

# Correction of Gravitational Acceleration at High Altitude and Low Pressure and the Application in Weighing

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**Abstract:** Earth gravity field data is the basic data and strategic data of a country. The accurate measurement of Earth gravity field is of great scientific significance to the fields of metrology, earthquake prevention and disaster reduction, surveying and mapping, geodynamics and so on. It is of great strategic significance to the fields of Marine science, resource exploration and national security. China has a vast territory and diverse landforms. From the southeast coast to the Qinghai-Tibet Plateau, the elevation difference is more than 5,000 meters, and the elevation difference in a small range is small, and the acceleration of gravity can also be ignored. However, when the altitude difference is large, the change of acceleration of gravity will have a great impact on high-precision measurement. The effect of gravity acceleration in low altitude area and Lhasa under high altitude and low-pressure environment on the weighing instrument is compared and analyzed, and the correction method of altitude on the weighing instrument is proposed.

**Keywords:** Acceleration of Gravity; Elevation Difference; High Altitude Low Pressure; Weighing.

## 1. Introduction

The gravity field of the earth is one of the most important physical fields of the earth, which reflects the spatial distribution, movement and change of the earth's materials, and restricts all physical events occurring on the earth and its adjacent space.

## 2. Basic Concepts

(1) Mass: in physics, the amount of matter contained in the object is called mass, and the mass does not change with the shape, state, and spatial position of the object, which is the basic attribute of the object, that is, the same object has the same mass all over the earth. Mass is usually denoted. The unit of mass in the SI system of units is the kilogram, kg.

(2) Acceleration of gravity: The acceleration of objects near the Earth's surface when only subjected to gravity is called the acceleration of gravity,  $g$ , also known as the acceleration of free fall, which is expressed. The acceleration of gravity increases with the increase of latitude and decreases with the increase of altitude. Our country has a vast territory and a large latitude span, so the variation of the acceleration of gravity is larger. It requires us to pay attention to the influence of gravity acceleration value when the weighing instrument is used and verified across regions  $g$ .

(3) Gravity: due to the attraction of the earth and the force of the object, called gravity, life often refers to the size of the object by gravity as weight. Mass and weight are completely different and should not be confused. The unit of gravity is  $G$ , represents the symbol bit, the formula is:  $G = mg$ . It's the mass of the object,  $m$  and  $g$  is the local acceleration of gravity.

## 3. The Influence of Gravity Acceleration on the Stability of the Weighing Instrument

According to the principle of mechanics, weighing can be divided into dynamic effect weighing and static effect weighing.

### 3.1. Dynamic Effect Weighing

also known as gravity balance weighing, is the use of known objects in the gravitational field of the earth's gravitational acceleration and the size of the mass to measure the mass of the said object. Such as mechanical lever scale, balance is the use of lever balance principle for measurement. As shown in the picture:

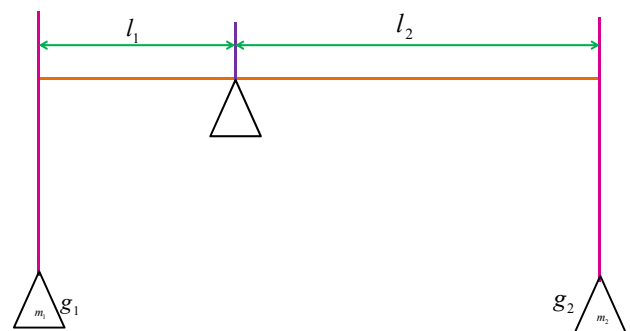


Fig 1. Dynamic effect principle weighing diagram

According to the lever balance principle,  $m_1 \times l_1 \times g_1 = m_2 \times l_2 \times g_2$ . Since the distance between the measured object and the measured object is very close, the difference between the acceleration of gravity is negligible, that is, it can be seen that  $g_1 = g_2$   $m_1 = m_2 \times l_2 / l_1$  when the lever is balanced, the mass of the measured object is equal

to the product of the lever ratio and the mass of the known weight, and the measured result is the mass of the object, and the result is independent of the acceleration of gravity.

### 3.2. Static Effect Weighing

Static effect weighing, also known as gravity deformation method weighing, is to use the size of the deformation or internal stress generated by the elastic body of the object under the action of gravity to measure the magnitude of gravity, such as electronic scale and spring scale are to use gravity deformation method for weighing and measuring, as shown in Figure 2

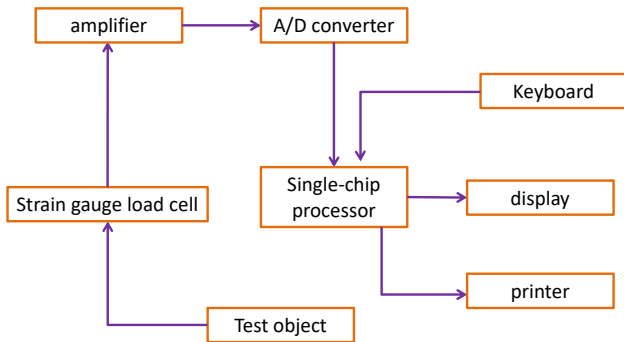


Fig 2. Work diagram of static effect weighing system

The weighing principle of the electronic weighing device is to convert the gravity of the object acting on the sensor into the number of electrical parameters (voltage, current, capacitance or frequency) according to a certain functional relationship to show the weight of the object being measured. Therefore, the weighing result of the electronic weighing device (sensing principle) is not the mass value of the object, but the gravity value, which is affected by the change of the gravitational acceleration value.

### 3.3. Calculation Formula of Gravitational Acceleration Changing with Latitude

The normal gravity formula recommended by the International Geophysical and Geodesy Association in 1979:

$$g_{\varphi} = 9.780327(1 + 0.0053024 \sin^2 \varphi - 0.000005 \sin^2(2\varphi)) m/s^2$$

$\varphi$  -Latitude of the Earth at the measuring point.

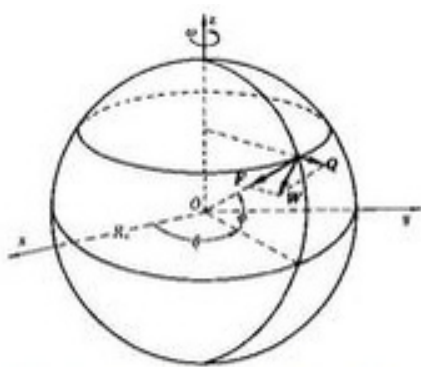


Fig 3. Geographical position and gravitational acceleration position relationship diagram

### 3.4. Calculation Formula of the Change of Gravitational Acceleration with Altitude Common Approximate Formulas are as Follows:

$$g = g_0 \left(1 + \frac{h}{R}\right)^{-2} \approx g_0 \left(1 - 2\frac{h}{R}\right)$$

$$= g_0 (1 - 3.14 \times 10^{-4} h)$$

$h$  - Height above ground;

$R$  - Radius of the earth;

$g_0$  - The acceleration of gravity when an object is on the Earth's surface

This is the approximate formula for the change of gravitational acceleration with height. It can be obtained from the formula for every increase in elevation 1 km The acceleration of gravity decreases by about 3.1 mm/s<sup>2</sup>.

The common formulas used in field practice are as follows:

$$r(\varphi, h) = r(\varphi) \left[ 1 - \frac{2}{a} \left( 1 + f + m - 2f \sin^2 \varphi \right) h + \frac{3}{a^2} h^2 \right]$$

$$m = \frac{\omega^2 a^2 b}{GM}$$

$r(\varphi)$  is the normal gravity value of the projection point of the point on the ellipsoid;

$f$  is the ellipsoid oblateness;

$\omega$  is the angular speed of the earth's rotation;

$GM$  is the earth's gravitational constant (including atmospheric mass)

$\varphi$  is the geodetic latitude of the point;

$h$  is the height of the point from the normal to the elliptic surface

### 4. Influence of the Change of Gravity Acceleration Value on the Weighing Result

When installing and purchasing electronic weighing instruments across provinces the variation of the acceleration of gravity between provinces is easy to attract attention because the variation of the acceleration of gravity is mainly affected by geographical latitude and altitude. In this paper, the influence of latitude and altitude on the accuracy of electronic weighing results is discussed under the circumstance that latitude and altitude vary greatly in the province.

Lhasa measuring point: 91.029° E, 29.632° N; 3643 m above sea level;

Beijing measuring point: 115.903° E, 40.227° N; 35 m above sea level;

By adding relevant parameters, the gravitational acceleration of Beijing and Lhasa can be obtained as follows:

Table 1. Formula modification and absolute gravimeter measurements in Beijing and Lhasa

Point position	Formula correction	Absolute gravimeter measurement
Beijing	9.8014	9.8012
Lhasa	9.7813	9.7810

Choose the same set of grade weights, choose the same model, the same manufacturer's electronic balance:

National Metrology Institute use balance information: balance model: 224S; Number: 18562177; Manufacturer: Sartorius; Actual indexing value: 0.0001g; Calibration index value: 0.001g. Experimental conditions: Temperature 22°C, humidity 41.2%.

Balance information used in Xizang measurement: Balance model: 224S; Number: 18561538; Manufacturer: Sartorius; Actual indexing value: 0.0001g; Calibration index value: 0.001g. Temperature 21.6°C, humidity 40.7%.

Select 100g weight in the same set of grade weights, Beijing measuring point, continuous measurement 10 times, the average is 100.0002g; Using the same measurement method, the average value of continuous measurement in Lhasa is 99.7935;

From the above measurement results, it can be seen that the same weight in Beijing and Lhasa, ignoring the influence of air density and temperature and humidity, causes the measurement error mainly because of the change of gravity acceleration caused by the difference in elevation.

According to the working principle of the electronic balance, ignoring the mass changes caused by environmental conditions in the two places of the experiment, according to Hooke's law:  $F = kx$  The process of gravity measurement is the change caused by the gravity of the object, resulting in the difference of the shape variable, which affects the final measurement result. Because  $G = mg$ , For convenience,

the acceleration of gravity in Beijing is  $g_1$ , and the acceleration of gravity in Lhasa is  $g_2$ .  $G_1 = mg_1$ ,

$$G_2 = mg_2, \frac{m_1}{g_1} = \frac{m_2}{g_2}$$

It can be obtained from the above formula:  $m_2 = \frac{m_1 g_2}{g_1}$

so we can get  $m_2 = 99.7941$ .

## 5. Conclusion

By comparing the above experimental results, it can be seen that the absolute error value of the experimental result is 0.0006 and the relative error is as follows when the weighing device is modified based on the absolute value of the local gravitational acceleration: 0.0006012%, which is about 6 parts per million, the experimental results have a high reliability. In summary, the experimental process is reliable, and the weighing error in the weighing process can be accurately corrected through the measurement of gravitational acceleration at different points.

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