Jacobs Ladder Construction Project

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The purpose of my project was to construct a apparatus that would allow me to visibly overcome the dielectric breakdown of air. In other words, I wished to build a Jacobs Ladder. I decided to do this project because it was my last opportunity to build something at the undergraduate level. The previous semester I had worked laboriously upon a lovely 10 page paper on dark matter and universal expansion, that was probably a bit out of the scope of my physics I class. So I decided, this time would be different! I would construct an apparatus.

To begin to overcome the dielectric breakdown of air I had to find a good, accurate figure of what that might be. I found this value to be 3×10^6 V/m.[1] This was a good piece of information to start with, it gave me an idea of the amount of voltage I would need to run to be able to overcome a gap. Then the search for something that could produce this type of voltage began.

This problem was solved for the project when a good diagram of how to build such an apparatus was located. In the search for such a good diagram I came across an old article in a magazine, Popular Science, that was able to tell me how such a device could be constructed. It also helped that it had a description of where to get the items needed to devise such a construct as well as some safety tips[2].

Once the topic of safety was broached, it seemed logical to find out a bit more information about what these voltages could do to an unwary person, so another book from the physics library was consulted on this matter. It turns out that there is an inherent danger although

[1] Paul Tipler, *College Physics* (Worth, 1987), 467.
[2] H. Strand, *Popular Science* 184, 110 (1964).

it is fairly low, depending on the contact that the device makes with the target and the amount of time that the two spend in contact together[3].

After the preliminary research was completed, it was time to build. I called around to several neon sign shops to find a transformer, because they do something very similar to what I was trying to do inside of a contained environment with noble gasses. I was able to locate a suitable part, a 9kV 30mA transformer from an old sign, and the project began in earnest.

It was fairly simple to put together, I used wood to insulate the apparatus from the ground (in this case, the metal bars in the floor of the concrete surface I anticipated putting it upon) as well as insulated wires capable of carrying the 9kV to the target rods. I used a 12 gauge solid wire for transmission, a heavy duty 3 pronged plug for my initial power supply from the wall to get the most consistent power flow, and straightened coat hangers for the "ladder" itself that I sanded the paint from to allow for easier transmission. A diagram of the basic set up used for construction is included in appendix. A.

A foot switch was offered for safety and the apparatus was taken in and tested under the watchful gaze of Dr. Stewart to ensure that there were no accidents with the handling of the high voltage equipment. After successful testing the device was left in the physics lab until presentation day.

The purpose of the device, and science behind it is the topic of the next few paragraphs. While a Jacobs Ladder is not a terribly useful device, it can be kind of impressive. The plasma arc that travels between the leads can be exciting to watch. The truly fun part of how it works however is in the fact that the arc moves up the wires "climbs the ladder," as the case may be.

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[3] A.D. Moore, Electrostatics exploring, controlling, and using electricity (Laplacian Press 1997), 19-20.

When the device is activated, a voltage that is a percentage of the full voltage[4] appears across the wires at the point where they are closest together, where the electric field is highest. The voltage then drops to a lower value because the impedance of the arc between the wires is lower. The arc heats the air fairly quickly because it is very hot and the hot air begins to rise. As the arc rises, its impedance increases, and the voltage between the wires rises. Eventually the arc gets so long enough that the voltage is not sufficient to sustain it, and the arc goes out. Then the voltage rises to its full open-circuit value, and the arc forms again at the bottom. There is also a magnetic force causing the arc to move in an upward fashion but this effect is not the driving force in moving the arc in an upward path[5].

This is about all the project was meant to be able to show, that the dielectric breakdown of air can be overcome and that the values are consistent with the measurements that have been made on it. This apparatus really has very few functions besides making an appealing lights display. It is capable of setting things on fire, especially paper products from the arc itself and should be able to score, if not break CD-ROMs.

I would say this project was a success. I wanted to build something simple that was easily able to show the effects of air as an insulator could be overcome with charged potential between two surfaces. This apparatus clearly shows this. While I was hoping for a flashier display of plasma, and the arc does not always cooperate and move upwards because of the wires being a bit bent still from their original shape as coat hangers, I think my project was successful in its ability to show the basic mechanics of potential and electricity moving from areas of high potential to areas of lower potential in an attempt to complete a circuit.

[4] This voltage is a percentage because the transformer is not 100% efficient.
[5] Strand, 110.

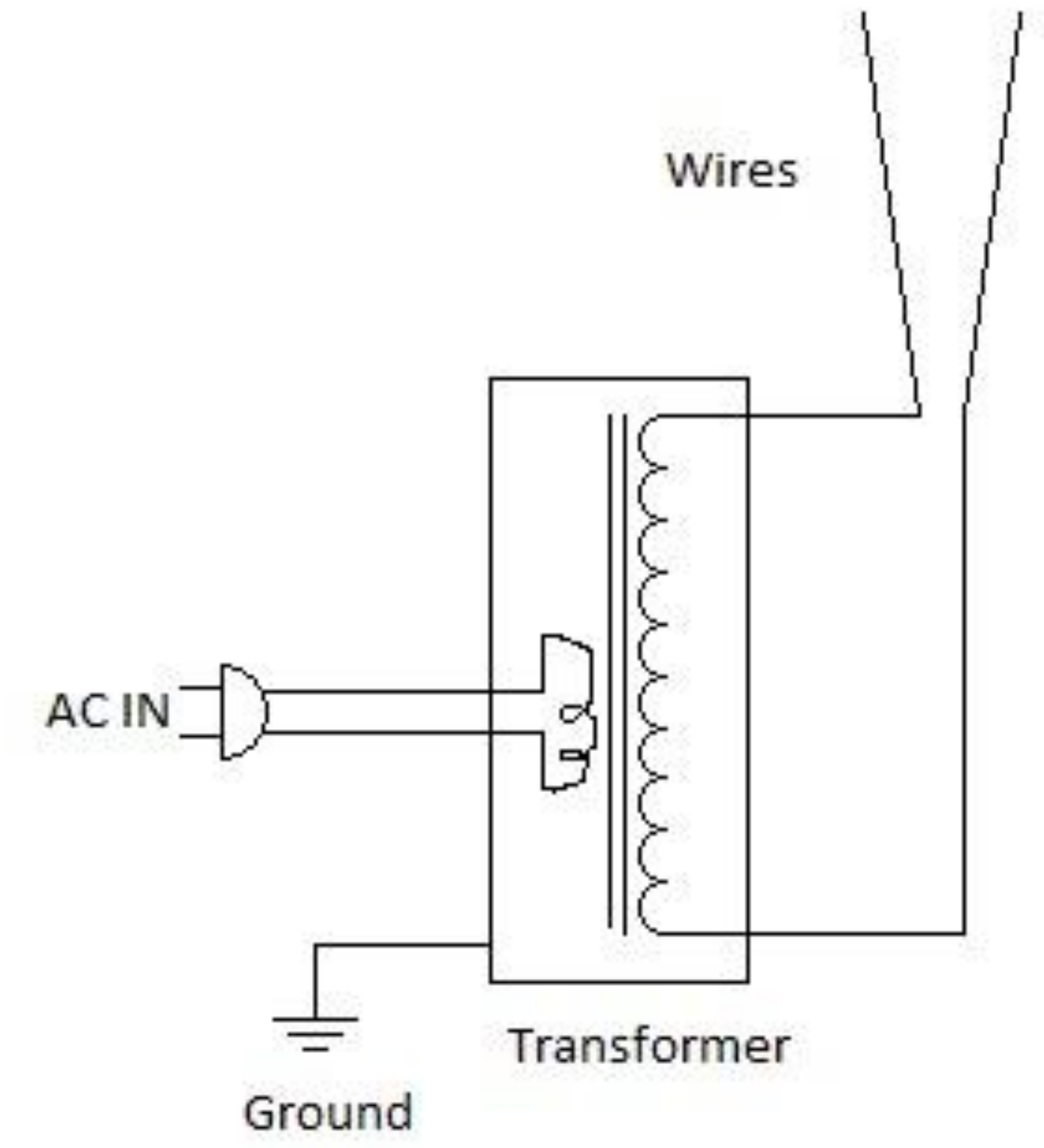
Works Cited

Moore, A.D. *Electrostatics exploring, controlling, and using static electricity*. Morgan Hill: Laplacian Press, 1997.

H. Strand. *Popular Science.* Issue 184, 1964.

Tipler, Paul A. *College Physics*. Worth, 1987.

Appendix A



This is a simple diagram of the construction of the ladder.