DESIGN OF ELECTRONIC GRAVIMETER

BY

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FEBRUARY, 1994.

ABUBAKAR TAFAWA BALEWA UNIVERSITY, BAUCHI

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DEDICATION

This project is dedicated to my parents Mr. and Mrs. Ahmed.

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Ahmed Zubairu
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ABSTRACT

Electronic gravimeter is a three block instruments - viz: the electron gun systems the electron deflection system and the electron detection system. The electron gun system emits beam of electrons which moves vertically upward. The electron deflection system controls the movement of electrons in the electronic gravimeter. The electrons detection system detects the electrons that are emitted by the electron gun system and are recorded as current on a meter. All the blocks are enclosed in a glass envelop in which the air inside is evacuated.

Electronic gravimeter measures the potentials on the electron detection system at a given current at different stations. From these, the values of the acceleration due to gravity at different station can be calculated, and the difference in acceleration due to gravity between based station and any other station can be calculated.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Gravity prospecting evolved from the study of the variation of the earth's gravitational field, g.

Over the period, studies have shown that the magnitude of this gravity on the earth's surface is influenced by five factors: latitude, elevation, topography of the surrounding observation point, earth tides and lateral variations in density of the subsurface.

The last factor is the only one of significance in gravity exploration. Even though its effect is generally very much smaller than those of the other four combined. For example, the change in gravity from equatrial to polar regions amount to 5gals, or 0.5% of the average value of g, while the effect of elevation in some cases might be as large as 0.1gal or 0.01% of g. A large gravity anomaly in 0:1 exploration, on the other hand would be 10mgals (0.001% of g), while in mineral areas the value would usually be one tenth of this.

1.2 Literature review

Introduction

Since the detection of an anomaly in gravity prospecting requires that we measure changes in g at least as small as 0.1mgal, it is not possible, as mentioned earlier to determine g and absolute g with the same instrument. The absolute measurement is carried out at a fixed installation and involves the accurate timing of a swinging pendalum or of a falling weight.

Relative measurements may be made in various ways. Three types of instruments have been widely used at different times for gravity exploration. These are the forsion balance, the pendalum, and the gravimeter. The latter is the sole instrument now used for prospecting.

1.2.1 Absolute measurement of gravity

(a) Falling body

Although the timing of a freely falling body was the first method of measuring g, the accuracy was very poor because of the difficulty in measuring small time intervals. Within the last fifteen years this method has been revived as a resolt great improvements in instrumentation. Flaborate installations for this purpose are now located at several national laboratories.

The acceleration of gravity can be found from Newton's equation of motion by noting the time interval between two points in a vertical fall. If the falling body, which starts with an unknown initial velocity, falls distances S_1 and S_2 in time intervals of t_1 and t_2 respectively (all quantities being measured from the starting point), then

$$g = 2(s_2 t_1 - s_1 t_2)/(t_2 - t_1)\ t_1 t_2 \quad .....(1.2)$$

In order to obtain an accuracy of 1mgal with a fall of one or two metres, it is necessary to measure time to about 10^{-8} seconds and distance less than 0.5 micron.

(b) Pendalum

Until recently the standard method for measuring g employed a modified form of the reversible pendalum originally developed by Kater in 1818. Installations of this type exist at Postdam, Washington and Teddington. The value of 981.274 gals obtained at Postdam in 1906 is still used as the nominal value for comparison of g at other stations, although it is now known to be too large by about 14mgals.

The value of g is obtained by timing a large number of oscillations, then using the simplified formula.

$$g = 4\Pi^2 I/T^2 MH \quad \ldots\ldots. (1.3)$$

where I is the moment of inertia, T the period m the mass and h the distance from the pivot to the centre of mass of the pendalum. In the reversible pendalum the factor I/mh, which cannot be determined with high precision, is replaced by l, the length of the equivalent simple pendalum - in effect a weightless, perfectly rigid connection between pivot and point mass. The accuracy required for T and l here is similar to that of falling weight apparators.

1.2.2 Relative measurement of gravity

Any method of determining changes in g (or, in fact, of comparing g - values from station-to-station) is a relative measurement in that it has not been obtained by a specific determination of time and length. Obviously the great majority of measurements are of this type. Here various techniques for making relative measurements of g are describe.

(a) Portable pendalum

The pendalum has been used both for geodetic and prospecting purposes. For example Bouger compared the periods of a pendalum at various location in South America, Lapland and Paris about 1750.

If we differentiate equation (1.3) we get

$$\frac{dg}{dt} = -\frac{8\Pi^2}{T^3} \cdot \frac{I}{mL} = \frac{2g}{T},$$

so that the difference in gravity (to the first order) is given by

$$dg = -2gdT/T = -2g(T_2-T_1)/T_1 \quad \cdots\cdots\cdots \quad (1.4)$$

Thus if we can measure the periods at two stations to about 1k sec, the gravity difference is accurate to 1mgal. This is not difficult with the precise clocks (quartz crystal, caesium, etc.) now available.

The pendalum has been used extensively for geodetic work in determining relative g over the earth surface, both on land and at sea. The three pendalum apparatus of vening meinesz was designed specifically for submarine operation. Portable pendalums were used in oil exploration during the early 1930s. The usual arrangement employed two instruments and compared the periods at a base and a movable station. In this case the relation for dg is more complicated than equation (1.4), since the constants of the two pendalums are not necessarily equal. The oscillations were recorded on light-sensitive paper and the records correlated by radio time signals. Sensitivity was said to be about 0.25mgal.

Pendalum apparatus is complex and bulky. Two pendalums, swinging in opposite phase to reduce sway of the mounting, are required at each station. These are enclosed in an evacuated, thermostatically controlled chamber to eliminate pressure and temperature effects. To get the required accuracy in T_1 and T_2 it is necessary to record for about half an hour.

(b) Gravity meter-stable type

The development and application of gravimeters for field measurements of g_z dates from the early 1930s. They may properly be considered in the order of their development, the early modes being of stable type. These have been superseded entirely by the more sensitive unstable meters and so are of historic interest only. However, the principles involved are similar to those in modern instruments.

All gravimeters are essentially extremely sensitive mechanical balances in which a mass is supported by a spring. Small changes in gravity move the weight against the restoring force of the spring. The stable type of instrument, which has a linear dependence on gravity over a large range, requires a considerable amplification of the minute changes in length of the spring. This amplification may be mechanical, optical or electrical, or a combination of these.

The basic elements of a stable gravimeter are shown in fig. 1.1. Since the displacement of the spring is small, Hooke's law applies, i.e, the force is proportional to the change in length, hence

$$F = M\Delta g = K\Delta s \text{ or } g = K\Delta s/M \text{ ......(1.5)}$$

where k is the spring constant in g N/M.

In orther to measure Δg to 0.1mgal or better, we must detect a fractional changes in spring length of $1/10^7$ (since $g/g = s/s$), hence the need for some form of magnification. Mechanically we can make k/m small by using a large mass and a weak spring, but obviously this enhancement of sensitivity is quite limited. The period of oscillation of this system is

$$T = 2\pi \sqrt{(M/K)} \quad \ldots\ldots\ldots \quad (1.6)$$

Combine (1.5) and (1.6) we get

$$g = 4\pi^2 \Delta s/T^2 \quad \ldots\ldots\ldots\ldots \quad (1.7)$$

Thus the period is very large for good sensitivity and a measurement of g requires considerable time.

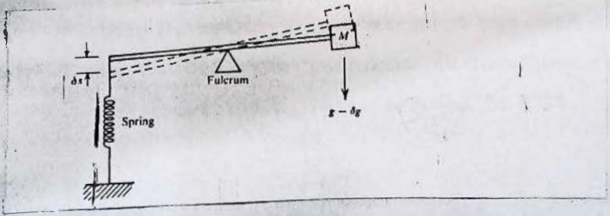


Fig. 1.1 Basic principle of the stable gravimeter.

Several versions of the stable gravimeter were developed between 1932 and 1938, employing ingenious means of magnification.

(c) Gulf gravimeter

This instrument measured the rotation of a spring, wound from a flat ribbon, rather than its elongation. For this flat spiral the rotation is in fact, greater than the relative elongation. The essential parts are shown schematically in fig. 1.2a. The mirror underneath the mass (100g) on the end of the spring, in conjunction with a fixed mirror or set of mirrors, the better partially silvered to permit multiple reflections, produces optical amplification of the original small rotation angle. The sensitivity was said to be better than 0.1mgal. This instrument was used extensively in the U.S.A for petroleum exploration. The weight was about 100Ib, later reduced to 25Ib.

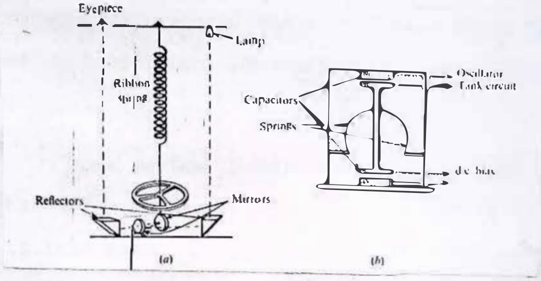


Fig. 1.2 Typical stable gravimeters (a) Gulf gravimeter, (b) Boliden gravimeter.

(d) Boliden gravimeter

Developed in Sweeden in 1938, this instrument employed an electronic detector and electrical balancing device. Fig. 1.2b is a schematic view. The mass is in the form of a bobbin suspended by bowed springs; the flat end discs are concentric with a pair of fixed discs to form two electrical capacitances. The upper plates form the capacitor in a tuned oscillator circuit so that small changes in capacitances vary the frequency of oscillation. The lower pair are connected to a d.c. supply produces an electrostatic balance. Measurement of g is achieved by adjustment of the d.c. voltage to restore the plates to a fixed reference or null position. The sensitivity was about 0.1mgal.

Some further development on this type of meter has since been carried out, in an effort to make it into airborne instrument which would measure vertical gradient or dg/dz. The parts were all extremely small, the end discs being capacitance variations to an accuracy of $1/10^8$, this electrical approach seems promising.

(e) Extraneus effects on gravimeters

Apart from the difficulties of achieving good sensitivity in measuring dg, the instruments are extremely sensitive to other physical effects, such as changes in pressure, temperature and small magnetic and seismic variations.

The effect of temperature changes on the older instruments, which were generally made with rather bulky metal parts, was enormous about

10mgal/°C. To maintain the temperature constant within 0.01°C, the working parts of the meter are mounted in a well-insulated thermostatically controlled inner box, surrounded by one or more outer containers. Although this regulation of temperature is equivalent to only 0.1mgal, it is sufficient, since sudden fluctuations of temperature could not occur in the sealed inner chamber. The thermal control requires 10-20 watts of power, generally supplied by a storage battery. With these additions the equipment becomes relatively heavy and bulky. Furthermore, the temperature regulator must be in operation for some hours to reach equilibrium.

(f) <u>Gravimeters-unstable types</u>

Also known as labilized or astatized gravimeters, these instruments have an additional negative restoring force, operating in the same sense as gravity against the restoring spring. They are essentially in a state of unstable equilibrium and thus have greater sensitivity than the stable meters. The range over which the readings vary linearly with depth is less than for stable gravimeters, so they are usually operated as null instruments.

(g) Thyssen gravimeter

Although now obsolete, this instrument illustrates the instability effect particularly well and is worth discussing for this reason. It is illustrated in fig. 1.3.

The addition of the mass m above the pivot raises the centre of gravity and produces the instability condition. If g increases, the beam tilts to the right and the moment of m about the pivot enhances the rotation: the converse is true for a decrease in gravity. The increase in sensitivity can be shown by taking moment about the pivot for the position shown in fig. 1.3 and when the beam is horizontal (in the latter case mass m has no effect). Then we have $M(g + \Delta g)\, t \cos \theta + M(g + \Delta g)\, h \sin \theta$ $= k(g + \Delta g)\, t \cos \theta$, and $mgl = kst$.

Dividing the first expression through by $\cos \theta$, subtracting the second from the result, substituging $g = ks/m$ and $\tan \theta$ $\delta s/l$, we obtain

$$g = \frac{k}{m}\left(\frac{1-(mhs)/Ml^2}{1+(mh\Delta s)/ml^2}\right)\Delta s$$

$$\frac{k}{m}\left(1 - \frac{m}{m}\,\frac{h}{t}\,\frac{s}{l}\right)\Delta s \; \ldots\ldots. \; (1.8)$$

Since the term in the bracket is less than unity, the inherent sensitivity of this arrangement is greater than the stable condition of equation (1.5).

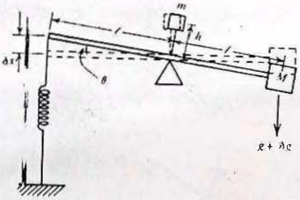


Fig. 1.3 Thyseen gravimeter.

The Thyseen meter employed two parallel beams with the end weights reversed. It was rather big and heavy (beam length 20cm) and had a sensitivity of 0.25mgal.

(h) LaCoste-Romberg gravimeter

This type of meter, which has been manufactured under various names (Askania, Frost, Magnolia, North American), is a modified vertical seismograph of long period, originally designed by LJ.B. LaCoste about 1934.

In connection with this seismograph LaCoste introduced the zero-length spring,

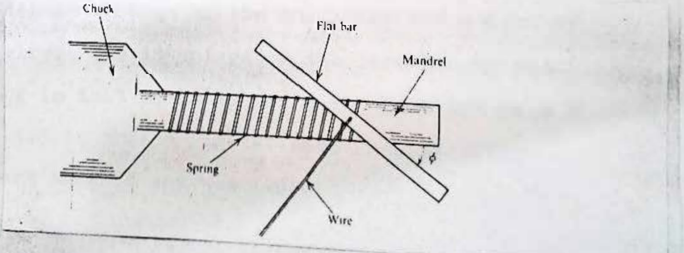


Fig. 1.4 Construction of the zero-length spring.

which has been incorporated in almost all gravimeters since that time. The arrangement for winding this spring is shown in fig. 1.4. The wire is fed through a hole in a flat respect to the mandrel on which the spring is wound. Thus a pre-tension, proportional to θ and the wire tension, is put into the spring during the winding. When it is removed from the mandrel the spring shrinks to a minimum length.

A zero-length spring is defined as one in which the tension is proportional to the actual length of the spring, that is if all external forces were removed the spring would collapse to zero length. Of course, this is physically impossible because of the thickness and weight of the wire. The advantage of the zero-length position spring is that if it supports the beam and mass M fig. 1.5 in the horizontal position, it will support them in any position.

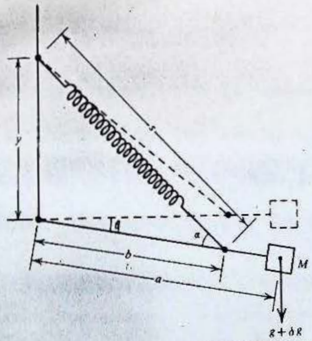


Fig. 1.5 LaCoste-Romberg gravimeter.

To derive the expression for the sensitivity of the LaCoste-Romberg gravimeter, we write k(s-z) for the tension in the spring when its length is S; thus, Z is a small correction for the fact that the spring is not truly zero-length. Taking moments about the pivot in fig. 1.5, we get

$$\begin{aligned} Mga \cos \Theta &= k(s-z)\ b \sin\alpha \\ &= k(s-z)\ b\ (y \cos \Theta)/S, \end{aligned}$$

using the sine law.

Thus $g = (\frac{k}{m})\ (\frac{b}{a})\ (1 - \frac{z}{s})y.$

When g increases by Δg, the spring length increases by Δs where

$$g = (\frac{k}{m})\ (\frac{b}{a})(\frac{z}{s})\ (\frac{y}{s})\ \Delta s \ ...... \quad (1.9)$$

For a given change Δg, Δs is increased when one or more of the factors on the right-hand side is decreased; moreover, the closer the spring is to the zero-length spring, the smaller z is and the larger s becomes.

In operation this is used as a null instrument, a second spring being used which can be adjusted to restore the beam to the horizontal position. The sensitivity is about 0.01mgal.

Early models of this meter were quite bulky and sensitive to temperature changes since the working parts were metal, like the stable types, the meter required an elaborate temperature regulating system and the moving parts had to be clamped for transportation.

1.3 Scope of the project

The scope of this project is to design a conveniently shaped, light weight, robust and durable electronic gravimeter from major components such as low voltage electron gun and an electron detection system.

The electronic gravimeter is intended to be light weight because of the believe that a field equipment must be so designed beside being accurate, and precise enough to be accepted.

CHAPTER TWO

THEORY

2.1 Introduction

Newton's law of gravitation states that the force of attraction between any two given masses M and m is inversely proportional to the square of their distance, r apart. Applied to the earth of mass M and any other object of mass m on its surface this law can be expressed as

$$F = \frac{GMm}{r^2} \quad \ldots\ldots\ldots\ldots \quad (2.1)$$

where G = gravitational constant.

By Newton's second law of motion, the earth thus attracts the object with an acceleration

$$g = \frac{F}{m} = \frac{GM}{r^2} \quad \ldots\ldots\ldots\ldots (2.2)$$

For distances close to the earth's surface, this acceleration is assumed constant for most practical purposes even though we are aware that it varies with elevation.

2.2 Motion of electron in gravity field

An electron of mass m projected in the earth's gravity field at a certain angle θ with a certain initial velocity, U. The equation of motion in the vertical direction can be written as

$$v = u \sin \theta - gt$$

$$h = ut \sin \theta - \tfrac{1}{2}gt^2 \quad ....(2.3)$$

$$v^2 = u^2 \sin^2 \theta - 2gh$$

where

u = initial velocity of the electron

v = final velocity of the electron in the vertical direction.

h = height covered by the electron

t = time of flight.

For a vertical motion $\theta = 90^\circ$,

$$v = u - gt$$

$$h = ut - \tfrac{1}{2}gt^2 \quad . ...(2.4)$$

$$v^2 = u^2 - 2gh$$

At maximum height $v = o$. Equation (2.4) become

$$u = gt$$

$$h = ut - \tfrac{1}{2}gt^2 \quad ....(2.5)$$

$$u^2 = 2gh.$$

Using $u^2 = 2gh$ he come

$$h = \frac{u^2}{2g} \quad ....(2.6)$$

A graph of height against initial velocity of projection can be plotted as shown in page 17.

The force acting on the electron can be written as

$$F = mg \quad \dots\dots\dots\dots\dots(2.7)$$

2.3 Acceleration of electron by an electric field

If an electron of mass, m and charge, e is moved through a potential difference, V. (From electron gun system to electron detection system), in which the electric field is E.

The force on the electron can be written as

$$F = eE \quad \dots\dots\dots\dots(2.8)$$

But $E = \frac{V}{h}$ $\quad \dots\dots\dots\dots\dots(2.9)$

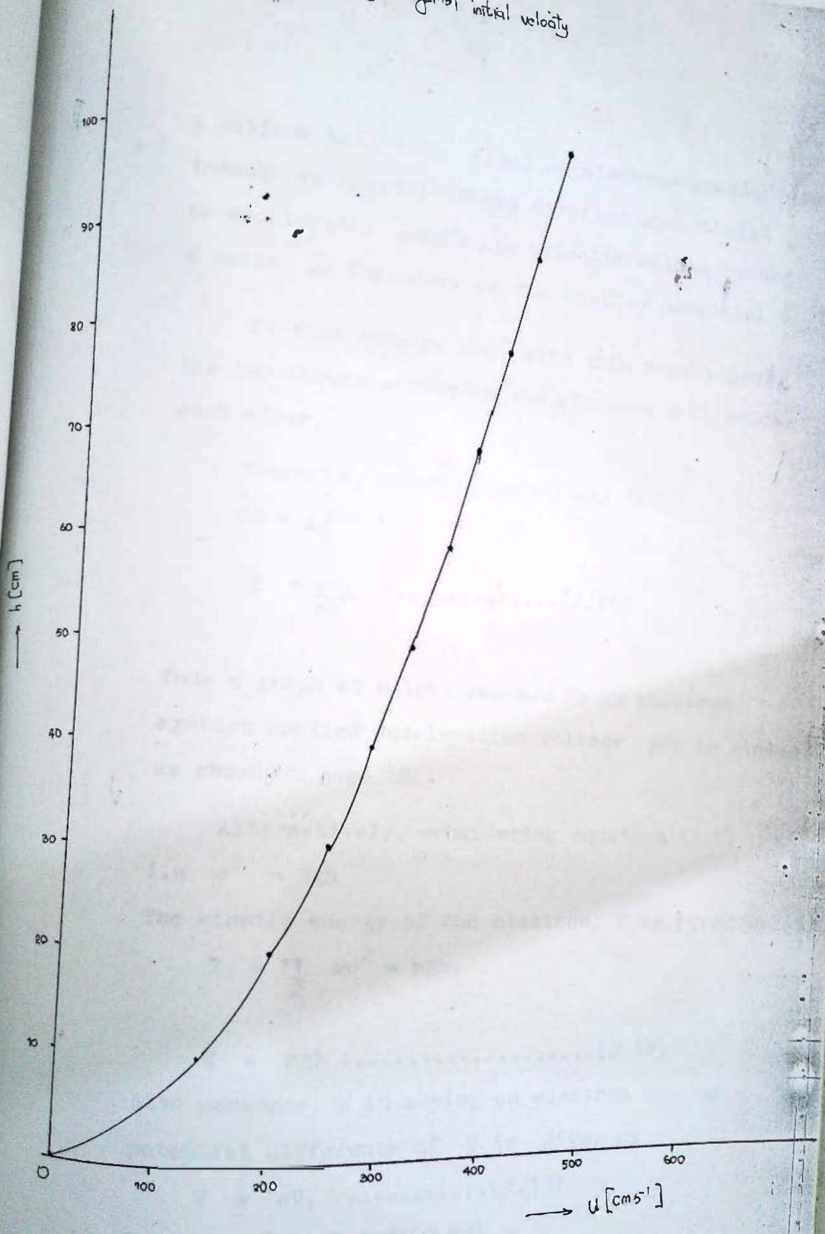
where h = distance between the electron gun system and electron detection system.

$$F = \frac{eV}{h} \quad \dots\dots\dots\dots(2.10)$$

2.4 Motion of electron in book gravitational and electric fields.

An electron projected vertically upward is retarded by an acceleration equal to g and depending on the initial velocity of projection, it will reach

A graph of height against initial velocity



a maximum height h. Also, an electron accelerated through an electric field directed upward will be accelerated until its velocity values reaches a value, u, depending on the applied potential V.

It thus appears that with this arrangement, the two forces acting on the electron will oppose each other.

Comparing equation (2.10) and (2.7)

$$mg = \frac{eV}{h}$$

$$g = \frac{eV}{mh} \quad \ldots\ldots\ldots\ldots\ldots (2.11)$$

Thus a graph of height reached by an electron against applied acceleration voltage can be plotted as shown on page 24.

Alternatively, considering equation (2.5)

i.e $u^2 = 2gh$

The kinetic energy of the electron, T is given by

$$T = \frac{1}{2} mu^2 = mgh.$$

$$T = mgh \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.12)$$

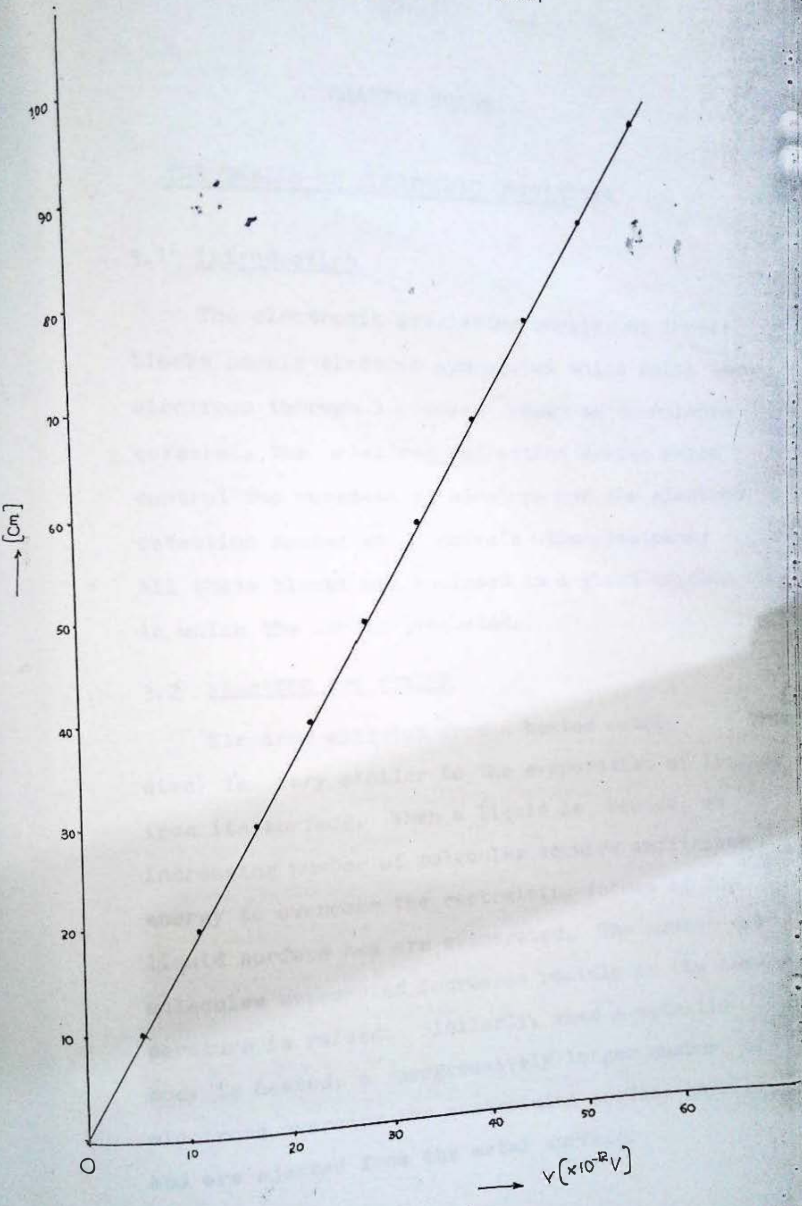
Also workdone, W in moving an electron through a potential difference of V is given as

$$W = eV, \quad \ldots\ldots\ldots\ldots (2.13)$$

Comparing (2.12) and (2.13)

$$g = \frac{eV}{mh} \quad \ldots\ldots\ldots\ldots\ldots (2.14).$$

A graph of height against Potential



CHAPTER THREE

THE DESIGN OF ELECTRONIC GRAVIMETER

3.1 Introduction

The electronic gravimeter consist of three blocks namely electron gun system which emits the electrons through a process known as thermionic emission, the electron deflection system which control the movement of electron and the electron detection system which detects the electrons. All these blocks are enclosed in a glass envelop in which the air is evacuated.

3.2 Electron gun system

Electron emission from a heated metal thin disc) is very similar to the evaporation of liquids from its surface. When a liquid is heated, an increasing number of molecules acquire sufficient energy to overcome the restraining forces of the liquid surface and are evaporated. The number of molecules evaporated increases rapidly as the temperature is raised. Similarly, when a metallic body is heated, a progressively larger number of electrons overcome the restraining surface barrier and are ejedted from the metal surface.

The number of electrons ejected per unit area of an emitting surface is related to the absolute temperature T ($^{\circ}A$) of the emitter and a quantity b that is a measure of the work an electron must perform when escaping the emitter surface, according to an equation derived by O.W. Richardson.

Emission current, $I = AT^2 e^{-b/T}$ ......(3.1)

(ampere per square centimeter)

where e = 2.7183 (base of natural log) and A is a constant which has a value of about 60 for pure metals, such as tungsten or tantalum, but varies widely for other practical emitters. Also $1^{\circ}C = 1.21^{\circ}A$.

3.3 Electron deflection system

The electron deflection system in the electronic gravimeter is circular (ring) of fine wire (nichrome, molybdenum, iron, nickel or tantalum). The electron deflection system is nearer to the electron gun system than the electron detection system. The electron detection system has a controlling effect on the current in the electron detection system.

If the electron deflection system is at a high negative voltage, no electron can pass through it to the electron detection system. The electron deflection system neutralized the electrostatic field and hence, the attraction of the electron detection system.

If the negative bias voltage of the electron deflection system is reduced the electron deflection system is no longer capable of neutralizing the field between the electron detection system and the electron gun system. Some electrons will be attracted by the electron detection system and will be recorded as current.

If the battery polarity is reversed, thus making the electron deflection system positive. The electron deflection system potential now aids the electron detection system voltage and produces a very strong electrostatic field at the electron gun system resulting in al large current in electron detection system. If the electrom deflection system is made sufficiently positive a point will be reached when the electrons are attracted as fast as they can be emitted from the electron gun system, the electron detection system current reaches its saturation value. Still further increase in either electron deflection system or electron detection system voltage cannot cause an increase in electron detection system current.

If the electron deflection system is positive some of the electrons from the electron gun system are attracted to the positive electron deflection system and cause an electron deflection system current to flow. Under these conditions power is dissipated in the electron deflection system circuit. To avoid this power consumption and also large saturation current, which eventually can damage the electronic gravimeter, the electronic gravimeter must be operated at negative electron deflection system voltage.

3.4 Electron detection system

The electron detection system of an electronic gravimeter is circular (in disc) of fine wire (nickel, molybdenum, graphite, tantalum, monel, or iron).

A basic law of electricity states that like charges repel each other, while unlike charges attract each other. Electrons emitted from the electron gun system are negative charges. These are attracted by the electron detection system only when it is at high positive voltage and low negative electron deflection system voltage. The attracted electrons will be recorded as current on a meter.

The electron detection system can be in the form of a fluorescent screen in which when the electrons are detected the screen fluorescence and the intensity is recorded on a meter.

3.5 Final design

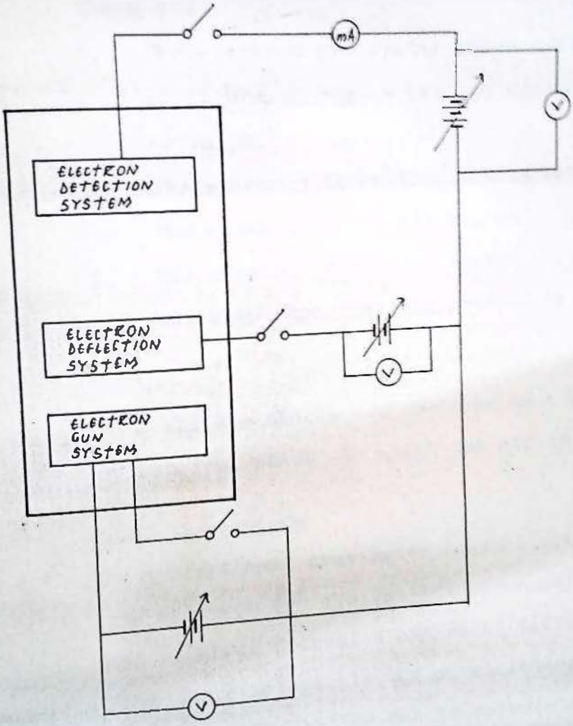


Fig. 3.1 Block diagram of electronic gravimeter.

CHAPTER FOUR

SUMMARY, DISCUSSIONS AND CONCLUSION

4.1 Summary

Electronic gravimeter consist of three blocks, these are:

1. The electron gun system which emits beam of electrons through a process known as thermionic emission,
2. The electron deflection system which controls the movement of electrons, and
3. The electron detection system which detects the electrons that are emitted by the electron gun system.

All the blocks are enclosed in a glass of a cylindrical shape in which the air is evacuated.

4.2 Discussions

Electronic gravimeter measure potentials in the electron gun system, lelectron deflection system and electron detection system at different stations. From these potentials the acceleration due to gravity at different station can be calculated using equation (2.), i.e

$$g = \frac{eV}{mh}$$

Hence the difference in acceleration due to gravity between base station and any other station can be computed base on the following conditions:

1. If the potential and current in the electron detection system are fixed, the potential in the electron deflection system is fixed and the distance between the electron gun system and the electron detection system is fixed, but the potential in the electron gun system is variable. Then the acceleration due to gravity at the reference point A is

   $g_1 = \frac{e}{mh} V_1$ .... (4.1)

   at a given detector current I.

   V_1 = potential of the electron gun system at the reference point A.

   At any other point B the potential in the electron gun system can be varied until the current I is reached, such that

   $g_2 = \frac{e}{mh} V_2$ .... (4.2)

   at a given detector current I.

   From equation (4.2) and (4.1)

   $g_2 - g_1 = \frac{e}{mh} (V_2 - V_1)$

   $\Delta g = \frac{e}{mh} \Delta V$ .... (4.3)

   where $\Delta g = g_2 - g_1$, $\Delta V = V_2 - V_1$

2. If the potential and current in the detector are fixed, the potential in the electron gun system is fixed, the distance between the electron gun system and the electron detection system is fixed, but the potential in the electron deflection system is variable. Then the acceleration due to gravity at the reference point A is

$$g_1 = \frac{e}{mh} V_1 \quad . \ldots\ldots\ldots (4.4)$$

at a given detector current I.

V_1 = potential in the electron deflection system at point A.

At any other point B the potential on the electron deflection system can be varied until detector current I is reached, such that

$$g_2 = \frac{e}{mh} V_2 \quad \ldots\ldots\ldots\ldots (4.5)$$

at a given detector current I.

From equation (4.4) and (4.5)

$$g_2 - g_1 = \frac{e}{mh} (V_2 - V_1)$$

$$\Delta g = \frac{e}{mh} \Delta V \quad \ldots\ldots\ldots\ldots (4.6)$$

at a given detector current I.

$\Delta V = V_2 - V_1$

3. If the potential and current in the electron detection system are fixed, the potentials in the electron gun system and electron deflection system are fixed, but the distance between electron gun system and the electron detection system is variable (either the electron gun system or electron detection system movable or both are movable).

   Then the acceleration due to gravity at the reference point A is

   $$g_1 = \frac{eV}{m} \cdot \frac{1}{h} \quad \cdots\cdots\cdots\cdots \quad (4.7)$$

   at a given detector current I'

   h_1 = distance between the electron gun system and electron detection system.

   V = Constant potential of electron detection system or electron deflection system or electron gun system.

   At any other point B the distance between the electron gun system and the electron detection system can be until the detector current I is reached, such that

   $$g_2 = \frac{eV}{m}\frac{I}{h_2} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (4.8)$$

   at a given detector current I.

   From equation (4.7) and (4.8)

$$g_2 - g_1 = \frac{eV}{m} \left(\frac{I}{h_2} - \frac{I}{h_1} \right)$$

$$\Delta g = \frac{eV}{m} \left(\frac{I}{h_2} - \frac{I}{h_1} \right) \quad \ldots\ldots\ldots (4.9)$$

at a given detector current I.

4. If the detector current is constant, the potentials in the electron gun system and the electron deflection system are fixed, the distance between the electron gun system and electron detection system is fixed, but the potential in the electron detection system is variable. Then the acceleration due to gravity at the reference point A is

$$g_1 = \frac{e}{mh} V_1 \quad \ldots\ldots\ldots\ldots\ldots (4.10)$$

at a given detector current I.

V_1 = potential in the electron gun system at point A.

At any other point B the potential in the electron detection system can be varied until the detector current I is reached, such that

$$g_2 = \frac{e}{mh} V_2 \quad \ldots\ldots\ldots\ldots\ldots (4.11)$$

at a given detector current I

V_2 = potential in the electron detection system at point B.

From equation (4.10) and (4.11)

$$g_2-g_1 = \frac{e}{mh} (V_2-V_1)$$

$$\Delta g = \frac{e}{mh} \Delta V \quad \ldots\ldots\ldots\ldots (4.12)$$

at a given detector current I.

$$\Delta V = V_2-V_1$$

The first two methods can easily destroy the electronic gravimeter because of the saturation effect and power dissipation. In the third method it is difficult to devise a suitable method of moving either the electron gun system or electron detection system or both in the electronic gravimeter. The fourth method is the most easiest method of measuring the differences in potential between stations because the saturation effect and power dissipation are minimised.

4.3 Conclusion

The electronic Gravimeter measures the potentials at different stations at a given current; from these potentials the difference in acceleration due to gravity between one station and any other station can be calculated. The causes of the variation in the acceleration due to gravity is because of the local variation in the density of rocks near the surface of the earth. The observations should be made within a few metres of the earth's surface or airborne test.

Beck, A.E. (1981). *Physical Principles of Exploration Methods*, London: The MacMillan Press Ltd.

Brophy, J.J. (1977). *Basic Electronics for Scientist*, 3rd ed. Tokyo: McGraw-Hill International Book Company.

Calvert, J.M., and M.A.H. McCavsland (1985). *Electronics*. New York: John Willey and Sons.

Dobrin, M.B. (1976). *Introduction to Geophysical Prospecting*, 3rd ed. Tokyo: McGraw-Hill International Book Company.

Garland, G.D. (1971). *Introduction to Geophysics*, Toronto: W.B. Saunders Company.

Nelson, M. and J.M. Ogborn (1982). *Advanced Level Practical Physics*, 3rd ed. London: Heinemann Educational Books Ltd.

Serway, R.A. (1982). *Physics for Scientist and Engineers*, London: Sounders College Publishing Company.

Telford, W.M. *et al.* (1980). *Applied Geophysics*, Cambridge: Cambridge University Press.