# MAGNETIC LEVITATION

**Magnetic levitation**, **maglev**, or **magnetic suspension** is a method by which an object is suspended with no support other than magnetic fields. Magnetic force is used to counteract the effects of the gravitational acceleration and any other accelerations.

The two primary issues involved in magnetic levitation are *lifting forces*: providing an upward force sufficient to counteract gravity, and *stability*: ensuring that the system does not spontaneously slide or flip into a configuration where the lift is neutralized.

Magnetic levitation is used for maglev trains, contactless melting, magnetic bearings and for product display purposes.

### Mechanical constraint (pseudo-levitation)

With a small amount of mechanical constraint for stability, achieving pseudo-levitation is a relatively straightforward process.

If two magnets are mechanically constrained along a single axis, for example, and arranged to repel each other strongly, this will act to levitate one of the magnets above the other.

Another geometry is where the magnets are attracted, but constrained from touching by a tensile member, such as a string or cable.

Another example is the Zippe-type centrifuge where a cylinder is suspended under an attractive magnet, and stabilized by a needle bearing from below.

## Servomechanisms

The Transrapid system uses servomechanisms to pull the train up from underneath the track and maintains a constant gap while travelling at high speed

The attraction from a fixed strength magnet decreases with increased distance, and increases at closer distances. This is unstable. For a stable system, the opposite is needed, variations from a stable position should push it back to the target position.

Stable magnetic levitation can be achieved by measuring the position and speed of the object being levitated, and using a feedback loop which continuously adjusts one or more electromagnets to correct the object's motion, thus forming a servomechanism.

Many systems use magnetic attraction pulling upwards against gravity for these kinds of systems as this gives some inherent lateral stability, but some use a combination of magnetic attraction and magnetic repulsion to push upwards.

Either system represents examples of ElectroMagnetic Suspension (EMS). For a very simple example, some tabletop levitation demonstrations use this principle, and the object cuts a beam of light to measure the position of the object. The electromagnet is above the object being levitated; the electromagnet is turned off whenever the object gets too close, and turned back on when it falls further away. Such a simple system is not very robust; far more effective control systems exist, but this illustrates the basic idea.

EMS magnetic levitation trains are based on this kind of levitation: The train wraps around the track, and is pulled upwards from below. The servo controls keep it safely at a constant distance from the track.

## Induced current

These schemes work due to repulsion due to Lenz's law. When a conductor is presented with a time-varying magnetic field electrical currents in the conductor are set up which create a magnetic field that causes a repulsive effect.

These kinds of systems typically show an inherent stability, although extra damping is sometimes required.