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P2_3 Balloon Ovens

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Abstract

In this paper we investigate the amount of energy which can be extracted from a balloon which has built up charge due to the Contact Electrification. We then investigate the possibility of using charged balloons to generate enough electricity to cook a whole chicken. We found that 3.0×10^{10} balloons would be needed to cook the chicken so it would be safe for consumption. We conclude that the electricity generated from electrically charged balloons likely has no practical application.

Introduction

Contact Electrification (CE) is the process where two objects become electrically charged via contact with each other. The results of this effect can be seen as lightning and allowed our ancestors to produce fires for the first time. This phenomena has been recorded for over 2000 years [1], however, is still poorly understood. The potential applications of research in this field are important to improving safety in manufacturing and could possibly lead to a new source of sustainable energy. In this paper, we investigate the potential use of the CE produced in an everyday scenario of a rubber balloon gaining charge by being rubbed against another insulator. We then calculate whether this could realistically be used to cook a whole chicken.

Theory

When a rubber balloon is rubbed against another insulating material, such as wool, the balloon gains a net negative charge and the other material is left with a net positive charge. This potential difference causes an electric field to be produced. When the balloon makes contact with a conductor, the electrons flow through the conductor causing an electric current. In a circuit, a current could be passed through a resistor and due to its resistance to the current, heat is generated. This means that, by modelling the chicken as a resistor, the electricity from the balloon can be used to heat the chicken.

To estimate the charge typically built-up on a party balloon, we will assume that the force due to this charge is enough to allow the balloon to resist the force of gravity, F_g, at a distance of $1mm$. This assumption is based on the common party trick of rubbing a balloon against an insulator and making it "stick" to a wall. This will allow us to obtain a practical value for the charge of the balloon. Starting with Newton's second Law,

$$F_g = ma, \tag{1}$$

where a typical value for party balloon mass, m, is assumed to be $1.3g$ [2] and acceleration due to gravity, a, is $9.8ms^{-2}$. We find that the force needed is $0.013N$. Then, using the equation for the force, F, between two charged plates:

$$F = \frac{q_0}{4\pi\epsilon_0}\int_0^R \frac{\sigma}{r^2} dS, \tag{2}$$

where q_0 is the charge of the second insulator, $\sigma = q/S$ is the charge density of the balloon, q is charge of the balloon, $S = \pi r^2$ is the surface area of the balloon, r is the distance between the balloon and the insulator - $1mm$ - and R is the radius of the balloon. Solving the integral, equating this to Eq. (1), we can rearrange this to find the charge of the balloon, q, by assuming the charge of the balloon and insulator, q_0, would be equivalent. This gives a charge of $1.7 \times 10^{-9}C$. Using the force and charge calculated, we can calculate the electric field, E, produced to be $7.6 \times 10^6 NC^{-1}$ using the following equation:

$$E = \frac{F}{q}, \tag{3}$$

assuming a uniform electric field. Then use the following equation to find the voltage, V:

$$V = Er, \tag{4}$$

which was found to be $7600V$. This can then be used to calculate the work done by the electric field, W, which was found to be $1.3\times10^{-5}J$ using the following equation:

$$W = Vq. \tag{5}$$

Next, we calculated the energy needed to heat a whole chicken from room temperature ($20°C$) to $85°C$, the temperature required for the chicken to be safe for consumption [3]. Assuming the mass of a typical chicken, m_c to be $1.7kg$ [4] and the specific heat capacity of chicken to be $3.5 \times 10^3 Jkg^{-1}K^{-1}$ [5] the energy required, Q, can be calculated using

$$Q = m_c c \Delta T, \tag{6}$$

and was found to be $3.9 \times 10^5 J$. Dividing this by W gives the number of balloons needed to heat the chicken to be 3.0×10^{10}.

Discussion

Due to the number of balloons needed, the electricity resulting from charged balloons would not be useful in a realistic scenario. In these calculations, we assumed that the process of heating the chicken would be 100% efficient which is an unrealistic assumption and would lead to our result to be an underestimate. Other effects not accounted for such as the temperature of the balloon, could also affect the result as this has been shown to effect the amount of electron transfer [1], however, it is poorly understood. It is possible that by adjusting the temperature at the point of CE and using a material with a higher surface charge density [1], the electricity generated could be a realistic source of sustainable energy.

Conclusion

We calculated the number of balloons needed to cook a chicken to $85°C$ was 3.0×10^{10}. We conclude that the energy generated by electrified balloons does not have a practical application due to the number of balloons required. However, with further research into this phenomenon, it is possible that this process could be used as a realistic source of sustainable energy.

References

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