Gravimetry

- Gravimetry is the science and practice of measurement of the strength of a gravitational field.

  i.e gravimetry is the measurement of gravity.
- Historically, only the measurement of the length (i.e only magnitude) of the gravity vector is meant.
- More recent techniques allow vector gravimetry, i.e. they give the direction of the gravity vector as well.
- Gravity survey has application in the solution of a number of problems including:
  - First order triangulation Net work
  - Levelling.
  - The determination of the shape of the Earth
  - Deviations of the vertical.
  - Geoids/ Spheroid Separation.
  - Mineral Exploration.
  - Certain navigational problems.
  - The evaluation of satellite orbits

Gravimeter

- A Gravimeter is a scientific instrument for measuring the value of gravity g at a place
- Gravimeter is designed to measure relative differences in the acceleration due to gravity between two locations.
- In principal, a gravimeter is simply an extremely sensitive weighing device

Show two models of LaCoste-Romberg gravimeters. Aliod G gravimeter (left side) and EG gravimeter (right side).

Gravimeters

- An attracting force, called gravitational force, operates between the earth and every object that is located within, on, or above the earth's surface.
- At the same time, any object within or on the earth's surface pursues a circular path as the earth rotates on its axis.
- The body as it pursues a circular path exerts an outward force called the centrifugal force
- The sum of the gravitational force and centrifugal reaction acting on a body is called gravity.

Contd…

- Since the gravitational force is much stronger than the centrifugal force gravity causes an object to have weight and, if the object is free to move, to fall with increasing speed (i.e., the body accelerates) toward the center of the earth.
- The acceleration experienced by that object as it moves toward the earth's center is called the acceleration of gravity, which is the quantity observed when gravity measurements are made.

Contd…

- Two distinctly different types of gravity measurements are made:
  - a. **absolute gravity measurements**
  - **b. relative gravity measurements.**

Absolute Gravity Measurement

- If the value of acceleration of gravity can be determined at the point of measurement directly from the data observed at that point, the gravity measurement is absolute.
- By an “absolute" gravity measurement, it actually refer to the determination of gravity value from the fundamental acceleration quantities length and time.

Contd…

- Way of determining Absolute gravity

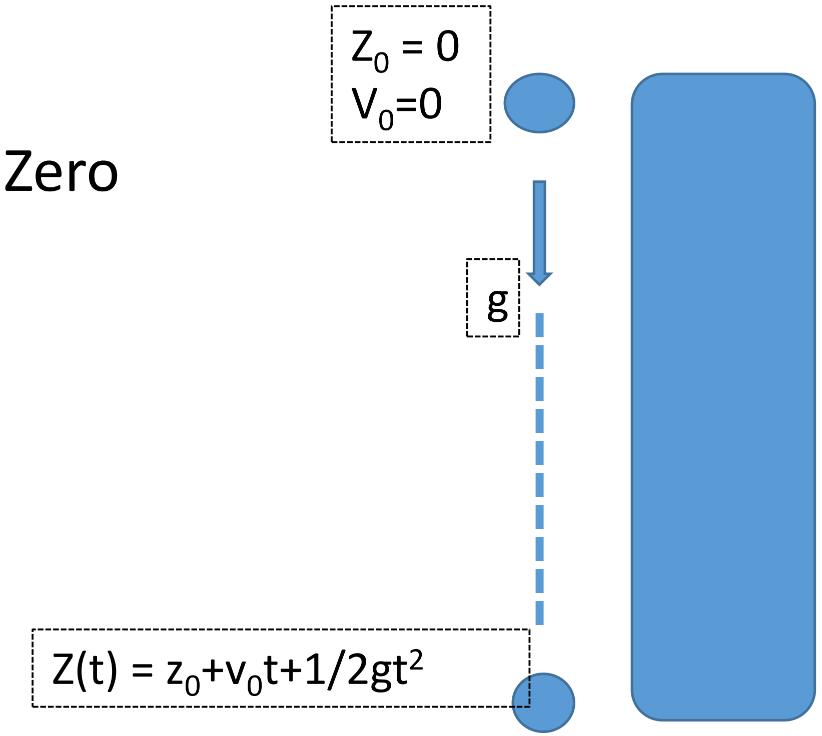
➢ free-fall

➢ rise-and-fall methods

➢ the pendulum methods are significant in determining absolute gravity

Cont…

A. <u>Free-fall method</u>



- Simply we know that

  initial velocity and stating height are Zero

- Thus $Z(t) = z_0+v_0t+1/2gt^2$

  $= 0+0+1/2gt^2$

  $= 1/2gt^2$

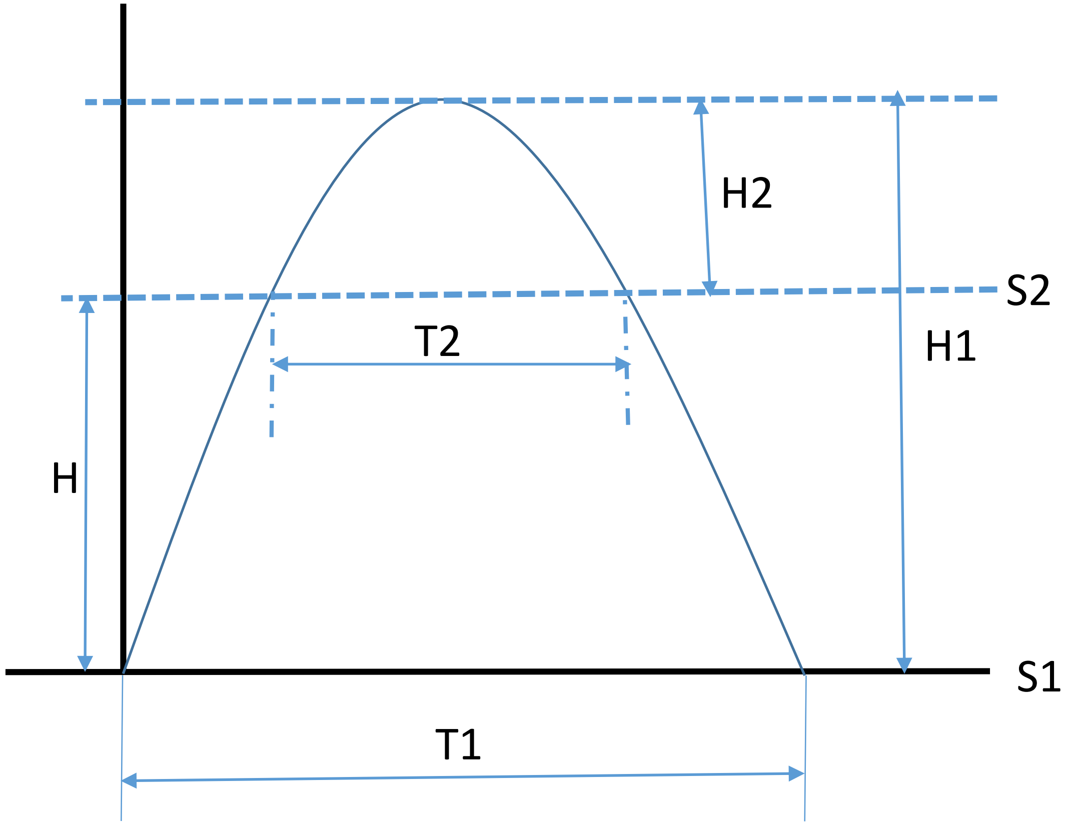
- Thus, $g=2z/t^2$

::::The gravity is determined from measuring the time it take a mass to fall a certain vertical distance z. This free-fall principle yields Absolute gravity

Cont…

B. Rise and Fall

- Here the object is thrown vertically upward and than allowed to fall freely
- Let label two position S1 and S2.
- The time interval T_1 and T_2 of falling body pass each position are determined.
- Let H_1 and H_2 be distance from two measuring position to the peak of its motion



Initially

- $H_1 = \frac{1}{2}g\left(\frac{T_1}{2}\right)^2$ and $H_2 = \frac{1}{2}g\left(\frac{T_2}{2}\right)^2$

- Than, $H = H_1 - H_2 = \frac{1}{2}g[\left(\frac{T_1}{2}\right) - (\frac{T_2}{2})]$

Cont…

- On simplifying, we get

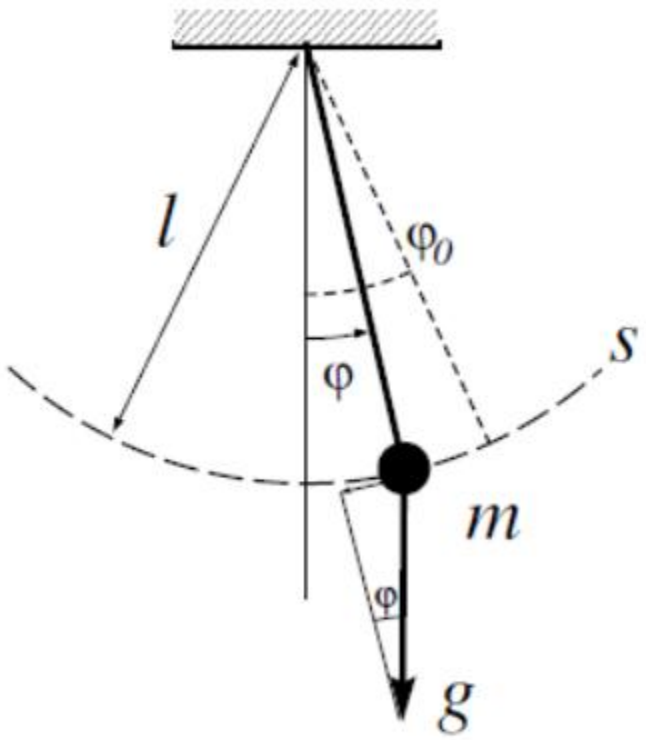
$$g = \frac{8H}{{T_1}^2 - {T_2}^2}$$

- Thus in rise fall to determine gravity it require the determination of time interval T_1 and T_2 of the objects passing through two position with a distance of H during its rise and fall

Cont…

- The pendulum method is based on the measurement of the period and the length (l) of a freely suspended pendulums
- We know that the time of a swing 'T' in second is given as :

$$T = 2\pi\sqrt{\frac{l}{g}}$$



where,

l = length of pendulum

g = value of gravity in gals

Φ = amplitude (generally remains less than 30 degree)

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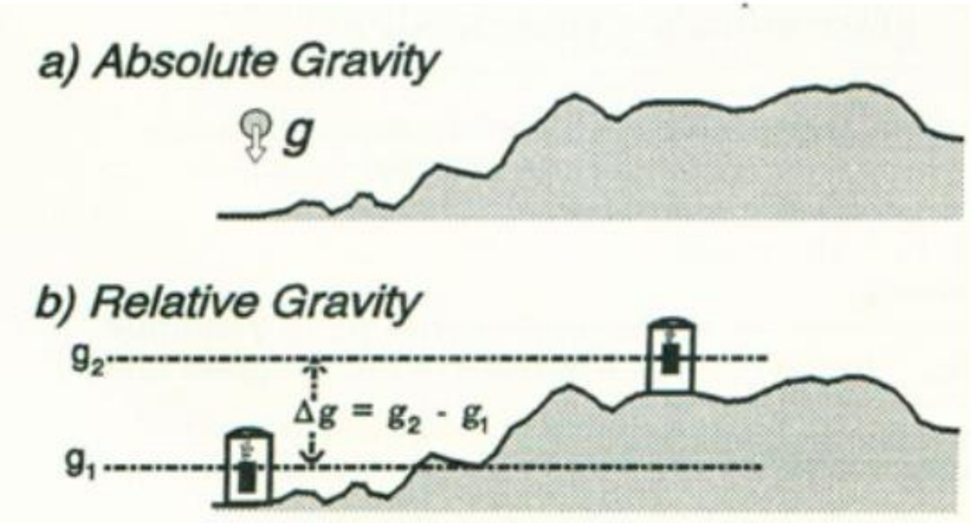
2. Relative Gravity Measurement

- *The* measurement of difference in gravity by the direct or indirect observation of one of the two acceleration quantities time or length keeping the other one fixed, is known as a “relative" gravity measurement.
- If only the differences in the value of the acceleration of gravity are measured between two or more points, the measurements are relative.
- It can be performed with considerably more ease than the “absolute" measurement of gravity.



True gravitational Acceleration

Difference in gravitational acceleration

Contd…

- Way of determining Relative Gravity Measurement

➢ Pendulum method

➢ Spring gravimeter measurement (based on the principle of spring balance)

a. Vertical Spring Balance

b. Lever torsion spring balance

c. General lever spring balance

➢ Airborne gravimetry

Cont…

A .Relative measurement by Pendulum

- In relative method of determining gravity a comparison ratio of value of gravity of two different places is obtained
- Since $T = 2\pi\sqrt{\frac{l}{g}}$
- So, $T_2 = 4\pi^2(\frac{l}{g})$ :::::: $g = 4\pi^2(\frac{l}{T_2})$

Cont…

- Hence if observation are made one at base station and other at field station we will have,

$$g_1 = 4\pi^2\left(\frac{l}{{T_1}^2}\right),\ g_2 = 4\pi^2\left(\frac{l}{{T_2}^2}\right)$$

where,

$$\pi\ and\ l\ are\ constant$$

- Therefore

$$\frac{g_1}{g_2} = \frac{{T_2}^2}{{T_1}^2}$$

$$\because\ g_2 = \left(\frac{{T_1}^2}{{T_2}^2}\right) g_1$$

Thus only the swing time at two station are to be noted. So it is necessary to establish at different places the gravity base station for comparision and to connect all other points to the same base

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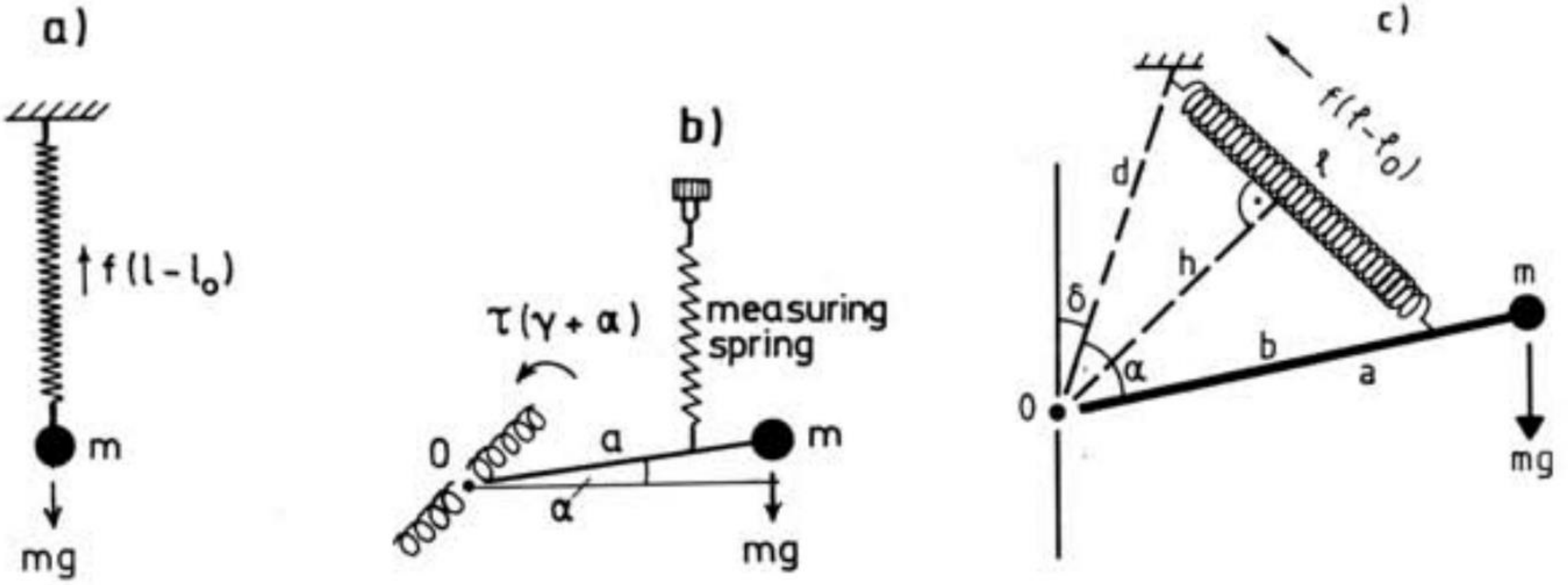
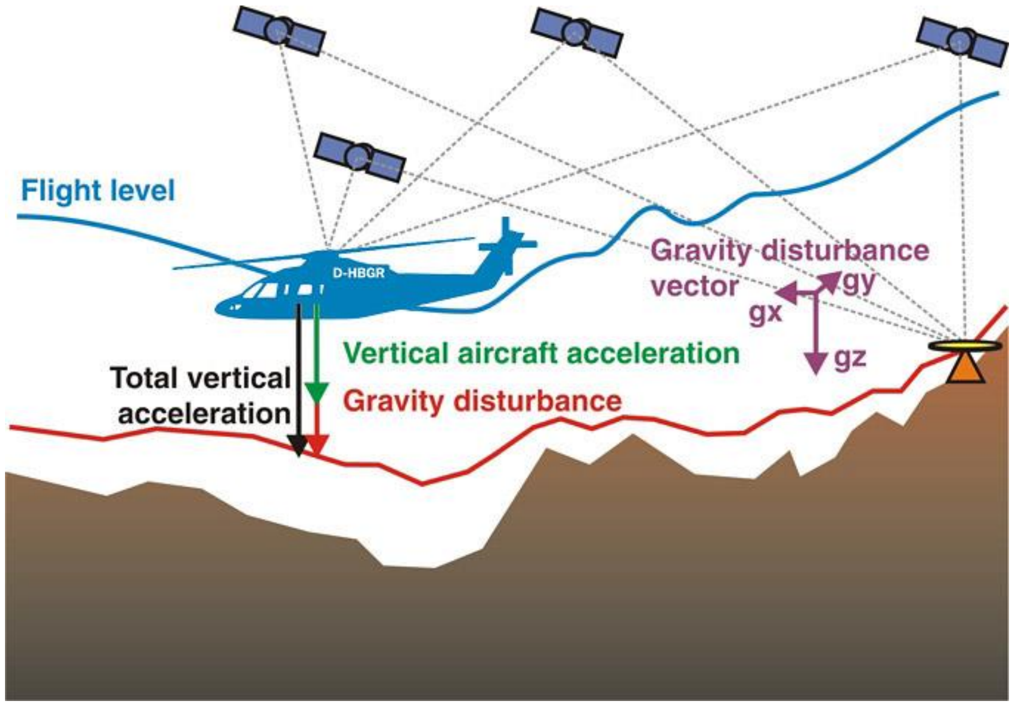


Fig. 4.13. Spring balance gravimeter principle a) vertical spring balance b) lever torsion spring balance c) general lever spring balance

Cont…

B. Airborne gravimetry for relative gravity measurement

- The aircraft is connected to a surface of a known point of known gravity
- This method is employed to determine the gravity using an integrated airborne gravity Remote sensing system which consist of an aircraft as carrier ,airborne gravimeter, GPS, altimeter, INS etc.



- It can operate in area where terrestrial gravity measurement is hard to conduct (such as desert, snow covered area, marshland)

Cont…

- It can acquire information on gravity field at a fast pace, with high precision.
- It was first conducted in 1958, where precision was obtained was low i.e +/- 10 mgal.
- But with the advent of GPS and DGPS the precision of a few milligals was obtained

Cont…

- There are mainly 2 category in the airborne gravimetry namely::
  i. Scalar gravimetry
  ii. Vector gravimetry
- Scalar gravimetry can only determines the acceleration due to gravity whereas vector gravimetry can measure both magnitude- gravity anomaly and direction- deflection of vertical.
- The basic principle of airborne gravimetry is to use the airborne gravimeter on the aircraft to determine the gravitational variation of the flight profile relative to the surface reference gravity point.
- Before take off, the aircraft is connected to a surface point of Known gravity

Cont…

- The basic data model for computition is

$$\Delta g_H = gb + \partial_g - Av - AE - Ah + 0.3056H - \gamma_0$$

Where,

ΔgH =gravity anomaly at a point in space at a Height

g_b = gravity value at ground gravity reference station

∂_g =gravitational variation relative to g_b observed by airborne gravimetry

A_v = vertical acceleration correction of the aircraft

A_E = Eotvos correction

A_h = is inclination correction to the horizontal acceleration

γ_0 = normal gravity value (on reference ellipsoid)

$0.3056H = free\ air\ correction$

Cont…

- Here the vertical disturbing acceleration (correction) of aircraft (A_V) is mainly due to vertical motion of the aircraft. It can be somehow reduced by using high damping (*system that has the effect of reducing or preventing its oscillation*) of the gravimeters sensing element
- We know that

  Resultant gravity = Gravitational force + Centrifugal force

But when measuring gravity on a moving platform, the centrifugal force will change due to resultant force of carrier's velocity and rotation velocity of the Earth and this result in Eotvos correction (A_E)

- Its computational formula is

$$A_E = (1 + \frac{H}{R})(2\omega V sinAcos\varphi' + \frac{V^2}{R})$$

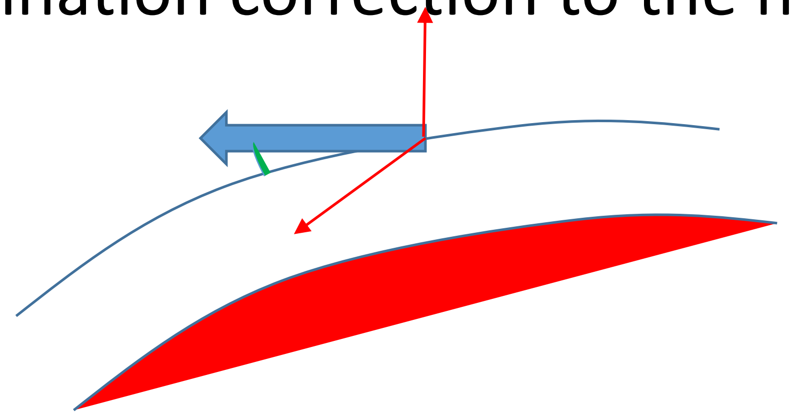
Where,

H = flight altitude
R = average radius of Earth
V = velocity of a carrier
A = azimuth of the motion
ω = angular velocity of earth rotation
φ' = geocentric latitude at measuring point

Cont…

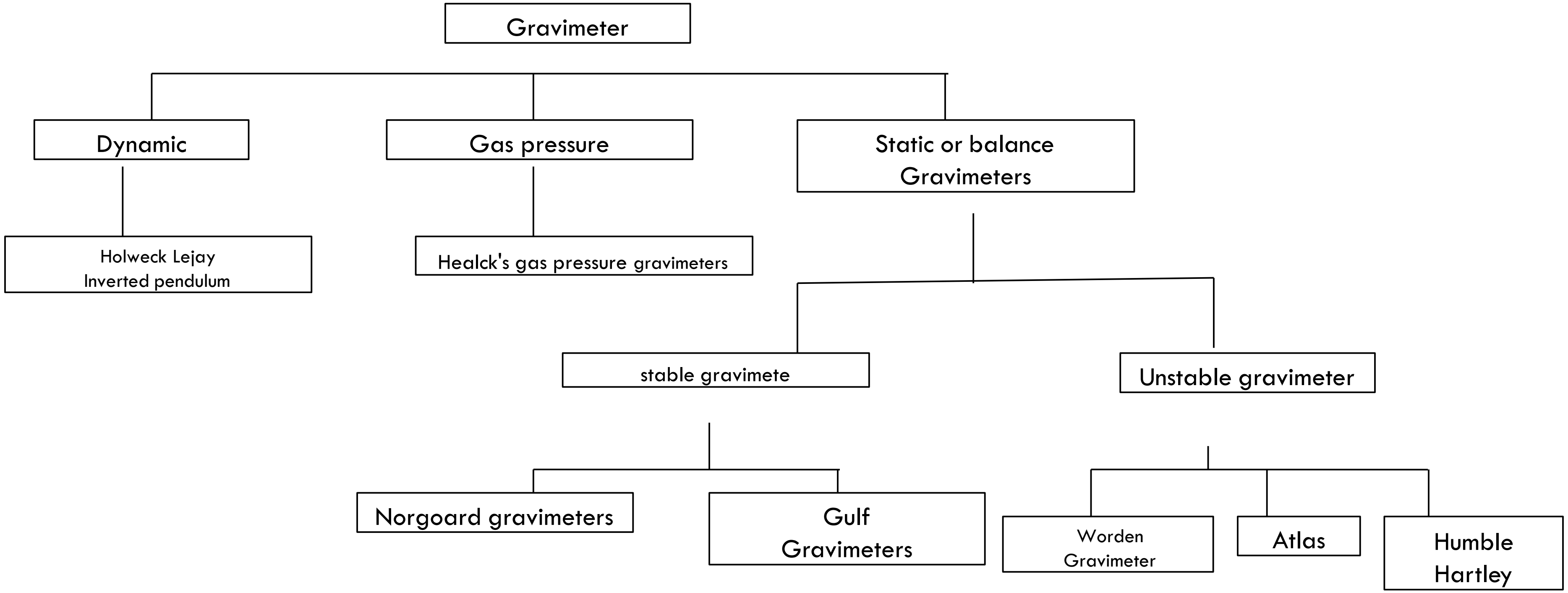
- And when determining gravity, gravimeters and level surface should be strictly parallel to each other.
- If the platform of gravimeter is not parallel to level surface it will not only affect gravitational acceleration but also exert influence on the vertical component of horizontal acceleration. This effect is called inclination correction to the horizontal acceleration.
- Let ‘g’ be actual gravity and ‘g_l’ be value measured by gravimeter, Ө be the inclination between the platform surface and the level surface. ‘A_E’ denotes Etovos correction, the inclination correction to the horizontal acceleration AH can be given as:

$$A_H = gl(cos\theta - 1) + AEsin\theta$$



Gravimeter

- Gravimeters are generally classified as dynamic, gas pressure and static gravimeters depending upon the mode of construction and principle of working



Characteristics of a good Gravimeter

- It is sensitive to a fraction of a milli gal and it will give relative values of "g" correct to 0.1 miligal provided it is returned to a local base at frequent intervals
- It is mostly handy and portable.
- Readings can be made in perhaps a few minutes

Airborne Gravimetry

Fig : Gravimeter

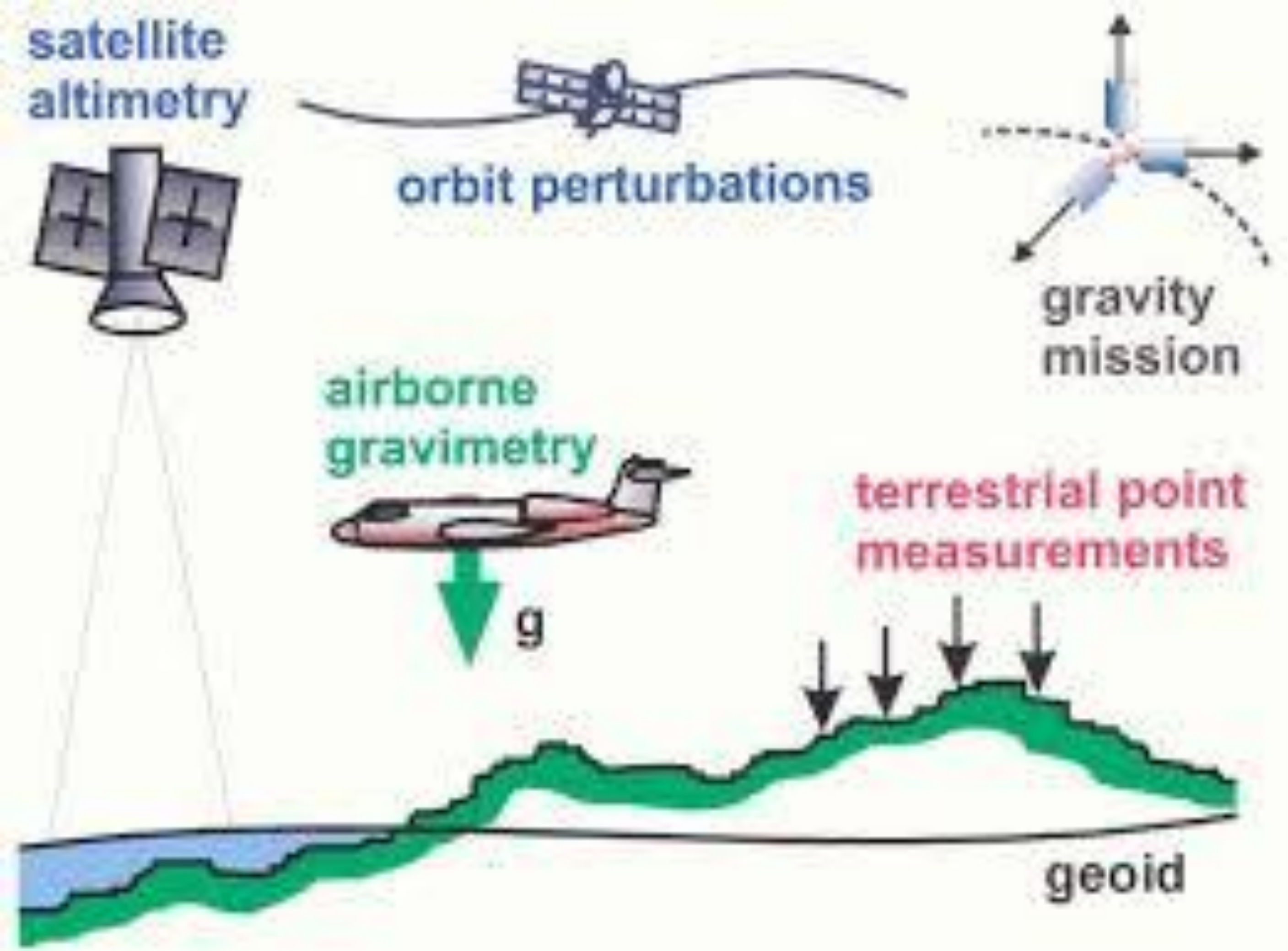


Fig : Airborne Gravimetry