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Reliable Weighing Results

Proper Handling of Laboratory Balances and Correct Handling of Samples

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Abstract

Weighing is a critical process in many laboratories that is influenced by physical effects and ambient conditions at the installation site. Some sample properties, such as the evaporation of liquids or static electricity of the sample, can also affect the weighing result. In order to perform high-precision weighing and avoid misinterpretation of weighing results, it is useful and necessary to know about possible disturbance variables and controlling them.

This white paper presents the most important influencing factors on the weighing result and describes options for minimizing disturbance variables. It also provides recommendations for the ideal location and correct operation of laboratory balances.

Proper Handling of Laboratory Balances and Correct Handling of Samples

Today, balances are used in many processes and tasks in laboratories. Weighing is one of the most frequently done, critical and time-consuming activities. Measurement errors that occur during weighing can have negative effects on the entire process.

When the company was founded in 1870 and produced the world's first short-armed analytical balances, Sartorius produced laboratory balances that made it possible to weigh the smallest amounts of substance with the highest weighing accuracy. Initially, the laboratory balances had to be operated in special weighing rooms, often by specially trained employees.

Today, laboratory balances have been perfected so that even weighing of very small amounts of substances can be done quickly, easily and yet with the most reliable results. Innovative technologies, such as fully automatic levelling and adjustment features, help to optimally adjust the balances to their ambient conditions. Thanks to an innovative human interface and a modern touchscreen display, it has become largely intuitive to operate balances today.

However, weighing still remains a critical process, which is affected by physical effects and the ambient conditions at the installation site. Some sample properties, such as the evaporation of liquids or static electricity of the sample, can also affect the weighing result. That is why knowing about possible disturbance variables and how to minimise them is useful and necessary to perform high-precision weighing and avoid misinterpretations of weighing results.

The aim of this information is to show the most important influencing factors that can affect the weighing accuracy and to present basic rules for how to properly handle laboratory balances. After presenting some recommendations for the ideal location and correct operation of laboratory balances, environmental disturbances and some points will be referenced that must be taken into consideration when working with laboratory balances to be able to achieve reliable weighing results.

Balance types

Different types of laboratory balances can be distinguished between with respect to their readability or resolution. The resolution is classified by the scale interval *d*. The scale interval describes the smallest mass difference that can be shown on the balance display.

In legal metrology, a different classification of balances is used, which refers to the verification scale interval of the balance (*e*). For this purpose, see the separate white paper on the topic of "Working in legal metrology" (1).

Designation	Scale interval *d*
Precision balance	≥ 1 mg = 0.001 g
Analytical balance	0.1 mg = 0.0001 g = 10^{-4} g
Semi-microbalance	10 µg = 0.01 mg = 0.00001 g = 10^{-5} g
Microbalance	1 µg = 0.001 mg = 0.000001 g = 10^{-6} g
Ultra-microbalance	0.1 µg = 0.0001 mg = 0.0000001 g = 10^{-7} g

Table 1: Common designations for balances depending on the scale interval *d*.



Figure 1: Weighing is one of the most frequently performed and critical tasks in many laboratories.

Location of the Balances

One of the most important characteristics of a balance is the standard deviation of the repeatability measurement. It is very important in calculating the measurement uncertainty and determining the minimum weight of a balance. The result of the repeatability measurement is closely linked to the ambient conditions at the location of the balance.
In addition, unfavourable installation conditions can lead to longer measurement times and unstable weighing values. The following points should be taken into consideration when choosing the installation location and the equipment installation in order to fully utilise a laboratory balance.

The working space

- The working space should be low-vibration. Building vibrations that, for example, result from vibrations of machines, can negatively impact the weighing result.
- Air movement from windows, heat sources, air conditioning system outlets or fans on technical equipment (PC or other laboratory equipment) creates turbulence, which affects the weighing result. The installation location should therefore be as free of disruptive air movements as possible.
- Access to laboratory rooms should ideally occur using a sliding door in order to reduce air flows caused by the door movement.
- Air conditioning systems should be set to a low air flow (take protective measures if necessary).

Corresponding filter settings in the device menu can be made to adjust laboratory balances to the ambient conditions. If the filter settings are set to "unsteady" or "very unsteady" ambient conditions, however, this may result in longer measuring times and more inaccurate results. We therefore recommend making the conditions in the workspace as ideal as possible.

Tip: As part of the Sartorius Service installation, the service technician will help to find the ideal installation location in your laboratory. The balance filter settings will be optimally set to the respective ambient conditions and to suit the weighing application.

The weighing table

- Weighing tables should be placed in the corner of the room if possible, as this is the place in a building with the least amount of vibration.
- Weighing tables should be as stable as possible. A permanently installed laboratory table, laboratory cabinet or a special weighing table with a stone slab is best.
- The weighing table should be so stable that it does not bend when leaning on it and so that it does not transmit any vibrations if possible. The balance display may not change when leaning on the table.
- Weighing tables should be anti-magnetic (no steel plate) and protected against static discharge (no plastic or glass).
- Soft pads, such as writing mats, under the laboratory balance, should always be avoided.
- The weighing table should either be on the ground or attached to the wall.

Sartorius offers various weighing tables that offer the ideal installation location for laboratory balances. A special weighing table can increase the quality of measurement results, especially for semi-micro and microbalances.

Temperature

Balances can exhibit a drift (slow change of the balance indication) due to temperature changes. The temperature drift is typically 1 ppm/K to 2 ppm/K for laboratory balances. At a temperature change of 4 K (i.e. from 19 °C to 23 °C) for example, this means an apparent change in mass by 4 ppm to 8 ppm. At a mass of 100 g, this is 0.4 mg to 0.8 mg. Laboratory balances must therefore be adjusted before use in the event of temperature changes.

- The room temperature in the laboratory should be as constant as possible.
- Direct sunlight at the balance installation location (and the heat development it causes) should be avoided. Darkened windows are ideal.
- Balances should not be placed in direct proximity to heaters or windows.
- The specified application temperature range of the balances, as described in the balance technical specifications, must be observed.

Most Sartorius laboratory balances are equipped with an automatic calibration | adjustment device "IsoCAL". This detects temperature changes and, if set accordingly, automatically implements internal adjustments.

This easily and automatically compensates for the influences of temperature changes. If a balance has the automatic calibration | adjustment device "IsoCAL", this should always be switched on.

Air humidity
The relative humidity (rH) at the balance installation location should be between 40 % and 60 %. A relative air humidity of 20 % to 80 % should never be fallen short of or exceeded, as condensation can occur at very high humidity or electrostatic effects can occur at very low humidity.

It is recommended to monitor the air humidity and temperature in the laboratory continuously. Sartorius offers what are known as climate modules to easily monitor air humidity, temperature and air pressure. With some balances, these can be installed directly in the rear panel of the draught shield. The climate data can then be displayed via the balance display and printed out with weighings.

Draught
High-resolution laboratory balances always have what is known as a draught shield to protect the weighing chamber from the influence of disruptive air flows. Nevertheless, the following points should be observed:

- Laboratory balances should not be installed in the airflow of air conditioning systems or equipment with fans, such as computers or large laboratory equipment.
- Keep a sufficient distance from heaters.
- Balances should not be installed next to doors and windows.
- High-resolution balances should not be operated in highly frequented places, as moving people cause a draught.

Operating the Balance

Initial start-up

- Before using the balance, adhere to the necessary warm-up time. This is necessary so that the balance achieves a thermal equilibrium. The balance is connected to the mains voltage for this purpose after being installed. The warm-up times depend on the type of balance and model (up to 12 hours for microbalances, for semi-microbalance and analytical balances about 6 hours, precision balances about 3 hours). The warm-up time specified in the operating instructions should always be complied with.
- Laboratory balances should not be disconnected from the mains at night or on the weekends, as otherwise the warm-up time has to be adhered to again when turned back on. Laboratory balances should therefore only be switched into standby mode when not in use.
- Avoiding position changes of the balance in continued operation increases the reliability of your weighing results.

Levelling the balance
In physical terms, balances are force sensors. Changes in the tilt of the balance lead to changes in the application of the force, falsifying the weighing result. Balances must therefore always be levelled.

- The balances must be aligned according to the level by using the adjustable feet screws. The air bubble must be within the circle, ideally right in the centre.
- The correct levelling should be checked regularly.
- The balance must be readjusted after every time it is levelled.

Some Sartorius balances have a permanent real-time levelling control. This immediately detects any tilted position of the balance and warns the user. Depending on the menu setting, a tilted position may also temporarily block the data transfer to the printer and computer. Balances from the Cubis® series also have a device for automatic motorised levelling. This system enables easy, quick and simple levelling.



Figure 2: Fully automatic levelling with balances from the Cubis® series.

Weighing tray and weighing pan

Weighing trays are typically pans, test tubes, bottles, vials or flasks. They are usually made of a polymer, glass or a metal. Users should make sure that the gross weight of the weighing tray plus the gross weight of the material to be weighed does not exceed the balance's maximum capacity.

- The smallest possible weighing tray should be used for weighing. This reduces the flow forces on the weighing tray. However, sometimes it is also useful to use larger weighing trays (e.g. graduated flasks) if a sample has to be diluted after weighing, as transferring the sample after weighing may lead to errors.
- It must be ensured that the weighing tray is compatible with the sample and there is no effect on the sample material.
- Weighing trays made of plastic materials may electrostatically charge (at low air humidity, this is also possible with glass).
  Weighing trays should therefore, if possible, be made of materials that do not electrostatically charge.
- Weighing trays should be made of non-magnetic materials to avoid magnetic forces on the weighing system (see below).
- Fingerprints on the weighing tray may falsify the weighing result. Weighing trays and weighing objects should therefore not be touched with bare fingers, but always with gloves or suitable forceps.

Sartorius offers a variety of different holders for sample trays for premium balances. These offer the ideal conditions for ergonomic and efficient work and allow for trouble-free and safe weighing.



Figure 3: Suitable sample holders make it easier to work with laboratory balances.

Placing the sample to be weighed

- Hand warmth can cause temperature and humidity effects that distort the weighing result. Reaching into the weighing chamber with your hands should therefore be avoided. The sample tray and samples should therefore always be inserted into the weighing chamber with suitable forceps.
- Balances may possibly have a small measurement error when excentrically loaded. To avoid or reduce this, the weighing tray or item to be weighed should be placed as centred on the weighing pan as possible.

Draught shield

- The draught shields should only be opened as far as is necessary so that the climate in the weighing chamber remains constant and the weighing result is not affected.

Automatic draught shield doors from the Sartorius premium balances are easy to configure. They can be used to easily set the ideal opening of the draught shield.

Weighing procedure and reading the weighing result

- At the start of every weighing, ensure that the balance reads exactly zero. Pressing the tare | zero key can set the balance to zero, avoiding a zero point error.
- The draught shield must always be closed before reading the indication.
- After applying the sample | test weight, wait for the balance to stabilise. The unit symbol, such as "g" or "mg", is used as the stability symbol on Sartorius balances and releases the weighing result.
- During longer pauses between individual weighings (> 15 min.), the weighing pan should be briefly loaded and unloaded before being used again and then the balance tared | zeroed.
- Continuous processes increase the measuring accuracy!

In the device menu, the stability conditions can be adapted to the needs of the respective weighing application. As part of the Sartorius equipment installation, the Sartorius service technician can advise you accordingly.

Maintaining the balance

- Always keep the balance pan and weighing chamber clean.
- Only use clean weighing trays for weighing.
- Sample particles should be removed with a brush or mini vacuum cleaner. If necessary, remove the balance pan and shield ring to clean.
- Mop up liquids with an absorbent cloth.
- Simple window cleaner and lint-free cloths are sufficient for cleaning.



Figure 4: Sartorius laboratory balances can easily be cleaned.

Calibration and Adjustment

- Balances should be calibrated with a precisely known test weight at regular intervals to ensure compliance with pre-defined requirements. During calibration, the deviation of the balance display from the setpoint value is checked.

  Calibration = determination of the deviation

- The frequency of the calibration should be defined in the quality management system and be based on the criticality of the application. For this purpose, see the separate white paper on the topic "Test intervals and tolerances" (2).
- During calibration, the tolerances of the test weights used must be observed! For example, when using a 200 g weight of class E2, the display may deviate from the nominal value of 200 by up to 0.30 mg due to the permissible weight tolerance alone.
- The balance must be adjusted in order to minimise deviations detected during calibration.

  Adjustment = minimising the deviation

- Calibrations are in particular also necessary when the balance is put into operation for the first time, after repairs, when changing locations, after levelling and if the ambient parameters (temperature, humidity or air pressure) have changed.
- If the "isoCAL" function is enabled, the balance will automatically adjust at regular intervals and in the event of temperature changes. The automatic calibration | adjustment may be used to increase the time interval for routine checks with external calibration weights.
- In addition to the routine checks, a regular traceability of the measurement results to the national standard should be established. This may be done via an accredited calibration, which also documents the measurement uncertainty of the balance in use. For this purpose, see the separate white papers on the topics "Calibration certificates from accredited providers" (3), "Calibration guideline EURAMET cg-18 for electronic, non-automatic balances" (4), "The calibration certificate according to EURAMET cg-18" (5).
- To validate the correctness of past weighing results, it is recommended to calibrate before and after performing maintenance work on the balance.

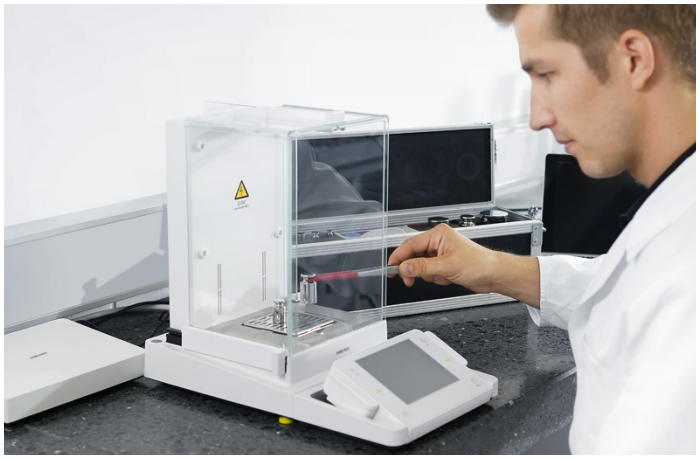


Figure 5: Balances should be calibrated at regular intervals with suitable test weights.

External or internal adjustment
In general, almost every balance can be adjusted with an external test weight ("external adjustment") – this function is only not permitted for balances for legal applications in order to prevent an intentionally incorrect adjustment and therefore manipulation.
When using external test weights, ensure that they are recalibrated regularly.

In addition to the option for external adjustment, most Sartorius laboratory balances also have an adjustment weight permanently built in the housing that can be used to easily and conveniently adjust the balances at the push of a button. Compared to external adjustment, this automatic adjustment device has clear metrological advantages, as an internally installed adjustment weight is determined very accurately at the plant and is ideally protected from changes due to use (fingerprints, scratches, wear etc.) and contamination (dust etc.).

As part of equipment maintenance by Sartorius Service, the mass of the internal adjustment weight is checked and, if necessary, redetermined. It is not recommended for the user to adjust the internal test weight.

Physical Influences

Analytical balances, especially semi-micro, micro and ultra-microbalances respond to the smallest changes. That is why they also have to display undesired physical influencing variables that are caused by the item weighed and | or the sample container.
Possible influencing variables leading to measurement errors:
- Sample container or weighed item are not acclimatised.
- The weighed item is hygroscopic or evaporating.
- The sample container or the weighed item are electrostatically charged.
- The sample container or the weighed item are magnetic.
- Effects from gravity.
- Air buoyancy | density of the weighed item.

Temperature differences
The following effects may occur:
- Poor repeatability.
- Unexpected weighing results.
- Weight indication "drifts", even though the indication is stable on an unloaded balance.

The weighing tray and samples should be acclimatised before weighing. A temperature gradient between the weighed item and environment causes air currents along the weighing tray. Air spreading along the tray generates a force directed upwards or downwards. A warm object appears lighter due to upflowing air. A cold object appears heavier due to downflowing air.

Ways to reduce this effect:
- Acclimatisation of the sample | sample container.

Moisture absorption | evaporation
The following effects may occur:
- The weight indication increases or reduces continuously. The weight indication "drifts" even though the indication is stable when the balance is unloaded.
- A loss of weight may occur when weighing liquid substances (e.g. evaporation of alcohol), but this may also occur, for example, with water or moist samples if the air humidity is very low.
- Weight increase can occur when weighing hygroscopic substances (moisture absorption from the air).

Ways to reduce this effect:
- Optimising the sample container, possibly covering it. When working with sealing caps, it should be ensured that the weighing tray, including the cap, is tared before weighing.
- Volumetric and Erlenmeyer flasks are more suitable than beakers with large openings.
- Usage of the smallest possible tray with small openings.

- The sample containers should generally be chosen to be as small as possible.
- Sample containers | samples should not be touched with bare fingers. Fingerprints are hygroscopic.
- Usage of what is known as an evaporation trap.

Electrostatics
Electrostatic discharges occur with substances or sample trays with a low electric conductivity and large surface (e.g. plastic, glass, powdery substances). Low air humidity favours electrostatic discharge.

The following effects may occur:
- The weight indication drifts in one direction.
- The indicated values cannot be reproduced.

Ways to reduce this effect:
- Increasing of the room humidity (a relative humidity of 40 % to 60 % is ideal).
- Shielding of the weighed item with a metal container or metal film.
- Usage of an ionisation fan that removes the static charging from the weighing tray or weighed item.

Some Sartorius models are available with an integrated ioniser. This is installed in the rear panel of the draught shield and can easily be activated via the balance's control panel. Electrostatic effects can be avoided by using an ioniser.



Figure 6: Balance with an ioniser installed in the rear panel.

Magnetic effects
Magnetic weighed items and magnetic sample containers (nickel, iron, steel etc.) create force fields that affect the weighing system.

The following effects may occur:
- The weighing values are stable, but cannot be reproduced.
- Different values are shown depending on the position or rotation of the weighed item on the balance tray.

Ways to reduce this effect:
- Usage of non-magnetic materials.
- Demagnetisation of weighed items and sample containers if possible.
- Magnetic forces can be shielded if the weighed item is placed on a Mu-metal film.
- Increasing of the distance between the weighed item and balance tray by placing the weighed item, for example, on an inverted beaker.

Magnetic effects occur if there is a magnetic stirring core in the sample tray. These generally do not belong on the balance.

Gravity
Balances measure gravity. This changes with altitude (approx. 1 ppm per 3 m elevation difference) and the geographic latitude (approx. 92 ppm/° whereby 1 ° corresponds to approx. 120 km in the north-south direction).
An increase of the location by about three storeys (9 m) is noticeable with an analytical balance: for example, instead of 200.0000 g, only 199.9994 g is shown, i.e. 0.6 mg less.

Ways to reduce this effect:
- Balances must always be adjusted at the installation location. This applies in particular in the case of any readjustment and when changing locations.

Air buoyancy effects
Balances always show a mass, but in physical terms actually measure a force. During an adjustment, the balance "learns" accordingly which mass m corresponds to the currently measured force F – in a slightly simplified representation by a factor c: $m = c \cdot F$. This factor is then used to convert each measured force into a mass to be indicated. So that this conversion is correct, all forces, except for the weight force of the weighed item, should be eliminated as much as possible (horizontal forces from tilted position, convection | frictional forces due to poor acclimatisation of the weighed item, magnetic and electrostatic forces etc.).

A force that cannot be eliminated, however, is the buoyancy force: The Archimedean principle states that a body experiences as much buoyancy in the surrounding medium as the volume of the surrounding medium it displaces weighs.

For weighing, this means that a weighed item, for example, has the same mass in air and in a vacuum, but does not generate the same (net) force on the balance, as the weight force in the air and vacuum counteract different buoyancy forces. Specifically, this physical effect has two important consequences for exact weighings:

1) For weighing, the surrounding medium is normally air. This has an average density of 1.2 mg/cm³.
A steel calibration weight (density 8 g/cm³) with a mass of 200 g, for example, has a volume of 25 cm³. The correspondingly displaced air volume of 25 cm³ has a mass of 30 mg with the aforementioned air density of 1.2 mg/cm³.

If the balance is now adjusted with the 200 g, the weight force (using the example from Göttingen) is 1.962310 N and the buoyancy force is 0.000294 N – which means the balance "learns" during the adjustment that a force of 1.962310 N - 0.000294 N = 1.962016 N corresponds to a mass of 200 g.

Now, for example, if a change in temperature, humidity and | or air pressure changes the air density to 1 mg/cm³, then the 25 cm³ of air displaced by the 200 g weight corresponds to a mass of 25 mg. In other words, the buoyancy force is only 0.000245 N and the balance uses the force 1.962310 N - 0.000245 N = 1.9620645 N to calculate a mass of 200.005 g. The 200 g weight therefore appears 5 mg heavier, even though its mass has not changed.

This example calculation illustrates how important it is to regularly adjust balances, especially after temperature changes, or why the internal adjustment function "IsoCAL" requires an adjustment even in the case of small temperature changes.

2) Balances are always adjusted with weights that have a density of approximately 8 g/cm³. The weighed item that has a different density, however, experiences a different buoyancy force. The balance above is named as an example here again, which was adjusted with a 200 g weight at an air density of 1.2 mg/cm³. If a weighed item with a density of 1 g/cm³ (e.g. water) and a mass also of 200 g is considered, this has a volume of 200 cm³ – the correspondingly displaced air volume then has a mass of 240 mg and the buoyancy force on the weighed item is 0.002355 N.

So, a force of 1.962310 N - 0.002355 N = 1.959955 N acts on the balance, which converts the balance to a displayed mass of 199.790 g. So, the balance shows a good 200 mg too few, even though it has been correctly adjusted.

To correct this error, the density ρ_W of the weighed item must be known – then users can use the indicated value I to calculate the true mass m_W of the weighed item according to the following formula:

$$m_W = I \cdot \frac{1 - \rho_L/\rho_M}{1 - \rho_L/\rho_W}$$

For the density ρ_L of the air and the density ρ_M of the adjustment weight, ρ_L = 0.0012 g/cm³ and ρ_M = 8 g/cm³ can typically be assumed so that the equation simplifies to:

$$m_W = I \cdot \frac{0{,}99985}{1 - \left(0{,}0012\ \text{g/cm}^3 / \rho_W\right)}$$

In the functional table "Air buoyancy correction", users can enter the indicated value I and density ρ_W of the weighed item in the table to calculate the true, buoyancy-corrected mass m_W of the weighed item on their own.

With Sartorius balances from the Cubis® series, the conversion can also be done on the balance itself. With the models MCA... from the Cubis® II-series, the optional app 306 "Air Buoyancy Correction" is available, which can be used to calculate the true mass by entering the density of the weighed item.

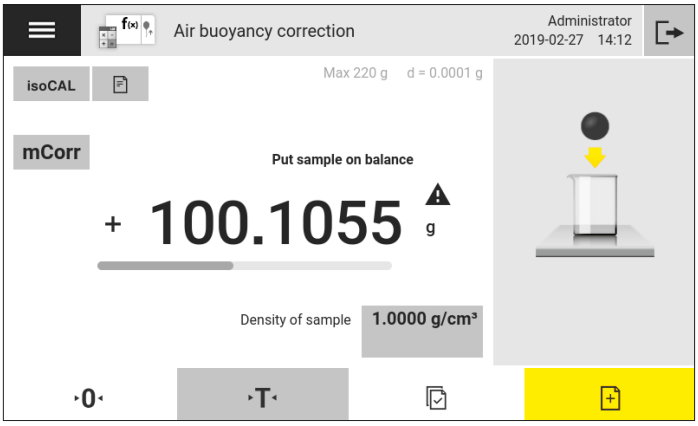


Figure 7: Calculation and representation of the air buoyancy effect.

Calculation of Air Buoyancy Correction

In the following table, the air buoyancy correction can be calculated by entering the indicated value *I*, as well as the density ρ_W of the weighed subject (in g/cm³).

If known, furthermore the air density ρa and the density ρ_M of the adjustment weight can be entered. Typically, a good approximation will be obtained with ρ_a=0.0012 g/cm³ and ρ_M=8 g/cm³ if these values are not exactly known.

Indicated Values	50.000000(	mg
Density of the weighed subject ρ_w :	1.00	g/cm³
Air density ρ_a	0.0012	g/cm³
Density of the adjustment weight ρ_M	8.00	g/cm³
Buoyancy corrected mass of the weighed subject m_w	50.0525631	mg

Table 2: Calculation of the air buoyancy correction from an indicated value I, the density ρ_w of the weighed subject, the air density ρ_a and the density ρ_M of the adjustment weight.

If the density of the goods to be weighed is not known, a value from the table below can be used to obtain a rough estimate. It is of course always better to know the true density value of the material to be weighed (e.g. from data sheets) or to determine the density oneself if possible.

Weighed Subject	Typical Density g/cm²	*Comment*
Water | aqueous solutions	1	
Ethanol	0.78	
Powder	~ 0.5 - -4	Strongly depending on the material and the bulk density
Steel	8	
Gold	19.3	
Diamond	3.5	

Table 3: Typical densities of some substances.

Literature

1. Sartorius white paper:
   Working in legal metrology (use and examination of laboratory balances in the legally regulated environment), 2020.
2. Sartorius white paper:
   (How Are Test Intervals and Tolerances Defined in a Practice-Oriented and Risk-Based Manner?), 2024.
3. Sartorius white paper:
   Calibration certificates from accredited providers (What benefits do our accreditations offer the user?), 2021.
4. Sartorius white paper:
   EURAMET cg-18 calibration guide for electronic, non-automatic weighing instruments (Specifications, options and implementation of the guide by Sartorius), 2020.
5. Sartorius white paper:
   The Sartorius calibration certificate for weighing instruments according to EURAMET cg-18 explained step by step (Explanations and notes on accredited and non-accredited calibration certificates according to EURAMET cg-18), 2022.

This white paper is part of the white paper bundle "Best Practice Guide: Lab Weighing". To be able to dynamically add updates and corrections and at the same time giving users as clear a reference as possible, for example in their QM documentation, versions are provided.

Version history

Version	Date	Changes
1.0	July 2020	First version
2.0	October 2024	Update of design and literature references, correction of example calculation on page

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