

Question From the Classroom

By Bob Becker

Q. Would a vacuum cleaner still work inside a vacuum?

Good question! If you think of a vacuum cleaner as something that pulls or sucks the dirt into it, then it should probably work in a vacuum. This way of thinking, however, is based on a belief in a force called "suction". Unfortunately, most people don't know that such a force does not exist.

Consider a suction cup—stick one on top of a table and ask 100 randomly chosen people what is holding it down. You will probably get the same answer: "Suction". It is a suction cup after all. If you questioned them further about the nature of the force, they will most likely attribute it to some kind of pulling force created by the vacuum beneath the suction cup.



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But when you ask, "What is a vacuum?" many will respond correctly, "A vacuum is nothing. It's the absence of any matter." "So if it's nothing", you say, "what's doing the pulling?" At this point you will probably hear a whole lot of "Hmmm's"—that's the sound of people reexamining their ideas about how the world works. The simple truth is that a vacuum is nothing and can therefore do nothing! So what supplies the force that keeps a suction cup stuck to the table? It's not a pulling force from within; it's a pushing force from without. That's right! Our atmosphere pushes with a force of 14.7 pounds per square inch. That's like having the weight of a bowling ball pushing on every square inch, of every surface around you, all the time. It is caused by an almost unimaginably large number of molecules moving at hundreds of miles per hour, colliding constantly with each other and with every object on our planet. We take that pressure for granted: We forget it's even there ... until it's gone, that is, and then we start attributing strange pulling forces to its absence! Hmmm ...

But if you simply place a suction cup on the table and try to lift it up, it comes off easily. Why is it easy with all that pressure pushing down on it? The explanation is simple: there's also air beneath the suction cup pushing upward with an equal force. But when you push the suction cup firmly to the table, you force that air out. In this instance, when you try to lift it, you fight against atmospheric pressure but receive no help from beneath. It's just you against the atmosphere. If it's a small suction cup with a surface area of only one square inch, then you will need to pull upward with a force of about 14.7 pounds to break it loose. That's assuming that you've created a perfect vacuum beneath the cup. If it's a larger suction cup with a surface area of 10 square inches ... good luck.

Let's get back to the vacuum cleaner. A dirt particle sitting on your carpet is pushed equally from all sides by atmospheric pressure. Normally, these forces cancel each other out, so the particle just sits there. A vacuum cleaner works because it creates an area of lower pressure above the particle. The dirt particle thus gets pushed (not pulled) into the vacuum cleaner by the greater air pressure on the underside of it. This means that every phenomenon you attribute to a vacuum pulling, you now have to rethink.

For example, what about a drinking straw? Certainly, that liquid is being pulled into our mouths by the suction we create. Right? Guess again! It's being pushed up the straw by the atmospheric pressure pushing down on the liquid surface outside the straw.

So would a vacuum cleaner work inside a vacuum? Not a chance. The same goes for suction cups and drinking straws. Would anything work inside a vacuum? Most definitely! Some things would even work better because air hinders their performance. So some things depend on air and some things don't, but how good are you at telling which is which?