DLR

DLR_School_Lab Köln

Vacuum

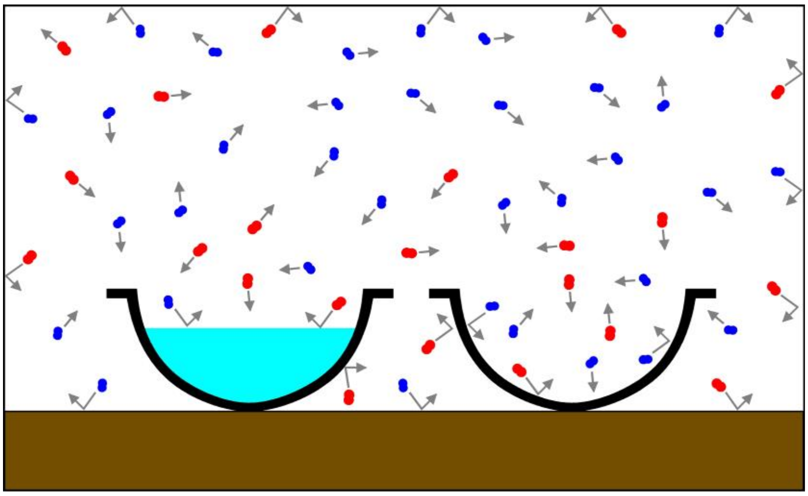
What use is nothing?

In 1654, the members of the Imperial Diet of Regensburg witnessed a spectacular demonstration: 16 horses attempt to pull a large copper sphere apart. But try as they might, they cannot pry the two halves apart. A child walks towards the sphere and suddenly the two halves part. With this experiment, Otto von Guericke, the mayor of Magdeburg, successfully demonstrated the results of his research on vacuums to the Emperor.

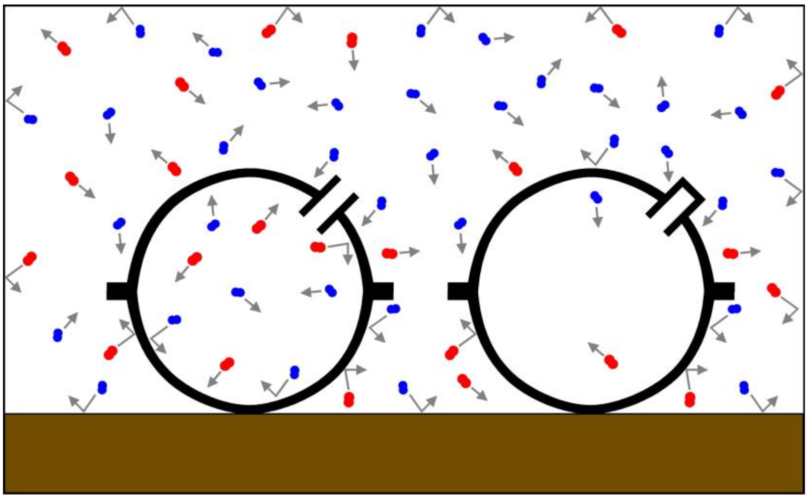
Using modern reproductions of the Magdeburg hemispheres, you can re-enact the experiment. If you use the right technique, you might be able to pull them apart…

What is a vacuum?

The Latin word "vacus" means "empty". If we drink all the water in a glass, we usually refer to it as being empty. However, in reality it isn't: Air now occupies the space in which the water was. Air is made up of many tiny gas molecules (mostly nitrogen and oxygen) that are constantly moving around. We might not be able to see them, but we can feel them on our skin, for example as wind. Usually we don't notice the air around us, as we are used to it being there.



Because air molecules move around quickly, they fill any space in which they are present. Putting the two Magdeburg hemispheres together doesn’t really change anything: molecules of air bounce off the inside and the outside of the hemispheres. This means the air pressure is the same on each side.



Pumping the air out of the hemispheres and sealing them means that only the air molecules on the outside bounce against the halves, pressing them together. This pressure is so great that it is very hard to pull the halves apart.

We use the same principle for vacuum-packed food. The air pressure surrounding the storage jar keeps it airtight. Otto von Guericke invented the air pump and was able to carry out lots of experiments in vacuums.

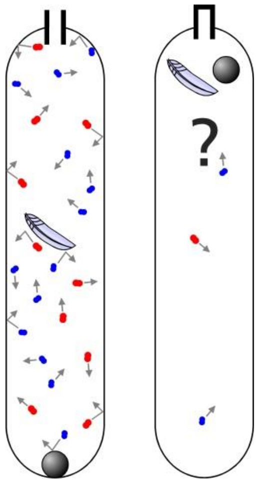
To produce a vacuum there have to be less gas molecules inside a container than on the outside.

A perfect vacuum would be a container in which there are no gas molecules whatsoever. But for technical reasons, this is impossible.

What does vacuum have to do with weightlessness?

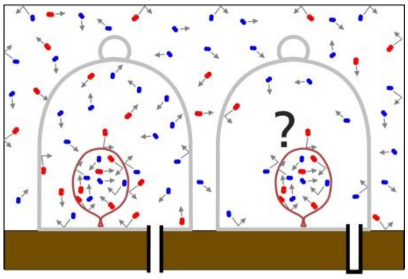
How do things fall in a vacuum? Let’s carry out an experiment: In a glass tube we have a feather and a piece of metal. The feather falls more slowly as the air molecules slow it down. What will happen in a vacuum?

And just so you know: Coffee powder would not float about in its packaging, even if there were enough room.



A balloon in a vacuum

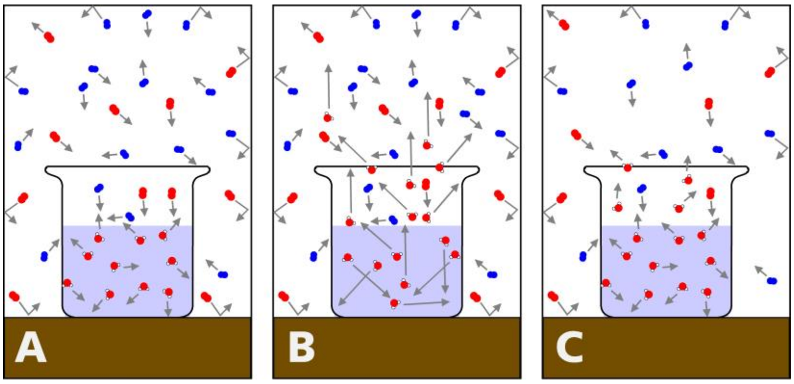
We will put an inflated balloon under a bell jar. The air molecules inside the balloon bounce against the elastic membrane, as do the air molecules surrounding the balloon. The balloon’s shape remains stable. What will happen when we evacuate the bell jar – that is, when we remove almost all the air molecules within it?



What would happen to a marshmallow in a vacuum?

Boiled eggs on the “Roof of the World

Water is also made up of molecules (H_2O) that move around quickly when they are liquid. Usually, only a very small amount of water evaporates, as air molecules “stop” water molecules from leaving the liquid. (A)



Heating up a liquid means its molecules move faster. Their kinetic energy increases. More water molecules are able to leave the liquid, as the gas molecules are unable to exert enough pressure to "stop" them. At 100°C water begins to boil. (B)

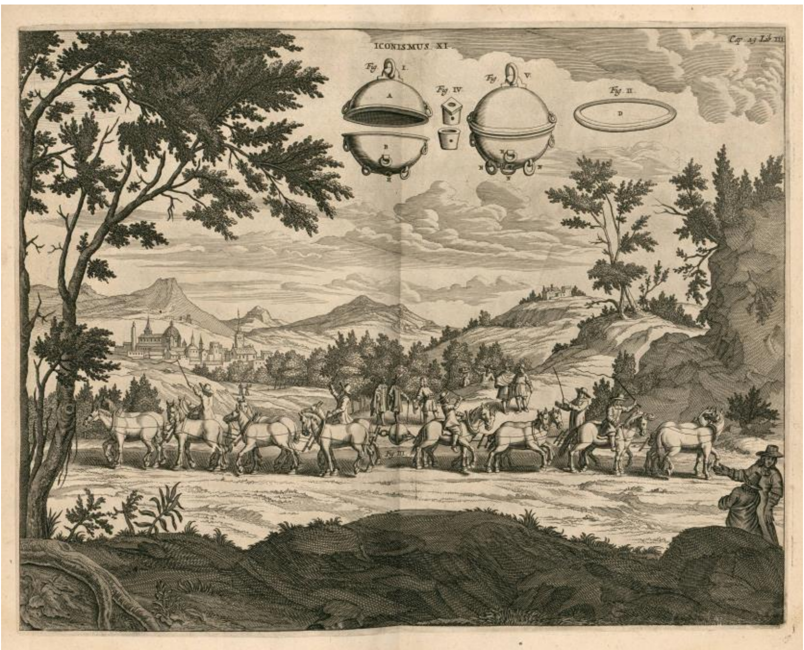
High up in the mountains, for example on Mt. Everest, air pressure decreases. As there are less air molecules to stop the water molecules from leaving the liquid, water boils below 100°C. (C)

You would have to do without a hard-boiled egg on Mt. Everest, as the boiling water is too cold!

Try this experiment under a bell jar- you might bring water to the boil at room temperature!

Noise in space?

The previous experiments have shown you that light travels through vacuums: You can still see our experiments, despite the absence of air. What about sound? Could you hear rocket engines in space? Try and find out with our electric bell under the bell jar!



Otto von Guericke's experiment before the Imperial Diet and Emperor Ferdinand III in Regensburg in 1654 (from a contemporary account)

Uses for vacuums

Vacuums are used in many inventions. See if you can identify some in your day-to-day life and explain how they work!

Here are a few examples:

About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

DLR Cologne

Aviation, space travel, transportation, energy and safety are the research areas pursued in the nine research facilities at DLR Cologne. The basis of the research and development carried out on site are the large testing facilities such as wind tunnels, turbine and materials test benches and a high-flux density solar furnace. The 55 hectare/ 136 acre site is home not only to the research and administrative facilities of the DLR, but also to the European Space Agency's (ESA) European Astronaut Centre (EAC). The DLR has around 1400 employees in Cologne.

DLR Deutsches Zentrum für Luft- und Raumfahrt

DLR_School_Lab Köln

Linder Höhe
51147 Köln

Head: Dr. Richard Bräucker
Telephone: 02203 601-3093
Telefax: 02203 601-13093
E-Mail: schoollab-koeln@dlr.de
Internet: www.DLR.de/dlrschoollab

_Vakuum 210516_GB.docx

About the experiment:

Recommended for grade(s): 4 to 9
Group size: 5 to 6
Duration: 50 minutes
Subject matter:
Physics