Journal of Young Investigators
Peer-reviewed, Undergraduate Science Journal

Issue Five
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The Science of Fixing Stuff

-or-

If I Can Do Quantum Mechanics, Then I Can Make That Thing Stop Leaking

by Margaret Harris, Duke University

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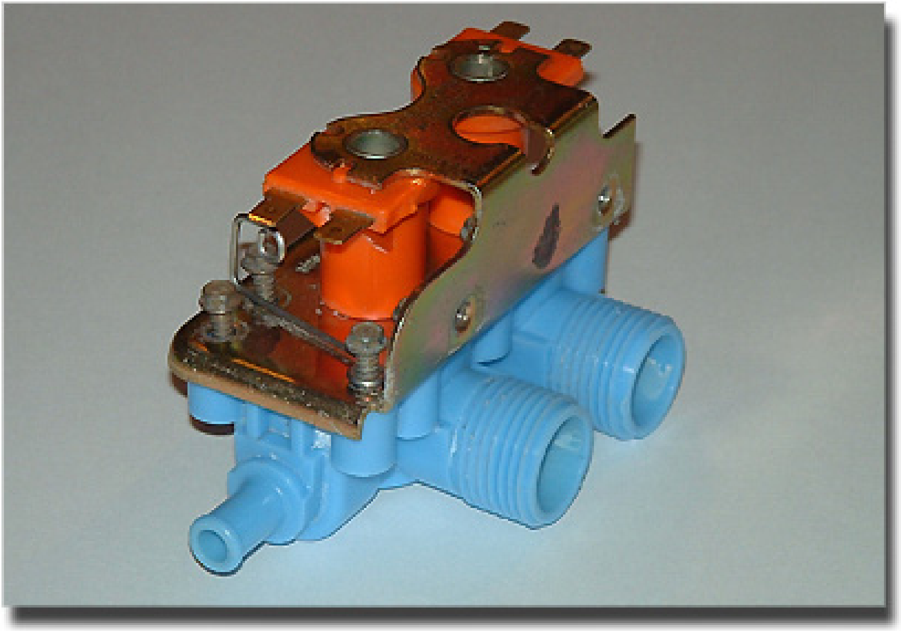
Four days before Christmas, the family washing machine developed a bad case of incontinence. Toss in a load of towels, add a cup of detergent, flip the switch, and a soapy flood would emerge from the appliance's nether regions - nice for cleaning the floor, but not so great for cleaning clothes. After some mopping and a few tentative efforts at "percussive maintenance" - kicking the washer and banging on it with the laundry basket - it became clear that we needed a repairman with years of experience, specialized tools, and intimate knowledge of washing machines.



"Orange and blue plastic doohickey" - the Universal Valve

Instead, we got my father the engineer, a set of screwdrivers and socket wrenches, a page of blurry, unlabeled diagrams, and an orange and blue plastic doohickey labeled "Universal Valve." Plus, we had one physics student, fresh from exams and convinced that compared to quantum mechanics, fixing a washing machine had to be a piece of cake, right?

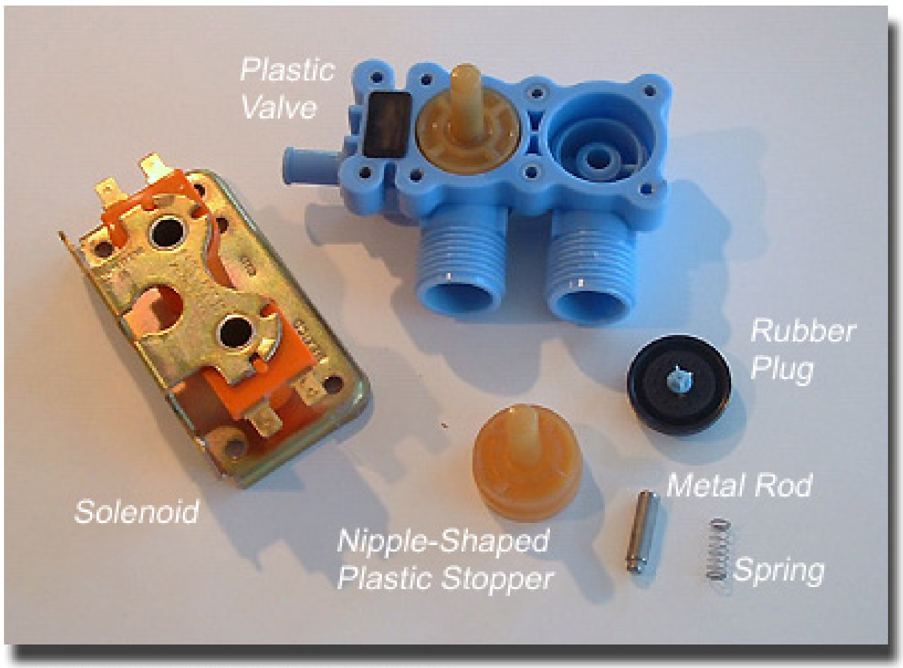
The good folks at Maytag don't make it easy to mess with their productsâ innards. Lying on his back on the laundry room floor and fiddling with a screwdriver, my father admitted that he had to call the celebrated Maytag Repairman the first time the washing machine broke, simply because he couldnât figure out how to get inside the darn thing. This time, he knew what he was doing. Two tiny, hidden screws later, I was easing aside the front cover of the machine and peering into its damp, fuzz-encrusted interior.

The most obvious component of a washing machineâs innards is a set of two nested metal drums, the outer one solid, and the inner one dotted with holes. When the spin cycle begins, centripetal force from the rotating drum flings the water out these holes and down the inside of the outer drum. From there, water leaves the machine through a tube at the base of the outer drum- unless, of course, the machine is broken, in which case the water makes a sopping mess of the dryer lint and other detritus on the laundry room floor.

The floor, however, is a relatively good final destination for misdirected soapy water. Water in an overflowing washing machine can, in theory, do any of three things: drain down the tube like it's supposed to, spill all over the floor, or siphon back into the pipes and contaminate the local water supply. (I am leaving out the interesting but irrelevant possibility of its shooting out the top of the machine, geyser-like, and creating damp splotches on the ceiling).

To prevent such contamination, the water-delivery system in a washing machine contains a device - called a vacuum breaker - between the faucet and the drum. A vacuum breaker consists of two rubbery tubes, a narrow one inside a much larger one. It does to water what a one-way mirror does to light: permits transmission in one direction and blocks it in the other. The process is remarkably simple. Water from the faucet flows through the hose, reaches the narrow inner tube, and sprays into the outer tube, creating an air bubble around the spray. If water pressure in the washing machine rises above the pressure in the pipes, then water will slurp backwards up the hose- but only as far as the air bubble. Itâs like trying to drink water through a straw with a hole near the far end. Although you can force water from your mouth down the straw and out the other end (or the hole), you can never suck water up the straw past the hole. Thus are we saved from drinking tap water that tastes like dirty socks and Tide.

In time, the pressure of fast-moving water can distort and stretch the tubes in a vacuum breaker. This creates gaps in the hose, allowing water to spray all over the place instead of into the drum, where it belongs. On our machine, a bulge in the outer tube of the breaker - plus the spray that issued from that part of the hose when we turned on the washer - indicated that was exactly what had happened.



The Universal Valve - undone.

Unfortunately, the breaker was not the only cause. Our multi-talented machine was also leaking water from somewhere nearer the water faucet. It was time for the Universal Valve.

If you're like me, you don't lose much sleep wondering how a washing machine "figures out"how to get the requested amount of hot and cold water from the tap to your clothes. You just push the button for "cold wash"or "bright colors"and walk away, confident that hot water won't seep in and shrink your sweaters.

It turns out that most of the credit for this phenomenon belongs to the Universal Valve, a fist-sized chunk of metal and plastic that sits near the back of the washing machine. When you turn on the washing machine, water from the tap flows into the valveâs blue plastic underside through two one-inch-diameter holes: one for hot water, one for cold. Each hole leads to a small chamber inside the valve. A quarter-inch tube runs between the two chambers and connects them to a single plastic nozzle, which fits inside the hose that carries water from the valve to your clothes (by way of the vacuum breaker, of course).

None of this, however, explains how cold water gets to clothes designated "cold wash only"and hot water gets to sweat socks and underwear. The part of the valve that pulls this trick is a uniformly wound coil of wire called a solenoid. When electric current runs through the wire, it creates a magnetic field inside the solenoid, along the coilâs central axis. The coil then acts like a magnet. This connection between moving electric charge and magnetic fields forms the basis of Ampere's Law, one of the great unifying laws of electromagnetism (which basically states that "Moving electric charges generate a magnetic field"). Because of Ampere's Law, the humble current-carrying solenoid appears frequently on introductory physics exams - where it causes almost as much grief as a leaky washing machine.

The Universal Valve contains two solenoids, one for each chamber. The solenoids are covered in orange plastic to keep water from touching the live wire inside (an event with potentially shocking consequences). Inside each casing is a rigid plastic stopper that resembles the nipple on a baby bottle. Within each stopper is a small metal rod with a spring at one end and a rubber plug at the other. The rubber plugs at the base of the stoppers fit snugly into the chambers on the blue, water-carrying half of the valve.

When current runs through the solenoid, it sets off a chain of events worthy of a Rube Goldberg invention. The current generates a magnetic field, which pulls the metal rod towards the solenoid. The moving rod yanks the plug upwards, water rushes from the chamber into the hose, and from there into the drum. After all the usual wash, rinse, and spin cycles, your clothes are clean. Once the current stops, the magnetic field disappears, the spring pushes the metal rod back to its original position, and the plug keeps water from going anywhere.

Letâs go back to the problem of hot and cold water. If you push the "cold water"button on the washing machine, a switch inside the machine prevents current from flowing in the hot-water solenoid. The hot-water plug stays closed, so only cold water can enter the hose. The reverse is true for the "hot water"button, and you can probably guess that all the in-between cycles require a combination of hot and cold solenoid action.

At least, that's what's supposed to happen. In our case, an ambiguous "something"in the Universal Valve had developed a leak, so while my father balanced the washing machine on its front edge and reached around the back to install a new valve, I took a screwdriver to the old valve and made a royal mess taking it apart. I understand this is a fairly typical division of labor for physicists and engineers. While making my mess, I discovered that the culprit was arguably the simplest part of the entire assembly: the spring inside the stopper. Years of boing-ing back and forth had reduced the spring to a fraction of its former glory, and without a stiff spring to push the metal rod back into place after the current stopped flowing, the water plug never closed all the way - hence, puddles.

After any fix-it job comes a moment of truth: will it work? Or do I have to stay awake another hour, buy another replacement part, dig into some unexplored area of the bleeping machine, stand on my head, build an altar to the gods of machinery or - horror of horrors - give in and call the repairman? The situation is not unique to shade-tree mechanics and amateur repairmen; any experimental scientist knows the "here goes nothing" feeling of trying a new piece of equipment or an untested process. Such uncertainty is part of what makes science exciting. So is the elation one feels when, after days or even years of hard work, everything comes together in beautiful harmony, the theory is suddenly clear, and everything works exactly as it should. Despite their vast differences in pay, dress code, and prestige (among other things), the field of appliance repair and the field of science are - in some respects - not so far apart as they seem.

For my family's washing machine, the time my father and I spent unscrewing, replacing, and making messes paid off. I know a lot more about machinery than I used to, my father has re-learned something about electromagnetic theory - and more important, the washing machine is working again. As of this writing, it has done about a dozen loads of laundry, nobody has been electrocuted, the basement has not floated away, and no repairman has invaded the domain of Super-Engineer and the Physics Kid. Considering the people in charge, I regard this as a minor miracle.

But I've also decided that if I can't make it as a physicist or a writer, I'm going into small appliance repair.

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JYI is supported by: The National Science Foundation, The Burroughs Wellcome Fund, Glaxo Wellcome Inc., Science Magazine, Science's Next Wave, Swarthmore College, Duke University, Georgetown University and many others.

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