Lab Report 1 (Electrostatics)

BSCYSev-F-24-A

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Lab Experiment No 1

To estimate the charge on a small piece of paper or comb with the help of electrostatic induction.

Objective

To estimate the magnitude and polarity of the electric charge on a small piece of paper or a plastic comb by using the principle of electrostatic induction.

Apparatus

- Plastic comb or small charged object (like a piece of rubbed plastic or paper)
- Electroscope (or homemade version using aluminum foil and a jar)
- Insulated stand or thread
- Known charged object (glass rod or ebonite rod rubbed with silk or fur)
- Milligram balance (optional, for more precise estimation)
- Scale or ruler
- Dry environment (to minimize discharge)

Introduction

Electrostatic Induction is a method to redistribute electric charge in an object, caused by the influence of a nearby charged object without direct contact.

When a charged comb or paper is brought near a neutral conductor, free electrons are attracted or repelled, depending on the polarity of the external charge. This leads to a measurable deflection or induced charge on the conductor.

Procedure

- **Weigh the Paper:** Use an electronic balance to measure the mass of a sheet of paper.
- **Cut the Paper:** Divide the sheet into smaller, equal-sized pieces.
- **Calculate Mass of One Piece**: Divide the total mass of the paper by the number of pieces to find the mass of one small piece.
- **Select a Piece:** Choose one small piece of paper and set it aside.
- **Charge the Comb**: Rub a comb with your hair for a few seconds to charge it, then bring it close to the small piece of paper.
- **Measure Distance:** Use a ruler to measure the distance at which the piece of paper is suspended in the air due to the comb's charge.

- **Apply Coulomb's Law:** Use Coulomb's Law and compare it with Newton's Second Law of Motion. Plug in your measured values to calculate the charge on the small piece of paper.
- **Repeat:** Perform the experiment three times for accuracy.

Observations and Calculations

Trial No.	Mass (m) (kg)	Distance (r) (m)	Acceleration due to Gravity (g) (m/s^2)	Coulomb Constant (K) (Nm^2/C^2)	Calculated Charge (q) (C)
1	3.2×10^{-5}	0.025	9.8	9×10^9	4.6×10^{-9}
2	3.5×10^{-5}	0.030	9.8	9×10^9	6.0×10^{-9}
3	3.0×10^{-5}	0.020	9.8	9×10^9	3.2×10^{-9}

As we know that

$$F = mg \text{ -------- } (1)$$

According to Coulomb's Law

$$F = \frac{Kq_1q_2}{r^2} \text{ ------- } (2)$$

Comparing the Equation 1 and 2

$$mg = \frac{Kq_1q_2}{r^2}$$

$$mg = \frac{Kq^2}{r^2}$$

$$q^2 = \frac{r^2mg}{K}$$

$$q = \sqrt{\frac{r^2mg}{K}} \text{ ------ } (3)$$

IF

Approximate Values

$r = 0.025m$

$m = 3.2 \times 10^{-5} kg$

$g = 9.8 m/s^2$

And $K = 9 \times 10^9 \ Nm^2/C^2$

Then the value of charge will be

$q = 4.6 \times 10^{-9}\ C$

Conclusion

In this experiment, the charge on a small piece of paper was estimated using the principle of electrostatic induction. When the charged object (like a comb) was brought near the paper, electrostatic force caused the paper to be attracted. By measuring the mass of the paper and the distance at which the force was just sufficient to overcome gravity, the charge was calculated using the formula:

$$q = \sqrt{\frac{r^2 \cdot m \cdot g}{K}}$$

This experiment demonstrated how basic electrostatic principles and simple measurements can be used to quantify charge, and it reinforced the inverse-square nature of the electrostatic force.

Lab Experiment No 2

Conversion of a Galvanometer into Ammeter

Objective

To convert a given galvanometer into an ammeter of a desired range by connecting a low resistance (shunt) in parallel and to verify the range.

Apparatus

- Galvanometer (with known resistance G)
- Ammeter (for verification)
- Low resistance wire (shunt)
- Voltmeter
- Battery or regulated DC power supply
- Rheostat
- Connecting wires
- Key (switch)

Introduction

A galvanometer is a sensitive instrument used to detect small currents. However, it cannot measure large currents directly due to its limited range. To convert it into an **ammeter**, a **shunt resistance** is connected in parallel with the galvanometer. This allows the majority of the current to bypass the galvanometer.

Formula for shunt resistance:

$$S = \frac{I_g \cdot G}{I - I_g}$$

Procedure

- Note the resistance G of the galvanometer and the current Ig required for full-scale deflection.
- Decide the desired range I of the new ammeter.
- Calculate the value of the shunt resistance S using the formula:

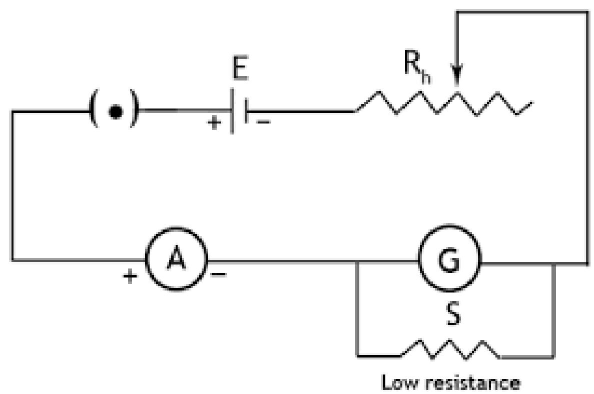
$$S = \frac{I_g \cdot G}{I - I_g}$$

- Connect the calculated shunt resistance in parallel with the galvanometer.
- Make the electrical connections as per the circuit diagram below.
- Use a rheostat to vary the current and observe the deflection in both the newly converted ammeter and a standard ammeter.
- Record readings from both meters to verify accuracy.

Observations and Calculations

S. No.	Current Set (A)	Galvanometer Deflection	Standard Ammeter Reading (A)	Converted Ammeter Reading (A)
1	0.1	Full scale	0.1	0.1
2	0.2	Full scale	0.2	0.2
3	0.3	Full scale	0.3	0.3
4	0.4	Full scale	0.4	0.4

Circuit Diagram



Conclusion

- The galvanometer was successfully converted into an ammeter using a parallel shunt resistance.
- The converted ammeter showed readings consistent with the standard ammeter.
- The experiment validates the theoretical approach of using shunt resistance to extend the range of a galvanometer.

Lab Experiment No 3

Conversion of a Galvanometer into Voltmeter

Objective

To convert a galvanometer into a voltmeter of a desired range by connecting a high resistance in series and to verify its functionality by measuring known voltages.

Apparatus

- Galvanometer (resistance G, full-scale deflection current Ig)
- High resistance (to be calculated and connected in series)
- Battery or regulated DC power supply
- Voltmeter (for verification)
- Rheostat
- Connecting wires
- Key (switch)

Introduction

A galvanometer is a sensitive instrument that can detect small currents. To measure potential difference (voltage), it is converted into a **voltmeter** by connecting a high resistance in **series** with it. This limits the current flowing through the galvanometer and enables it to measure larger voltages.

Formula for series resistance R:

$$R = \frac{V}{I_g} - G$$

Procedure

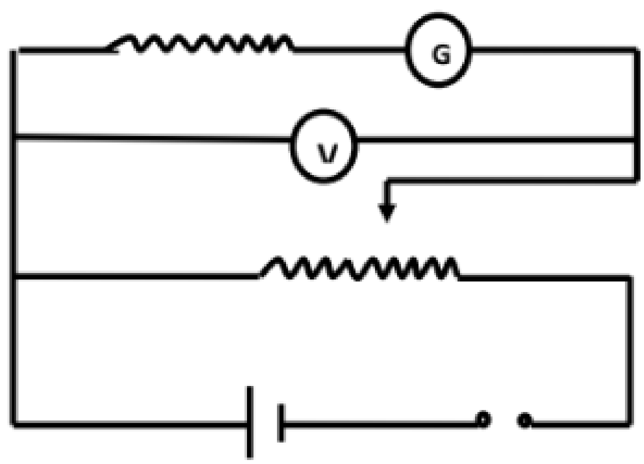
- Measure the internal resistance G of the galvanometer and note its full-scale deflection current Ig.
- Decide the maximum voltage V the voltmeter should measure.
- Calculate the required series resistance R using the formula above.
- Connect the resistance R in series with the galvanometer.
- Connect this modified galvanometer (now voltmeter) across various known voltages.
- Compare its reading with a standard voltmeter to verify accuracy.

- Record observations in a table.

Observations and Calculations

S. No.	Voltage Applied (V)	Standard Voltmeter Reading (V)	Converted Voltmeter Reading (V)	Remarks
1	2	2.00	1.98	Slight under-reading
2	4	4.00	3.95	Acceptable error
3	6	6.00	5.96	Good match
4	8	8.00	7.93	Minor deviation
5	10	10.00	9.88	Within tolerance range

Circuit Diagram



Conclusion

- A galvanometer was successfully converted into a voltmeter by connecting a high resistance in series.
- The converted voltmeter showed readings that closely matched those of a standard voltmeter, confirming the accuracy of the theoretical calculations.
- The method effectively extends the voltage measuring capability of a sensitive galvanometer.

Lab Experiment No 4

Find the resistance of galvanometer (Rg) by half deflection method.

Objective

To determine the internal resistance of a galvanometer (Rg) using the **half-deflection method**.

Apparatus

- Galvanometer
- High resistance box
- Variable resistor (rheostat)
- Battery or DC power supply
- Ammeter (optional)
- Key (switch)
- Connecting wires

Introduction

A **galvanometer** is a sensitive instrument used to detect current. Its internal resistance Rg cannot be measured directly using an ohmmeter, so the **half-deflection method** is used. The method is based on the principle that if a known resistance R is connected in parallel with the galvanometer and the deflection is reduced to half, then:

$$R_g = R$$

This is because when deflection is halved, it implies that equal currents are flowing through both the galvanometer and the parallel resistance.

Procedure

- Connect the circuit as shown below, with the galvanometer in series with a variable resistor and battery.
- Adjust the variable resistor so the galvanometer shows full-scale deflection θ (e.g., 30 divisions).
- Now, connect a resistance box in parallel with the galvanometer.

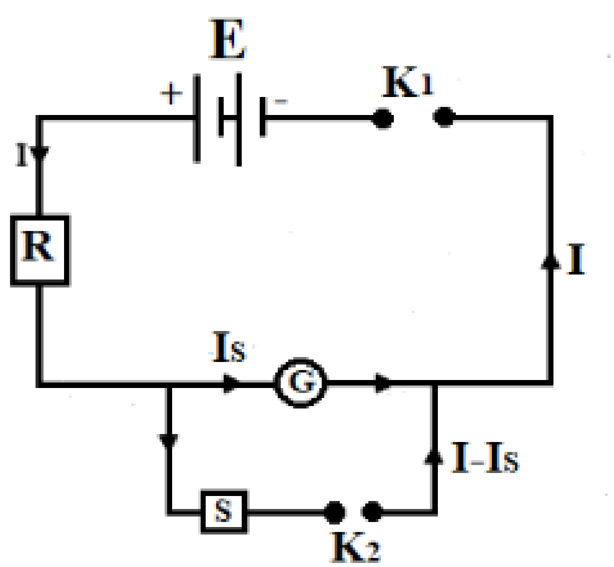
- Adjust the resistance in the box until the galvanometer shows exactly **half** of the original deflection (i.e., θ/2).
- Note the value of resistance from the resistance box. This value is equal to the resistance of the galvanometer Rg.
- Repeat the process for multiple initial deflections to increase accuracy.

Observations and Calculations

Trial No.	Initial Deflection (Divisions)	Half Deflection (Divisions)	Resistance in Parallel (Ω) = RgR_g
1	30	15	44
2	25	12.5	45
3	35	17.5	44.5
4	28	14	44.8

Average R_g = $\frac{44+45+44.5+44.8}{4} = 44.6\,\Omega$

Circuit Diagram



Conclusion

Using the **half-deflection method**, the internal resistance of the galvanometer was found to be approximately:

$$\boxed{R_g = 44.6\,\Omega}$$

This method is simple, reliable, and avoids the need for measuring current or voltage directly across the galvanometer. The close agreement in multiple trials confirms the consistency and accuracy of the method.

Lab Experiment No 5

Charging of Capacitor

Objective

To study the **charging behavior** of a capacitor in an RC (Resistor-Capacitor) circuit and to verify the exponential nature of voltage increase across the capacitor over time.

Apparatus

- Capacitor (e.g., $C=1000\ \mu F$)
- Resistor (e.g., $R=10\ k\Omega$)
- DC Power supply (e.g., 5V)
- Stopwatch or Data Logger
- Voltmeter (Digital/Analog)
- Breadboard or circuit setup
- Connecting wires
- Switch

Introduction

In an RC circuit, when a capacitor is charged through a resistor, the voltage across the capacitor increases **exponentially** over time. The voltage V(t) across the capacitor at any time t is given by:

$$V(t) = V_0 \left(1 - e^{-\frac{t}{RC}}\right)$$

Where:

- V0 = Final (maximum) voltage (same as supply voltage)
- R = Resistance in ohms
- C = Capacitance in farads
- t = Time in seconds
- RC = Time constant (τ), the time it takes for the voltage to reach 63.2% of V0

This experiment verifies this relationship by recording voltage at regular time intervals.

Procedure

- Set up the RC circuit with a known resistor and capacitor in series, connected to a DC power supply through a switch.
- Connect a voltmeter across the capacitor to measure the charging voltage.
- Close the switch to start charging the capacitor and simultaneously start the stopwatch.
- Record the voltage across the capacitor at regular time intervals (e.g., every 2 seconds) until it reaches the supply voltage.
- Plot a graph of voltage vs. time to observe the exponential charging curve.

Observations and Calculations

Time (s)	Voltage across Capacitor (V)
0	0.00
2	0.91
4	1.64
6	2.23
8	2.78
10	3.16
12	3.50

Given:

- R=10 kΩ
- C=1000 μF
- V0=5 V
- Time constant τ=RC=10 seconds

Derivation

$$E = V_R + V_C, \qquad C = \frac{q}{V_C}, \qquad V_C = \frac{q}{C}$$

$$E = iR + \frac{q}{C}, \qquad EC = RC\frac{dq}{dt} + q$$

$$EC - q = RC\frac{dq}{dt}$$

$$\int \frac{dt}{RC} = \int \frac{dq}{EC - q}, \qquad \int \frac{dt}{RC} = -\int \frac{d(EC - q)}{EC - q}$$

$$C_1 + \frac{t}{RC} = -\ln(EC - q). \qquad C_1 = Integration\ Cons\tan t$$

$$EC - q = e^{C_1 - t/RC}$$

$$EC - q = C_2 e^{-t/RC} \text{.................}equation \quad 1$$

C_2 = EC, substitute into equation 1

$$EC - q = ECe^{-t/RC}$$

$$\boxed{q = EC\left(1 - e^{-t/RC}\right)}$$

$$V_C = \frac{q}{C} = E\left(1 - e^{-t/RC}\right) \quad \Rightarrow \quad \boxed{V_C = E\left(1 - e^{-t/RC}\right)}$$

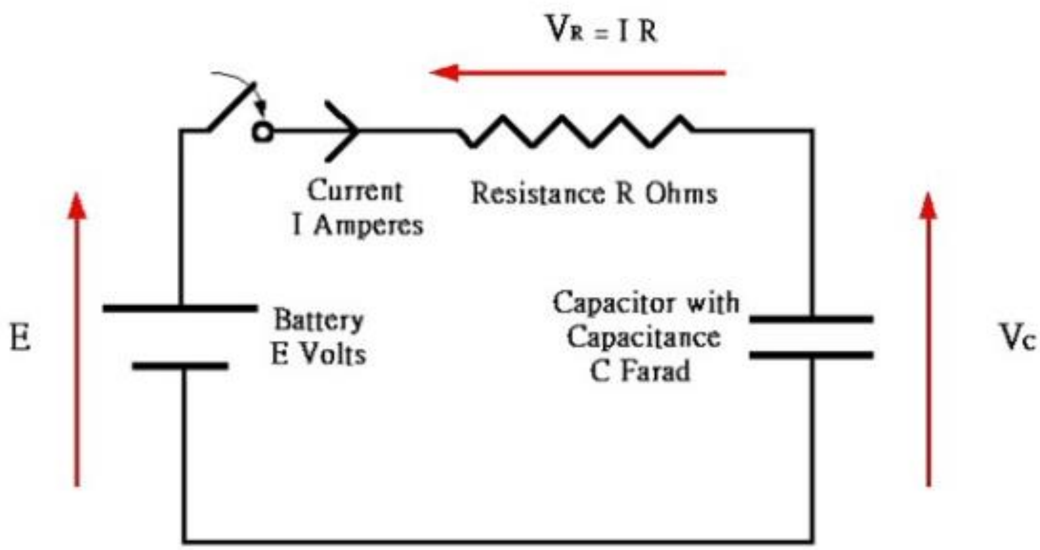
$$i = \frac{dq}{dt} = EC\frac{d}{dt}\left(1 - e^{-t/RC}\right)$$

$$i = EC\left(0 - e^{-t/RC} \times -\frac{1}{RC}\right) \quad \Rightarrow \quad \boxed{i = \frac{E}{R}e^{-t/RC}}$$

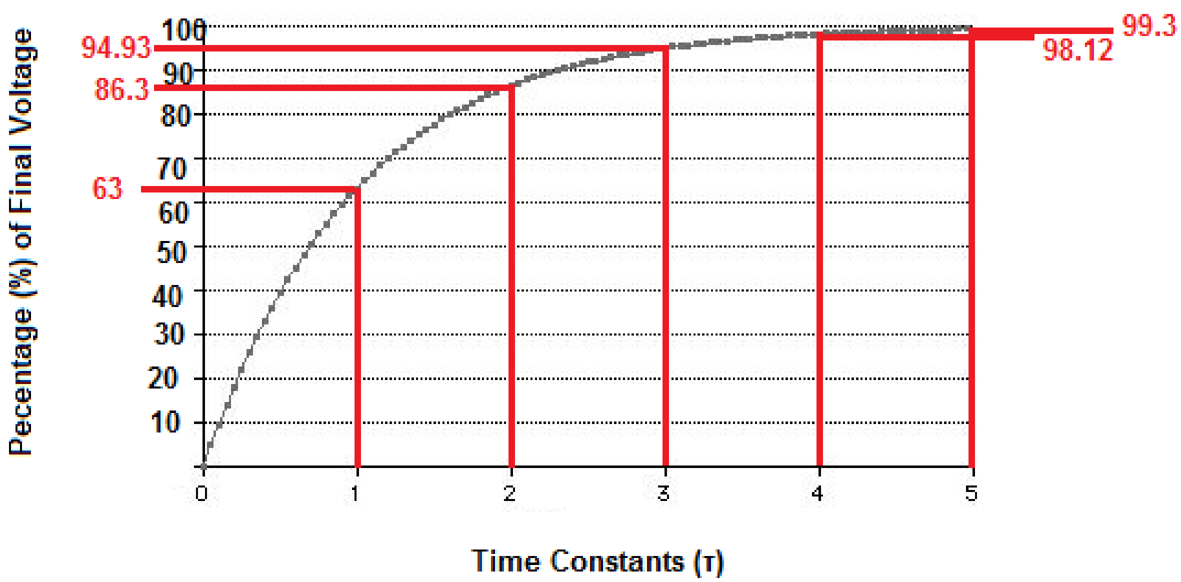
Final Result

$$V_C = \frac{q}{C} = E\left(1 - e^{-t/RC}\right)$$

Circuit Digram



Graph



Conclusion

The experiment successfully demonstrated the **exponential charging behavior** of a capacitor. The voltage across the capacitor gradually increased and approached the supply voltage, confirming the theoretical equation:

$$V(t) = V_0\left(1 - e^{-t/RC}\right)$$

The time constant $\tau = RC$ was observed to be approximately 10 seconds, matching calculated expectations. The plotted graph of voltage vs. time would form an exponential curve, validating the theory behind capacitor charging.

Lab Experiment No 6

Discharging of Capacitor

Objective

To study the **discharging behavior** of a capacitor in an RC circuit and verify the exponential decrease in voltage over time.

Apparatus

- Capacitor (e.g., $C = 1000\ \mu F$)
- Resistor (e.g., $R = 10\ k\Omega$)
- DC power supply
- Voltmeter (digital or analog)
- Stopwatch or Data Logger
- Breadboard or circuit setup
- Switch (double-pole preferred)
- Connecting wires

Introduction

In an RC circuit, a **charged capacitor** discharges through a resistor when disconnected from the power supply. The voltage V(t) across the capacitor decreases exponentially over time and is given by:

$$V(t) = V_0 \cdot e^{-t/RC}$$

Where:

- V0 = initial voltage (at t=0)
- t = time
- R = resistance
- C = capacitance
- RC = time constant τ, the time taken for the voltage to drop to ≈36.8% of V0

This experiment verifies this mathematical relationship by recording voltage at regular time intervals.

Procedure

- Assemble the RC circuit and charge the capacitor fully by connecting it to a DC supply through a resistor.
- Once the capacitor is fully charged (voltmeter shows the supply voltage), disconnect the supply and start discharging the capacitor through the resistor.
- Simultaneously start the stopwatch.
- Record the voltage across the capacitor at regular time intervals.
- Stop taking readings when the voltage nears zero.
- Repeat if needed for consistency.

Observation and Calculations

Time (s)	Voltage across Capacitor (V)
0	5.00
2	3.93
4	3.09
6	2.43
8	1.91
10	1.35
12	1.01

Given:

- R=10 kΩ
- C=1000 μF
- V0=5 V

- Time constant τ=RC=10 seconds

Derivation

$$0 = V_R + V_C$$

$$0 = i \times R + \frac{q}{C}$$

$$-\frac{q}{C} = i \times R$$

$$-\int \frac{dt}{RC} = \int \frac{dq}{q}$$

$$-\frac{t}{RC} + C_1 = \ln q \qquad C_1 = Constant$$

$$q = e^{-t/RC + C_1}$$

$$q = C_2 e^{-t/RC} \qquad C_2 = Constant$$

Substitute boundary condition, at t = 0,

Voltage across C = E, q = EC

$$C_2 = EC$$

$$\boxed{q = ECe^{-t/RC}}$$

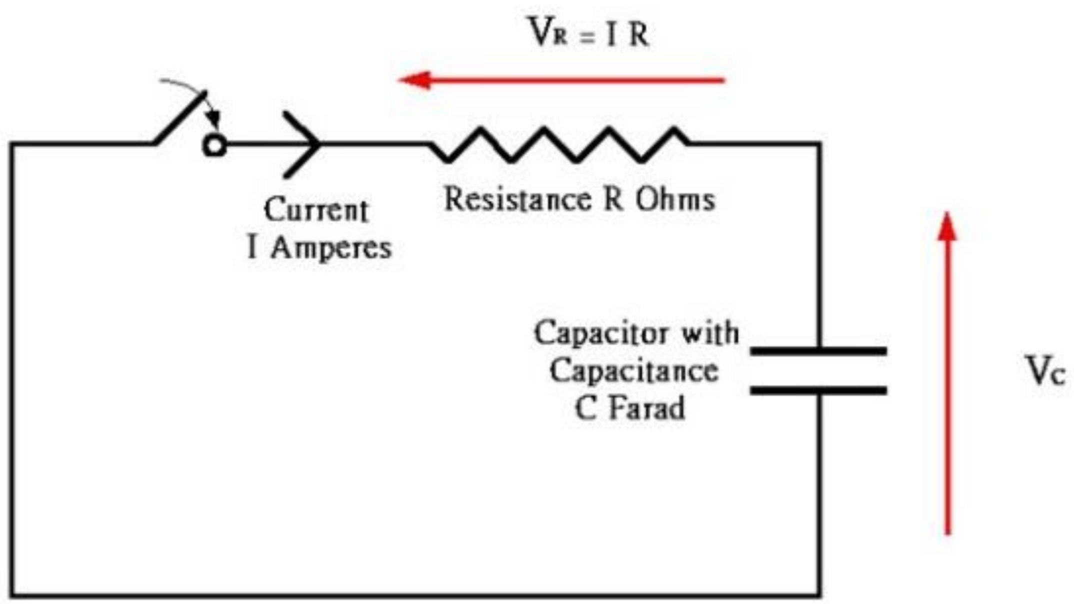
$$\boxed{V_C = \frac{q}{C} = Ee^{-t/RC}}$$

$$i = \frac{dq}{dt} = EC \times -\frac{1}{RC} e^{-t/RC} \qquad \boxed{i = -\frac{E}{R} e^{-t/RC}}$$

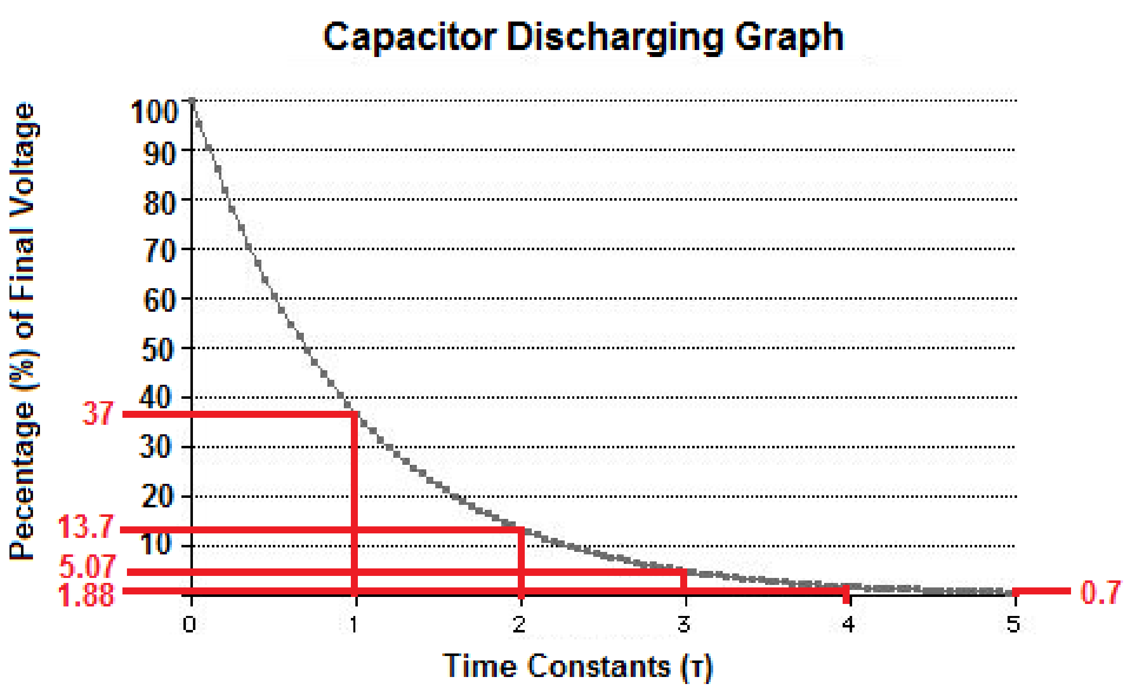
Final Result

$$V_C = \frac{q}{C} = Ee^{-t/RC}$$

Circuit Diagram



Graph



Conclusion

The experiment successfully demonstrated the **exponential decay** of voltage across a discharging capacitor. The voltage values over time closely followed the equation:

$$V(t) = V_0 \cdot e^{-t/RC}$$

The measured time constant $\tau \approx 10$ seconds matched the calculated value for the RC combination. This confirms the theoretical behavior of capacitor discharge and the concept of the RC time constant.