Electric Discharge System Based On Franklin Bells

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***Abstract*—Franklin bells are an innovative and high-risk project to perform in the science lab, since it involves high voltage electric discharges but nearly zero current. Published in literature initially was a prototype that made use of electric charges produced on a TV screen. Using the electric charges as source of high voltage, these charges were concentrated on a 20 x 30 cm aluminum sheet adhered to the screen. The system consists of a metallic sphere tied to a thread, which hangs from an isolated support situated between two metallic cans, A and B, one of which is connected to an aluminum sheet and receives all electric discharges, while the other is grounded for its discharge. Its operation is simple: at the discharge of the TV on the A can, a polarization of the sphere occurs as well as an attraction toward the can followed next by a transfer process, equilibrium of charges, and repulsion toward the B plate to transfer one part and its final discharge to ground. The charge-transfer and discharge process produce the chime of the sphere when these touch the cans. However, this prototype is not very practical for education purposes in our labs. In this work, we propose a wood prototype that uses a simple circuit and two 1.5V batteries that produce discharges of 1,609V with a small current, enough to demonstrate the original effects with lower risk. For the design of the circuit, the Multisim software program was used to determine current and voltage.**

Keywords—Franklin bell; electrical fields; Circuit.

I. INTRODUCTION

Benjamin Franklin is credited with creating Franklin bells (FB) in the 18th century; his general objective being the detection of an electrical field produced by an electrical discharge generated by a cloud thus creating a sound [1-6]. Franklin bells consist of a pair of bells located at a distance and one conductive sphere among them that produces the chime. Its operation occurs when one of them receives an electrical discharge while the other bell conducts the discharge to the ground

Therefore, when an electrically charged cloud crosses above the device and produces the discharge on the A bell, we can physically appreciate the separation of the charges of the conductive sphere and its coulomb attraction, followed by the transfer and equilibrium of bell-sphere charges [7-10]. Next, the repulsion that conducts and transfers it to the B bell equilibrates its charge that is conducted by the bell to the ground. This process produces the chime and sound of the collisions of the metallic sphere against the bells, resulting in the observation and detection of large electrical discharges of the clouds in line with the work originally presented by Franklin.

Because of the risky design used by some educational institutions to show the electrical effects through a system [9], namely the TV screen, aluminum sheet, and two cans of the same material (a device that was considered highly dangerous [10] to work with our students in our physics lab) we felt motivated to implement this work as a safer alternative. In the model proposed by the FB, an electric circuit able to transfer voltage and reduce the current almost to zero replaced the capacitor formed by the aluminum foil and the TV screen. This model uses two 1.5 V batteries and produces discreet discharges of 1,609V; enough to demonstrate the electrostatic effect proposed by Franklin while posing no risk to the student. Additionally, the Multisim software was used for the calculation and design of the electrical circuit. This circuit was connected to a pair of aluminum plates along with an aluminum wrapped Styrofoam ball.

The operation of the FB depends initially on the discharge [1] of the circuit on plate 1 and the polarization of the conductive sphere that is attracted by the plate, to which half of its electric charge is transferred. This in turn produces the repulsion that exists toward plate 2, to which half of its charge is transferred to, again being repelled and attracted by plate 1, which in this moment, receives a new discharge from the circuit and causing the charge-discharge cycle between the plates to begin again. This way the sphere experiences continuous harmonic movement and chiming between the plates.

An advantage of this new FB design [4,17,18,20] is that it reduces risk during use when performing activities in the science lab, since the electrostatic charges are deposited on the plates and are very localized within the system. Although, if the plates are touched simultaneously, or when some electronic device or flammable system is put close to the plates during their operation, this could produce burns to the student.

When studies about electrostatic effects [3,6,8,10] under controlled conditions are performed, an improvement in the safety of human resources, the operation of electronic and electric equipment, and the management of hazardous materials (which on contact with electrical fields can have devastating effects) is observed. The implementation of this work is described in subsection I.2, where the electrical circuit diagram [12,13,15,16] is described and through which the electrical discharges are calculated, these electrical discharges being the source of energy to the prototype. In subsection I.3, a description of the charge-discharge physical process is presented. In section II, materials and methods that were used for the implementation of this project are described. In subsection II.1 the procedure carried out in the construction of the prototype is explicitly shown. Finally, in the last section work conclusions are presented.

II. CIRCUIT FOR ELECTRICAL DISCHARGES

Taking advantage of Multisim, software used to design electrical circuits, a simulation of a circuit for discharge [16] of high voltages and zero currents was performed. This circuit is based on the generation of an electrical field sufficiently large enough to produce the power necessary to produce oscillation amplitude allowing contact between the metallic sphere and the plates.

Fig. 1 shows the circuit beginning with a switch that closes the circuit and activates the voltage source of 3V of direct current. Next, a light-emitting diode lamp (LED) with its respective resistance followed by a transistor that operates as frequency oscillator and creates a square wave, that is, converts direct current (DC) to alternate current (AC).

This is due to the fact that the transformer only works with alternate current. Finally, there is a multiplier power stage formed by diodes that rectify the alternate current to direct current and capacitors that store voltage.

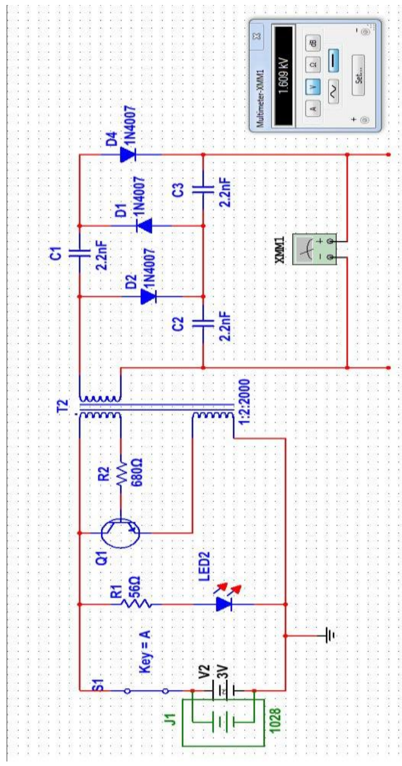

Fig. 1. Image showing the simulation of the circuit, with 3V of direct current (DC) in the left side, a terminal voltage in the right side is obtained in the meter XMM1 of 1.609 KV.

III. CHARGE-DISCHARGE PHYSICAL PROCESS

The electrostatic force created by an electrical field [11,14] is used to move the pendulum that hits two metallic plates (Fig. 2 presents the physical system).

In this system, the transfer of electrons of the discharge produced initially in plate 1 occurs, thus the discharge is conducted by the sphere to plate 2 which, in turn, conducts it to earth ground. Next, figures 3a, 3b, 3c and 3d describe the process itself through the following steps:

(a) The circuit produces a high-voltage discharge on Plate 1, acquiring a negative charge. Generating a uniform electric field, **E**, Therefore, the metallic sphere is polarized with a distribution of surface charge $\sigma = 3\varepsilon_o \mathbf{E}\cos(\theta)$, where attracted to Plate 1.

(b) A transfer process of negative charge from Plate 1 to the sphere occurs, until it reaches equilibrium. In this state they have the same negative charge and the repulsion of the sphere is directed toward Plate 2.

(c) Discharge process of the sphere with negative charge to Plate 2, until it reaches equilibrium. Plate 2 conducts the electric charge to ground.

(d) They reach equilibrium of negative charges of the sphere with Plate 2, causing repulsion, with a force **F** = q**E** Then the sphere is redirected toward Plate 1.

(e) The sphere impacts Plate 1; again, there is an energy exchange with its respective repulsion, so the process repeats, and then moving back to the opposite side, repelled by the force of electrical repulsion.

$$ml\frac{d^2\theta}{dt^2} = -mg\sin\theta + qE\cos\theta \quad (1)$$

where *m* is the mass of the sphere and *l* the wire length.

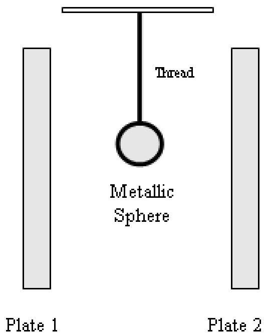

Fig. 2. Physical system used to explain the operation of the proposed system equivalent to Franklin bells, by means of which this work is implemented. It is comprised of two metallic plates and a pendulum with a Styrofoam ball wrapped in aluminum.

In Fig. 2 the metallic sphere carries and conducts the excess of charge from plate 1 to plate 2. Plate 1 is the receptor of electrons captured by the high voltage electronic system. Plate 2 receives electrons from the sphere and conducts them to ground.

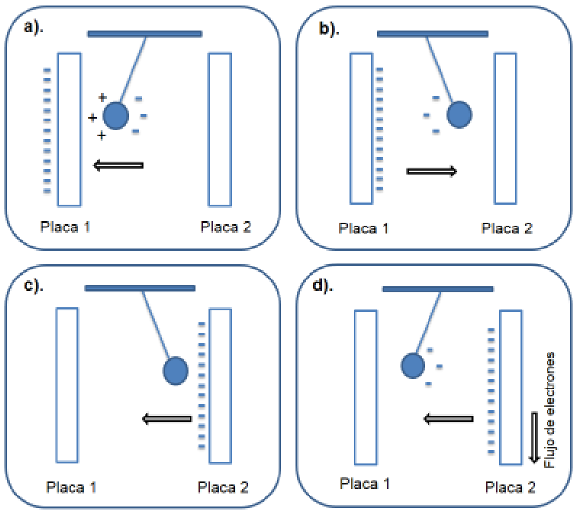

Fig. 3. Stages of the Franklin bells charge-discharge process: Discharge of high voltage in plate 1, polarizing the metallic sphere and attracting it; b) Transfer-equilibrium of charge to end in a repulsive force; c) Discharge-equilibrium of charge ending in the repulsion of the sphere; d) Discharge to ground of plate 2 and a new discharge occurs in plate 1.

IV. MATERIALS AND METHOD

Fig. 4 shows a prototype, which has been built with different materials according to the following method.

(a) Make a wood base with the specifications described at the end of this document (carpenter).

(b) Cut two aluminum plates measuring 18 cm long and 3.5 cm wide; bend a piece measuring 1.5 cm long in each plate and make two holes in the bent part (Optional: blacksmith).

(c) Design the electric circuit.

(d) Verify the position of the LED; carry out this step with care so the electronic card is not damaged.

(e) Introduce the plates through the slots and secure them with ½ inch screws.

(f) Isolate the LED with tape and stick it on using silicone; do the same with the button. Weld the button and LED with the corresponding cables paying close attention to the position of the LED.

(g) Close the circuit, stick it on with silicone and secure it with tape.

(h) Stick the RCA cables that leave the circuit to the edge of the box and tie a knot to the entrance of each hole. Next pass the cables through the holes.

(i) Cut two RCA cables measuring 10 cm long and peel the tips. Unscrew a connector (female), and then weld the cable with an RCA connector with help of the soldering equipment. After, secure them with silicone in the corresponding holes in the wood base. Repeat this step for the other connector (female). Finally, weld a cable to an aluminum plate.

(j) Cut the cables that leave the circuit and that already pass upwards, to the necessary distance to connect them. After that unscrew the RCA connector (male), pass the cap through the cable and weld the cable with the connector and close it. Repeat this step with the other cable and connector.

(k) Pass the thread (non-conductive) through the Styrofoam ball with the help of a needle. Then, wrap the Styrofoam ball with aluminum foil.

(l) Center the eyebolt in the wood arch; once this is done secure the thread to the eyebolt in such a way that it stays in the center of the aluminum plates.

V. CONCLUSION

The explanation of basic electricity concepts in the classroom is important due to the large amount of applications in both the science and engineering fields. Thus, in this work, a proposal of a model for "Franklin Bells was developed in a more compact, functional, inexpensive and less risky form. Now it is possible for any educational institution to acquire it as didactic material. Research shall move forward in the application of this model within the industry, and if possible, to use the energy discharged in several processes and machinery [19] in the industrial field.

In the classroom, the analysis of the discharge circuit can be conducted using varying voltages and discharge currents as well as the physical system itself. Electrical current, voltage, charge area, capacitance, electrical field, and Coulomb force are some of the parameters to be considered in the exposition of this prototype.

Moreover, we are currently working on improving the model in the search for alternate applications of this model in the industrial field.

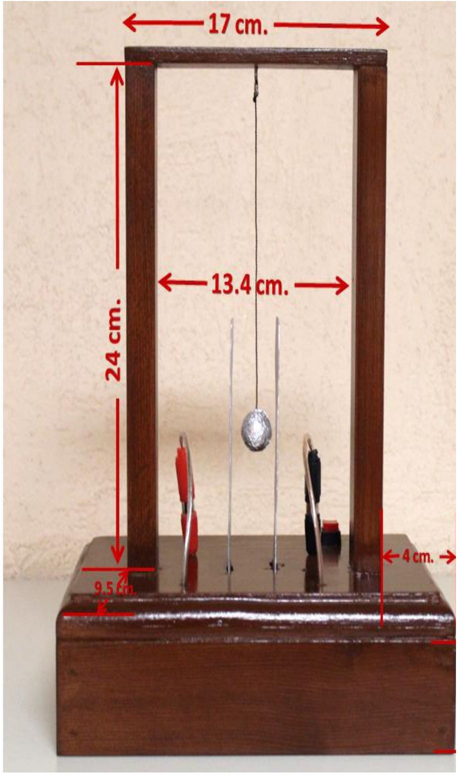

Fig. 4. Proposed prototype model of Franklin bells that reveals the electrostatic effects, discharge and transfer of electrical charges in a basic science lab.

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