- Electronic apparatus and appliances

SCIENCE

WHAT IS A VACUUM?

More than just a common name for a household appliance, real vacuums help heal the human body, dominate large parts of the universe and help scientists study the unknown

WORDS SCOTT DUTFIELD

When a volume has no matter within it, it's considered a true vacuum. To create one, matter needs to be pumped out of a space, which in turn lowers its atmospheric pressure. This is something vacuum cleaners are constantly trying to achieve. For a vacuum cleaner to function, a high-speed fan spins to push air out of the machine. This creates a difference in air pressure between the inside of the vacuum cleaner and the air surrounding it. The air pressure within a typical working vacuum cleaner is around 20 per cent lower than the air outside. Creating a low air pressure environment within the vacuum cleaner forces the air outside the machine to rush inside, balancing out the pressure and creating suction. If the nozzle of a vacuum cleaner were to be blocked and the fans continued to spin, it would pump out the majority of the gas molecules within until it created a vacuum. Since vacuum cleaners carry air from the nozzle through to an exhaust, a proper vacuum doesn't form.

DID YOU KNOW? Evangelista Torricelli, a student of Galileo, proved the existence of a vacuum in 1644

Cleaning carpets is just one of the many ways that we take advantage of vacuum physics. In hospitals, for example, vacuums are vital tools for healthcare. Creating X-ray filaments, sterilising equipment and surgical suction machines are just some of the ways vacuums can come in handy in medicine. They can even be used to directly treat patients' wounds. Known as 'negative pressure wound therapy', this vacuum-assisted treatment is used to pump out excess fluids and help heal tricky wounds, such as diabetic ulcers or skin grafts.

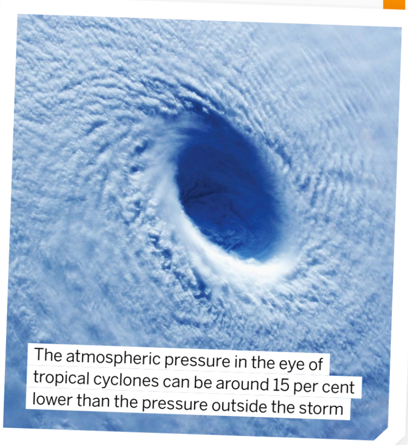
Any vacuum created on Earth isn't a 'true vacuum', and can't remove 100 per cent of matter from an enclosed volume. The closest thing to the existence of a true vacuum is the vacuum of space. Due to the vast size of the known universe and gravity's ability to clump matter together to form galaxies and star systems, the majority of the space between them isn't filled with very much of anything. The vacuum of interstellar space contains just one atom for every square centimetre, meaning there isn't anywhere in the known universe completely devoid of matter. While it's near impossible to recreate these conditions on Earth, it hasn't stopped scientists from trying to replicate it.

In Geneva, Switzerland, the Large Hadron Collider (LHC) particle accelerator conducts experiments to test our understanding of particle physics. By smashing particles together near the speed of light, the LHC can study their qualities and interactions to better understand the smallest mechanisms in physics. But to do this, it needs the help of vacuums. There are three different types of vacuum inside the LHC. The first is in the

> "Any vacuum created on Earth isn't a 'true vacuum'"

WHERE ARE THEY?

Around 350 BCE, the ancient Greek philosopher Aristotle claimed that there is no such thing as nothing – that "nature abhors a vacuum". He proposed that the dark void of space was filled with something he called aether. Despite our modern-day understanding of the vacuum of space, in many ways Aristotle was right: on Earth, at least, nature does abhor a vacuum. Matter fills every nook of our planet, leaving no room for naturally forming vacuums. The closest naturally created vacuum on Earth can be found at the heart of a cyclone. Much like the spinning fan of a vacuum cleaner, the cyclical power of thunderous cyclones can whip the air into a column of low pressure atmosphere that sucks air from sea level to the top of the column.



The atmospheric pressure in the eye of tropical cyclones can be around 15 per cent lower than the pressure outside the storm

CREATING SUCTION

How vacuum cleaners use a change in pressure to suck up dirt

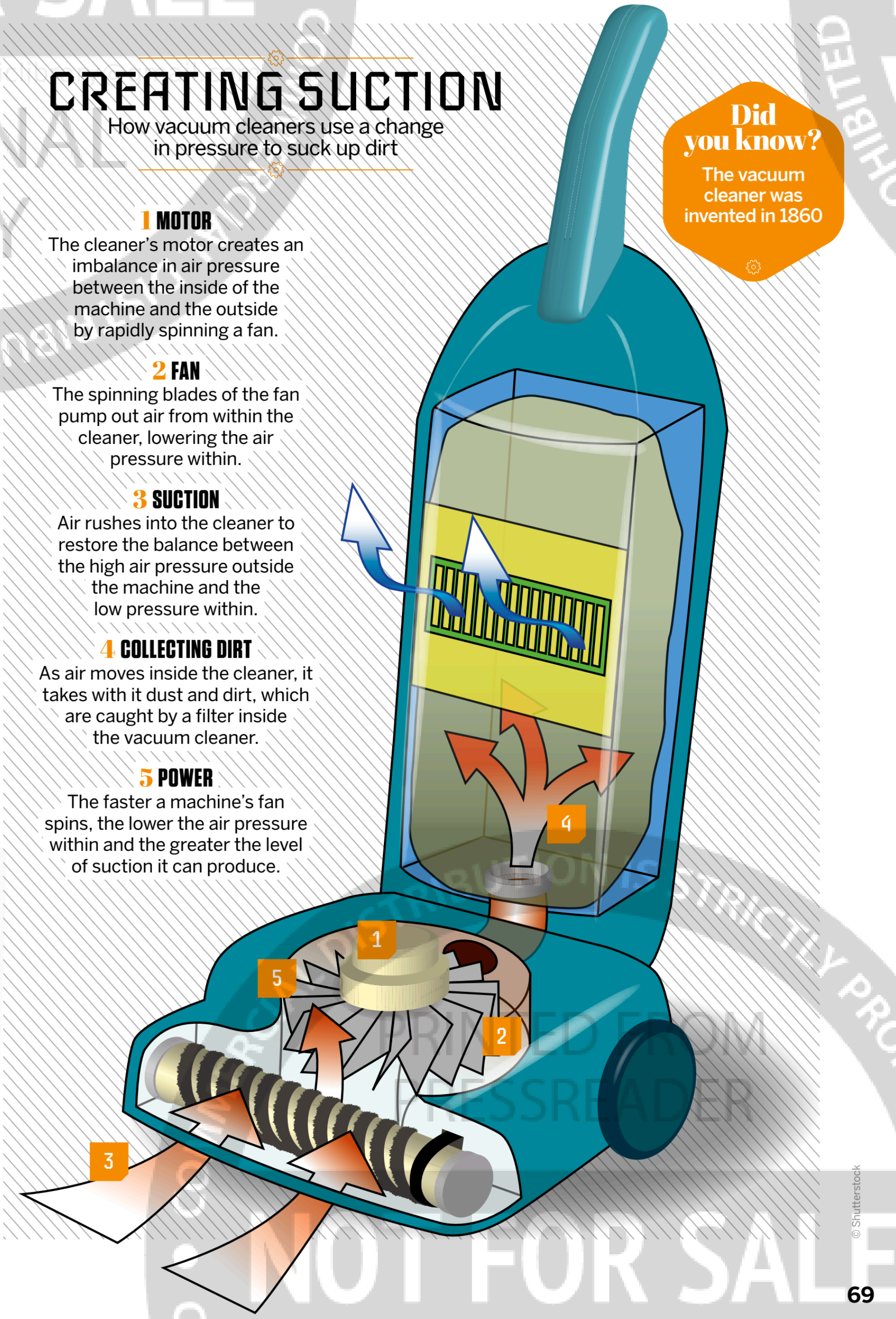
1 MOTOR
The cleaner's motor creates an imbalance in air pressure between the inside of the machine and the outside by rapidly spinning a fan.

2 FAN
The spinning blades of the fan pump out air from within the cleaner, lowering the air pressure within.

3 SUCTION
Air rushes into the cleaner to restore the balance between the high air pressure outside the machine and the low pressure within.

4 COLLECTING DIRT
As air moves inside the cleaner, it takes with it dust and dirt, which are caught by a filter inside the vacuum cleaner.

5 POWER
The faster a machine's fan spins, the lower the air pressure within and the greater the level of suction it can produce.

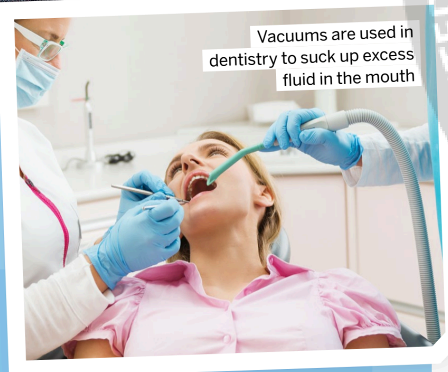


Did you know? The vacuum cleaner was invented in 1860 beam pipe, which prevents particles from colliding with unwanted gas molecules. The second and third vacuum systems are found around the machine's super-cooled magnets and helium distribution line. These vacuums act as a thermal insulator to block the heat from the room outside from seeping into the machine's frigid innards. Unlike the fan-based pumping systems of a household cleaner, the LHC creates its vacuum through 'cryo-pumping'. By cooling the walls of the vacuum chambers, gas molecules such as nitrogen, oxygen and argon move to the walls and freeze onto them. This leaves a space within the chamber mostly devoid of atoms.

Around 64 miles of piping within the LHC is in a vacuum environment. Using a supercooled cryogenic pumping system, around 900 cubic metres of gas is pumped out of the LHC. It takes around two weeks to pump the air out of the LHC, creating a vacuum that's as close to the vacuum of space as possible.

Did you know?
'Vacuum' comes from the Latin 'vacuus', meaning 'empty'

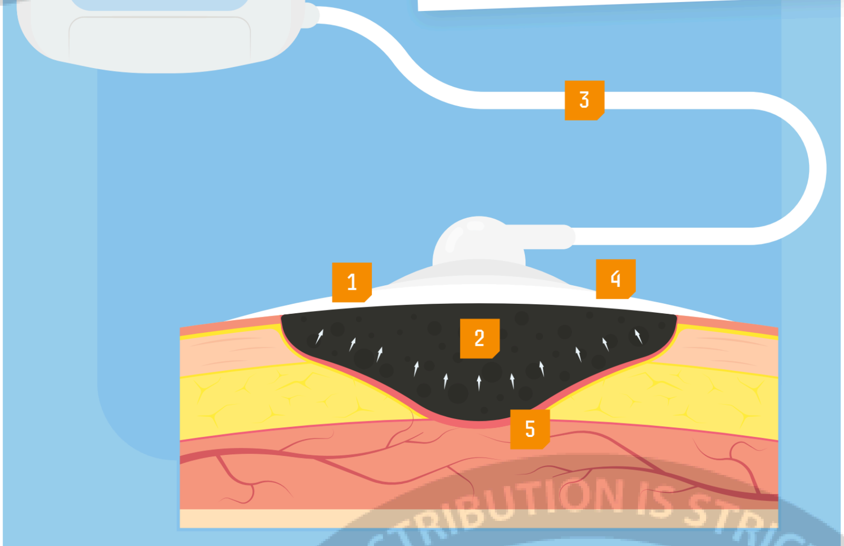
A patient undergoing negative pressure wound therapy


Vacuums are used in dentistry to suck up excess fluid in the mouth


Thank gravity for keeping our atmosphere from escaping into the vacuum of space

STEALING EARTH'S ATMOSPHERE

If Earth is surrounded by the vacuum of space, why isn't our atmosphere pulled away into the void? Despite popular belief, a vacuum doesn't suck air inside itself. Imagine a vacuum pump connected to a jar with all the air pumped out, leaving a vacuum within. When the pump is removed, the air outside the jar comes rushing back in. This isn't the vacuum pulling air inside, but rather the high air pressure outside the jar pushing air molecules inside. The same principle applies to space. Space isn't pulling against our atmosphere. Instead, the force of gravity on Earth is strong enough to prevent the atmosphere from flying off into space. Without gravity, the air would escape.



TREATING WOUNDS

How vacuums can be used to help heal the body

1 SEAL An adhesive film covers the wound, forming a seal between the wound and the vacuum pump.

2 PRESSURE A portable vacuum pump reduces the pressure over the wound.

3 DRAINAGE During treatment, excess fluid and blood is pulled from the wound through a drainage tube.

4 DRESSING A porous foam dressing is placed onto the wound for protection during treatment.

5 HEALING The vacuum pump and foam dressing promote closure of the wound and the growth of new tissue.

DID YOU KNOW? The atmospheric pressure in the beam pipes of the LHC is around one hundredth of that of the Moon

THE WORLD'S BIGGEST VACUUM

How the LHC keeps its components cool and free from unwanted molecules

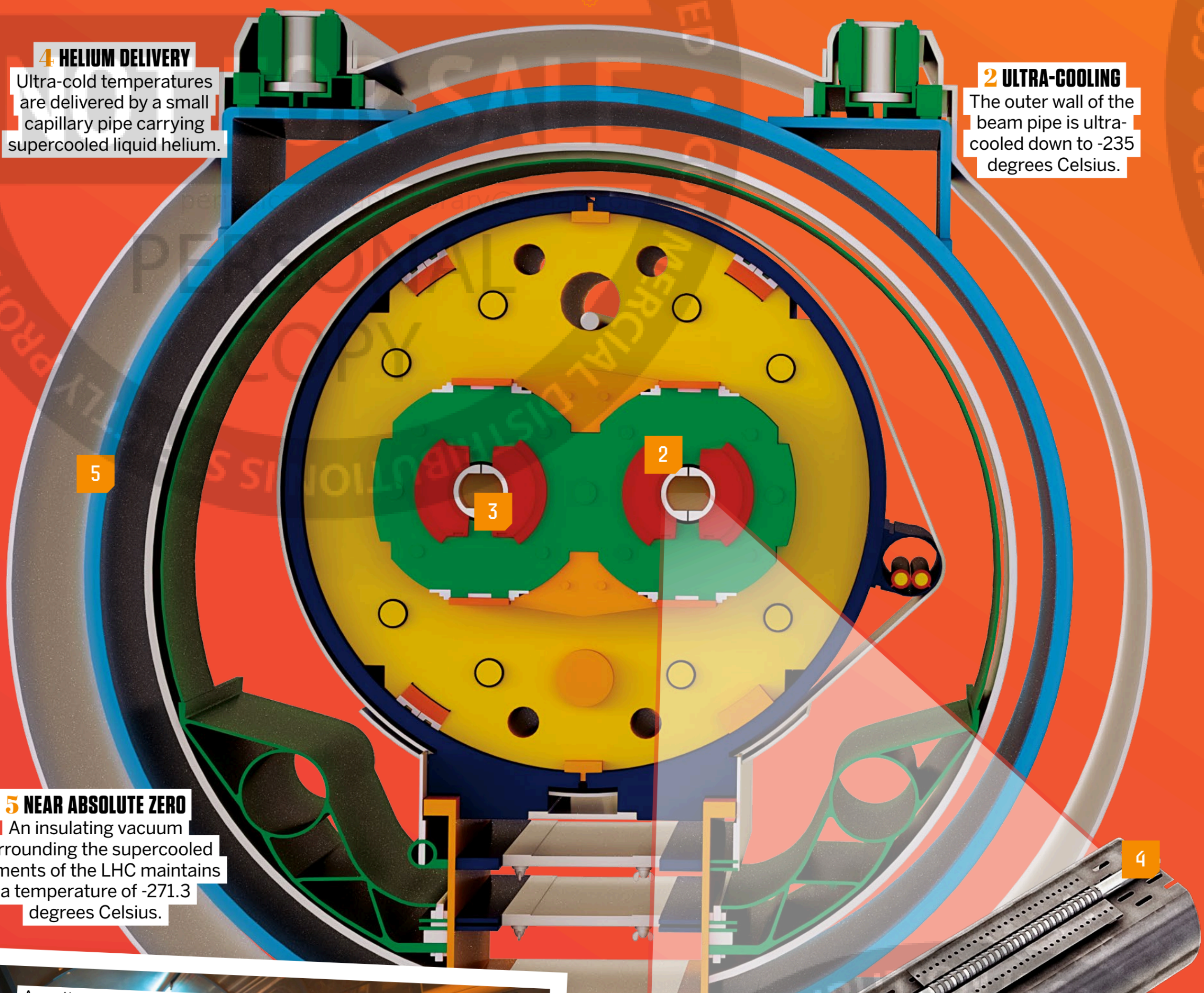
1 SLITS
There are small slits in the inner wall of the beam pipe for gas molecules to escape.

2 ULTRA-COOLING
The outer wall of the beam pipe is ultra-cooled down to -235 degrees Celsius.

3 INNER BEAM PIPE
Gas molecules move out of the inner beam pipe, where they collect and freeze on an outer wall.

4 HELIUM DELIVERY
Ultra-cold temperatures are delivered by a small capillary pipe carrying supercooled liquid helium.

5 NEAR ABSOLUTE ZERO
An insulating vacuum surrounding the supercooled elements of the LHC maintains a temperature of -271.3 degrees Celsius.



A portion of the Large Hadron Collider (LHC) in Switzerland

> "The LHC creates its vacuum through 'cryo-pumping'"

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