Weighing the Right Way

Guide

Improved Weighing

Better Technique

Precise Results

Proper Weighing

with Laboratory Balances

METTLER TOLEDO

Proper Weighing with Laboratory Balances

1. Introduction

Weighing is one of the most common, critical and time consuming tasks in the laboratory. Balances have developed to the point that, in general, no special weighing room is necessary, except maybe for ultra-micro balances.

Technological advances in electronics have considerably simplified the operation of balances, reducing weighing times. Moreover the touchscreen digital display makes operation of the balance intuitive.

However, this apparent ease of use can lead to insufficient care being taken to avoid the effects of external influences acting on the weighing, leading to inaccurate results. External influences are defined as physical effects which are measurable for all laboratory balances. Examples of external influences include:

- Electrostatic forces
- Airflow
- Environmental vibrations
- Magnetism effects
- Evaporation
- Moisture uptake

Certain sample characteristics could also be mistaken for external influences – such as evaporation of liquids, or hygroscopic/hydrophobic solid materials gaining or losing weight.

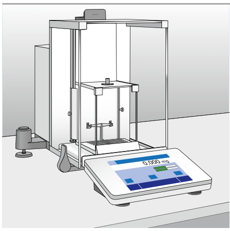
The purpose of this guide is to explain the most important points to be noted when working with laboratory balances.

This guide starts by offering suggestions for the optimum location of a balance. It then explains proper operation of this sensitive instrument, before analyzing possible external influences and their effects. Most of these influences are recognizable by a slow change in the weight display (drift).

Since correct interpretation of the technical data is also of immense importance in the assessment of a weighing result, the most common technical terms are explained at the end.

2. Optimum Location

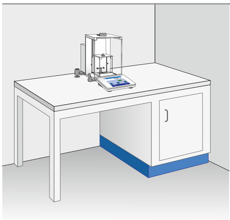
The precision and reproducibility of weighing results are closely linked to the location of the balance. To ensure that your balance works under the optimum conditions, observe the following guidelines:



The weighing bench should be

- Stable (lab bench, lab table, stone bench)
  The weighing bench should not sag when weighing and should transfer as few vibrations as possible
- Antimagnetic (no steel plate built inside or on top of the bench)
- Protected against electrostatic charges
- Wall or floor installation:
  The weighing bench should be fixed either to the floor or to the wall, not both. Mounting the bench on both places at once transfers vibrations from wall and floor
- Reserved for the balance(s) only

The place of installation and the weighing bench must be stable enough that the balance display does not change when someone leans on the table or steps up to the weighing station. Do not use soft pads underneath the balance, such as writing mats.
It is better to position the balance directly over the legs of the bench, since this area is subject to the least vibration.

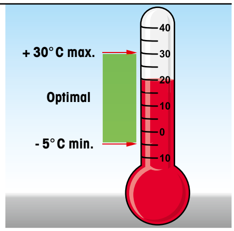


The lab or weighing room should be

- Vibration-free
- Free from drafts
- Under constant temperature

Place the weighing bench in a corner of the room. These are usually the vibration-free areas of a building. Ideally, the room should be accessed through a sliding door to reduce the influence of door movements.

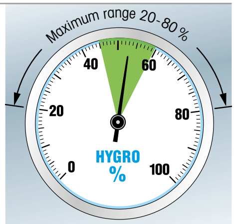
Temperature



- Keep the temperature of the room as constant as possible. Weighing results are strongly influenced by rapid changes of temperature
- Do not weigh near radiators or windows

TIP: METTLER TOLEDO balances with "FACT" (fully automatic calibration technology) can compensate for temperature drift. For this reason, "FACT" should always be switched on.

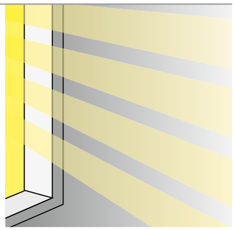
Atmospheric humidity



Ideally the relative humidity (% RH) should be between 45 % and 60 %. Balances should never be operated above or below the measuring range of 20 % to 80 % RH.

Constant monitoring is advisable with micro balances. Changes should be corrected whenever possible.

Light



- If possible, place the balance near a window-free wall. Direct sunlight (radiant heat) will influence the weighing result
- Place the balance a significant distance from lighting fixtures to avoid heat radiation. This especially applies to light bulbs. Use fluorescent tubes (if possible)

3. Proper Operation of the Balance

Laboratory balances are measuring instruments of the highest precision. The following tips will help you to obtain reliable weighing results:

Standby/Switch on

- Do not disconnect the balance from the power supply and always leave it in standby mode. This allows the balance to maintain thermal equilibrium
- When you switch the balance off, use the display key. The balance is now in standby mode. The electronics are still working and no warm-up period is necessary

TIP: We recommend a different acclimatization time for each balance when it is first connected to the power supply. These are:

- Up to 24 hours for micro balances
- Approximately 120 min for semi-micro and analytical balances
- Approximately 30 min for precision balances

Always observe the minimum times specified in the operating instructions of your balance.

Leveling

Always check that the air bubble is in the center of the level indicator before each weighing. Use the leveling feet to make adjustments. Once leveled, always perform an internal adjustment. The exact procedure is described in the operating instructions for the balance.

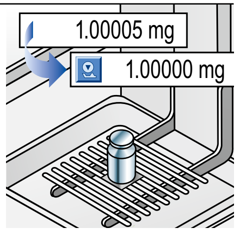
TIP: To ensure and document that the balance is correctly leveled every time, for example in order to comply with GxP[1], we recommend the XPE and XSE families of balances with the built-in "LevelControl" automatic warning function.

[1] GxP Good Laboratory Practice (GLP) or Good Manufacturing Practice (GMP)

Adjustment

Adjust the sensitivity of the balance regularly:

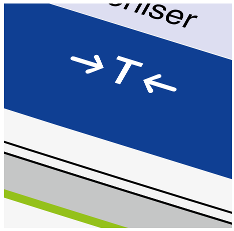
- When you operate the balance for the first time
- When you change the location of the balance
- After leveling the balance
- After changes in temperature, humidity or air pressure.



Zero/Tare

→0← When the Zero button is pressed, the user manually sets a new zero point on the balance. Here, the new zero point could be used where the weighing pan is not clean, or there is a holder for another container present, where that weight is not required. In this case the balance only records the gross weight.

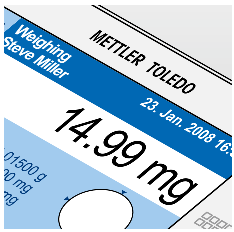
→T← The Tare button is used to manually add a tare point to the weighing process. This is useful when weighing a sample into a beaker, where the weight of the beaker is also important, or, when you need to add more than one sample to one single container. The balance records gross, tare and net weights.

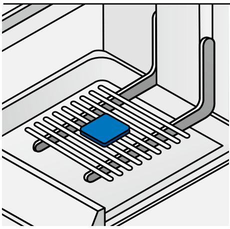


Reading the results

- Check that the balance displays exactly zero at the start of each weighing.
- Read off the result only after the small round circle in the balance display has disappeared. The weighing result is released by this stability detector

TIP: XPE and XSE balances offer an advanced stability detector. These balances display unstable measurement values in **blue**. Once stability is achieved the display immediately changes to **black** and the circle in the upper left disappears. This allows you to identify a stable weighing result faster, more safely and reliably.

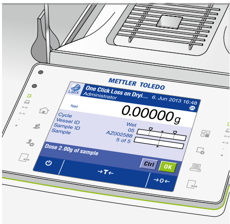




Weighing pan

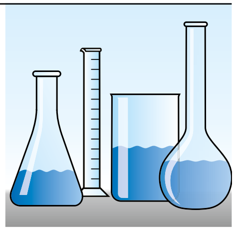
- Always place the weighing vessel in the middle of the weighing pan, shown in blue in the diagram. This will prevent corner load errors

TIP: METTLER TOLEDO provides unique weighing platforms for both analytical and precision balances, which substantially reduce the effects of drafts.



StatusLight

With XSE and XPE balances from METTLER TOLEDO, the innovative built-in StatusLight™ at the front of the balance terminal lets you see at a glance if you have the green light for weighing: balance calibration and routine tests are up to date, the balance is level, and routine tests are satisfied. Any warnings, such as routine tests due, are shown in yellow and errors are shown in red.



Weighing vessel

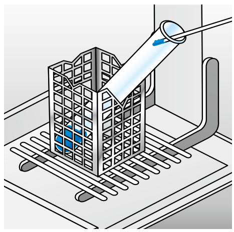
- Use the smallest possible weighing vessel
- Avoid weighing vessels made of plastic when the atmospheric humidity is below 30-40 %. These conditions increase the risk of electrostatic charges

- Materials with a high degree of electrical insulation, such as glass and plastic, can become electrostatically charged. This can drastically affect the weighing result. For this reason, make sure you take the appropriate corrective measures (see page 14: Electrostatics)

- The weighing vessel and the sample it contains should have the same temperature as the surroundings. Temperature differences can lead to air currents that distort the weighing result (see page 7: Temperature).
  After removing the weighing vessel from a drying oven or dishwasher, allow it time to acclimatize to ambient temperature, before placing it on the balance.

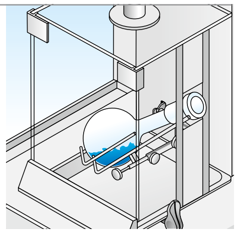
- If possible, never use your bare hands to hold the weighing vessel. This could alter the temperature and atmospheric humidity of the weighing chamber and the weighing vessel, which has an adverse effect on the measurement process.

The "ErgoClip Basket" taring container holder.



! TIP: Different weighing vessels holders (ErgoClips) offer optimal conditions for error-free and safe weighing (see illustrations).

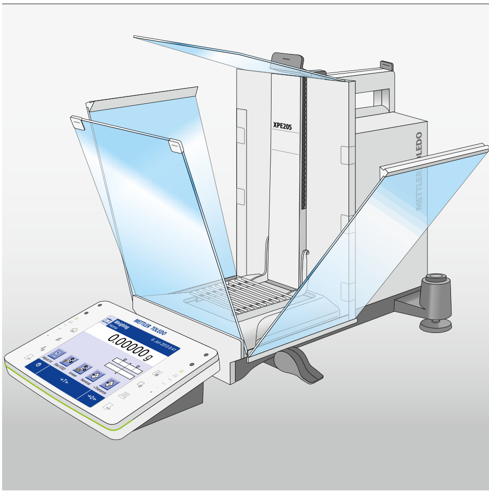
Draft shield



Use the ErgoClip Flask and Min-Weigh door for efficient standard preparation tasks

- Only open the draft shield as far as necessary. This will keep the climate in the weighing chamber constant, and the weighing result will not be influenced
- Adjust balances that have an automatic and configurable draft shield, such as the XPE and XSE balances, so that the opening of the draft shield is minimal.

TIP: To make weighing simpler and more precise, even under the most challenging conditions, we recommend specific accessories made for our XPE and XSE balances. These balances provide the best results, even when you are weighing small samples with narrow tolerances under unfavorable ambient conditions. Our special "MinWeigh Door" draft shield, " for example, is designed for use in weighing cabinets. But it also offers advantages for "normal" weighing conditions. It can improve the repeatability of the net reading by up to a factor of 2!



Cleaning

- Keep the weighing chamber and weighing pan clean at all times
- Use only clean vessels for weighing
- The balance can be cleaned using conventional window-cleaning fluid
- Use a lint-free cloth
- Before cleaning, take away all removable parts, such as the weighing pan.

TIP: With XSE and XPE analytical balances, each of the draft shield panes can be removed for cleaning in a dishwasher.

4. External Physical Influences

If the weight display does not stabilize, the result slowly drifts in one direction. This is usually due to undesired physical influences.

The most frequent causes are:
- Influences on the balance from its surroundings
- Moisture gain or loss of the weighing sample
- Electrostatically charged weighing samples or vessel
- Magnetized sample or weighing vessel
- Temperature differences between the sample, the weighing vessel, the balance and the surroundings

The next section explains these influences and what causes them in more detail, and describes possible corrective measures.

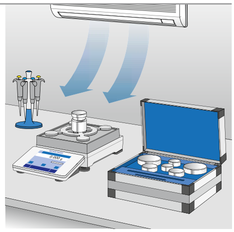
The effects of air-drafts on weighing

Problem

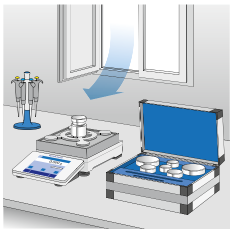
The displayed weight value drifts continuously, resulting in difficult zero/tare operations, slower settling times and poor measurement accuracy.

Possible reasons

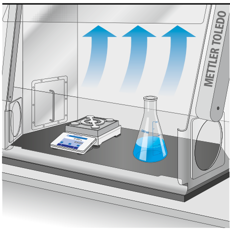
The balance is located and operated in an environment where air-drafts occur. Likely causes and circumstances:
- Balance is too close to air conditioning outlets, a ceiling fan, windows or radiators
- Balance is exposed to the air-flow coming from laboratory devices having a cooling fan
- Large temperature difference between the sample and its surroundings leading to thermal currents
- Balance is located in an open, unprotected area (e.g. production environment)
- Balance is placed inside a ventilated safety enclosure such as a fume hood, safety or biohazard cabinet



XPE6003SD5 precision balance with SmartPan™ exposed to air currents caused by air conditioning unit



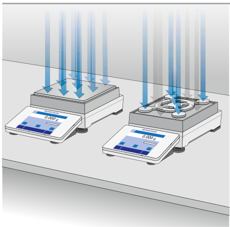
XPE6003SD5 precision balance near open window



XPE6003SD5 precision balance
in a safety cabinet

Example

To avoid exposing the user to toxic fumes, vapors, dust and aerosols, laboratory fume hoods are frequently used to handle and weigh samples.
Ventilated through a turbulent air-flow with air speeds between 0.3 m/s to 0.5 m/s, fume-hoods represent one of the harshest environments in which to operate a balance.



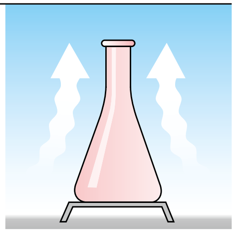
Forces caused by air currents on standard pan versus SmartPan™. The SmartPan™ displays less air resistance

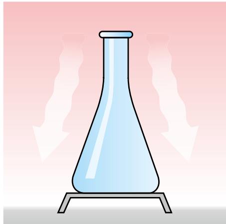
Corrective measures

- When possible, place your balance at a sufficient distance from air-flow sources
- To protect the weighing pan from exposure to air currents, draft shields with manually or automatically-operated doors can be used
- To minimize the disturbance of air-drafts, certain Mettler-Toledo balances use weighing pans suitable for use under harsh conditions, such as the SmartGrid (Analytical) and the SmartPan (Precision)

The SmartPan for precision balances is specifically optimized for minimal flow resistance, allowing weighings to be performed under harsh conditions even without the use of a draft shields.
Compared to a traditional weighing pan, the SmartPan shows a more than 50% improvement in speed of settling time and repeatability.

The effect of changing temperature on weighing





Problem

The balance display drifts in one direction.

Possible reasons

The balance has not been connected to the power supply for long enough.

There is a temperature difference between the weighing sample and its surroundings which leads to air currents along the weighing vessel. The air flowing along the side of the vessel generates a force in an upward or downward direction that falsifies the weighing result. This effect is called dynamic buoyancy. The effect does not die away until a temperature equilibrium is reached. A cold object appears heavier and a warm object lighter.

Experiment

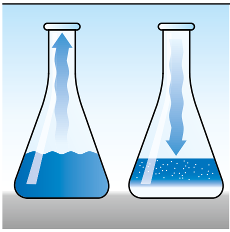
You can test the dynamic buoyancy with the following experiment: Weigh a conical or similar flask and record the weight. Hold the flask in your hand for about one minute and repeat the weighing. Because of its higher temperature, the flask appears lighter on the balance.

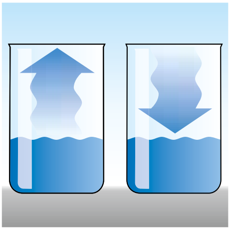
Note

The perspiration from your hand plays no role in this effect. Otherwise the sample would become heavier.

Corrective measures

- Never weigh samples taken directly from a drying oven or refrigerator
- Acclimatize the sample to the temperature of the lab and weighing chamber
- Hold weighing vessels with tweezers (not bare hands)
- Try to avoid putting your hand in the weighing chamber
- Use a weighing vessel with a small surface area





Using a weighing vessel with a larger opening increases the risk of measuring errors through evaporation or condensation.

Hygroscopy/evaporation

Problem

The weight display of a sample drifts permanently in one direction.

Possible reasons

You are measuring the weight loss of volatile substances (e.g. the evaporation of water) or weight increase of hygroscopic samples (atmospheric moisture gain).

Experiment

You can reproduce this effect by weighing alcohol or silica gel without a lid.

Corrective measures

Use clean and dry weighing vessels and keep the weighing pan free from dirt and water drops. Use vessels with narrow necks and add a lid or stopper. Do not use cork or cardboard supports for flasks with a circular base. Both can absorb a considerable amount of water. The ErgoClips metal triangular holder for the XSE/XPE balances is designed for this.

Ergonomics

Problem

Weighing workplaces and the way balances are used can be a source of user injury and low productivity.
For example, prolonged and repetitive weighing tasks may be performed by the user in unfavorable working postures, with mechanical overload and high visual demands.
Common injuries in laboratories are work-related musculoskeletal pains affecting the upper limbs and the neck, and eye problems.

Corrective Measures

To prevent user injury and improve productivity, the workplace and the equipment used must be configured according to some basic ergonomic rules.

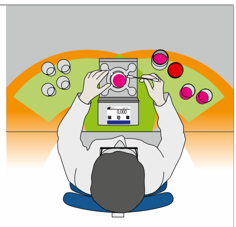
Seated working position

Is a weighing table available for high-precision tasks?
Are arms supported by the work surface, chair armrests, or pads for prolonged weighing tasks?

Tips for optimization

- Evaluate weighing tables with special arm rests

Reach at the seated workplace



Can you reach your material without streching or unduly twisting your body? Are work items within close reach (max. 45 cm)?

Tips for optimization

- Reposition tools and supplies within 10-45 cm distance
- Provide tool organizers, turntable workstations, storage bins, pipette holders and carousels

Standing working position

Can the balance be positioned to promote natural head, neck, shoulder and arm posture during use?

Tips for optimization

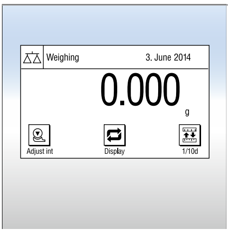
- Reposition the balance
- Use a stand for the balance display

Display viewing angle

Is the balance display placed at a viewing angle of 15-35° below horizontal eye level?

Tips for optimization

- Adjust the angle to reduce neck/eye strain
- Put the balance display on a stand



Size of the display

Can you easily read numbers on the balance display from all angles? Can the displayed numbers be temporarily enlarged if needed?

Tips for optimization

- Adjust the display angle, brightness and contrast
- Use a balance with a large-digit display
- Use computer reading glasses for prolonged weighing sessions

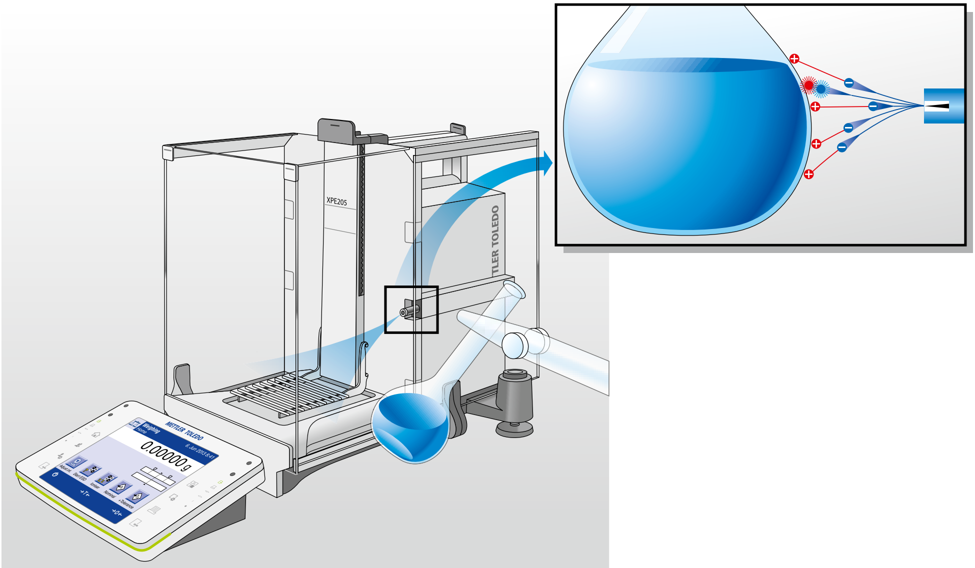
Electrostatics

Problem

Each weighing shows a different result. The weight display is unstable. The repeatability of the weighing is poor.

Possible reasons

Your weighing vessel or the sample has become electrostatically charged. Materials with low electrical conductivity such as glass, plastics, powder or granulates can not easily shed off these charges, oftentimes the charges dissipate over minutes or hours. Dry air with less than 40 % relative humidity increases the risk of this effect.
Weighing errors arise through electrostatic forces that act between the weighing sample, vessel and the surroundings.

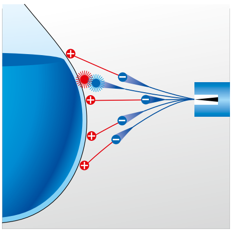


Experiment

A clean glass or plastic vessel that has been gently rubbed with a wool cloth shows this effect quite clearly, provided that the humidity is <40 %.

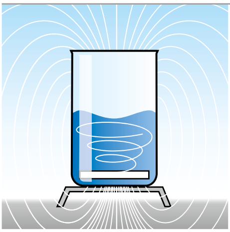
Corrective measures

- Increase the atmospheric humidity:
  Electrostatic charging is particularly a problem in winter in heated rooms. In air conditioned rooms, setting the air conditioning to increase the humidity (45-60 % relative humidity) can help
- Screen electrostatic forces (Faraday effect):
  Place the weighing vessel in a metal container
- Use different weighing vessels:
  Plastic and glass charge quickly and are therefore unsuitable. Metal is a better material
- Use an antistatic kit



TIP: The compact anti-static kit is highly effective at removing static charges on the weighing vessel.

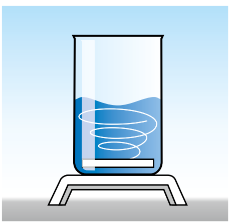
Note: The balance, and hence the weighing pan, should always be grounded. All METTLER TOLEDO balances with three-pin power plugs are automatically grounded.



Magnetism

Problem

The weight of a weighing sample depends on its position on the weighing pan. The repeatability of the result is poor, but the display remains stable.



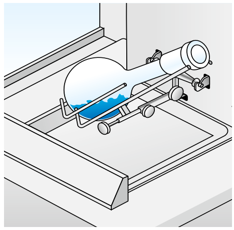
Possible reasons

A magnetized material is being weighed. Magnetic and magnetically permeable objects exert a mutual attraction/repulsion. The additional forces that arise are wrongly interpreted as a load.
Practically all objects made of iron (steel) are highly permeable to magnetic forces (ferromagnetic).

Corrective measures

If possible, eliminate the magnetic forces by placing the weighing sample in a vessel made of Mu Metal film, for example. Since the magnetic force decreases with increasing distance, the sample can be distanced further from the weighing pan by using a non-magnetic support (e.g. beaker or aluminum stand). The same effect can be achieved by means of a weighing hook underneath the balance. This "below-the-balance" setup is built in as standard with most METTLER TOLEDO laboratory balances. Wherever possible, METTLER TOLEDO uses non-magnetic materials to keep this effect to a minimum.

"ErgoClip Flask" tare container holder for the XPE and XSE balances.



TIP: To weigh average- and large-sized magnets with precision balances we recommend an "MPS Weighing Pan" (Magnetic Protection System). For analytical balances, we recommend using a triangular holder, which increases the distance between the magnets and the weighing pan. For balances in the XSE and XPE lines, we offer special "ErgoClips" for this purpose.

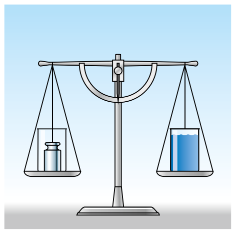
Air buoyancy

Effect

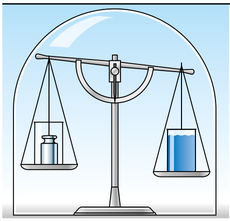
A sample weighed in air and then in a vacuum does not have the same weight.

Reason

A body experiences a loss in weight equal to the weight of the medium it displaces (the Archimedes principle). This principle provides an explanation of why ships float, a hot-air balloon rises, or why the weight of a sample is affected by atmospheric pressure.



The medium that surrounds us is air. The density of air is approximately 1.2 kg/m³ (depending on the temperature and atmospheric pressure). The buoyancy of the weighing sample (body) is thus 1.2 kg per cubic meter of its volume.



Experiment

Place a 100 g calibration weight in a beaker on a beam balance and then add water to an identical beaker on the other weighing pan until the weighing beam is in equilibrium. The two weighing samples, weighed in air, have the same weight.

Then enclose the beam balance with a bell jar and generate a vacuum in it. The weighing beam will tilt to the side with the water, since the water displaces more air owing to the larger volume. Therefore it experiences greater buoyancy. In a vacuum there is no buoyancy.

Reference weight	Water	
Weight in air	100 g	100 g
Density	8000 kg/m³	1000 kg/m³
Volume	12.5 cm³	100 cm³
Buoyancy	15 mg	120 mg
Weight in vacuum	100.015 g	100.120 g

Corrective measures

The sensitivity of the balance is adjusted with reference weights of density 8.0 g/cm³. When weighing samples having different densities, an air buoyancy error arises. For weighings requiring high measurement accuracy, the displayed weight should be corrected accordingly.

For weighings made over a longer time period (differential weighings, comparative weighings), check atmospheric pressure, atmospheric humidity and temperature, and calculate the air buoyancy correction as follows:

Procedure to accurately determine the mass of a weighing sample

1. Calculate air density

$$\rho_a = \frac{0.348444\,p - h(0.00252\,t - 0.020582)}{273.15 + t}$$

ρ	air density in kg/m³
P	atmospheric pressure in hPa (= mbar) (use the air pressure level at weighing station)
h	relative atmospheric humidity in %
t	temperature in °C

2. Determine the mass of the sample (correct air buoyancy)

$$m = \frac{1 - \frac{\rho_a}{\rho_c}}{1 - \frac{\rho_a}{\rho}} W$$

m	mass
a	air density in kg/m³
ρ	density of the weighing sample
c	conventional body density (8000 kg/m³)
W	weighing value (balance display)

Example

Balance display 200.000 g

Atmospheric pressure 1018 hPa

Relative atmospheric moisture 70 %

Temperature 20 °C

Density of weighing sample 2600 kg/m³

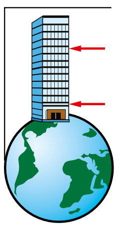
$$\rho_a = \frac{0.348444 \cdot 1018 - 70\,(0.00252 \cdot 20 - 0.020582)}{273.15 + 20} = 1.2029\ \text{kg/m}^3$$

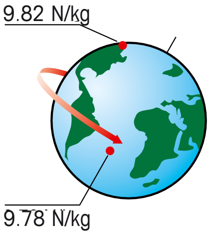
$$m = \frac{1 - \frac{1.2029\ \text{kg/m}^3}{8000\ \text{kg/m}^3}}{1 - \frac{1.2029\ \text{kg/m}^3}{2600\ \text{kg/m}^3}}\ 200\ \text{g} = 200.0625\ \text{g}$$

Gravity

Effect

Weighing results are different when the height above sea-level changes. For example, the weight display changes when the weighing is performed 10 m higher (e.g. moving from the first floor to the fourth floor of a building).





Explanation

To determine the weight of a body, the balance measures the weight force, i.e. the force of attraction (gravitational force), between the earth and the weighing sample. This force depends essentially on the latitude of the location and its height above sea level (distance from the surface of the earth).

The following holds

1. The further a weight is from the surface of the earth, the smaller the gravitational force acting on it. It decreases with the square of the distance.

$$F_G = G\frac{m_1 \cdot m_2}{d^2}$$

2. The nearer a location is to the equator, the greater the centrifugal acceleration due to the rotation of the earth. The centrifugal acceleration counteracts the force of attraction (gravitational force).

The poles are the greatest distance from the equator and closest to the earth's center. The force acting on a mass is therefore greatest at the poles.

Example

In the case of a 200 g weight that shows exactly 200.00000 g on the first floor, the following weight results on the fourth floor (10 m higher):

$$200\text{ g}\,\frac{r_{\text{Earth}}^2}{(r_{\text{Earth}} + \Delta)^2} = 200\text{ g}\,\frac{(6\,370\,000\text{ m})^2}{(6\,370\,010\text{ m})^2} = 199.99937\text{ g}$$

Corrective measures

Level and adjust the balance whenever it is moved or before using it for the first time.

! TIP: Balances with built-in "FACT" fully automatic calibration technology perform this adjustment automatically. METTLER TOLEDO balances of the XSE/XPE line come standard with "FACT".

5. Technical Weighing Terms

Readability

The readability of a balance is the smallest difference between two measured values that can be read on the display. With a digital display this is the smallest numerical increment, also called the scale interval.

Standard readabilities (or scale intervals) for various balance types

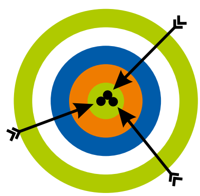
Ultra-micro balances	1d1)	=	0.1 µg	=	0.0000001 g	7-digit
Micro balances	1d	=	1 µg	=	0.000001 g	6-digit
Semi-micro balances	1d	=	0.01 mg	=	0.00001 g	5-digit
Analytical balances	1d	=	0.1 mg	=	0.0001 g	4-digit
Precision balances	1d	=	1 g to 1 mg	=	1 g to 0.001 g	0 to 3-digit

1d1) = 1 digit = one numerical increment

! TIP: "DeltaRange" and "DualRange" balances from METTLER TOLEDO feature two different levels of readability, which gives them more weighing flexibility in your laboratory.

Accuracy

Accuracy is a qualitative name for the degree to which test results match the reference value, which can be the correct or expected value, depending on the definition or agreement. Refer to [DIN[2] 55350-13].



Or in short: how close the balance display comes to the actual weight of the sample.

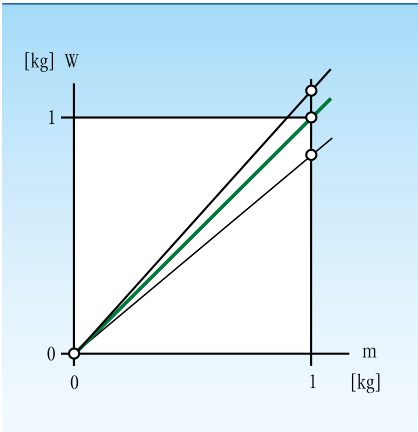
Accuracy classes of test weights

The recommendation of the weight class according to OIML[3] R111 ensures that the tolerance limits with regard to the weight classification are observed and that the material and surface quality of each weight corresponds to this international recommendation. **www.oiml.com**

[2] DIN German Institute for Standardization

[3] OIML International Organization of Legal Metrology

As part of control of inspection, measuring and test equipment, quality management standards require that balances be calibrated and adjusted at regular intervals using traceable weights. Certified weights with a corresponding accuracy class must be used for this purpose.



Sensitivity between weighing value W and load m, on a balance with a nominal range of 1 kg. The middle line shows the characteristic curve of a balance with correct sensitivity (slope). The upper characteristic curve is too steep (sensitivity too high, exaggerated for reasons of illustration), while the lower curve is not steep enough (too little sensitivity).

Sensitivity

Change in the output variable of a measuring instrument divided by the associated change in the input variable ([VIM] 5.10)[4].

For a balance, sensitivity means the change in the weighing value ΔW divided by the load variation Δm:

$$\boxed{S = \frac{\Delta W}{\Delta m}}$$

Sensitivity is one of the most important specifications of a balance.

Temperature and sensitivity

Sensitivity is temperature-dependent. The degree of dependence is determined via the reversible deviation of the measured value based on the influence of temperature change in the surroundings. It is measured by the temperature coefficient of the sensitivity (TC) and corresponds to the percentage deviation of the weight display (or sample weight) per degree Celsius. With an XPE balance, for example, the temperature coefficient of the sensitivity is 0.0001%/°C.

This means that for a temperature change of 1 degree Celsius, the sensitivity changes by 0.0001 % or (one millionth).

[4] VIM International Vocabulary of Basic and General Terms in Metrology

The temperature coefficient is calculated as follows:

$$TC = \frac{\Delta S}{\Delta T} = \frac{\frac{\Delta R}{m}}{\Delta T} = \frac{\Delta R}{m\,\Delta T}$$

In this equation, ΔS is the change in sensitivity and ΔT the temperature change. The sensitivity change ΔS is equal to the result change ΔR divided by the weighing load m, or after taring by the sample weight. With this information the deviation of the measuring result at a specified temperature change can be calculated by rearranging the above equation.

For the display value we can then obtain:

$$\Delta R = (TC\ \Delta T)\ m$$

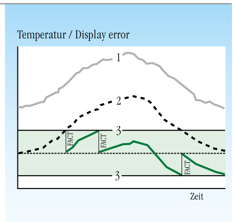
If you weigh a load (sample weight) of 100 g on an XPE/XSE analytical balance, and the ambient temperature in the laboratory has changed by 5 °C since the last adjustment, this can lead to the following maximum result change ΔR (with the temperature coefficient of the XPE of 0.0001 %/°C):

$$\Delta R = (TC\ \Delta T)\ m = (0.0001\ \%/°C \cdot 5\ °C)\ 100\ g = 0.5\ mg$$

If, on the other hand, the load is only 100 mg, in other words 1000 times less, the maximum deviation would also be correspondingly less and amount to only 0.5 µg.

FACT

This abbreviation stands for "Fully Automatic Calibration Technology" There is automatic adjustment of the sensitivity, depending on the type and linearity of a balance. This adjustment is triggered whenever a predetermined temperature change is exceeded.

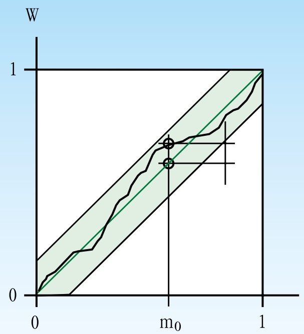


During the production process for a balance, internal weights are traceably connected to international measuring standards by means of "primary calibration." In this process, the mass of the internal weight is determined by placing a certified weight on the balance and storing the value in the balance.

proFACT

This abbreviation stands for "Professional Fully Automatic Calibration Technology". It takes automatic adjustment of sensitivity to a further level.

TIP: XSE and XPE, analytical balances have two internal weights. This means that, during adjustment, the balance tests not only the sensitivity but also the non-linearity (see below).



Linearity (Non-linearity)

Expresses how well the balance is capable of following the linear relation between the load m and the displayed value W (sensitivity). Here, the characteristic weighing curve is imagined as a straight line between zero and maximum load (see: Sensitivity).

The non-linearity defines the width of the band within which a positive or negative deviation of the measured value from the ideal characteristic curve can occur.

For the METTLER TOLEDO Excellence Plus Analytical Balance XPE205, for example, the deviation from the linear course of the characteristic curve is maximum ±0.15 mg over the entire weighing range of 200 g.

Repeatability

Repeatability is a measure of the ability of a balance to show the same result in repetitive weighings with one and the same load under the same measurement conditions ([OIML[5] R 76 1] T.4.3).

The series of measurements must be carried out by the same operator, using the same weighing method, in the same location on the same pan support, in the same installation location, under constant ambient conditions, and without interruption.

The standard deviation of the measurement series is the proper means for expressing the value of the repeatability.

[5] International Organization of Legal Metrology

Particularly with high resolution balances, the magnitude of the repeatability is a property that depends not only on the balance. Repeatability is also affected by the ambient conditions (drafts, temperature fluctuations, vibrations), by the weighing sample, and in part by the skill of the person performing the weighing.

The following example shows a typical series of measurements performed on a semi-micro balance with a readability of 0.01 mg.

x_1 = 27.51467 g	x_6 = 27.51467 g
x_2 = 27.51466 g	x_7 = 27.51467 g
x_3 = 27.51468 g	x_8 = 27.51466 g
x_4 = 27.51466 g	x_9 = 27.51468 g
x_5 = 27.51465 g	x_{10} = 27.51467 g

Let us now determine the mean value and the repeatability of this series of measurements.

Mean value:

$$\boxed{\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i}$$

x_i = i-th result of the series
n = number of measurements (weighings), usually 10
The mean value is x = 27.514667 g.

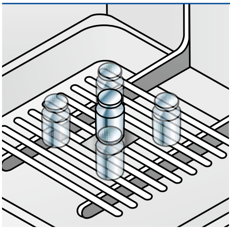
$$\boxed{s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$

The standard deviation "s" is used as a measure of the repeatability "t". Consequently, the repeatability of the measurement series is s = 0.0095 mg. The uncertainty in the measurement result is around two to three times the repeatability 2s ≤ u ≤ 3s i.e. the true result x lies within the interval x - u < x < x + u

In our series of measurements u ≈ 2 s ≈ 2 x 0.01 mg = 0.02 mg, so that we can specify the weighing result by x ± u = 27.51467 g ± 0.02 mg
The very lowest measured value to be expected for this load with the balance used in the above series of measurements is thus 27.51465 g and the largest is 27.51469 g, which agrees with the series of measurements.

Traceability

The property of a measurement result, via an unbroken chain of comparative measurements with stated measurement uncertainties, relative to nationally or internationally applicable standards ([VIM][6] 6.10). The normal weight pieces used for mass measurements are traced to the superordinate standards.



The official designation for corner load is: "off-center loading error"

Corner load

Deviation of the measurement value through off-center (eccentric) loading. The corner load increases with the weight of the load and its removal from the center of the pan support.

If the display remains consistent even when the same load is placed on different parts of the weighing pan, the balance does not have corner-load deviation. For this reason, with high-precision balances, it is important to make sure the weighing sample is always placed exactly in the middle.

Reproducibility

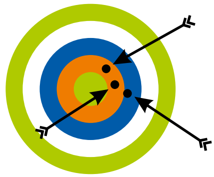
Similarity between the measurement values of the same measured variable, even though the individual measurements are carried out under different conditions (which are specified) with regard to:

- the measuring process
- the user
- the measuring device
- the measuring location
- the conditions of use
- the time

[6] VIM International Vocabulary of Basic and General Terms in Metrology

Precision

Qualitative term for repeatability of measurements



The closeness of agreement between independent measurement values obtained under stipulated conditions ([ISO[7] 5725] 3.12).
Precision depends only on the distribution of random errors and does not relate to the true value of the measurement variable (accuracy).

Remarks

Precision can be evaluated only when there are several measurement values.

Measurement uncertainty

A parameter associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably attributed to the measurement variable ([VIM][8] 3.9).

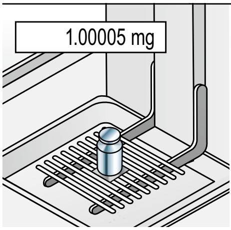
Measurement uncertainty is generally expressed by the standard uncertainty u or the expanded measurement uncertainty U (confidence interval). GUM[9] contains instructions on determining measurement uncertainty. According to GUM, measurement uncertainty is obtained by totaling the quadratic errors when these are not mutually influential.

Note

Various methods exist to determine measurement uncertainty. In the pharmaceutical industry the USP standard is normally used. ISO standards are an alternative method. The latter corresponds to the GUM method.

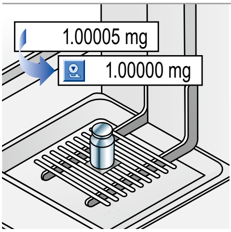
! TIP: In most countries, METTLER TOLEDO Service offers uncertainty measurement on-site, at the customer's request.

7 ISO International Standards Organization
8 VIM International Vocabulary of Basic and General Terms in Metrology
9 GUM Guide of Uncertainty of Measurement



Calibration

Determining the deviation between the measurement value and the true value of the measurement variable under specified measuring conditions.



Adjustment

Correcting the deviation between the measurement value and the true value.

6. GWP® - The Weighing Standard

GWP®
Good Weighing Practice™

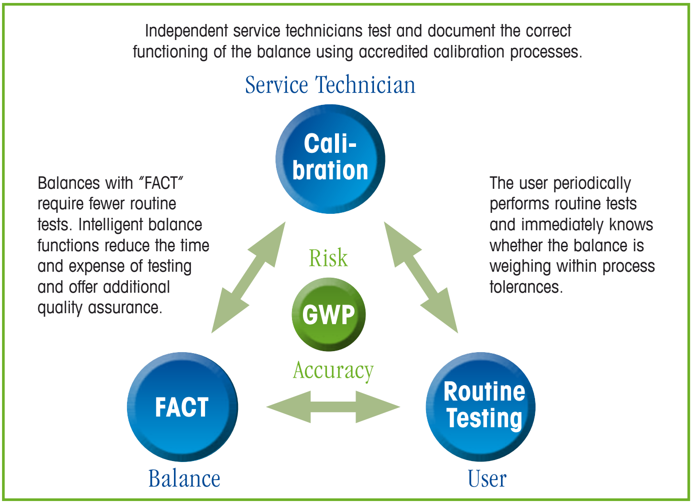
Developed with expertise from METTLER TOLEDO, GWP® is the only global, science-based standard for efficient lifecycle management of weighing systems. All GWP® based services and products ensure straightforward relevance to your needs, from the selection of the right weighing instrument to its appropriate verification procedures.

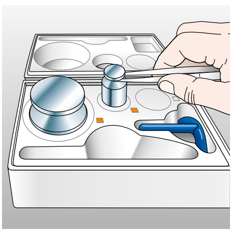
Designed according to Swiss precision and quality requirements, and developed to work globally in all markets, GWP® guarantees the safety and quality of your products. The requirements of all current weighing quality standards are addressed, and METTLER TOLEDO will help you put them into efficient weighing practice. With GWP®, you will get consistent weighing accuracy, audit readiness and cost efficiency.

GWP® Performance Verification answers the following questions

- What are best practices in weighing?
- How should my balance be tested?
- How often should routine tests and calibrations be performed?
- How can I minimize the testing time and reduce costs?

Regular maintenance and calibration of your laboratory balance by an authorized service technician is recommended in order to ensure that your weighing results remain consistently accurate. Preventative maintenance will also extend the life of your balance.
In the intervals between maintenance services, GWP® recommends routine tests using calibrated external weights.





With "CarePac" weight sets, you are always on the safe side.

TIP: It is important to use suitable test weights for these routine tests. With "CarePac" weight sets, METTLER TOLEDO offers the user worry-free testing. Tailored to the GWP® guideline, these weight sets contain the correct weights, testing tolerances, weighing tweezers, gloves and testing instructions.

▸ **www.mt.com/carepacs**

You can find more detailed information on Good Weighing Practice™ at

▸ **www.mt.com/GWP**.

7. Index of Keywords

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Benefit From Our Weighing Expertise

With decades of experience in laboratory weighing, METTLER TOLEDO can offer you a wide range of online learning resources. Take advantage of our expertise to enhance your weighing know-how and make the most of your balance. Check out the documentation on our internet pages for a range of relevant materials.

Videos

In an easy learning format, our videos demonstrate the use of our balances and inform you about our weighing solutions. For example:

- Antistatic Solutions
- Easy Cleaning
- ErgoClips

www.youtube.com/mtlaboratory

White Papers

Our scientific white papers contain a wealth of information on a range of different topics such as:

- GWP – Science Based Weighing
- Balance Safety Features
- Antistatic Technology
- Data Integrity

www.mt.com/balances

On-demand Webinars/E-Learning

Learn directly from our weighing experts and guest speakers. It's easy to register.

For starters, we recommend:

- Minimizing Out-of-Specification Errors
- Good Weighing Practice

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