Balances and Scales

Introduction

The history of balances and scales dates back to Ancient Egypt. A simplistic equal-arm balance on a fulcrum that compared two masses was the standard. Today, scales are much more complicated and have a multitude of uses. Applications range from laboratory weighing of chemicals to weighing of packages for shipping purposes.

To fully understand how balances and scales operate there must be an understanding of the difference between mass and weight.

Mass: A constant unit of the amount of matter an object possesses. It stays the same no matter where the measurement is taken. The most common units for mass are the kilogram and gram.

Weight: The heaviness of an item. It is dependent on the gravity on the item multiplied by the mass which is constant. The weight of an object on the top of a mountain will be less than the weight of the same object at the bottom due to gravity variations. A unit of measurement for weight is the newton. A newton takes into account the mass of an object and the relative gravity and gives the total force which is weight.

Although mass and weight are two different entities, the process of determining both weight and mass is called weighing.

Balance and Scale Terms

Accuracy: The ability of a scale to provide a result that is as close as possible to the actual value. The best modern balances have an accuracy of better than one part in 100 million when one-kilogram masses are compared.

Calibration: The comparison between the output of a scale or balance against a standard value. Usually done with a standard known weight and adjusted so the instrument gives a reading in agreement.

Capacity: Heaviest load that can be measured on the instrument.

Precision: Amount of agreement between repeated measurements of the same quantity. Also known as repeatability. Note: A scale can be extremely precise but not necessarily be accurate.

Readability: Smallest division at which the scale can be read. It can vary as much as 0.1g to 0.0000001g. Readability designates the number of places after the decimal point that the scale can be read.

Tare: Act of removing a known weight of an object, usually the weighing container, to zero a scale. This means that the final reading will be of the material to be weighed and will not reflect the weight of the container. Most balances allow taring to 100% of capacity.

Types of Balances and Scales

Analytical Balance - Most often found in a laboratory or places where extreme sensitivity is needed for the weighing of items. Analytical balances measure mass. Chemical analysis is always based upon mass so the results are not based on gravity at a specific location which would affect the weight. Generally capacity for an analytical balance ranges from 1 g to a few kilograms with precision and accuracy often exceeding one part in 106 at full capacity. There are several important parts to an analytical balance. A beam arrest is a mechanical device that prevents damage to the delicate internal devices when objects are being placed or removed from the pan. The pan is the area on a balance where an object is placed to be weighed. Leveling feet are adjustable legs that allow the balance to be brought to the reference position. The reference position is determined by the spirit level, leveling bubble, or plumb bob that is an integral part of the balance. Analytical balances are so sensitive that even air currents can affect the measurement. To protect against this they must be covered by a draft shield. This is a plastic or glass enclosure with doors that allows access to the pan.

Equal Arm Balance/Trip Balance - This is the modern version of the ancient Egyptian scales. This scale incorporates two pans on opposite sides of a lever. It can be used in two different ways. The object to be weighed can be placed on one side and standard weights are added to the other pan until the pans are balanced. The sum of the standard weights equal the mass of the object. Another application for the scale is to place two items on each scale and adjust one side until both pans are leveled. This is convenient in applications such as balancing tubes or centrifugation where two objects must be of the exact same weight.

Platform Scale - A scale that uses a system of multiplying levers. It allows a heavy object to be placed on a load bearing platform. The weight is then transmitted to a beam that can be balanced by moving a counterpoise which is an element of the scale that counterbalances the weight on the platform. This form of scale is used for applications such as the weighing of drums or even the weighing of animals in a veterinary office.

Spring Balance - This balance utilizes Hooke's Law which states that the stress in the spring is proportional to the strain. Spring balances consist of a highly elastic helical spring of hard steel suspended from a fixed point. The weighing pan is attached at the lowest point of the spring. An indicator shows the weight measurement and no manual adjustment of weights is necessary. An example of this type of balance would be the scale used in a grocery store to weigh produce.

Top-Loading Balance - Another balance used primarily in a laboratory setting. They usually can measure objects weighing around 150-200 g. They offer less readability than an analytical balance but allow measurements to be made quickly thus making it a more convenient choice when exacting measurements are not needed. Top-loaders are also more economical than analytical balances. Modern top-loading balances are electric and give a digital readout in seconds.

Torsion Balance - Measurements are based on the amount of twisting of a wire or fiber. Many microbalances and ultra-microbalances, that weigh fractional gram values, are

torsion balances. A common fiber type is quartz crystal.

Triple-Beam Balance - A balance less sensitive than a top-loading balance. They are often used in a classroom situation because of ease of use, durability and cost. They are called triple-beam balances because they have three decades of weights that slide along individually calibrated scales. The three decades are usually in graduations of 100g, 10g, and 1g. These scales offer much less readability but are adequate for many weighing applications.

Use and Care of Balances and Scales

A balance has special use and care procedures just like other measuring equipment. Items to be measured should be at room temperature before weighing. A hot item will give a reading less than the actual weight due to convection currents that make the item more buoyant. And, if your balance is enclosed, warm air in the case weighs less than air of the same volume at room temperature.

Another important part of using a balance is cleaning. Scales are exposed to many chemicals that can react with the metal in the pan and corrode the surface. This will affect the accuracy of the scale.

Also, keep in mind that a potentially dangerous situation could occur if a dusting of chemicals is left on the balance pan. In many lab and classroom situations, more than one person uses a single scale for weighing. It would be impossible for each person to know what everyone else has been weighing. There is a chance that incompatible chemicals could be brought into contact if left standing or that someone could be exposed to a dangerous chemical that has not been cleaned from the balance. To avoid damaging the scale or putting others in danger, the balance should be kept extremely clean. A camel's hair brush can be used to remove any dust that can spill over during weighing.

Calibration is another care issue when it comes to scales. A scale cannot be accurate indefinitely; they must be rechecked for accuracy. There are weight sets available that allow users to calibrate the scale themselves or the scales can be sent to a professional to calibrate.

The correct weight set needs to be chosen when calibrating a scale. The classes of weight sets start from a **Class One** which provides the greatest precision then to **Class Two**, **Three**, **Four** and **F** and finally go down to a **Class M** which is for weights of average precision. Weight sets have class tolerance factors, and as a general rule, the tolerance factor should be greater than the readability of the scale.

Class 1 provides the greatest precision and is used for calibrating high precision analytical balances. Class 2 is used for calibrating high precision top-loading balances. The remaining classes utilize weights of decreasing precision. In fact, calibration weights themselves often need to be re-certified depending on the degree of accuracy required from the weighing instrument. Many government and industry specifications require proof of accuracy. The weights can change due to scratches, wear, accumulation of dirt and atmospheric corrosion, thus reducing the accuracy of the set.

Commonly Asked Questions

Q. What is readability?

A. The smallest division at which a scale can be read. There are several ways of expressing readability.

Numerical Decimal	Number of Decimal	Fractions
0.1g	1 place	1/10 gram
.01	2 places	1/100 gram
.001	3 places	1/1000 gram
.0001	4 places	1/10,000 gram (1/10 mg)
.00001	5 places	1/100,000 gram (1/100 mg)

Q. What is the difference between accuracy and precision?

A. Accuracy tells how close a scale gets to the real value. An inaccurate scale is giving a reading not close to the real value. Precision and accuracy are unrelated terms. A precise scale will give the same reading multiple times after weighing the same item. A precise scale can be inaccurate by repeatedly giving values that are far away from the actual value. For instance a scale that reads 5.2g three times in a row for the same item is very precise but if the item actually weighs 6.0g the scale is not accurate.

Q. How often do I need to calibrate my scale?

A. A scale should be calibrated at least once a year. It can be done using calibration weight sets or can be calibrated by a professional. The readability of the scale will determine which weight set will be appropriate for calibrating the scale.