International Journal of Engineering Research and Advanced Technology (IJERAT)

DOI: http://dx.doi.org/10.7324/IJERAT.2018.3186

E-ISSN : 2454-6135

Volume.4, Issue 2

February-2018

Study of Acceleration due to Gravity (*g*) at Sokoto metropolis of Sokoto state, Nigeria

S. Abdullahi and R. Sani

Department of Physics

Usmanu Danfodiyo university

Sokoto, Nigeria

ABSTRACT

Gravity method was reportedly the first geophysical technique to be used in oil and gas exploration. Despite being eclipsed by seismology, it has continued to be important in a number of exploration areas. Gravity method is being used in mining applications to map subsurface geology and to directly calculate ore reserves for some massive sulphide ore-bodies. There is also a modest increase in the use of gravity techniques in specialized investigations for shallow targets. Acceleration due to gravity, g, of 7 different locations within Sokoto metropolis of Sokoto state Nigeria was determined using a Kater reversible pendulum. The measured acceleration due to gravity ranges from 9.791 to 9.813 m/s^2.

Key Words: *Acceleration Due To Gravity, Sokoto, Kater Reversible Pendulum, Newton's Law of Gravitation, Modern Gravity Meters.*

1. INTRODUCTION

Acceleration due to gravity is the acceleration experienced by an object in free-fall at the surface of the Earth, assuming air friction is neglected. It has the approximate value of 9.80 m/ s^2 or 32.2 ft/s^2, although it varies with altitude and location. We use gravity in many engineering calculations and many other gravitational works. Perhaps one may decide to stop and think about how precise the value of g is. Because it may not be always "correct" to read this value as constant for any gravity application.

Gravitation or "gravity" is a natural phenomenon by which physical bodies attract each other with a force proportional to their masses. Gravitation is most familiar as the agent that gives weight to object with mass, and causes them to fall to the ground when dropped [1]. Gravity can be regarded as the invisible force that pulls two masses together. However, if another look is taken on how this familiar force really works, we can begin to understand the idea of measuring gravity from space. Sir Isaac Newton discovered that as an object's mass increases, gravitational attraction of that object also increases [2]. For example, a container filled with a more denser material like granite rock, has more gravitational attraction, than same container filled with water. Modern physics described gravitation using the general theory of relativity by Albert Einstein, as a consequence of the curvature of space time governing the motion of inertial objects [3]. Gravitation is governed by single potential noted long ago [4] "as centrifugal force" which is responsible for keeping the earth and other planets in their orbits around the sun, for keeping the moon in its orbit around the earth, for the formation of tides for natural convection by which fluids flow occur under the influence of a density gradient and gravity, and for various other phenomena observed on earth [2].

For more than two millennia, the widely accepted theory of gravity as described by Aristotle (348-322BC), was that the velocity of a free–falling body is proportional to its weight [5]. In 1604, Galileo Galilee, using inclined plane and pendulum, discovered that free-fall is a constant acceleration independent of mass, where he later postulated air resistance as the reason that lighter objects may fall more slowly in the atmosphere [6]. Galileo's work set the stage for the formulation of Newton's theory of gravity [7].

A reversible pendulum is a special design of a normal physical pendulum. It is able to swing from either of two mounting points and can be set up in such a way that the period of oscillation is the same from both these points. The reduction in the length of the pendulum then matches the distance between the two mounting points. This makes it easier to determine the local acceleration due to gravity from the period of oscillation and the reduced pendulum length. Recall that the difference between a simple pendulum and a physical pendulum is that a simple pendulum has all of its mass concentrated at the tip while a physical pendulum has mass distributed throughout its length.

In this paper, the magnitude of acceleration due gravity of 7 different locations within Sokoto metropolis of Sokoto State Nigeria is determined by using a reversible pendulum (Kater's pendulum).

2. METHOD OF CALCULATION

According to the Newton's law of gravitation "everybody in the Universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. "The line of action being the line joining the bodies [8]. Mathematically,

$$F = \frac{GMm}{R^2} \text{ ---(1)}$$

where, F = force acting between the two bodies, M and R are the mass and the radius of the earth, m is the mass of an object located near the earth's surface and G is the gravitational constant given as ($6.673 \times 10^{-11} Nm^2/kg^2$).

Also according to the Newton's second law of motion force acting on a body due to gravity is written as;

$$F = mg \text{ ---(2)}$$

where g = acceleration due to gravity. Relating equation (1) and (2), equation (3) is derived;

$$g = \frac{GM}{R^2} \text{ ---(3)}$$

Equation (3) shows that g is independent of shape, size and nature of the body rather the distance (radius) of the earth. Modern gravity meters which measure extremely small variations in this acceleration, have a sensitivity of about $10^{-5}gal^s$ or 0.01 Milligas (mgal) as a result they are capable of distinguishing changes in the absolute values of g [9].

$$slope = \frac{T^2}{L} \text{ --- (4)}$$

Then

$$g = 4\pi^2.\frac{1}{slpoe} = 4\pi^2.\frac{L}{T^2} \text{ -----------------------------------(5)}$$

3. EXPERIMENTAL METHODS

This experiment was conducted at seven (7) different locations within Sokoto metropolis of Sokoto state Northern Nigeria. Sokoto metropolis is located between $12^0 52^` 02^{``}$N degrees of latitude and $5^0\ 08^` 8^{``}$ E and $5^0 19^` 24^{``}$E degrees of longitude, with an altitude of 318 m [10]. Figure 1 shows the map of Sokoto metropolis. The location or study areas are:

1. Mana area
2. Moreh area
3. Girabshi area
4. Gwiwa area

5. Bado area
6. Gagi area
7. Arkilla area

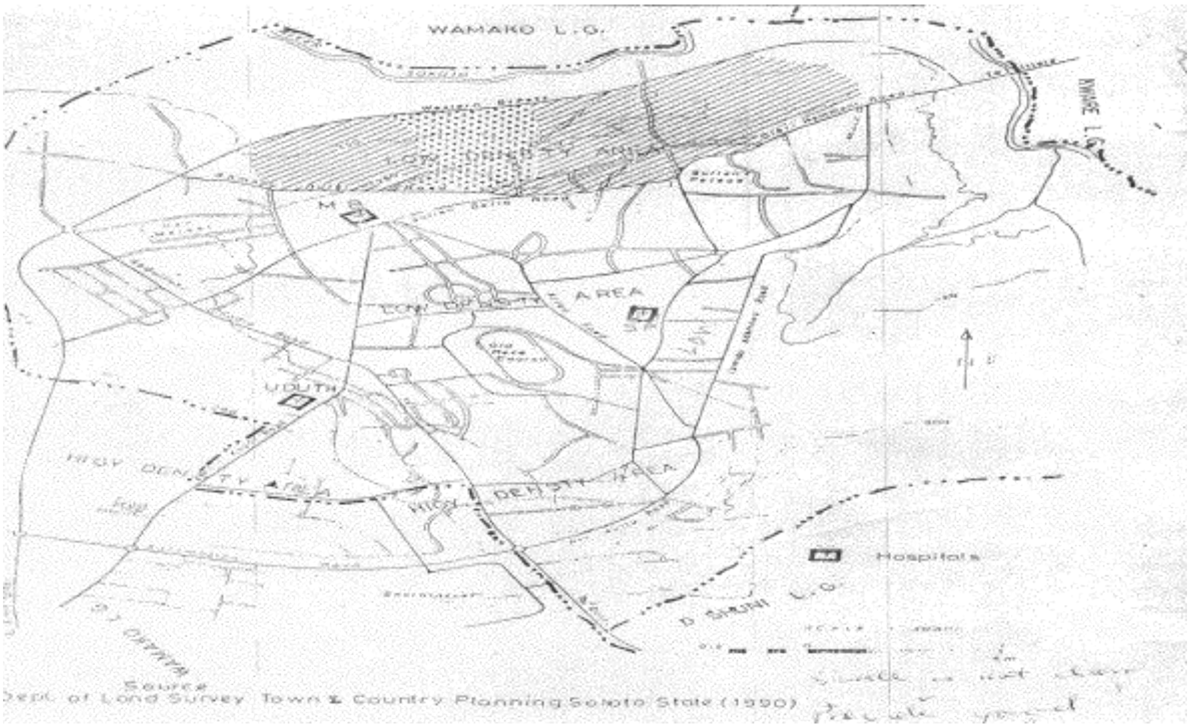

Figure 4: Map of Sokoto Urban

The apparatus used are reversible pendulum with support (a study metal stand with knife edges), two metal plates of 1000g and 1400g, a digital stopwatch and a meter rule. Figure 2 shows schematic of a reversible pendulum (Kater's pendulum) used in this work.

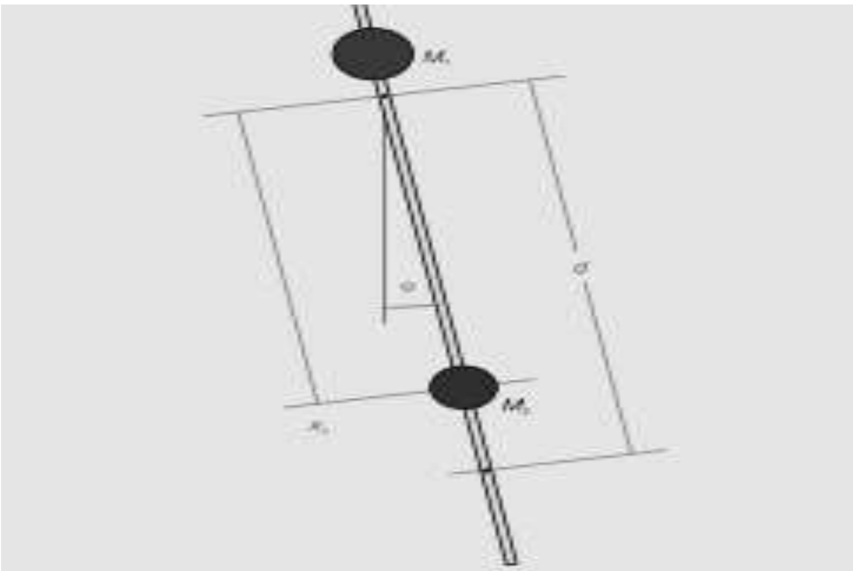

Figure 2: schematic of a reversible pendulum

The apparatus is set up in such a way that the two sliding masses are brought as close as possible to the knife edge between them. The pendulum is suspended first at an angle of 30^0 to swing about its axis for 30-oscillations. The period for 30-oscillations is noted and recorded. The sliding mass (1000g) which is between the knife edge, is moved further from the knife edge by 5cm and the period is recorded after every 30-oscillations. The length is adjusted about nine times. After taking the readings for the mass of 1000g between the edges, then the position of the masses was switched by placing the 1400g mass between the knife edge and suspended at an angle of 30^0 to move and oscillate for 30 oscillations. The period of the oscillations is also recorded, and the procedure in taking the periods of the two masses is the same. This procedure is the same and applied for all the seven (7) locations.

4. RESULTS AND DISCUSSION

Figure 3 represents the graphs of all the 7 study locations. In plotting the graph of Pendulum, the plot is distance against period. But in the case of reversible pendulum it is plotted in the reverse order i.e period (T^2) in Seconds Square against distance (d) in meters.

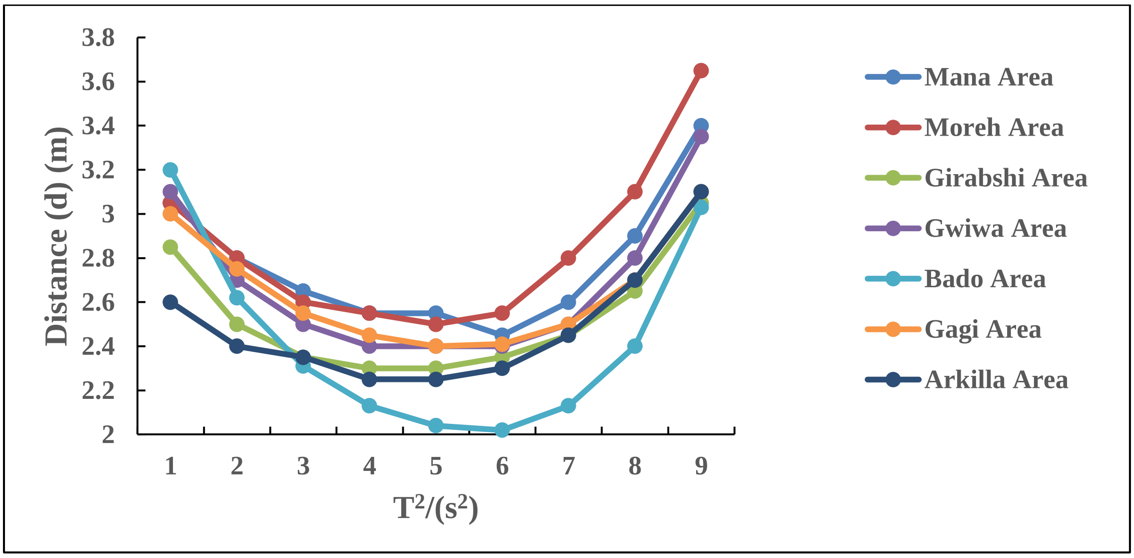

Figure 3: Graphs of the study locations

Table 1 show the magnitude of acceleration due to gravity (g) obtained from each of the 7 locations.

Table 1: Acceleration due to gravity of the study locations

S/No	Name of location	g (m/S^2)
1	Mana	9.791
2	Moreh	9.821
3	Girabshi	9.794
4	Gwiwa	9.801
5	Bado	9.811
6	Gagi	9.813
7	Arkilla	9.810

The result obtained proved some experimental and theoretical results of gravity which different scientists claimed to have different numerical values. Newton proved gravitational acceleration to be constant value (9.80m/S^2) independent of the nature of a body [8]. Glen thorn-croft in his paper title "How precise is earth's gravity" mentioned that the approximate value of gravity is (9.81m/S^2) [9]. The paper presented in 1901 by the international conference on weights and measures (in France), defined the standard gravity value as 9.80665m/s^2. Likewise, the U.S Geological survey has measured in Tucson this constant g, as 9.7926m/s^2 using physical pendulum and expensive gravimeters. This is the same gravity discussed by the great ancient scientist Galileo Galilee, which he measured as constant with numerical value (9.80m/S^2) on the earth's surface. With all precisions under this research we come to achieve an approximate average value of acceleration due to gravity within Sokoto metropolis to be (9.81m/S^2) which corresponds to the approximate values of some of the above mentioned experimental.

As the above result indicated, Moreh area is having (9.821m/S^2) value of acceleration due to gravity. The Federal ministry of land and surveys, Nigeria, (1969) topo sheet indicated that Moreh is at an altitude of 5^{0}16`10``E and latitude of 13$^0$05`20``N. Moreh area is considered to be among the densest areas within the Sokoto metropolis (Sokoto Town and Country planning, 1990). These are some known factors expected to make Moreh area among those areas with high acceleration due to gravity. Gagi area was at latitude of 13^{0}02`45`` and 0516`50``E location within Sokoto metropolis. And it is believed to be among the less dense areas [11]. Mana area is located at 13^{0}01`58``N and 0516`25``E latitude and altitude respectively. It is also believed to be among the less dense areas. Bado is at latitude of 13^{0}00`10``N and altitude of 05$^0$12`46``E and it is believed to be a high-density area. Gwiwa also is among the areas with high density and it is located at latitude and altitude of about 13^{0}02`25``N and 05$^0$13`45``E respectively. Arkilla with high density is located at an altitude about 0511`50``E and latitude of 13$^0$2`10``N respectively. Girabshi area located at an altitude of 05^{0}11`11``E and latitude of 13$^0$04`45``N and it is also a location with high density [11].

Acceleration due to gravity is not the same everywhere on earth surface. It can vary with many known and measurable factors such as earth tides, variation in mass, latitude, elevation, topography of the surrounding terrain and variations in density in the subsurface [12].

5. CONCLUSIONS

This research took measurements using Kater's pendulum (Reversible pendulum) for the magnitude of acceleration due to gravity at seven (7) different locations within Sokoto metropolis of Sokoto state, Nigeria. Factors such as latitude, elevation and variations in density in the subsurface are suggested to be responsible variations seen in acceleration due to gravity. Acceleration due to gravity decreases with increase in height above the surface of the Earth. The average value of g as seen in this work is 9.8 m/s^2 corresponding to what Glen Thorn Craft mentioned in his paper "How precise is earth's gravity?" This is often used in engineering calculations.

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