How Does Lightning Work? A Better Description of Electrical Discharge.

By Eric Mugisha Nzivugira

University Physics II

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Teacher: Dr. John Stewart

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I. Introduction

"There are only three things that can kill a farmer: lightning, rolling over in a tractor, and old age". ~Bill Bryson. As this quote suggests, lightning is one of the most dangerous and unpredictable disasters that menaces our species. In the United States, more than 1000 people are struck by lightning, causing an average of 300 injuries each year (Zavisa 2000).Over the past centuries, lightning has been a mystifying phenomenon to mankind. From ancient to more modern civilizations lightning has played an important role in religion and mythology, going from being a respected and terrifying divine tool of punishment to a symbol of power (Uman 1987).As years passed, many intellectuals tried to explain lightning, but many of them failed. It was not until Benjamin Franklin performed the "kite experiment" that he explained how lightening uses electricity (Stolzenburg 2008).Unlike our benighted ancestors, people were able to understand the lightning phenomenon and more scientists started to explore lightening in depth. However, some of the lightning mysteries can't be resolved up to now; such as predicting where the lightning is going to strike next.

The purpose of this paper is to explain how the lightning phenomenon works using a more electrical based approach, specifically the electric discharge. According to WordWeb Dictionary, an electrical discharge is "an electrical conduction through a gas in an applied electric field" (WorldWeb 2009). Living in a world where the weather changes from time to time, we often only see the lightning strike and hear the thunder. As a result the most curious of us ask themselves questions like how do the clouds become electrified? What is the origin of the electric discharge in the atmosphere? How does that electric discharge produce the lightning and that powerful sound of a thunderstorm? All these questions are going to be answered through this

paper using a scientific approach. Using the charge separation theory, a detailed explanation on how the clouds become charged will be given. Moreover, the electric discharge that takes place in the atmosphere is going to clarified using the electric field and electric potential approaches in addition to the capacitance.

2. The Birth of Lightning

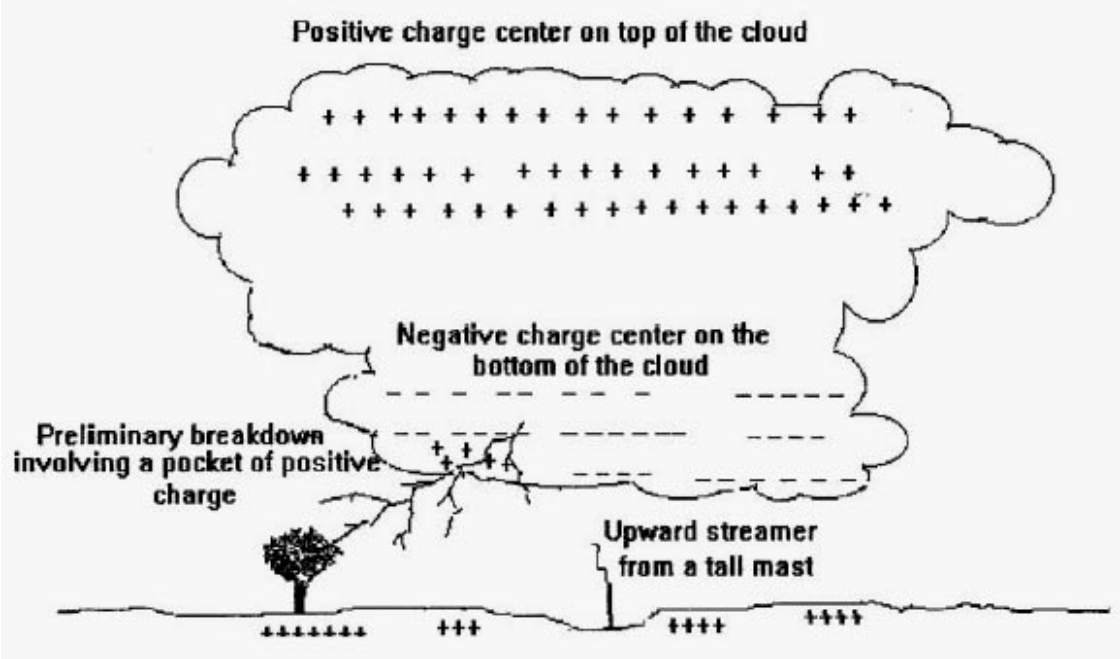
According to the Columbia Encyclopedia, "lightening is an electric discharge accompanied by thunder, commonly occurring during a thunderstorm" (Encyclopedia 2010). Lightning is a phenomenon that results from a collection of different phenomena at different times. In fact, it begins with a process that is much less mysterious: the water cycle (Zavisa 2000). The majority of people have probably heard that the famous water cycle process generates rain, but it is also capable of generating lightning. The water cycle starts with evaporation, which is a process by which water evaporates due to the heat from the sun (Blakeslee 2000). As this evaporation goes on, hot masses of air are lifted upward in the atmosphere.

From early Physics classes, it has been emphasized that the atmospheric pressure and temperature decrease with an increase in elevation. Therefore as these air masses go up in the atmosphere they get colder and colder to only turn back into a liquid state; this process is called condensation (Zavisa 2000). Due to different types of winds, the warm and humid air is lifted after evaporation, and as it cools and condenses it generates droplets that will later create clouds that can develop into a thunderstorm (Bentley 2010).The clouds seen every day are divided into different types and not all of them generate lightning. Most studies showed that the cumulonimbus or anvil cloud type, also referred as the thundercloud or thunderstorm, is the

cause of most lightning cases (Uman 1969).This does not mean that other type of clouds cannot create lightning, but this paper will focus the cumulonimbus type of clouds only.

Now that the process of cloud formation has been explained, let us return to the question of how the clouds get electrified. Several theories about the genesis of electricity in the process of lightning have been developed but this paper is only going to focus on two of the most relevant theories. Everyday experience shows that lightning takes place in different areas and either happens inside the clouds or between the clouds and the earth. Therefore, there three types of lightning: the one that takes place within a one cloud or intracloud, the one between one cloud and another or intercloud, and the terrorizing one that takes place between the cloud and the earth (Encyclopedia 2010). Both theories explain the origin of electricity depending on where the lightening happens.

The first theory explains where the electrification that later generates the intracloud and intercloud electric discharge is born. This theory suggests that as masses of warm air rise vertically, the particles contained in them collide with other particles in masses of cold air descending, therefore creating a huge sorting-out of charged water drops (Thone 1933).This is explained by the Physics principle of charging by friction. The particles in the rising air mass lose electrons during the collision of the two air masses while the descending air masses gain the electrons hence creating a positively charged upper region and a negatively charged lower region (Zavisa 2000). A common example of this electrification of two masses of air is when your car gets charged as you drive it through the dry air.

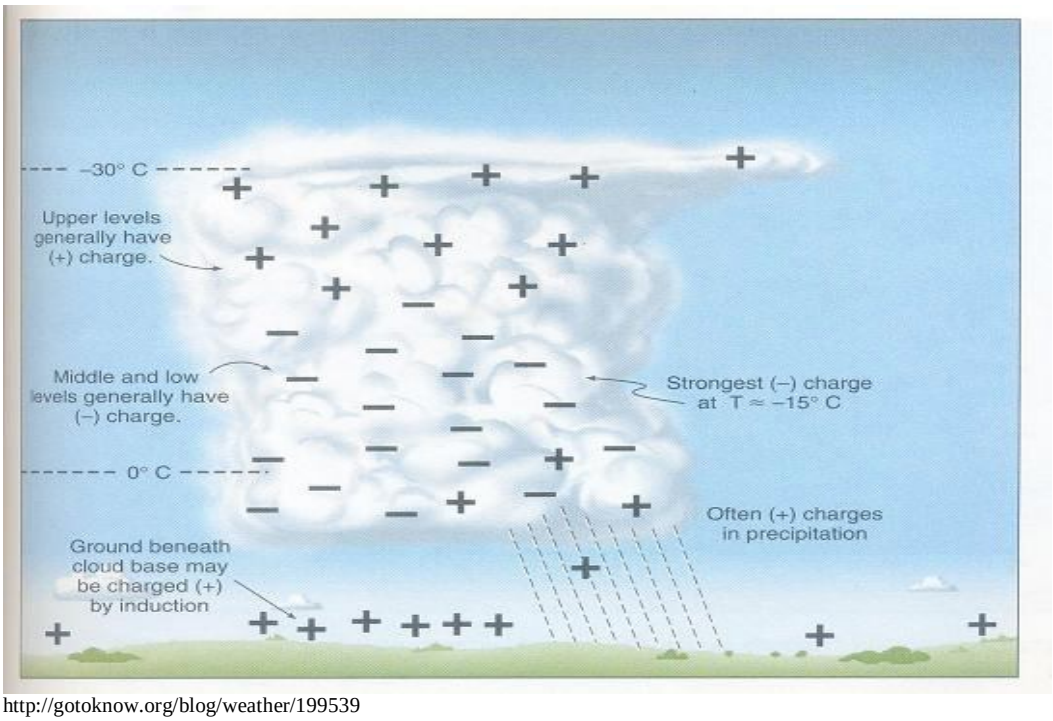


http://electrical-engineering-portal.com/characteristics-of-lightning-strokes

Figure 1. Charge distribution within a cloud.

The second theory explains where the electrification that generates a lightning strike between a cloud and the earth comes from. In the previous section, it was pointed out that cold masses of air descend due to gravity and that they carry a negative charge. In Physics, charges generate a field that decreases with distance and increases with the quantity of charges. As the negatively charged masses of air keep descending and more charge accumulates, the earth starts to feel the electric field from the negatively charged air mass (Zavisa 2000). Normally, the ground is neutral and this property is used frequently in electronics to ground devices. As the negative charges accumulate in the lower part of the cloud electrons start to get pushed away deeper in the region where the electric field is acting on the earth (Thone 1933).This process is a model for the principle of charging by induction in Physics. Dr. Stewart stated that "An object is said to be charged by induction if a fixed charge is brought near a neutral conductor causing

charge separation and the conductor is then grounded, removing separated charge not held in place by the fixed charge, thus leaving a net charge on the conductor" (Stewart 2011). After the electrons are pushed away towards the ground, the ground close to the lower part of the cloud becomes positively charged.



http://gotoknow.org/blog/weather/199539

Figure 2. Charge distribution between the bottom of the cloud and the ground

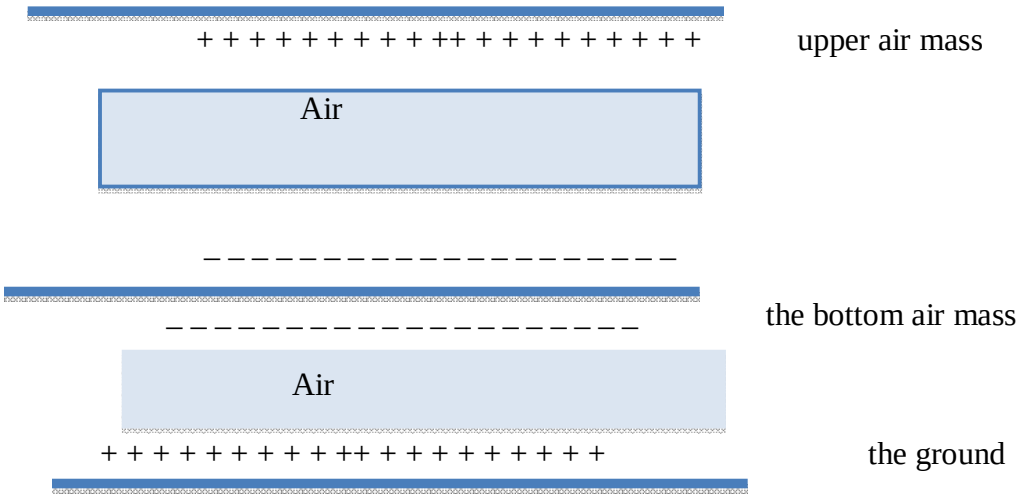
One question arises from these two theories: why do these charges in the two masses of air not attract each other and return to the stable state, since in physics opposite charges attract and same charges repel? It is important to note that during the water cycle different types of vertical winds act on the rising warm air, therefore creating a force that counters the force from the electric field between the two masses of air (Thone 1933).What happens is that as warm masses of air carrying a positive charge are rising in the atmosphere, the particles that make the big drops carrying negative charge are attracted by gravity despite the vertical winds. As these masses of ionized air separate, the medium between them is going to be the air. Normally the

ambient air is not a conductor. It is an insulator or dielectric with a dielectric constant of approximately one.

One more thing to note is that it is not always the upper layer of air mass that is going to be positively charged. As Dr. Stewart likes to say, “The universe is not that cooperative” (Stewart 2011). Depending on the conditions and on the types of clouds that are present, the charge distribution can change to be negatively charged in the upper layer and positively charged for the bottom layer of the air mass (Stolzenburg 2008).In this case the ground is going to be negatively charged as a result of charging by induction.

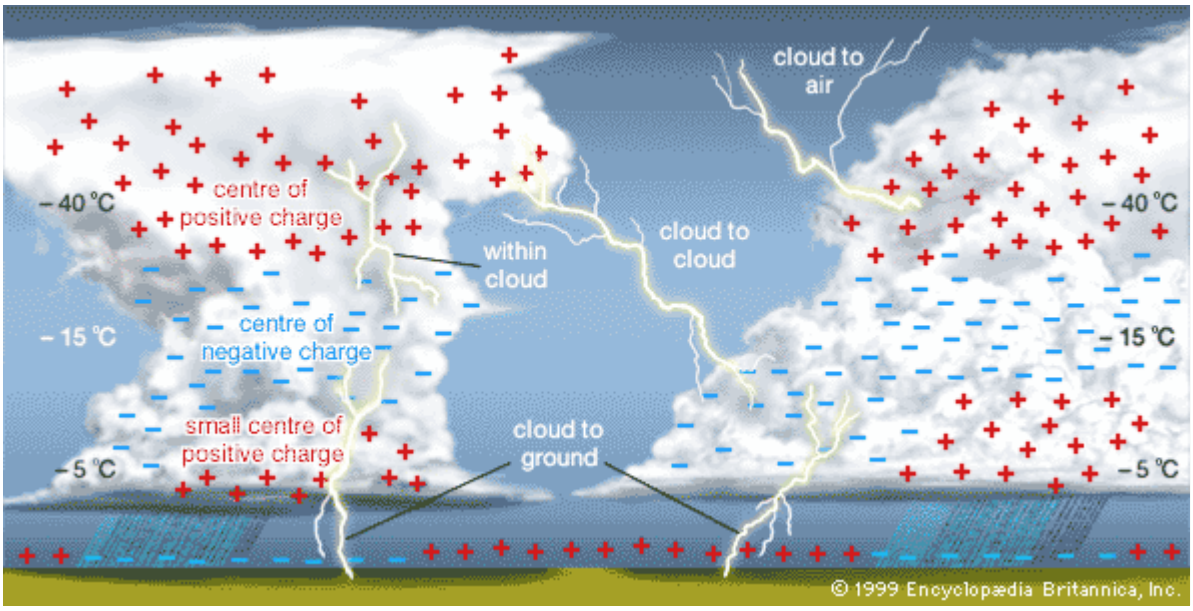
3.**The Electric Discharge**

We saw earlier that as charge separation takes place in the atmosphere, different mediums with different charges are created. With the upper layer of the cloud charged negatively and the bottom layer charged positively, in addition to the negatively charged ground, this model is a perfect representation of a system of parallel plate capacitors where we can calculate the capacitance. In this case air acted as the dielectric for our capacitors.



As we saw earlier, an electric discharge is an electric conduction through a gas in an applied electric field. What causes an electric discharge? Wherever we have two opposite charges of static electricity, they always tend to unite and end the state of tension that exists between them (Thone 1933). As the electric charges continue to build up, the electric field between our plates (masses of air and the ground) increases more and more. This field increases to the point that the air surrounding the clouds/earth become separated into positive ions and electrons, therefore causing the air to break down and thus allowing current to flow in an attempt to neutralize the charge separation (Zavisa 2000).In other terms, the air (dielectric) becomes ionized, thus becoming electrically conductive so our capacitor reaches the breakdown voltage. When the air around the clouds and the earth breaks down, the charges (electrons) leap the gap between the two charged mediums hence initiating a lightning bolt (Blakeslee 2000).In Electricity, whenever there is a flow of electrons in a medium, an electric current is generated, and heat is released as a result of the movement of electrons. Therefore, since there is an enormous amount of current in a

lightning strike, an enormous amount of heat is subsequently released, thus creating the brilliant white-blue flash that we see (Zavisa 2000).



http://severe-wx.pbworks.com/w/page/15957987/Lightning

Fig3. Picture illustrates charge separation for various types of lightning

Now that we know where the lightning we see comes from, what about the sound that we hear? As seen above, the bolt of lightning releases a massive amount of heat. As a result of this heating, the air around the lightning channel becomes so hot (hotter than the sun) that it explodes (Thone 1933). This powerful explosion generates a shock wave that is transmitted as a sound wave in the medium surrounding the lightning strike (Blakeslee 2000).This is where the powerful sound of the thunder that we hear after the lightning comes from. The reason why we hear the thunder after the seeing the flash from the lightning is because the speed of the light in

the air (around 186,000 miles per second) is greater than the speed of sound in the same medium (0.22 miles per second) (Zavisa 2000).

As stated at the beginning of this paper, lightning can cause a variety of injuries and even death. Here are some safety rules from the American Red Cross to help avoid those injuries. Most of the time lightning aims for projections. Therefore, it is important to avoid tall trees, or if you are in the forest, take refuge in short trees. If you're in the fields, lie down and you will have at least the same chance as the worms and toads to not be struck.

4. Conclusion

All in all, this paper reviewed the process of lightning from its start where evaporation is initiated to the end where the thunder occurs. Moreover, the paper explained the electric properties of the lightning and used the electrical discharge to explain specifically how lightning works. In a world where every source of energy is being exploited, the massive heat and current generated by the lightning can be used to accommodate demands in energy. Once this done, it could save millions of trees that are being destroyed to produce energy, and save the world.

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