CONSTRUCTION AND TESTING OF AN IMPROVISE LEAF ELECTROSCOPE (ILE)

Rex S. Rubidy

ABSTRACT

This study aimed to construct and test the improvised leaf electroscope (ILE) for Physics Laboratory experiments. It was only limited on the construction and testing of ILE. The finished products replaced the existing electroscope and provide hands – on learning experience to the students. The Improvised Leaf Electroscope was made of Erlen Meyer flask as chamber. Its major parts were the following: a) the metal rod which will serve as the stem and the knob b) cork stopper which will hold the aluminum leaves mounted on the metal rod, and c) aluminum foil which will serve as the leaves. The materials needed are locally available and less expensive. Nine samples of ILE were constructed in order to test which samples can produce the highest approximate angle of deflection. Three various ways of test were made with three trials for each testing. Results reveal that copper rod is the best metal stem to use with an approximate measured angle of deflection of 26^0. The appropriate length of the rod is 6 inches with 46^0 approximate measured angles of deflection. And the suitable width of aluminum leaves is 0.5 cm with 30^0 approximate measured angle of deflection. In order to improve the operation of the ILE, it is highly recommended to produce a good quality of plastic rod and woolen cloth in order to attain maximum results and not to depend on the imported rod and cloth.

INTRODUCTION

Background of the Study

Most modern applications of electricity involve moving electric charges or current electricity. Historically, however, the first studies of electricity involved static charges, or electrostatics.

Electricity comes from the Greek word *elektron* which means “amber”. Amber is a petrified tree resin, and the ancients know that an amber rod rubbed with a piece of cloth, will attract small pieces of leaves or dust. A piece of hard rubber, a glass rod, or a plastic ruler rubbed with a cloth will also display this “amber effect,” or electricity (Giancoli, 1998).

Electrostatics is the study of electrical charges and their characteristics. To experimentally investigate electrostatics, some charge–detecting or measuring device is needed (PASCO Scientific. 1999). A useful instrument for studying electrostatic phenomena is the electroscope. This instrument is consist of two thin leaves of gold foil attached to one end of metal rod which is terminated at the other end by a metal sphere. When the metal sphere is charged, part of the charge goes to the gold foils, causing them to repel and diverge. The greater the charge on the leaves, the greater the divergence (Smith & Cooper, 1979).

According to Noah Dorsey "The simple electroscope is consist of a metal case within which, and near its center, is supported in a vertical position by a well-insulated metal strip where a narrow strip of thin foil, preferably of gold leaf is attached to its top.

This strip is usually referred to as the leaf. The strip of metal and the leaf constitute the insulated system of the electroscope. When the insulated system is electrically charged by a suitable switch passing through the wall of the case, the leaf is repelled by the strip, and is deflected from its normal, vertical position. In opposite sides of the case are windows through which the position of the leaf can be observed. Such observation is usually made by means of a microscope mounted with an ocular micrometer (from http://inventors.about.com/library/inventors/blelectroscope.htm.)

The Braun electroscope as, illustrated in Figure 1 which is used in various experiments in Physics Class, is a deflection arm electroscope.

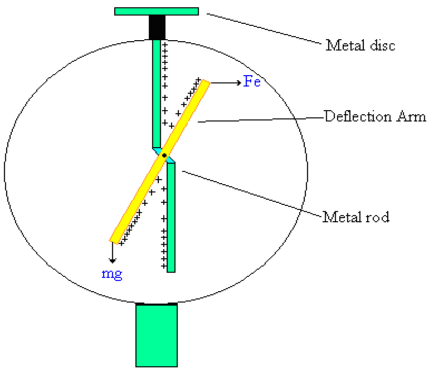

Figure 1. Deflection arm electroscope (Braun electroscope)

The electroscope is made of a metal disc connected to a metal rod inside a circular cylindrical ring. The metal rod is insulated from the outer ring by a rubber gasket; this is to shield the electroscope from the influence of external charges. The deflection arm which has a metal pin through its center of gravity is connected directly to the metal rod, thus it is free to rotate about its center axis. The metal rod is also bent such that the gravitational force acting on the deflection arm causes the arm to reside vertically on the right side of the metal rod the same with the top, left side and at the bottom.

When a positively-charged probe is touched to the metal disc, the positive charges will be induced on the surface of the metal rod and the deflection arm. Then Coulomb forces result in a repulsive force between the like positive charges. This then results in a clockwise directed torque on the deflection arm at the top and the bottom. The deflection arm is then rotated to a certain distance until the Coulomb force is in equilibrium with the gravitational force ($F=mg$) acts on the arm. The amount of deflection is proportional in some manner to the amount of charge induced on the electroscope.

A classical "gold leaf" electroscope is shown in Figure 2. The design is consist of a metal disc on top, a metal rod, and two strips of gold leaf at its lower end. The leaves are protected from air current and a simple scale in degree is provided for measurement. The charged probes are placed near the metal disc, and the leaves would diverge because of the Coulomb force.

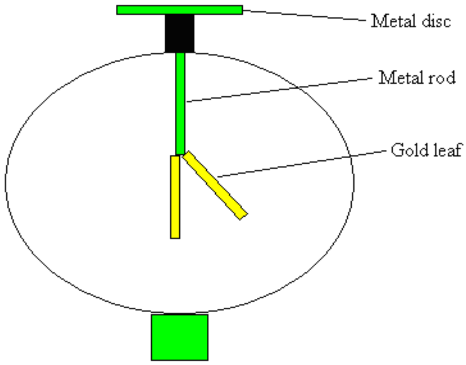

Figure 2. The Classical Electroscope

An electroscope developed by Sargent-Welch Scientific Company is used in the Physics Laboratory of Central Philippine University. This electroscope consisting of aluminum leaves is mounted on a metal rod held by a rubber stopper in a 250 mL Erlenmeyer flask. The round sides of the flask give ample space for the leaves to diverge when charged. The leaves are glued/pasted at the end of the stem.

As per Physics Stockroom Inventory Records for school year 2009 – 2010, a total of 17 units of Leaf Electroscope are in the list. Unfortunately, these 17 units of electroscope are also all in the damaged list. At present, there is no available electroscope that can be used by the students from the Colleges of Agriculture, Resources and Environmental Sciences; Arts and Sciences; Computer Studies; Education and Engineering.

With this situation, an improvised instrument is a must in order for the students to have hands–on learning experience in electrostatics. Thus, an improvised leaf electroscope was designed and developed. Apart from hands-on learning experience for the students, the developed improvised electroscope will also give ease and convenience to the lectures and demonstrations of the faculty members teaching electrostatics.

This improvised electroscope is very much cheaper than the one already available in the Physics Stockroom. If the department will purchase one set of the leaf electroscope, it will cost about P4, 900.00 as of July 15, 2009 price quotation. The Improvised Leaf Electroscope (ILE) will approximately cost only P900.00. This improvised instrument has an advantage over the old one in terms of the availability of the aluminum leaves. The old electroscope uses imported aluminum leaves from the U.S.A. that cannot function if the aluminum leaves have scratches while the leaves of the improvised electroscope can be easily replaced because the material needed is locally available.

Objectives of the Study

The main objectives of the study are to construct and test the improvised leaf electroscope (ILE) for Physics Laboratory experiments.

Specifically it aims to:

1. identify the basic components needed for a given system and function;
2. construct an improvised electroscope that will use locally available materials;
3. determine the cost of constructing an Improvised Leaf Electroscope (ILE); and,

4. conduct testing and evaluation of the system in terms of split distance between leaves and angle of deflection.

Scope and Limitation of the Study

The Improvised Leaf Electroscope was primarily designed for Physics Laboratory experiment in Central Philippine University. This instrument was designed based on the specifications and limitations of the materials. The primary material used was locally available. In order to determine the effect of a charged body, vinyl plastic strip was used.

This study was limited only to the construction and testing of an Improvised Leaf Electroscope. It made use of the presently available plastic strip and woolen cloth in the Physics Stockroom in order to test its functionality.

The length of the metal rod was based on the dimension of the Erlenmeyer flask used with an approximate volume of 250 ml and with a measured height and width of 14.5 cm x 8.5 cm, respectively. The rod was set to 10.16 cm (4 inches) for the minimum and 15.24 cm (6 inches) for the maximum length. In order to achieve the best result, the rods used did not go beyond the value set for its length.

The construction, testing and evaluation of the Improvised leaf electroscope was made at EN203, Physics Stockroom in the College of Engineering, Central Philippine University, Jaro, Iloilo City, Philippines. These were conducted by the Researcher, Stockroom Assistants of the Physics Laboratory, and College Physics Students.

Significance of the Study

Central Philippine University would save money from this study because this instrument is cheaper compared to the ones purchased from the Laboratory Suppliers.

The finished product would replace the existing electroscopes and provide hands–on learning experience to the students taking up Physics subjects.

The output of this study would comply with the Association of Christian Schools, Colleges and Universities, Accrediting Agency, Inc. (ACSCU) accreditation requirement on improvisation of laboratory equipment and for technology transfer program of the University through its Outreach Program.

Time and Place of the Study

The study was conducted from March 2015 to August 2015 at the Physics Stockroom, EN312, College of Engineering, Central Philippine University, Jaro, Iloilo City.

METHODOLOGY

Description of the Improvised Leaf Electroscope (ILE)

The improvised leaf electroscope, as presented in Figure 3, has the following major parts:

a. Chamber – It was made from an Erlenmeyer flask that encloses the entire parts except for the metal knob. The flask used had an approximate volume of 250 ml with a height of 14.5 cm and a bottom diameter of 8.5 cm.

b. Metal knob – This is where the plastic strip with a woolen cloth is closely pointed at to allow the transfer of electrons.

c. Cork stopper – This is where the metal knob and the metal rod were drilled at to make sure that these parts would not touch the circumference of the chamber. It has a diameter of 3 cm.

d. Metal rod – Part of the electroscope where two aluminum foil leaves are attached. The materials used for this study were aluminum, brass and copper. It has a fixed diameter of 0.33 cm but its length ranged from approximately 10 cm to 15cm.

e. Aluminum foil leaves – This part is responsible for showing whether there is an electrical charge flowing through the angle of deflection stand. The dimensions of the leaves varied from a width of 0.5 cm to 1 cm with a fixed length of 4 cm.

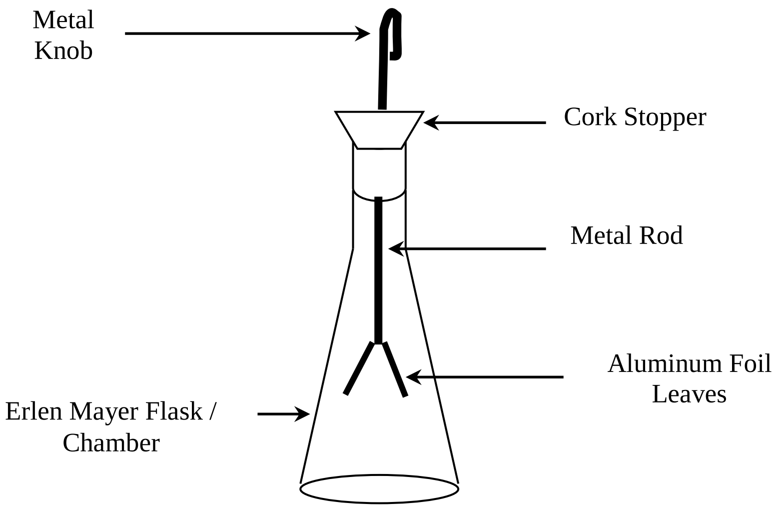

Figure 3. Schematic diagram of the improvised leaf electroscope showing its different parts

Charging the Electroscope by Induction

In order to determine the maximum approximate angle of deflection, the newly developed equipment was subjected to three tests. For the first test, three different kinds of metal rod namely, the aluminum rod, brass rod and the copper rod were used. Next, different sizes of the aluminum leaves which measure 0.5 cm, 0.7 cm and 1.0 cm were utilized. Lastly, the length of the metal rod used for this trial varied at 10.16 cm (4 inches), 12.7 cm (5 inches) and 15.24 cm (6 inches). The length of the aluminum leaves for the three tests was fixed to 4 cm. These were done to determine which sample can create the highest approximate measured angle of deflection.

The approximate measured angle of deflection was determined by mathematically based on the law of cosine ($\cos C = \frac{a^2 + b^2 - c^2}{2ab}$). The leaves will diverge during charging and the approximate distances between the two leaves were verified by taking a picture using a digital camera. Then the distance between the two leaves was measured using a ruler.

Evaluation and Testing of the Finished Design

Final evaluation of the improvised leaf electroscope was made at the EN312 Physics Stockroom. It was conducted by the Stockroom Coordinator with the help of the Laboratory Assistants of the Physics Laboratory. Testing was made by the Researcher, Physics Teachers and Students during the week of continuous operations.

Instrumentation

During the evaluation and testing of the improvised leaf electroscope, the following instruments were used:

Plastic rod. This rod was made of PVC tube. It is used to charge the electroscope by first rubbing it with a woolen cloth for a minimum of 1 minute.

Cork borer. It is used to bore cork stopper that was used to hold the metal knob and rod in place.

Ruler. This was used to measure the length of the aluminum foil.

Micrometer Caliper/Vernier Caliper. This was used to measure the width of the aluminum foil.

Digital camera. This was used to capture the approximate split distance between the two leaves.

Data Collection

During the performance evaluation of the improvised leaf electroscope, the following data were gathered:

1. Charging of the electroscope in terms of the different kind of metal rod versus the fixed length of the aluminum leaves.
2. Charging of the electroscope in terms of the different width of the aluminum leaves versus the fixed length of the metal rod.
3. Charging of the electroscope in terms of the different length of the metal rod versus the fixed length of the aluminum leaves.
4. Approximate angle of deflection formed by the foil in different width of the foil and different length of the rod used.
5. Specifications and dimension of the design.
6. Investment cost of the improvised leaf electroscope

RESULTS AND DISCUSSION

Principle of Operation

The electroscope is a sensitive detector of charge. It works on the principle that like charges repel. All kinds of friction can be shown to produce electrification by testing the rubbed object with this instrument. Before doing some testing, it should be made sure that there is no charge on the electroscope. The evidence that the electroscope has no charge is that the leaf hangs straight downward as shown in Figure 4. By rubbing the plastic strip with a woolen cloth and bringing the strip close to (but not touching) the knob of the electroscope, the electrons in the knob are repelled towards the leaves. Since, like charges repel, and since the leaves are free to move, they diverge as shown in Figure 5. When the plastic strip is removed from the knob of the electroscope, the electrons runs through the metal rod and the leaves would hang straight down together as shown in Figure 4.

Figure 4. Uncharged electroscope. The leaves hang straight down together.

Figure 5. Charged electroscope. The leaves diverge.

Approximate Measured Angle of Deflection

Data in Table 1 show that copper rod has the highest approximate split distance between the two leaves at 1.8 cm. which is numerically much higher compared to that of aluminum rod at 1.3 cm. and brass rod at 1.5 cm.

In terms of the approximate angle of deflection, copper rod also obtained the highest numerical value at 26^{o}. This was followed by the brass rod with a 22^{o} angle of deflection and aluminum rod with 19^{o}.

Table 1. Approximate Measured Angle of Deflection as Influenced by Different Kinds of Metal Rod Used as Stem

Test	Type of Rod	Length of the Leaf	Approx. Split Distance between the Two Leaves	Approx. Measured Angle of Deflection
		cm	cm	o
1	Aluminum	4	1.3	19o
2	Brass	4	1.5	22o
3	Copper	4	1.8	26o

Results in Table 2 show that out of the 3 samples of aluminum leaves with the width of 0.5 cm, 0.7 cm and 1.0 cm, the 0.5 cm width gave the highest approximate split distance between the two leaves at 2.1 cm and the 1.0 cm width attained the lowest value at 0.8 cm.

In terms of the approximate measured angle of deflection, the 0.5 cm width also gave the highest value at 30^{o} while that of the 1.0 cm width was 11^{o}. This shows that width is inversely proportional to the approximate measure angle of deflection which means that as the width of the leaves increases, the approximate measured angle of deflection decreases. Copper rod with a length of 6 in. were used in this particular test.

Table 2. Approximate Measured Angle of Deflection are Affected by Different Width of the Aluminum Leaves Used

Test	Width of the Aluminum Leaf	Length of the leaf	Approx. distance between the two leaves	Approx. angle of deflection
		cm	cm	o
1	0.5 cm	4	2.1	30o
2	0.7 cm	4	1.6	23o
3	1.0 cm	4	0.8	11o

Table 3 presents the approximate measured angle of deflection as influenced by different length of the copper metal rod as stem. Copper rod was already used here because this was the metal that produced the highest angle of deflection as presented previously in Table 1. As shown in Table 3, out of the 3 samples used in testing the improvised leaf electroscope, the 6 in gave the widest split distance between the two leaves at 3.1 cm. followed by the 5 in. length at 2.5 cm. That of the 4 in. rod was only 1.8 cm.

When it comes to the approximate measured angle of deflection, the 6 in long rod also gave the highest numerical value at 46^0 which is much higher compared to the other two samples; the 5 in. rod deflected up to 36^0 while that of the 4 in. rod's deflection was 26^0 only. This test shows that the length of the copper rod was directly proportional to the approximate measured angle of deflection which means that as the length of the rod increases, the approximate measured angle of deflection also increases.

Table 3. Approximate Measured Angle of Deflection as Influenced by Different Lengths of the Copper Rod Used as Stem

Test	Length of the Copper Rod	Length of the leaf	Approx. Split Distance between the Two Leaves	Approx. Measured Angle of Deflection
1	4 in.	4 cm.	1.8 cm.	26^0
2	5 in.	4 cm.	2.5 cm.	36^0
3	6 in.	4 cm.	3.1 cm.	46^0

Construction/Fabrication Cost of Improvised Leaf Electroscope

The Improvised Leaf Electroscope has a very low investment cost of Php580.50 per unit compared to the other equipment already available inside the Physics Laboratory that has an investment cost of Php4,900.00 per unit. The benefit from using this improvised equipment is that it uses locally available materials but can operate and function in the same manner as the branded leaf electroscopes. It also shows that the market price of one unit of Improvised Leaf Electroscope was very much cheaper compared to the other equipment already available in the Physics Stockroom (Table 4).

Table 4. Construction/Fabrication Cost of Improvised Leaf Electroscope

A. Product Costing	
Direct Cost:	
Metal Rod	50.00
Erlenmeyer Flask	170.00
Cork	25.00
Alligator Clip	10.00
Total Direct Cost, Php	255.00
Indirect Cost:	
Labor	300.00
Contingency Cost (10% of direct cost)	25.50
Total Indirect Cost, Php	325.50
Production Cost:	
Total Direct Cost	255.00
Add: Total Indirect Cost	325.50
Production Cost per Unit, Php (Investment Cost	580.50
B. Product Pricing	
Production Cost per Unit, Php	580.50
Add: 20% Mark-up of the Production Cost, Php	116.10
Mark-up Price per unit, Php	696.60
Market Price, Php	750.00

SUMMARY, CONCLUSION, AND RECOMMENDATION

Nine improvised leaf electroscopes were constructed to test which samples can produce the highest approximate measured angle of deflection. Three various ways of tests were made with three trials for each testing.

In the first test, the researcher used three different types of metal rod (aluminum, brass and copper). During the second test, three copper rods of different length (4in, 5in and 6in) were constructed to determine which would get the highest result in measured angle of deflection. In third testing, three copper rods of the same length with various width of the aluminum leaves (0.5cm, 0.7cm and 1.0cm) were considered. All construction and tests were done at the Physics Stockroom located in En312.

Results revealed that the newly developed improvised leaf electroscope has the lowest operating cost per day of Php0.78. In case the aluminum leaves will be worn-out, the Improvised Leaf Electroscope has the cheapest value for repair and maintenance of Php0.19 compared to the other brands having the same function and operation.

It can be concluded, that copper rod is the best metal stem to use with approximate measured angle of deflection of 26^0. The appropriate length of the rod to use is 6 inches with 46^0 measured angles of deflection. The suitable width of the aluminum leaf is 0.5 cm. with 30^0 approximate measured angles of deflection. This study also shows relationship between length of the rod and width of the aluminum leaf. The length of the rod is directly proportional to the angle of deflection. As the length of the metal rod increases, the angle of deflection also increases while the width of the aluminum leaf is inversely proportional to the angle of deflection. As the width of the aluminum leaves increases the angle of deflection decreases.

It can also be concluded that copper rod with 6 inches length of the metal stem and 0.5 cm width of the aluminum leaf is the appropriate measurement and combination for future mass production.

Furthermore, the description of the electroscope in this study is similar to those of Noah Dorsey and Jean Antoine Nollet, physicists who invented one of the first electroscope.

Based on the findings and conclusion of the study, the following are recommended to improve the operation of the improvised leaf electroscope:

1. Good quality of plastic strips/rod (used to generate heat by rubbing) is needed to produce the widest split distance between the two leaves, which will also create the highest approx. measured angle of deflection. The plastic strips/rod used in this experiment were acquired outside the Philippines.
2. It is highly recommended to conduct a study on construction and testing of different kinds of plastic strips/rod to be used in electrostatic and electroscope experiments to minimize if not totally eliminate the use of materials bought outside the Philippines.
3. Good quality woolen cloth (material used to rub the plastic strip) is needed to attain maximum results.

REFERENCES

Giancoli, Douglas C. (1998). *Physics principles with applications,* (5^{th} ed). New Jersey: Prentice – Hall, Inc.

Smith, Alpheus W. & Cooper, John N. (1979). *Elements of physics, 9^{th} ed.* New York: Mc Graw – Hill International Book Co.

PASCO Scientific (1999). *Physics labs with computers, Volume 1: Teachers Guide.* USA.

Electroscope. Retrieved July 8, 2009 from http://www.engr.uky.edu/~gedney/courses/ee468/expmnt/escope.html

History of Electroscope. Retrieved July 6, 2009 from http://inventors.about.com/library/inventors/blelectroscope.htm.

ACKNOWLEDGMENT

The researcher wishes to express his sincerest thanks to the following:

To Dr. Randy Anthony V. Pabulayan, Dr. Reynaldo N. Dusaran and the rest of the University Research Center, for providing the funds in accomplishing this research work;

To the editors, for their patience in reviewing and editing this research report;

To Dr. Aries Roda D. Romallosa, for the generous assistance in the completion of this study;

To Engr. Ramon A. Alguidano, Jr., for his technical assistance;

To the Physics Laboratory Assistants, for their valuable assistance during the construction and testing of the improvise leaf electroscope;

To his wife for the unceasing encouragement and support;

And above all, to God Almighty for the strength and wisdom which made this work possible.