# THE EXPERIMENTAL STUDY OF COMPLETE PLATE CAPACITORS FOR DETERMINING A DIELECTRICAL CONSTANTA OF A MATERIAL

*Kurniasari[6](kurniasari@ukwms.ac.id)*

***Abstract***

*Experiments and theories are two parts that cannot be separated in studying Physics. Many theories are built on experimental data and many theories fall because they conflict with experimental data. In addition, the role of experiments can also be used to help understand a physics material obtained in class. With this regard, a development research has been carried out to determine the dielectric constant of a material through parallel plate capacitor experiments, and experimental instructions.*

*The research was carried out through stages: literature study, tools testing, experiments: taking and analyzing data, developing practical instruction modules and testing modules to the students. The results showed that through practicum parallel plate capacitors, dielectric constant of a material can be obtained. From the results of the experiment, the value of the dielectric constant was (8.60 ± 0.01) x* $10^{-1}$ *for air; (2.1 ± 0.2) for plastic; and (4.3 ±0.2) for glass. Based on the results of testing the module practicum instructions for students of a Physics Education Study Program, it was obtained the fact that students stated that the practicum instruction module was already developed well and could assist in carrying out parallel plate capacitor practicum.*

**Keywords:** *parallel plate capacitors, dielectric constants, practicum tools, lab modules*

---

[6] *Author is a lecturer at Department of Physics Education, Widya Mandala Catholic University Surabaya.*

## INTRODUCTION

Physics material, especially electricity, is one of the subjects that needs a high level of understanding. Many things can cause electric subject matter to be abstract, including difficult electrical material or unclear material delivery from the instructor. Electricity learning is not enough just to be done theoretically, but also requires practice or experimentation to prove the theory taught in the classroom to be valid. A theory can fall if it is not in accordance with the experimental results. Experiments can be done through various learning medium or props. A good physics teaching tool includes physics props that can be practiced by students and help students understand the material. In this study, the author discusses electrical materials, namely capacitors specifically parallel plate capacitors.

Capacitors are electrical components that are often used in making electrical circuits. Capacitors are devices that function to store electric potential energy or electric charge (Young & Freedman, 2006). Whereas, a parallel plate capacitor is a capacitor consisting of two conductors with an area of each A that are close together but isolated from each other, separated by distance $d$ and carrying an equally large but opposite charge, namely $+q$ and $-q$. In an experiment, the parallel plate capacitors have several variables, namely capacitance (C), dielectric constant ($\varepsilon r$), electric field (E), and electric potential (V).

Among the two conductor plates, it can be inserted a material namely dielectric material. Dielectrics are non-conductor materials, such as glass, paper, or wood (Tripler, 2001). Dielectric materials can affect the capacitor variables. For example, when plate capacitors are aligned with glass, the resulting electric field must be different when the parallel plate capacitors are inserted into wood. This research was then conducted to develop a parallel plate capacitor practicum to determine the dielectric constant of a material and the preparation of a module for practical instructions that can be used to support the practicum.

## Capacitance Capacitors

Capacitors are passive components that can store electrical charges. The ability to store charges is called capacitance (*C*), with farad units (F). Capacitors consist of two pieces of conductor which are separated at a certain distance. If the capacitor is given a potential difference, the two capacitors will be electrically charged with the same size but the sign is different. To store energy in this tool, the charge is moved from one conductor to another, so that one conductor has a negative charge and the other conductor has a positive charge. In a circuit diagram, the capacitors are expressed by the following symbols:

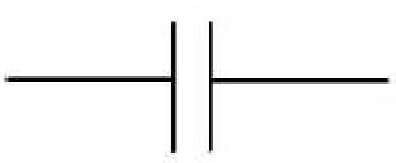
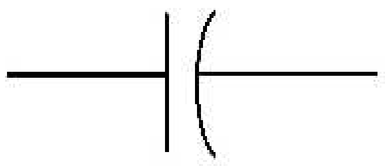

*Figure 1. Symbols for Capacitors*

Capacitance is a measure of the "storage capacity" for a certain potential difference. To write a capacitance symbol is usually denoted by the letter C which is italicized (*C*), this is to distinguish with C which is the unit of charge, namely Coulomb.

In the electric field, there is a point inside the area between conductors, proportional to the amount of charge q in each conductor. It is found that the potential difference $V_{ab}$ between conductors is proportional to q. If the amount of charge is doubled in each conductor then the charge density, the electric field at that point is doubled and the potential difference between the conductors also doubles. However, the load ratio against the potential difference does not change. The charge ratio of the potential difference is called the capacitance *C* of the capacitor, which is formulated as follows

$$C = \frac{q}{V_a} \quad (1)$$

The capacitance value depends only on the shape and size of the conductors and the nature of the insulating material between the conductors.

**Parallel Plate Capacitors**

The simplest form of capacitor consists of two parallel conduction plates, with the area of each A separated by a small distance d when compared to the dimensions of the plate.

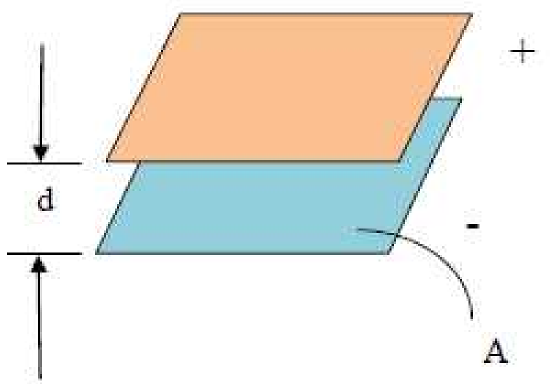


*Figure 2. A charged parallel plate capacitor*

When the plates are loaded, the electric field is almost completely localized in the area between the plates. The plate between the plates is homogeneous, and the load on the plates is homogeneously distributed on the facing surfaces. The arrangement is called the parallel-plate capacitor.

**Electric Field and Electric Potential in Parallel Plate Capacitors**

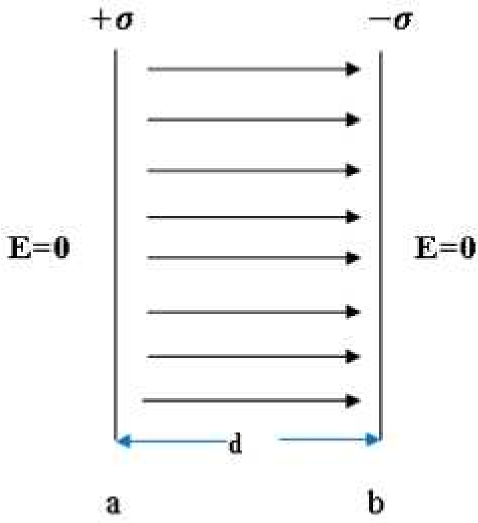


*Figure 3. The electric field outside the plate capacitor is parallel*

The electric field in the capacitor is only found in the space between the two pieces. The electricity between the two pieces is homogeneous. The magnitude of the electric field outside the chip is zero (E = 0). While the magnitude of the electric field between the two pieces can be calculated through the following equation:

$E = \frac{\sigma}{\varepsilon_0}$ with $\sigma = \frac{q}{A}$, then

$$E = \frac{q}{\varepsilon_0 A} \quad \ldots(2)$$

In plate capacitors parallel to the generated electric field, it is homogeneous or all in the same value. Therefore, the potential difference between positive and negative pieces in this homogeneous field can be calculated using the following equation:

$$V_a = V_a - V_b$$

$$V_a = E\,d$$

By substituting equation (2), the magnitude of potential difference is obtained as follows:

$$V_a = \frac{q\,d}{\varepsilon_c A}$$

… (3)

In addition to the electric field and potential difference, the parallel plate capacitors also have capacitance. In parallel plate capacitors, it consists of two pieces of the same area, namely A and separated at distance d, where d is smaller than the length and width of the pieces. In one piece, the charge is given + q and the other chip is given the charge -q. The electric field at a point between the pieces (not including the points near the tip of the chip) approaches the size of the field caused by two infinite fields parallel but the charge is opposite. The capacitance formula on the capacitor is as follows:

$$C = \frac{q}{V}$$

$$C = \frac{\varepsilon}{d} \qquad \text{… (4)}$$

The amount of capacitance does not depend on the charge or voltage of the capacitor, but only depends on the geometrical factors, namely the area of the chip and the distance between the pieces.

**Dielectric and Dielectric Constants**

Dielectric is a non-conductor material such as glass, paper or wood. Michael Faraday experimentally discovered when between two conductors on a capacitor filled with a dielectric, the capacitance of the capacitor would increase in proportion to the factor k. This k factor is a dielectric characteristic called the dielectric constant.

When metal is in an electric field area an induction charge will form which will cause an induction field in the opposite direction to the outside field. If the strength of the metal field is zero, then the induction field will stop forming. The following is an illustration of the external electric field and the induction field present in parallel plate capacitors.

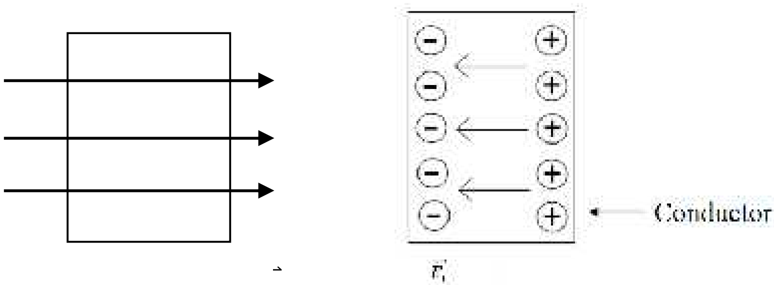


*Figure 4. Induction electric power on parallel plate capacitors*

In the discussion of capacitors there is one constant called the permittivity of the material or the dielectric constant. The dielectic constant for each material is not the same. This dielectric constant represents the density of electrostatic flux in a material when given an electric potential. This dielectric constant is also a comparison of the electrical energy stored in the material if given a potential difference, relative to vacuum (vacuum). Mathematically, the dielectric constant of a material is defined as

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} \qquad \dots 5$$

This dielectric constant also relates to the electrical susceptibility (vulnerability) which is represented by $X_e$, so that the mathematical relationship obtained is

$$\varepsilon_r = (1 + X_e)$$

…6

In a plate capacitor parallel to the cross-sectional area A and spacing d, inserted by a dielectric material with a cross-sectional area equal to A and having a thickness t. These capacitors are identical to the capacitors which are arranged in series.

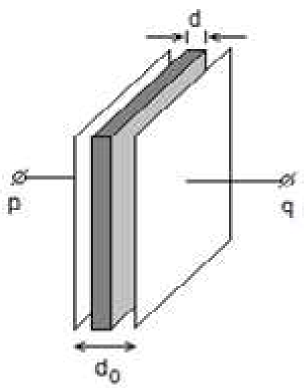


*Figure 5 Plate capacitors parallel to the dielectric material*

For parallel plate capacitors inserted in a dielectric material with thickness d as shown in Figure 5, formulation is obtained to determine the dielectric constant as follows:

$$C_p = \frac{\varepsilon_r \varepsilon_0 A}{\varepsilon_r (d - t) + d}$$

… 7

$C_p = \frac{Q}{V_E}$, dengan Q = $Q_1$ = $Q_2$

$$\frac{\varepsilon_r \varepsilon_0 A}{\varepsilon_r (d - t) + d} = \frac{\varepsilon_0 A E_1}{V_p}$$

$$\varepsilon_r = \frac{E_1 d}{V_p - E_1 (d-t)} \qquad \ldots 8$$

For the formula the dielectric constant in air is obtained by the following formula:

$Q = \varepsilon_0 A$ , dengan Q = C V

$$C = \varepsilon_0 A$$

$$\frac{\varepsilon_0 \varepsilon_r A}{E} V = \varepsilon_0 A$$

$$\varepsilon_r = \frac{E}{V}$$

## RESEARCH METHODS

This study uses a development research method oriented on the production of products in the form of improvements to parallel plate capacitors and practicum instruction modules. Broadly speaking, the research procedure is carried out through the steps of a literature study, reviewing and compiling a practicum tool, making a tool, experimentation, data analysis, improvement, making a module for practicum instruction, testing a module for practicum instructions, and ending with module analysis.

The procedure for conducting the experiment in this study was carried out several steps until a dielectric constant value was obtained for the materials tested.

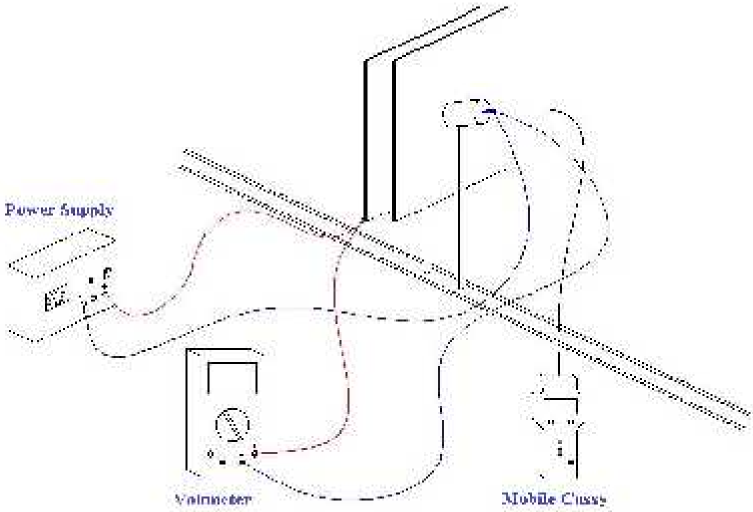


*Figure 6. The parallel plate capacitors experiment circuit without dielectric material*

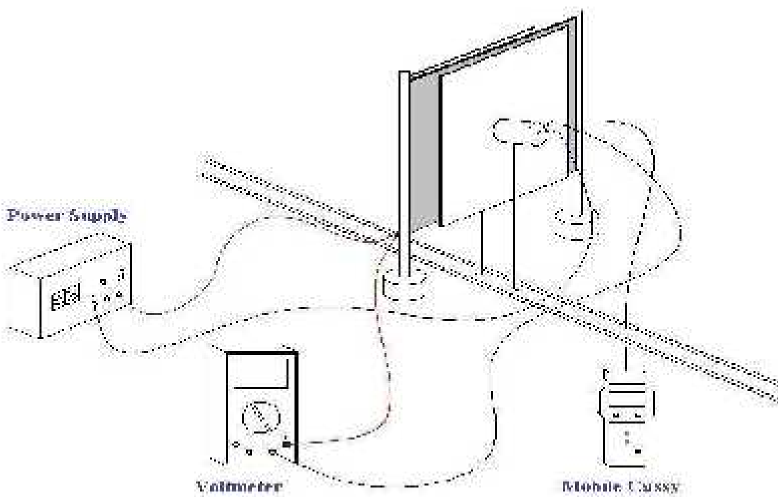


*Figure 7. The plate capacitor experiment circuit is parallel to the dielectric material*

Figures 6 and 7 are a series of experiments to determine the dielectric constant. In this experiment an electric field (E) and voltage (V) measurement will be carried out using the Mobile Cassy sensor that will be attached to the circuit. Also measured is the distance between two capacitor chips (d) and the thickness of the material inserted in the two capacitor plates. Measurements are made on air, glass dielectric materials and plastic.

## RESULTS AND DISCUSSION

When first conducting an experiment, researchers have difficulty in placing dielectric material. The researcher made a wooden static rod (figure 8) to hold the position of the dielectric material between the capacitor plates. Statip is made of wood which is an insulator so that the statip does not flow through the load. When placing glass dielectric materials, researchers must be careful so that the distance between the capacitor plates does not change. The researcher must ensure that the glass does not come into contact with the capacitor plate because it can cause the glass to become charged and reduce the accuracy of the experimental results. With the presence of the wooden station, the experimental results are expected to be more accurate and in accordance with the theory.

*Figure 8 Dielectric material support tool*

Based on measurements made on air, plastic and glass, a graph of the relationship between the electric field and the voltage is obtained as shown in Figure 9.

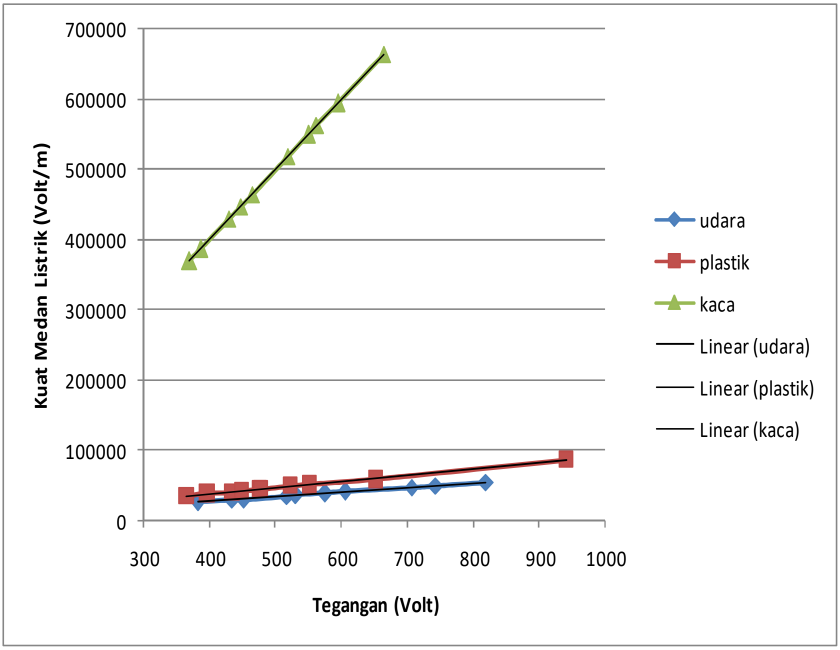


*Figure 9. Graph of Electric Fields to Voltage on Capacitors*

From the graph above, it can be seen that the increase in voltage is directly proportional to the increase in the strength of the electric field in glass, plastic and air: the greater the voltage, the greater the electric field strength. Based on the graph, it can be seen that there is a difference between air, plastic and glass. This difference is caused by the difference in the dielectric constant value. Of the three dielectric materials the largest dielectric constant value is glass and the smallest is air. Based on the increase in the graph, it can be concluded that the dielectric constant value affects the electric field strength in parallel plate capacitors, i.e. the greater the dielectric constant value, the greater the electric field strength.

## Air Dielectric Constant Value

In the experiment the plate capacitor parallel to the air dielectric material is obtained by the value of the dielectric constant of $(8.60 \pm 0{,}01)$x $10^{-1}$ with a relative error of 1.29%. The results of this experiment are not exactly the same as the dielectric constant value found in the capacitor manual, which is 0.98. This difference arises due to various factors. In calculating the dielectric constant value is strongly influenced by the magnitude of the electric field (E) and voltage (V), the E and V values are measured by the Casy mobile device which is a set of sensors, making it very sensitive and very easy to produce different results. Besides that, the existence of climate differences also affects the difference in the dielectric constant of this air. The climate in countries producing parallel plate capacitors (Germany) is different from where researchers conducted experiments (Indonesia).

## Plastic Dielectric Constant Value

Based on the results of the experiment, when parallel plate capacitors are inserted with plastic dielectric material, a plastic dielectric constant value is obtained $(2.1 \pm 0.2)$ with a relative error of 8.9%. There is a difference in the value of plastic dielectric constants from the results of experiments with the dielectric constant values in the manual. Besides the sensitivity of the measuring sensors E and V, this difference arises because of a systematic error. The systematic error here is the difficulty of making both plates precisely aligned so that it affects the electric field strength in the plate. In calculating this misalignment factor is ignored and in the experiment the factor of this misalignment is minimized.

Another factor the researchers could not ascertain was that the plastic dielectric material used in the experiment was truly a polystyrene type of plastic; this was due to the limitations of measuring instruments to investigate the structure of the material.

## Glass Dielectric Constant Value

In the manual of parallel plate capacitors, the dielectric constant value is 6.5. In the experiment conducted by the researchers obtained a dielectric constant value of (4.3 ± 0.2) with a relative error of 3.58%. This difference is caused by several factors. The first factor that researchers have not been able to ascertain is the type of glass used because of the limitations of measuring instruments. The second factor is that researchers find it difficult to make both plates precisely aligned when the glass-electric material is inserted, thus affecting the electric field that comes out. The third factor, the glass dielectric material is quite slippery so it is difficult to place it right in the middle between the two plates.

## CONCLUSION

Experiments compiled by the researchers using parallel plate capacitors can be used to determine the value of the dielectric constant of a material. Based on the results of the study, the dielectric constant values obtained are different from the user manual for using parallel plate capacitors. The experimental result of the air dielectric constant amounted to (8.60 ± 0.01) x $10^{-1}$ and in the manual is 0.98. In the plastic dielectric material, the researcher identified a dielectric constant value (2.2 ± 0.2) while in the guidebook it was 2.1. For glass dielectric materials, the researcher obtained a dielectric constant value of (4.3 ± 0.2) while in the user manual obtained a dielectric constant value of 6.5. The difference in the value of the dielectric constant is caused by several factors in the experiment.

## References

Giancoli, Douglas C. 1999. *Fisika Edisi Kelima Jilid 2*. Jakarta: Erlangga

Halliday, David. et al. 1978. *Fisika untuk mahasiswa* (jilid 2). (Pantur Silaban, penerjemah). Jakarta: Penerbit Erlangga.

Halliday, D. dkk. 2010.Fisika Dasar Edisi 7 Jilid 2 Jakarta: Erlangga.

Herminegari. 2013. *Fungsi danManfaat Media Pembelajaran*.(Diakses pada 7 Februari 2017 dari http://herminegari.wordpress.com)

Pattiiha, Hendra. 2009. *Menentukan Diameter Kawat Tipis dengan Menggunakan Metode Difraksi Cahaya*. Skripsi S1. Universitas Katolik Widya Mandala Surabaya.

Purnamawati & Eldarni. 2001. Pengertian Media. (Diakses pada 23 Januari 2018 dari http://www.ialf.edu/kipbipa/papers/OudaTedaEna.doc)

Sears, Francis W. & Zemansky, Mark W. 1962. *Fisika untuk Universitas 2 Listrik, Magnet* (Nabris Chatib, penerjemah). Jakarta: Yayasan Dana Buku Indonesia

Tipler, Paul. 2001. *Fisika untuk Sains dan Teknik*. (Bambang Soegijono, penerjemah). Jakarta: Penerbit Erlangga.

Young, Hugh D. & Freedman, Roger A. 2006. *Fisika Universitas Edisi Kesepuluh Jilid II.*