6S6A Experiment: Decay of Charge

Objective: To investigate the decay of charge in a capacitor.

Apparatus: electrometer, 100 \mu A microammeter, potentiometer (variable resistor 5k\Omega), voltmeter, battery box with 1.5V battery, stop-watch and connecting wires.

Procedure and results:
1. **Check** the electrometer amplifier according the instruction in page 2. Turn the rotary switch of the electrometer of the resistor and capacitor to the SHORT position to discharge the capacitor each time.

2. Set up the electrometer as shown. The electrometer must be earth with the potentiometer. Turn the rotary switch of the capacitor to 1, 10 or 100\mu F. ($\eta=10^6$)

3. Use the voltmeter to adjust an output of exactly 1V from the potentiometer. Set the rotary switch of the resistor to the OPEN position near the $10^4\Omega$ resistor. Apply 1V from the potentiometer to the input sockets of the electrometer. The applied voltage will charge up the capacitor. The microammeter will deflect adjust to full scale. Thus, the capacitor is charged up completely.

4. Disconnect the potentiometer from the electrometer carefully. Take care not to touch the input sockets with your hand. The charge stored will be earthed.

5. Connect up the $10^5\Omega$ or $10^4\Omega$ internal resistor of the electrometer by turning the rotary switch anti-clockwise. Start the timer to record the decay of charge at the same time. The capacitor discharges through the resistor. The pointer of the output meter goes down slowly.

PQ1. Why does the pointer of the meter go down slowly?

6. Record the time as the pointer passes the 0.9, 0.8, 0.7, … divisions of the scale. (The meter reading gives directly the charge remained in the capacitor.)

Tabulate the results

<table>
<thead>
<tr>
<th>R = _____________________ \Omega</th>
<th>C = _______________F</th>
<th>V = 1V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge Q / x10^{-8}C</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Time / s</td>
<td></td>
<td></td>
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</tbody>
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Plot a graph of charge Q against time.
PQ2. From your graph, read the time taken for the charge to decay

(i) from 1.0 x10^-8 C to 0.5 x10^-8 C : ______________________

(ii) from 0.5 x10^-8 C to 0.25 x10^-8 C : ______________________

PQ3. What is the average half-life $T_\frac{1}{2}$ of the decay?

Questions:
1. Find the theoretical time constant $\tau$ of the above circuit.
2. Show that $T_\frac{1}{2} = 0.69\tau$
   
   (Hint: The charge $Q$ on a capacitor as it decays through a resistor $R$ is given by $Q = Q_0 e^{-\frac{t}{\tau}}$)

3. Calculate the percentage error of the experimental result compared with the theoretical half-life.


Checking Procedure for d.c. Electrometer Amplifier

(* The following procedure must be checked before the operation.)

1. Checking the state of battery
   
   Connecting a high resistance voltmeter across the output sockets and set the function switch to the BATT position.
   
   If the output voltage is 0.75V or higher, the batteries are satisfactory.
   
   Disconnect the voltmeter.

2. Selecting the appropriate output
   
   Set the function switch to 100 $\mu$ A.

3. Setting the resistance and capacitance
   
   Connect the output terminals to a 0-100 $\mu$ A ammeter. Set both of the resistance and capacitance rotary switches to the SHORT position.

4. Calibration of the meter
   
   Adjust the ZERO control to provide an output of 0 $\mu$ A.

*** (1) The SHORT positions of the resistance and capacitance rotary indicate a SHORT circuit connection with the appropriate resistor and capacitor (i.e. the resistor/capacitor is/are in short circuit). When the capacitor is in short circuit, the capacitor is discharged completely.

(2) The OPEN positions of the resistance and capacitance rotary indicate a DIRECT input from the input signal without passing the resistor or/and capacitor.