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SUPERMAN SCHOOLS SPIDER-MAN—

ELECTRICAL CURRENTS

LET'S NOW TAKE a closer look at those electric bolts emanating from Electro's hands. A large enough positive charge can pull electrons from very far away, even through miles of copper wire. A fancy term for the pull exerted on electrons as they move through a wire is "voltage." Electrons are negatively charged so that a positive voltage pulls them in one direction while a negative voltage repels the electrons in the opposite direction. The current is just another way of expressing the number of electrons moving past a given point in the wire per second.

Imagine a garden hose connected to an outdoor faucet. In this case the voltage plays the role of the water pressure that pushes the water through the hose. The amount of water that comes out the end in a given time period is the current. The resistance of the hose arises both from minor blockages as well as small holes along its length, from which some water can escape before making it to the end. The more defects in the hose, the greater the water pressure needed to maintain the same water flow (current) from the end of the hose. However, just like a faucet being turned on in a sink—with water flowing without a hose connecting the faucet to the drain—an electrical current can be pushed by a large enough voltage even in the absence of a wire. This is what happens when a spark jumps from your fingertip to the doorknob or from a cloud to the ground during a lightning strike. The greater the distance, the bigger the force needed to pull the charges. This is a consequence of the Coulomb electrostatic force expression becoming smaller by the square of the separation of the charges. A long garden hose, with various imperfections and holes, will have more resistance to water flowing through it than a similar short segment of hose. This is why you don't receive a static shock until your fingers are very close to and just about to touch the doorknob: Air is a pretty good electrical insulator, and it takes an electric field of more than 12,000 volts per centimeter before the pull on the electrical charges is sufficient to make them jump the gap. Which is why when it happens, it stings. And why you most definitely do not want to be zapped by Electro's massive discharges.

When you turn on the water in the kitchen sink, the water flows from the tap to the drain. It does not flow from the faucet to the ceiling,* under ordinary circumstances. Why not? For the water analogy, the reason is obvious: There is a downward pull of gravity on the water, directing its flow. For electrical charge, the direction the current flows is determined by the location of the "drain." Electrical charge can't flow if there is no place for it to go. Actually, this is true for our water analogy as well. Want to know how you can overturn a glass of water filled to the brim and manage to not spill a drop? Do it when the glass is underwater in a swimming pool! If there is no place for the water in the glass to go, it will stay inside the container (provided you ignore random collisions between the water molecules in the pool and those at the top of the glass that will cause those molecules to switch locations).

The same is true for electricity. Regardless of the magnitude of the net electrical charge an object possesses, it will not discharge if every other object surrounding it has exactly the same charge. Technically the voltage that pulls or pushes electrical charges around is a measure of the "potential difference," which is defined as the difference in potential energy of the charges on one object relative to another. This is what makes Electro so dangerous (in addition to his daring fashion sense): He is able to control his potential difference relative to his surroundings at will, so he can decide when and where he will discharge the excess electrical charge he has stored up.

By applying a voltage across a conductor, I raise the potential energy of the electrons within the conductor, just as when lifting a

* Unless you employ the Moe, Larry, and Curly plumbing agency.

brick over my head I raise its potential energy. The brick keeps this extra potential energy until I release it, at which point the potential energy is converted into kinetic energy and the brick speeds up as it falls. But this conversion cannot take place until I let go of the brick. Similarly, the electrons in a wire speed up and increase their kinetic energy in the form of an electrical current, in response to the voltage applied across the wire—but only if the electrons have someplace to go. Just as the raised brick will keep its potential energy indefinitely until I drop it, the electrons cannot speed up in response to an applied voltage if the wire is not electrically connected to anything. Think again of a garden hose connected to a faucet. No matter how much I turn the faucet tap, absolutely no water will flow through the hose if it is completely sealed at the other end. I have to uncap the end of the hose so that the water can drain out before it flows through the hose (a current), in response to the water pressure (voltage) at the faucet. The technical way of expressing this is to say that in order for an electrical current to flow through a wire, it must be grounded.* The Earth, or "ground" is obviously a large object, with many electrical charges; consequently, it can take up extra electrons, or donate electrons to a wire without difficulty. This notion, that in order for a current to flow, it must have someplace to go, is fairly reasonable, but not every superhero seems to have grasped it.

In chapter 1 we mentioned the early exploits of the Man of Steel, as described in *Superman* # 1, before the world at large knew of his existence. In this story Superman sought to learn the identity of the person bankrolling the Washington lobbyist who was bribing a senator with the goal of embroiling our country in the war in Europe. (Recall that this story occurred in 1939.) The secret employer of Alex Greer, "the slickest lobbyist in Washington," turns out to be Emil Norville, the munitions magnate (war being

* Strictly speaking, the wire does not have to be connected to "ground," but simply to another point at a lower potential than the starting point. But, ultimately, the terminus of any current must be the ground. Following the water analogy, we can have a flow of water through a hose that is connected from one faucet at one end to *another* faucet at the other end. As long as there is a difference in water pressure between the two faucets, there will be a net flow of water, but for this to keep up indefinitely the second, lower-pressure faucet must be able to eventually discharge its excess water down some drain (or "ground" back to the electrical situation).

good for business, from Norville's point of view]. For some reason Greer initially refuses to divulge the name of his employer to this strange man wearing a blue-and-red long-underwear ensemble accessorized with a flowing red cape. In chapter 1 we mentioned that Superman purposely falls from the top of a high building holding Greer, pretending that the fall will kill them both. Prior to this scene, in order to loosen Greer's tongue, Superman picks him up like a sack of potatoes and leaps atop some high-tension lines, as illustrated in fig. 23. Greer protests that they'll be electrocuted, but Superman finds the time to give the lobbyist a physics lesson. Whether this lecture should be considered an additional part of Superman's efforts to psychologically torture and force information from the lobbyist I leave to the reader to decide. "No, we won't," the Man of Steel explains, since after all, "birds sit on telephone wires

Fig. 23. *A scene from* Superman # 1, *where the defender of truth, justice, and the American Way coerces information from a Washington lobbyist, by giving him a "hands-on" demonstration of the principles of electrical grounding.*

and *they* aren't electrocuted—not unless they touch a telephone-pole and are *grounded*!"

Superman is exactly right. It is only when you touch a high-voltage wire and simultaneously grab the telephone pole (or touch another wire at a different voltage), and thereby provide a pathway for the current in the wire to flow to the lower voltage, that you have to worry. In this unfortunate situation the flow of electrons (a current) passes through the conductor—namely, your body—connecting the two points.

Alas, just such a basic understanding of electrical circuitry is lacking in *Amazing Spider-Man* # 9, where Spidey first tangles with Electro. In one scene during their climatic battle, Spider-Man manages to deflect an electrical bolt that Electro has hurled at him by tossing a metal chair over Electro's head. "Anyone with any knowledge of science knows that anything metal can act like a lightning rod," Spider-Man says, lecturing Electro, "as this steel chair is doing!" Actually, Spider-Man's mistaken understanding of how lightning rods function suggests that his allegedly advanced knowledge of science isn't all it's cracked up to be. The electrical bolt is shown arcing away from Spider-Man and chasing after the soaring chair—even though the chair is not electrically connected to anything! Why would Electro's lightning bolt be pulled toward the chair, metal or not, if once it reaches the chair there is nowhere for the electrical current to go?

The situation further degrades (from a physics point of view) in *Amazing Spider-Man* Annual # 1 (Feb. 1964) where Spidey again faces off against Electro and this time, as an extra precaution, he deliberately attaches a wire to his ankle to ensure that he remains electrically grounded at all times! When fighting a supervillain capable of hurling lethal lightning bolts at you, a good solid electrical connection to the ground is exactly what you *don't* want.

The whole point of a lightning rod is not that it's made of metal, but that the lightning will strike the tallest feature on the building (the rod), and the electrical current is then carried from the rod by way of a wire safely to ground, thereby avoiding igniting a fire on the roof of the building. The static shock between your fingertip and the metal doorknob occurs only when your finger is very close to the door, since the shorter the distance the less resistance the arc has to overcome. Similarly, the lightning bolt is trying to minimize the distance and hence resistance on its way to electrical ground. This is why you don't want to stand under a tree during a lightning storm, as you increase the chance that the lightning striking the tall tree will take a detour through your body. When alone in an empty field during a thunderstorm, one should lie flat on the ground in order to decrease the chance of being struck by lightning. If a building's lightning rod is not connected to ground, the electrical current entering the rod will find a higher resistance pathway to ground, through the roof and building, with concomitant damage to the structure.

Just such damage will surely be Spider-Man's fate when he intentionally connects himself to ground, thereby guaranteeing that all of Electro's electrical energy will pass through his body on its way to a lower potential state. Spider-Man's "spider-strength" will enable him to withstand some of the damage of the electrical strike, but grounding himself as he does makes the situation much worse than it needs to be.

It's not clear which of Spider-Man's co-creators, the writer Stan Lee or artist Steve Ditko, should get the blame for these goofs. This ambiguity stems from the "Marvel method" of producing comic books in the 1960s. At Marvel's Devilish Competitors (as Lee would jokingly refer to DC Comics), a comic-book writer would generate a script that detailed not only the captions and dialogue and thought balloons in each panel, but also what the artwork in each panel should look like. An editor would then go over the script, making changes as needed, and pass it along to the artist, who would draw the comic story as described in the script. The artwork would then be inked, lettered, and colored, using the dialogue and captions in the script, and the writer would commonly not see the story again until it was available for sale on newsstands. This system works fine as long as one has enough writers and editors to cover the number of comics produced per month, but at Marvel in the early 1960s, the number of writers and editors was low—namely one: Stan Lee. Lee was both the editor and writer of (in 1965, to pick a particular year) the *Fantastic Four; Spider-Man; The X-Men; The Avengers;* Captain America and Iron Man stories (both in *Tales of Suspense*); Dr. Strange, solo Human Torch stories, and Nick Fury, Agent of

S.H.I.E.L.D.* (in *Strange Tales*); Giant-Man, the Sub-Mariner, and the Incredible Hulk (in *Tales to Astonish*); *Daredevil*; and *Sgt. Fury and His Howling Commandos* (a World War II comic). If the stories in the Marvel universe had a coherent structure and feel, this was no doubt due to the fact that there was a single creative voice guiding the varied comic books.

With so many stories being created every month, there was simply no way that Lee had the time to craft full scripts for all of these comic books. Meanwhile the artists working for Marvel were freelancers, and would bring in the artwork for one issue, get paid, and then need to pick up instructions for the next issue's story line (if they weren't working, they weren't being paid). I should mention, by the way, that the artists working for Marvel at the time were some of the very best in the business and included such titans as Jack Kirby, Steve Ditko, Don Heck, John Romita, and Gene Colan. These artists were so talented that they were able to continue making a living through the comic-book Dark Ages of the mid-1950s, when the entire industry was on the verge of extinction thanks in part to the "Seduction of the Innocent" brouhaha. Consequently, they were experts in how to tell a story in graphic terms, and did not need a comic-book writer holding their hands with panel-by-panel instructions of what should be drawn on every page.

Stan Lee therefore hit upon a clever solution to the problem of not enough time and too much available talent: Let the artists tell the story. Lee would write up a brief synopsis, varying in length from a few pages to a few paragraphs,† describing what the latest issue's story line would be. In essence, he gave the artists a plot outline of the major points of the story, such as who the villain would be and what his powers were and how he obtained them, as well as how the hero would lose the initial skirmish with the villain, and finally the clever stratagem that would provide the hero's

* Supreme Headquarters International Espionage Law-Enforcement Division.

† Or sometime even less. One legend has it that Lee's précis to Jack Kirby for the classic *Fantastic Four* # 48, where the FF encounters the cosmic being Galactus read as follows: "The FF fight God." Kirby, reasoning that such an entity would have a herald to prepare the unlucky planet for the devourer's arrival, created the character the Silver Surfer. Lee first learned of the Surfer when Kirby's artwork for FF # 48 arrived at the Marvel office.

victory by the issue's conclusion. The artists would then go back to their studios and construct a graphic story that followed Lee's synopsis. When the finished artwork would return, Lee would then write the captions and dialogue in each panel, and the comic book would be ready to be sent off to the printer. Consequently both Lee and the artists could legitimately be said to co-write or co-plot any given issue of a comic book created in the Marvel style. Thus it is on both Lee's and Ditko's shoulders that the blame for Spidey's ignorance of basic electrical current theory must be placed.

Lee and Ditko may not have had a firm grasp of the concept of electrical grounding, but they understood that electricity plus water equaled a short circuit. The climax of Spider-Man's battle with Electro in issue # 9 came when Spidey grabs a nearby fire hose, such as used to be commonplace in most professional buildings before the advent of ceiling-based sprinkler systems, and doused Electro with a heavy spray of water. As Spider-Man grabs for the hose and turns open the main pressure valve, he thinks *Say!! What kind of science major am I, anyway! Why didn't I think of this right away!!* As he lets Electro have a full blast, he continues, *Water and electricity just don't mix!!!*

Well, as mentioned above, we are beginning to have some doubts about what kind of science major Peter Parker is, but he is certainly correct that water and electricity don't mix. This is because city-water, while technically electrically neutral, contains a high concentration of impurity ions. Ordinary tap water is consequently a pretty good conductor of an electrical current. Electro is at a high potential difference, which is why he is such a lethal threat to superheroes. By dousing him with water, Spider-Man essentially connects a wire between Electro and ground, allowing the large excess charge Dillon has stored to flow out of his body. This is one physics lesson that seems to be well learned in the Marvel universe. When Electro is bested by Daredevil in the second issue of that hero's comic, the police keep him drenched with a water hose (Electro, that is, not Daredevil) in order to safely transport him to the paddy wagon and the station house.