How Vacuum Cleaners Work

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Vacuum Cleaner Image Gallery

In its 100-year history, the electric vacuum cleaner has become an indispensable home appliance for most people, and it's obvious why. Imagine picking all this sawdust out of the carpet by hand! See more vacuum cleaner pictures.

Introduction to How Vacuum Cleaners Work

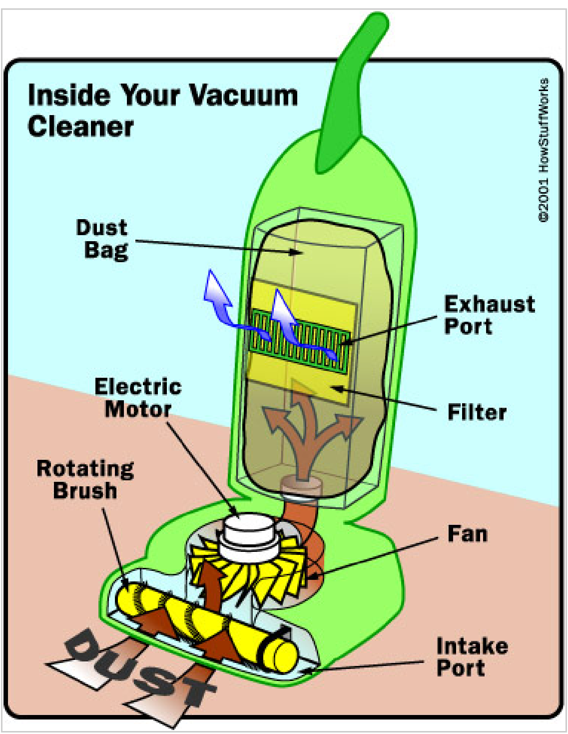
When you sip soda through a straw, you are utilizing the simplest of all suction mechanisms. Sucking the soda up causes a pressure drop between the bottom of the straw and the top of the straw. With greater fluid pressure at the bottom than the top, the soda is pushed up to your mouth.

This is the same basic mechanism at work in a vacuum cleaner, though the execution is a bit more complicated. In this article, we'll look inside a vacuum cleaner to find out how it puts suction to work when cleaning up the dust and debris in your house. As we'll see, the standard vacuum cleaner design is exceedingly simple, but it relies on a host of physical principles to clean effectively.

Vacuum Cleaner Image Gallery

It may look like a complicated machine, but the conventional vacuum cleaner is actually made up of only six essential components:

- An **intake port**, which may include a variety of cleaning accessories
- An **exhaust port**
- An **electric motor**
- A **fan**
- A **porous bag**
- A **housing** that contains all the other components



When you plug the vacuum cleaner in and turn it on, this is what happens:

1. The electric current operates the **motor**. The motor is attached to the **fan**, which has angled blades (like an airplane propeller).

2. As the **fan blades** turn, they force air forward, toward the **exhaust port** (check out How Airplanes Work to find out what causes this).

3. When air particles are driven forward, the **density** of particles (and therefore the **air pressure**) increases in front of the fan and decreases behind the fan.

This **pressure drop** behind the fan is just like the pressure drop in the straw when you sip from your drink. The pressure level in the area behind the fan drops below the pressure level outside the vacuum cleaner (the **ambient air pressure**). This creates suction, a **partial vacuum**, inside the vacuum cleaner. The ambient air pushes itself into the vacuum cleaner through the intake port because the air pressure inside the vacuum cleaner is lower than the pressure outside.

As long as the fan is running and the passageway through the vacuum cleaner remains open, there is a **constant stream of air** moving through the intake port and out the exhaust port. But how does a flowing stream of air collect the dirt and debris from your carpet? The key principle is **friction**.

DID YOU KNOW?

Space mission technologies developed by Black and Decker led to the invention of the Dustbuster. Learn more about cool NASA innovations in this interactive animation from **Discovery Channel**.

Upright vacuum cleaners usually have rotating brushes on the bottom to knock dirt loose from your carpet. The brushes may be rotated by the vacuum's motor or simply by the rushing air.

The vacuum cleaner bag is simply a filter that lets air pass through but keeps dirt in.

Vacuum Cleaner Brushes and Bag

In the last section, we saw that the suction created by a vacuum cleaner's rotating fan creates a flowing stream of air moving through the intake port and out the exhaust port. This stream of air acts just like a stream of water. The moving air particles rub against any loose dust or debris as they move, and if the debris is light enough and the suction is strong enough, the **friction** carries the material through the inside of the vacuum cleaner. This is the same principle that causes leaves and other debris to float down a stream. Some vacuum designs also have **rotating brushes** at the intake port, which kick dust and dirt loose from the carpet so it can be picked up by the air stream.

As the dirt-filled air makes its way to the exhaust port, it passes through the **vacuum-cleaner bag**. These bags are made of porous woven material (typically cloth or paper), which acts as an **air filter**. The tiny holes in the bag are large enough to let air particles pass by, but too small for most dirt particles to fit through. Thus, when the air current streams into the bag, all the air moves on through the material, but the dirt and debris collect in the bag.

You can put the vacuum-cleaner bag anywhere along the path between the intake tube and the exhaust port, as long as the air current flows through it. In upright vacuum cleaners, the bag is typically the last stop on the path: Immediately after it is filtered, the air flows back to the outside. In **canister vacuums**, the bag may be positioned before the fan, so the air is filtered as soon as it enters the vacuum.

Using this basic idea, designers create all sorts of vacuum cleaners, with a wide range of suction capacities. In the next section, we'll look at a few of the factors that determine suction power.

Vacuum Cleaner Variables

In the last section, we saw that vacuum cleaners pick up dirt by driving a stream of air through an air filter (the bag). The power of the vacuum cleaner's suction depends on a number of factors. Suction will be stronger or weaker depending on:

- The **power of the fan**: To generate strong suction, the motor has to turn at a good speed.
- The **blockage of the air passageway**: When a great deal of debris builds up in the vacuum bag, the air faces greater resistance on its way out. Each particle of air moves more slowly because of the increased drag. This is why a vacuum cleaner works better when you've just replaced the bag than when you've been vacuuming for a while.

Vacuum cleaner attachments serve to concentrate the flow of air as it enters the vacuum. Since suction depends on the size and shape of the passage, different attachments are better suited to different cleaning jobs.

- The **size of the opening at the end of the intake port**: Since the speed of the vacuum fan is constant, the amount of air passing through the vacuum cleaner per unit of time is also constant. No matter what size you make the intake port, the same number of air particles will have to pass into the vacuum cleaner every second. If you make the port smaller, the individual air particles will have to move much more quickly in order for them all to get through in that amount of time. At the point where the air speed increases, pressure decreases, because of Bernoulli's principle (see How Airplanes Work to learn about this physical principle). The drop in pressure translates to a greater suction force at the intake port. Because they create a stronger suction force, narrower vacuum attachments can pick up heavier dirt particles than wider attachments.

At the most basic level, this is all there is to a vacuum cleaner. Since the electric vacuum's invention a century ago, many innovative thinkers have expanded and modified this idea to create different sorts of vacuum systems.

So far, we have looked at the most typical types of vacuum cleaners: the **upright** and **canister** designs, both of which collect dirt in a porous bag. For most of the history of vacuum cleaners, these have been the most popular designs, but there are many other ways to configure the suction system. We'll look at some of these in the next section.

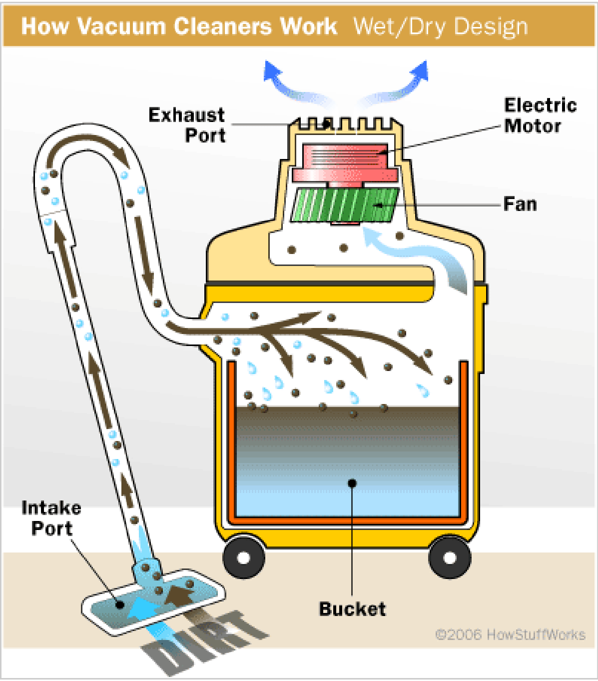
Two upright vacuum cleaner models, one with the conventional bag system (right), and the other with the new "cyclone" system (left).

Central Vacuum Systems and Wet/Dry Vacs

The first vacuum cleaners, dating from the mid 1800s, used **hand-operated bellows** to create suction. These came in all shapes and sizes, and were of minimal help in daily cleaning. The first electric vacuum cleaners showed up in the early 1900s, and were an immediate success (though for many decades they were sold only as a luxury item).

One very popular vacuum-cleaner design from this era is finding a resurgence in popularity today. This design, the **central vacuum system**, turns your whole house into a cleaner. A motorized fan in the basement or outside the house creates suction through a series of interconnected **pipes in the walls**. To use the cleaner, you turn on the fan motor and attach a hose to any of the various pipe outlets throughout the house. The dirt is sucked into the

A Fairfax S-1 dating from the 1950s: The Fairfax combined functionality with aesthetic appeal.
Photo courtesy Charles Lester



pipes and deposited in a large canister, which you empty only a few times a year. For more information, see How Central Vacuum Systems Work.

Wet/Dry Vacuums

For heavy-duty cleaning jobs, a lot of people use **wet/dry vacuum cleaners**, models that can pick up liquids as well as solids. Liquid material would soak paper or cloth filters, so these cleaners need a different sort of collection system.

The basic design is simple: On its way through the cleaner, the air stream passes through a **wider area**, which is positioned over a **bucket**. When it reaches this larger area, the air stream **slows down**, for the same reason that the air speeds up when flowing through a narrow attachment. This drop in speed effectively loosens the air's grip, so the liquid droplets and heavier dirt particles can fall out of the air stream and into the bucket. After you're done vacuuming, you simply dump out whatever has collected in this bucket.

Next, we'll look at two more innovations in vacuuming: the cyclone vacuum and the robotic vacuum.

One type of wet-dry vacuum is the steam cleaner. These vacuums dispense cleaning fluid onto the carpet, massage it in, and then suck up the fluid along with any dirt.

James Dyson with the Root Cyclone™ DC07
Photo courtesy Dyson

Cyclone Vacuums and Robotic Vacuums

One recent vacuum-cleaner variation is the so-called "cyclone vacuum." This machine, developed in the 1980s by James Dyson, doesn't have a traditional bag or filter system. Instead, it sends the air stream through one or more **cylinders**, along a **high-speed spiral path**. This motion works something like a clothes dryer, a roller coaster or a merry-go-round. As the air stream shoots around in a spiral, all of the dirt particles experience a powerful **centrifugal force**: They are whipped outward, away from the air stream. In this way, the dirt is extracted from the air without using any sort of filter. It simply collects at the bottom of the cylinder.

The cyclone system is a marked improvement on traditional vacuum cleaners -- there are no bags to replace and the suction doesn't decrease as you suck up more dirt.

Robotic Vacuums

Until recently, no matter how powerful the vacuum, someone still had to be there to push it around. Enter the robotic vacuum. These little gadgets clean all by themselves, thanks to a combination of motors, sensors and a navigation system. To explore one in more detail, check out How Robotic Vacuums Work.

In the future, we are sure to see even more improvements on the basic vacuum-cleaner design, with new suction mechanisms and collection systems. But the basic idea, using a moving air stream to pick up dirt and debris, is most likely here to stay for some time.

For more information on vacuum cleaners and related topics, check out the links on the next page.

The Root Cyclone™. High volumes of air simultaneously move through several cyclones, providing higher, continuous suction power.
Photo courtesy Dyson

Lots More Information

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