Answer Question #65306 – Physics – Electric Circuit

It was a dark and stormy night.4 A cloud having a potential difference of $8.5 \cdot 10^8$ V relative to a nearby tree discharges to the tree, delivering $1.75 \cdot 10^9$ J of energy. Determine the capacitance of the cloud-tree system, as well as the amount of charge if the discharge is complete (i.e., the final potential difference between the cloud and the tree is zero). How many electrons does this amount of charge imply?

Solution. The energy charged the capacitor can be found by the formula

$$E = \frac{CV^2}{2} = \frac{qV}{2}$$

where q – the charge of the capacitor, V – potential difference, C – the capacitance of the capacitor.

At the initial moment of the energy of the system cloud-tree is equal to $E_1 = \frac{CV_1^2}{2}$, $V_1 = 8.5 \cdot 10^8 V$. After discharging the energy of the system cloud-tree is equal to $E_2 = \frac{CV_2^2}{2} = 0$, $V_2 = 0$V.

According to the law of conservation of energy delivered energy is equal to

$$E = E_1 - E_2 = \frac{CV_1^2}{2}.$$

According to the condition of the problem $E = 1.75 \cdot 10^9 J$. Hence

$$C = \frac{2E}{V_1^2} = \frac{3.5 \cdot 10^9}{(8.5 \cdot 10^8)^2} = 4.84 \cdot 10^{-9} F.$$

On the other hand $E = \frac{qV}{2}$ therefore $q = \frac{2E}{V} = \frac{3.5 \cdot 10^9}{8.5 \cdot 10^8} = 4.12C$. The total charge can be represented as $q = eN$, where $e = 1.6 \cdot 10^{-19} C$ – the charge of the electron, N – the number of electrons. Hence

$$N = \frac{q}{e} = \frac{4.12}{1.6 \cdot 10^{-19}} = 2.57 \cdot 10^{19}.$$

Answer. $C = 4.84 \cdot 10^{-9} F$, $N = 2.57 \cdot 10^{19}$.