VOLUME and DENSITY of MATERIALS

density = mass / volume

Definition of Mass

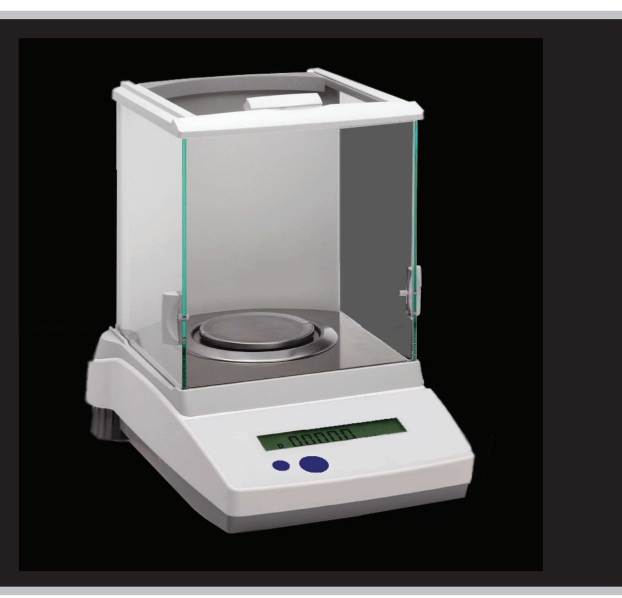
The quantity of matter in a body regardless of volume; quantified by measuring the resistance to being accelerated by an applied force. Newton's Second Law: mass = force / acceleration.

Measurement of Mass

An analytical balance determines mass by measuring the force required to prevent the body from accelerating and dividing that force by gravitational acceleration ($m = F/g$).

A beam balance determines mass directly. The force on the sample side of the pivot is $F_x = m_x g$. Balance is achieved by adjusting the known mass m_K on the opposite side of the pivot until $F_K = F_x$ or $m_K g = m_X g$. Since g is constant, the unknown mass equals the known mass.

A classical beam balance
based on a principle used since antiquity and which measures mass directly regardless of gravitational force.



A contemporary electronic analytical balance
typically designed around a force measuring device and dependent upon the local value of gravitational force.

Sources of Mass Measurement Error

To obtain the most accurate value, be aware of the following sources of error:

- Buoyancy of the sample material in the surrounding medium, typically air.
- Electrostatic charge and resulting attractive forces.
- Adsorption of contaminants from the air, especially water.
- Magnetic attraction (if the sample material is magnetic).

The error sources above are largely sample material related and will vary from sample to sample. Two sample independent influences on mass measurement follow; these are nullified by calibration. A beam balance compensates automatically for these effects.

- The gravitational acceleration at different latitudes on the earth's surface can vary by as much as 0.53% and the balance must be calibrated accordingly.
- The gravitational acceleration at different altitudes on the earth's surface can vary by as much as 0.26% from sea level to the highest elevations.

Volume and Density by Mercury Intrusion Porosimetry

Although its primary function is to determine the distribution of pore volume by pore size, a mercury porosimeter also is quite capable of determining bulk, envelope, and skeletal densities. The unique feature of this instrument is that the operator not only knows the lower pore size of the excluded voids, but can control this limit.

Micromeritics' AutoPore Mercury Intrusion Porosimeter

Micromeritics' GeoPyc Solid Displacement Envelope and Bulk Density Analyzer

Volume and Density by Displacement of a Solid Medium

By this technique, a piece or pieces of a solid sample are placed into a cylinder filled with specially treated glass microspheres that behave similar to a fluid. As the cylinder vibrates, a piston compacts the medium around the sample under a specified force. The distance the piston travels compared to the distance traveled with only the medium in the cylinder combined with the diameter of the cylinder allows envelope volume to be determined.

Definition of Volume

The quantity of space occupied by an object measured in three dimensions.

Measurement of Volume

There are numerous methods by which to determine the volume of a body and all depend on the extent to which the volume of voids within the body will be included in or excluded from the measurement. Some of those methods and techniques follow.

Calculated from Measurements of Linear Dimensions

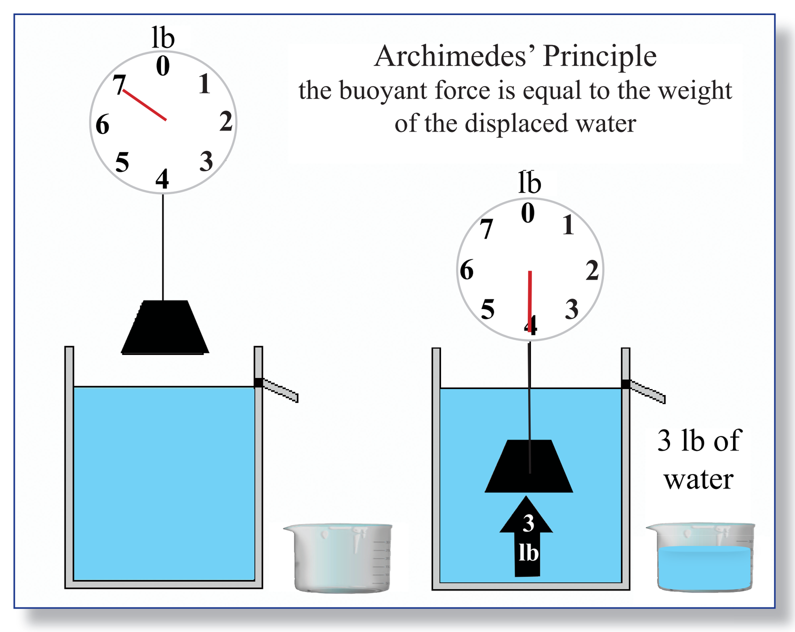
Applicable to:
- Solid bodies of regular shape

Volumes included:
- Solid material below the surface
- Surface protuberances and indentations
- All pores, cracks, and crevices originating at the surface
- All internal voids that do not communicate with the surface

Type of volume obtained:
- Geometrical volume

Sources of Measurement Error:
- Linear measurements

Archimedes' Principle



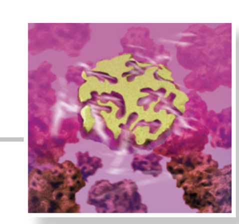
Applicable to:
- Solid bodies of regular and irregular shapes

Volumes included (depending on the liquid type and its ability to wet the solid material)**:**
- Solid material below the wetted surface
- Those surface indentations too small for the fluid to enter
- Those pores, cracks, and crevices too small for the liquid to enter
- All internal voids that do not communicate with the surface (closed voids)

Type of volume obtained:
- Apparent particle volume

Sources of measurement error:
- Initial and final measurement of liquid volume
- Unexpected liquid-solid interactions (dissolution, wetting, absorption, reaction, etc.)
- Entrainment of air that prohibits liquid to enter voids

Gas displacement



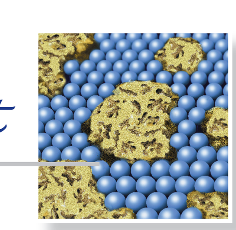
Applicable to:
- Solid bodies of regular and irregular shapes, and liquids having low vapor pressure

Volumes included (somewhat dependent upon the gas type):
- Solid material within the envelope of the gas solid interface
- Any minute pores, cracks, and crevices that are too small for the gas to enter
- All internal voids that do not communicate with the surface

Type of volume obtained:
- Skeletal volume

Sources of measurement error:
- Failure to calibrate instrument
- Outgassing of solid sample material due to inadequate preparation or excessive vapor pressure of liquid samples
- Thermal variations or failure to achieve thermal equilibrium

Solid medium displacement

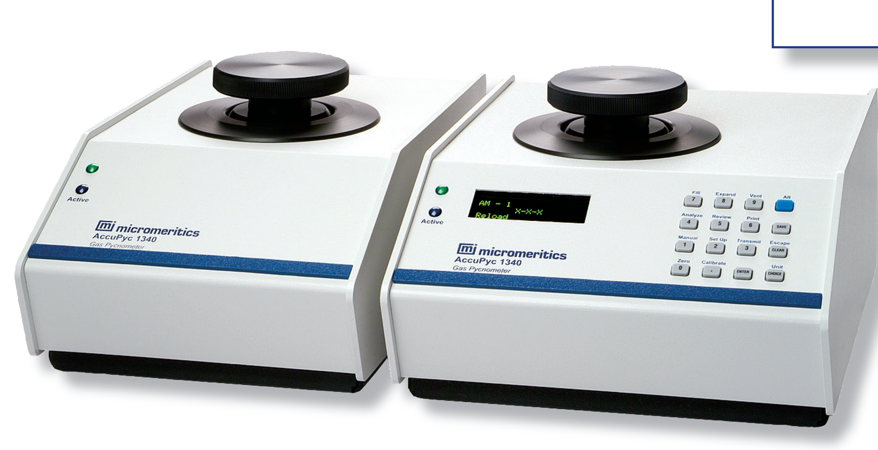


Applicable to:
- Solid bodies of regular and irregular shapes

Volumes included (dependent upon the ability of the solid medium to conform to surface features):
- Solid material within the envelope created by the interface of the solid
- Any minute pores, cracks, and crevices that are too small for the particles to enter
- All internal voids that do not communicate with the surface

Type of volume obtained:
- Envelope volume

Sources of measurement error:
- Failure to zero instrument
- Taking measurement with an applied force different from the reference force
- Not entering the correct sample chamber size



Micromeritics' AccuPyc II 1340 Pycnometer

Volume and Density by Gas Pycnometry

A gas pycnometer measures the pressure difference between an empty sample cell and the cell including sample. The increase in pressure is directly related to the volume of gas displaced. When helium is used as the analysis gas, essentially all open voids are filled, thus Helium density is often termed true density.

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