## P4_05 Many Abilities Some Consider to be Unnatural

R. Savage, T. Rawlins, A. Hammerton, R. Dev Choudhury

*School of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH*

November 20, 2020

**Abstract**

In this paper we explore some basic physical concepts linked to the ability of casting bolts of lightning from one's fingers. We find that, if two parallel bolts are cast, they attract each other with a force of 120N, additionally the power of each bolt is found to be $10^{13}$W.

**Introduction**

In Star Wars the Sith Lord Sheev Palpatine, also known as Darth Sidious was capable of utilising the ability Force Lightning. With this he could unleash devastating continuous bolts of lightning from his fingertips to strike at his opponent. Sidious was very proficient with this ability, mastering it to the highest degree. Lightning bolts can carry between 5kA and 200kA of current [1], given that Sidious' mastery of the ability, we think it would be fair to say he's capable of conjuring at least 10kA, this amount of current is definitely capable of killing.

**Theory**

Whenever an electrical charge moves, it causes a magnetic field to be generated. The strength of the magnetic field created by a current can be calculated using the Biot-Savart Law:

$$dB = \frac{\mu_0 I dl r}{4\pi r^2} \tag{1}$$

where $B$ is the magnetic field strength, $I$ is the current, $\mu_0$ is the permeability of free space, $l$ is the length of the wire and $r$ is the perpendicular distance from the wire. If we model the lightning as a straight line of current as demonstrated in Figure 1, by considering only the radius perpendicular to the current, the Biot-Savart law becomes:

$$B = \frac{\mu_0 I}{2\pi r} \tag{2}$$

At 1mm from the lightning bolt, the magnetic field strength would be 2T, this is a considerably large field strength when compared to the magnetic field of a typical MRI scanner which is 1.5T [2]. However this produced magnetic field quickly decreases in strength as its strength is inversely proportional to the distance from the current.
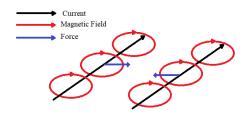


Figure 1: The magnetic field around two parallel lines of current and the direction of the force between them.

However, Sidious often uses both hands to hurl lightning at his enemies, and if each bolt is producing a magnetic field then there would be some interaction between them. With both hands out-

stretched, we estimate that the bolts would be about 0.5 meters apart.

Using (2), the magnetic field at 0.5m is $4 \times 10^{-4}$T. The force that this magnetic field will exert on the second bolt can be given by:

$$F_2 = B_1 I_2 l \tag{3}$$

where $F$ is the force on one bolt carrying the current $I_2$. Since we are assuming that $I_1 = I_2$ (3) can also be combined with (2) to give:

$$F = \frac{\mu_0 I_1^2 l}{2\pi d} \tag{4}$$

where $d$ is the separation between the two bolts of lightning.

We take the length of the lightning bolts to be 3m, as this would be a suitable distance for Sidious to attack from while remaining out of reach of his opponent's weapon. Using these values we obtain a force of 120N acting on each bolt in an inwards direction, i.e. each bolt is attracting the other with a force of 120N.

This is a considerable amount of force which would likely result in the bolts quickly being drawn together and as they do, the attractive force would become even larger due to it being inversely proportional to the separation of the bolts.

Lightning typically only lasts for a fraction of a second, but in this case we're considering a continuous current. The power of a single bolt of lightning can be calculated using:

$$P = IV \tag{5}$$

where $P$ is the power and $V$ is the voltage of the lightning, which can be up to $10^9$V [3]. Using (5) we estimate that the power output of a single bolt of lightning could reach $10^{13}$W. For comparison, the average rate of energy consumption of the entire human population in 2008 was $1.65 \times 10^{13}$W [4].

### Discussion and Conclusion

In conclusion, the Force lightning produced by Darth Sidious, which can be maintained for extended periods of time could power the entire human population and would more than likely kill any opponent it impacts, especially if maintained for several seconds.

The 120N attractive force between the two bolts of his lightning would likely cause the bolts to accelerate rapidly towards each other, given that their masses would be very small. However, given that powerful Force-wielders are capable of lifting heavy objects through telekinesis, it is not unreasonable to assume that this attraction could be easily overcome.

Based on our calculations as well as several other factors that we have not discussed (i.e. the electromagnetic radiation produced and the heat released from the bolt as it passes through the air), it is safe to say that Darth Sidious' signature ability would be very unstable and deadly, not only to the desired target but anyone within the immediate vicinity and likely himself, since lightning can heat the surrounding air to $50,000^oF$ or about $27,760^oC$ [5].

### References

[1] V. A. Rakov, Lightning Discharge and Fundamentals of Lightning Protection, Journal of Lightning Protection **4**, 7 (2012).

[2] https://www.gehealthcare.co.uk/feature-article/15t-compared-to-30t-mri-scanners. [Accessed 19 October 2020]

[3] https://www.nationalgeographic.com/environment/natural-disasters/lightning/#:~:text=Cloud%2Dto%2Dground%20lightning%20bolts,one%20billion%20volts%20of%20electricity. [Accessed 20 October 2020]

[4] https://www.climatecentral.org/blogs/helpful-energy-comparisons-anyone [Accessed 26 October 2020]

[5] https://www.weather.gov/safety/lightning-temperature#:~:text=Air%20is%20a%20very%20poor,the%20surface%20of%20the%20sun).