type-B (Fig. 1). The sensor measures the magnitude of Y-directional magnetic flux density of the permanent magnet (Fig. 1). Two experiments have been done in Jeju volcanic island.

In the first experiment, the plane of the rotating table which is made of acrylic plate is set to be parallel to the horizontal plane (Fig. 2). All the surrounding appliances are turned off. Changes in the magnetic flux density of the permanent magnet are measured while the table rotates 360°. In this case, it is expected to see no changes in the magnetic fields strength, because the magnetic field distribution is symmetric at the table's plane according to Maxwell's equation in curved spacetime (Fig. 3).

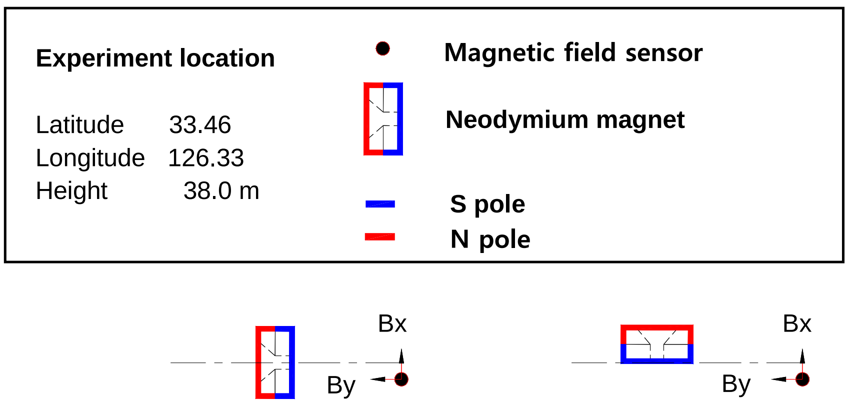
In the second experiment, the plane of the rotating table is set to be vertical to the horizontal plane (Fig. 4). Again, changes in the magnetic flux density of the permanent magnet are measured while the table rotates 360°. In this case, it is expected to see the changes in the magnetic fields strength, because the magnetic field distribution does not maintain symmetry at the table's plane when the table rotates vertically. The magnetic field lines will be deflected to the center of the Earth, as expected in Maxwell's equations in curved spacetime (Fig. 3).

Fig. 5 and Fig. 6 show the measured and the net magnitude of magnetic flux density from the experiments. The net magnitude of magnetic flux density represents the measured magnitude of magnetic flux density, excluding Earth's magnetic field (Fig. 7 and Fig. 8). Repetition of both the first (horizontal rotation) and second (vertical rotation) experiments were done for four times and average measures were recorded. The rotation of table was made manually and the measured data are obtained digitally. The graphic processes are made by using Microsoft Excel.

The results are consistent as expected. When the table rotates horizontally, the net magnetic flux density has the average value of 2599.85 μT and the standard deviation value of 1.24 throughout the table's 360° rotation (Fig. 5). The changes in the net magnetic flux density during the rotation of table are negligible, as the small standard deviation implies.

On the other hand, the results from the vertical rotation are different. There are noticeable changes in the net magnetic flux density during 360° rotation of the table. The net magnetic flux density has the average value of 1303.35 μT with the standard deviation of 2.96 (Fig. 6a). The net magnetic flux density increases when the S pole faces toward the center of the Earth. The maximum changes are about 10 μT and 17 μT during the rotation of table for the type-A and -B, respectively (Fig. 6a and Fig. 6b). The results are worth our attention, given that magnetic field distribution of a permanent magnet is widely known to be not changeable on the ground.

Here, the results from the vertically rotating experiments have been analysed and discussed in details. When the magnetic sensor is located in zone A during the rotation of the table (Fig. 6 and Fig. 9), the magnetic field lines are moving away from the sensor, because the strength of the magnetic field is decreasing. On the other hand, when the magnetic sensor is located in zone B during the rotation of table (Fig. 6 and Fig. 9), the magnetic field lines are moving closer to the sensor, because the strength of the magnetic field is increasing. The increase and decrease that are observed in zone A and B indicate that magnetic field distribution is no more symmetric. Rather, the magnetic field lines are deflected toward the Earth’s center as shown in Fig.9.



(a) Neodymium magnet type-A. (b) Neodymium magnet type-B

Fig. 1. Neodymium permanent magnet and the magnetic sensor locations.

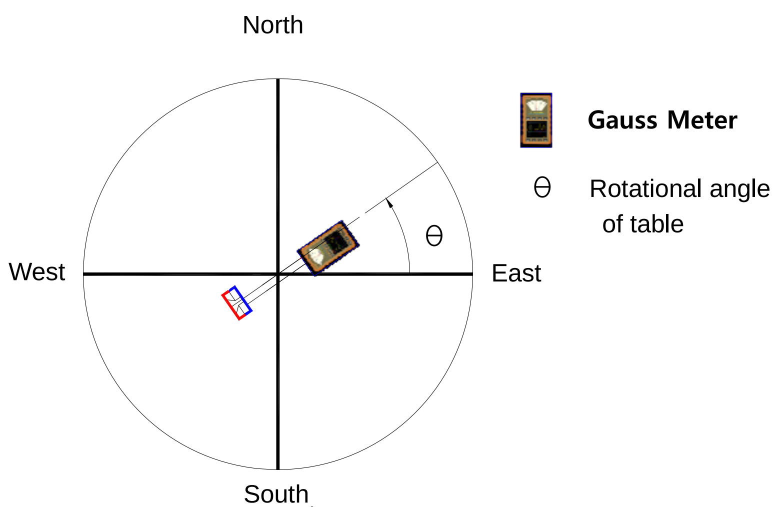


Fig. 2. In the first experiment, the permanent magnet and the magnetic sensor are fastened to the rotational table which is set to be parallel to the horizontal plane.

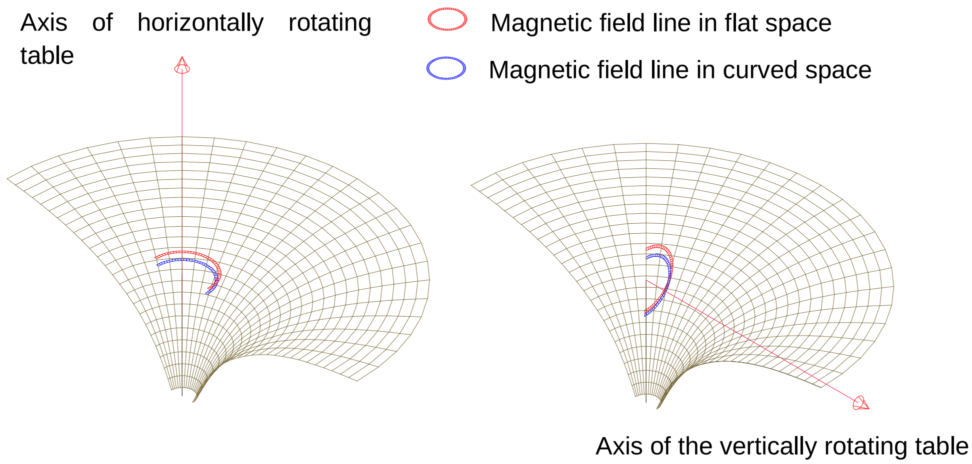


Fig. 3. The conceptual diagram of magnetic field line in curved space both horizontally and vertically rotating table.

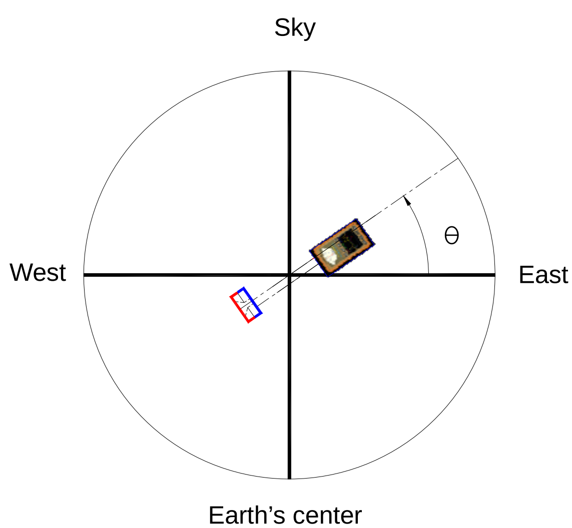


Fig. 4. In the second experiment, the permanent magnet and the magnetic sensor are fastened to the rotational table which is set to be vertical to the horizontal plane.

By(μT **)**

Magnetic flux density

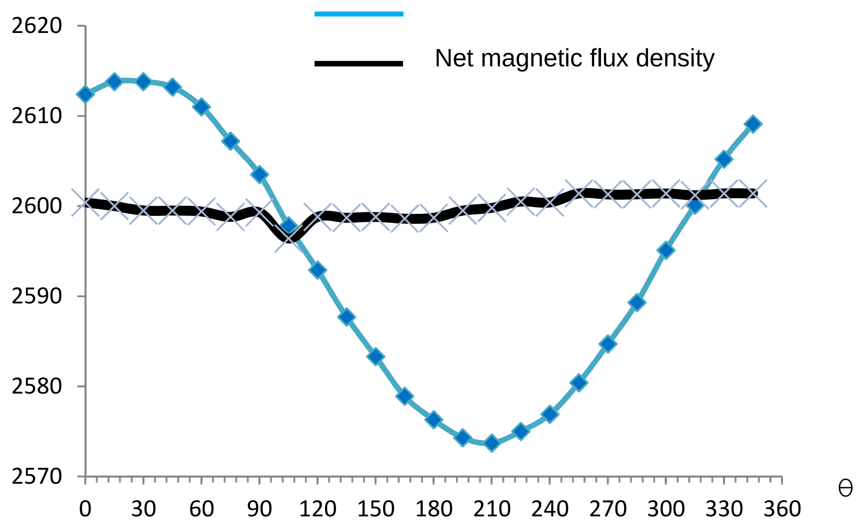
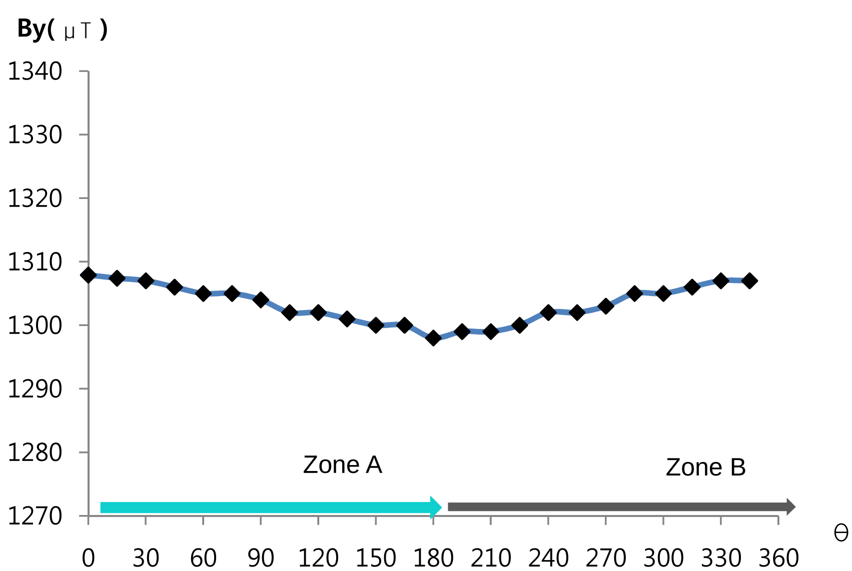
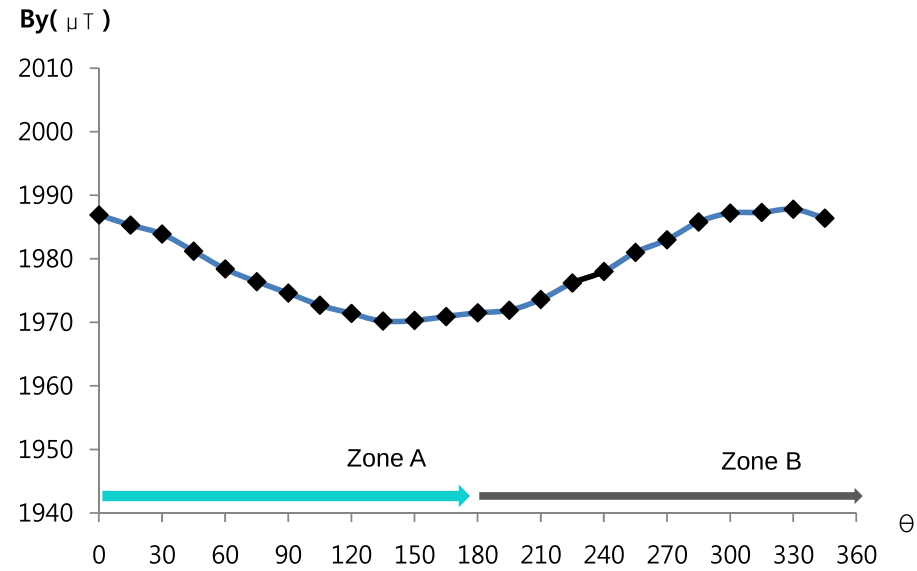


Fig. 5. Net magnetic flux density during 360 degree of horizontal rotation of table for type-A.



(a) Neodymium magnet type-A.



(b) Neodymium magnet type-B

Fig. 6. Net magnetic flux density during 360 degree of vertical rotation of the table for type-A and Type-B

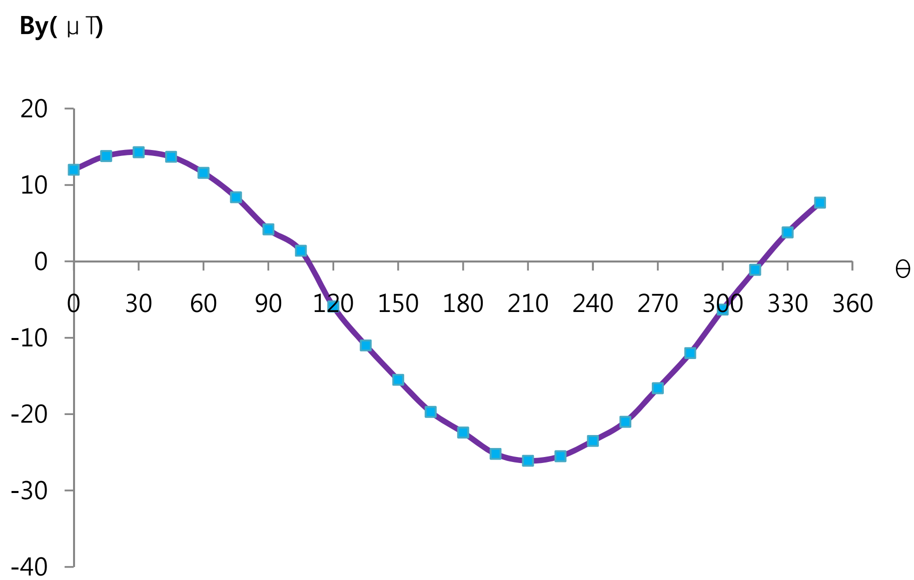


Fig. 7. The observed Earth's magnetic flux density during 360 degree of horizontal rotation of table for type-A.

By(μT)

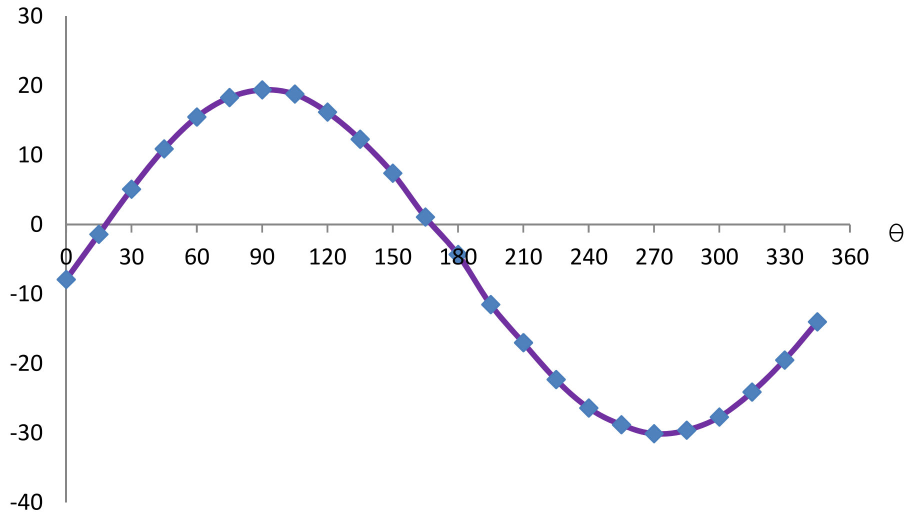


Fig. 8. The observed Earth's magnetic flux density during 360 degree of vertical rotation of the table for type-A.

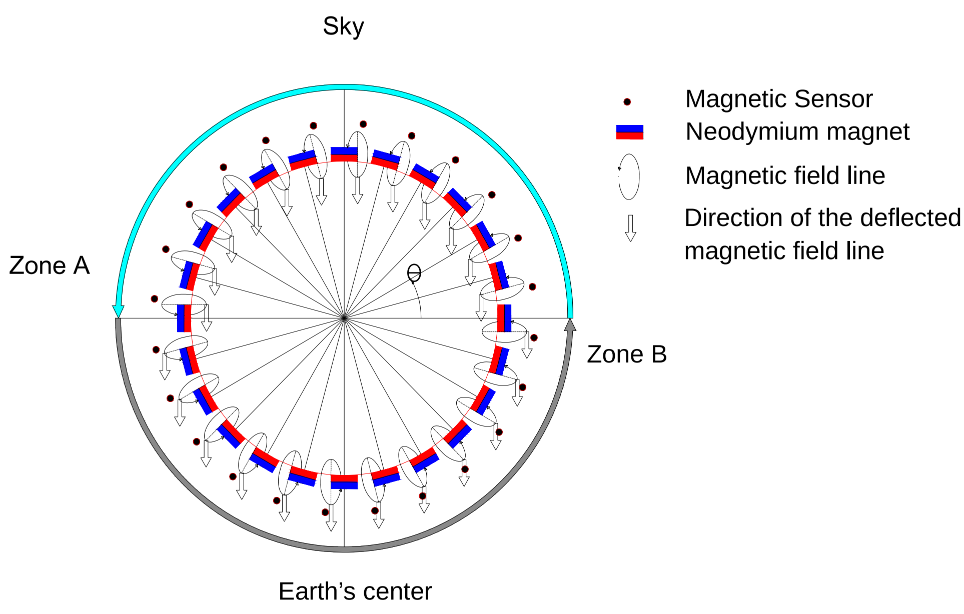


Fig. 9. The conceptual diagram of the deflected magnetic field lines during the 360 degree of vertical rotation of the table, which are obtained from analyzing the changes in the measured magnetic flux density.

3. DISCUSSIONS

This study, at the present stage, could equally be considered as the effect of Earth's gravitation on the charges. However, it is possible in future to differentiate whether the effect is due to the Einstein's spacetime curvature or due to the Newton's gravitational pull by our simple experiment if that could be performed with adequate accuracies. The solar winds ejected by Sun also affect the magnetic field on the ground. However, the solar wind's effects are taken into account in the measured Earth's magnetic flux density. The tests were carried out in two places in the basic experiment, Jeju Island and Cheongju City, are chosen to attempt the same experiment with different types of magnets with various sensor positions. It was found that there exists a similar trend in the deflection of the magnetic field. The results of the vertical rotation experiments show that the magnetic field distribution of a permanent magnet is changing with the rotation of the table. The Earth's magnetic field is actually changing a lot every day and every second. Solar winds seem to be the main cause. The variation in the time of 5 second shown by the magnetic sensor was measured to be ± 1.2 μT. Yet, it is believed that those errors are negligible, because the observed changes in magnetic field of these experiments are about 10 - 17 μT. The net magnetic field density excluding Earth's magnetic field is thought to be entirely that of the neodymium permanent magnet. The deflections observed in the vertical rotation experiments are thought to be caused by the curvature of the local spacetime by Earth. In other words, this study shows the possibility of using magnetic fields to measure the curvature of spacetime. Future studies could examine the vectors of deflections in the magnetic field lines in order to verify the geodetic effects. Compared to the gyroscopes, magnetic field has many advantages in measuring the curvature of spacetime as it is easier to handle and manufacture

4. CONCLUSIONS

Many studies [3-9] till date have verified the distortion in spacetime. However, not many tools are available to measure the curvature of spacetime, which is the key to describe gravity in the Einstein field equation. As shown in NASA's GP-B experiments [11-13], precise gyroscopes are the only available tools to measure the curvature of spacetime at this time. A precise gyroscope needs a lot of effort in handling and manufacturing. This study shows the possibility of using a magnetic field to measure the curvature of spacetime, which could be a more efficient tool than gyroscopes. In a series of experiments, it is found that there are noticeable changes in the magnetic field distribution of the permanent magnet fastened to rotating table. Magnetic field lines of a permanent magnet are deflected towards the Earth's centre. The deflections are considered to be caused by the curvature of local spacetime of the Earth, as predicted in the Maxwell's equations in curved spacetime. In the future, the results of this study should be compared with the theoretically obtained values of curvature of spacetime from Einstein field equation.

COMPETING INTERESTS

No competing interests.

AUTHOR'S CONTRIBUTIONS

The sole author analyzed, interpreted and prepared the manuscript.

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