Marmara University
Faculty of Engineering

PHYS 1104

PHYSICS LABORATORY II

Capacitor Charge and Discharge

Section:
Group:
Instructure: Date:

	Department	Student Id Number	Name & Surname
1			
2			
3			

1 Purpose

To observe the effects of capacitance, resistance and voltage on the charging of a capacitor in an RC circuit .

2 Theory

Basically a capacitor can be built by placing two metal conductive plate face to face in a small distance. Then the plates are connected to a voltage source and when the potential is applied one of the plates are charged (+) Q ,while other is (–) Q. The voltage difference between the two plates are approximately V applied potential. Capacitance is the ratio of the charge to the potential difference between the plates. It is shown by "C" with a unit of Farad (F) which is in SI unit system. Capacitance of the capacitor:

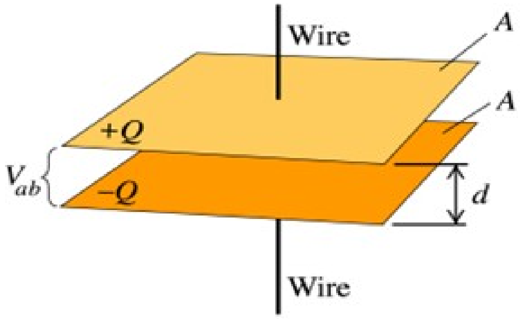

Figure 1: Example of parallel plate and cylindrical capacitors with the one that is used during the experiment

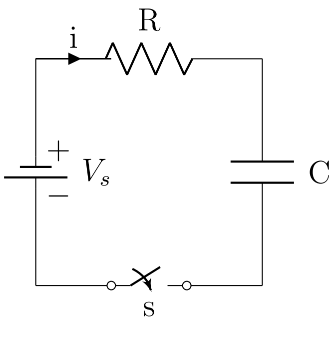

Figure 2: Capacitor charging circuit diagram

The relation of current and voltage with time *I(t)* (Figure 2), when a capacitor which has a capacitance of C is charged through a resistor R at a fixed voltage V is given by

$$I(t) = \frac{V_s}{R} e^{-\frac{t}{RC}} \tag{1}$$

$$V_c = V_s(1 - e^{-\frac{t}{RC}}) \tag{2}$$

Here, Vs is the source voltage, R is the resistance, V_c is the voltage on capacitor and the product of RC is named as the time constant (τ). The dependence of the current on the capacitance, the resistance and the voltage should be worked out by systematically varying these parameters. In the case of discharging of the capacitor the relation can be seen below

$$I(t) = -\frac{V_s}{R} e^{-t/RC} \tag{3}$$

$$V_c = V_s e^{-t/RC} \tag{4}$$

3 Experimental Setup

3.1 Equipment List

1. Board x1
2. Dc voltage source x1
3. Digital multimeter x2
4. Capacitor x2
5. Resistor x1
6. Connection cables x9

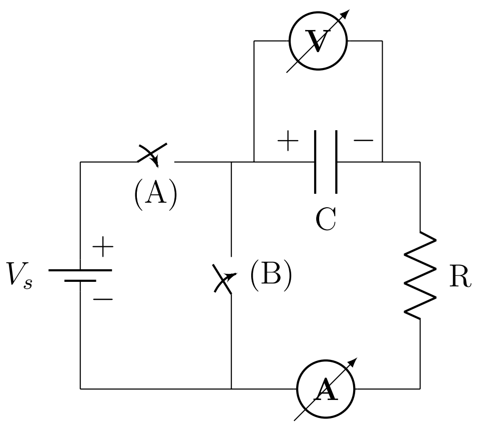

Figure 3: Circuit diagram

The experimental setup is shown in Figure 3. The internal resistance of the digital multimeter and the setting time can be disregarded. R is a protective resistor that limits the current while discharging (Switch setting B) the capacitor.

In this experiment, you will record the voltage across the capacitor and current passing through the circuit as a function of time for various capacitance and voltage source values. To observe the theoretical relation given in Eq. 1, it is best to graph natural logarithm of the current as a function of time. In that case, the theoretical expression can be written as

$$\ln I = \ln\left(\frac{V}{R}\right) - \frac{1}{RC}t \tag{5}$$

Therefore, in the graph the slope is $-\frac{1}{RC}$ and the y intercept is $\ln(V/R)$. Using the slope of the graph, time constant of the circuit can be easily calculated.

4 Procedure

1. Ensure that the capacitor and resistance are working properly. Check with multimeter.
2. Adjust the voltage source to the desired value precisely and ensure that it works correctly using a digital multimeter.
3. Build the circuit shown in Figure 3 but be careful the minus part of the capacitor should be plugged in the correct direction of the current. If it is plugged in a wrong way the circuit does not work as requested.

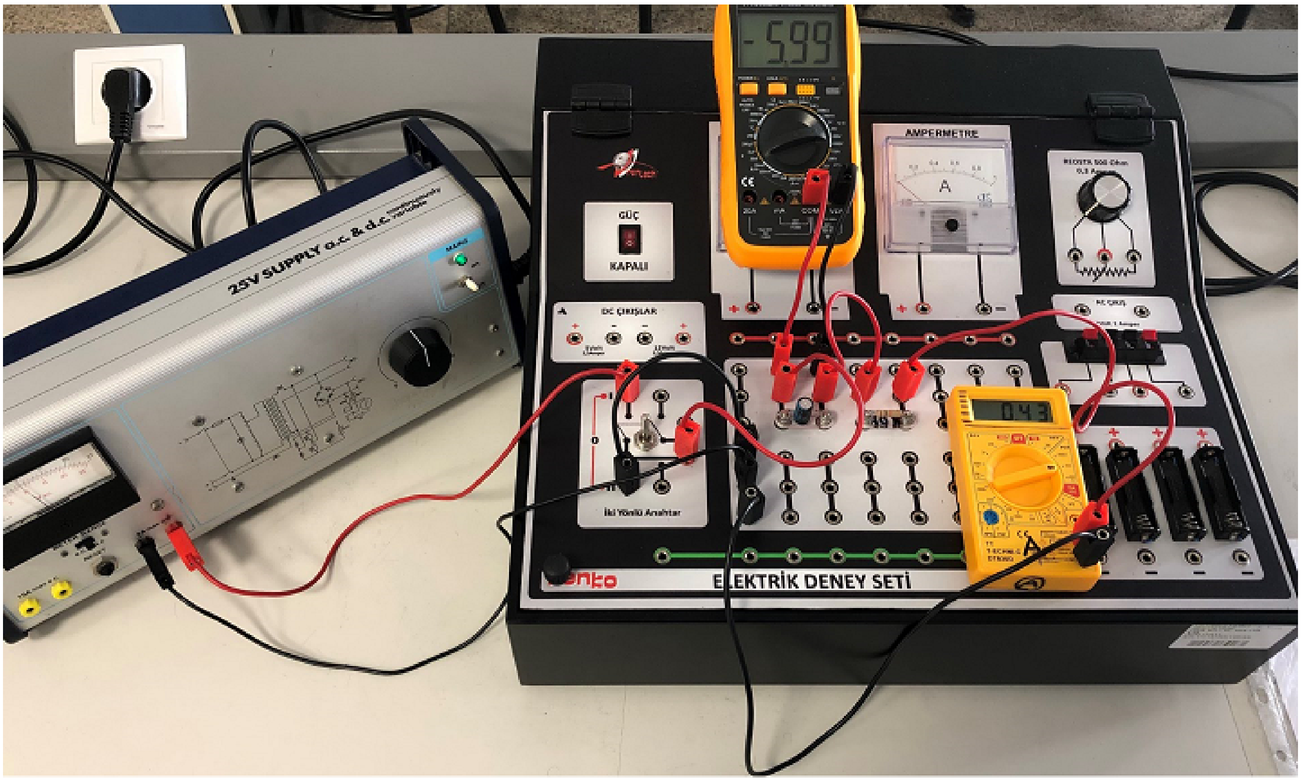

Figure 4: Experiment setup

Part I

By using the multimeter and the chronometer, record the experimental voltage value of the capacitor and current passing through the circuit as a function of time using the capacitor $C_1 = 1000\ \mu$F and resistance R = 10 kΩ. Set the voltage source to $V_s = 10$V. (In the case of charging that means switch A is closed when switch B is opened).

NOTE: First, ensure that the capacitor is fully discharged by changing the switch to the position of II (position II corresponds to the closure of switch B in Figure 3).

Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)
5				115				225		
10				120				230		
15				125				235		
20				130				240		
25				135				245		
30				140				250		
35				145				255		
40				150				260		
45				155				265		
50				160				270		
55				165				275		
60				170				280		
65				175				285		
70				180				290		
75				185				295		
80				190				300		
85				195				305		
90				200				310		
95				205				315		
100				210				320		
105				215				325		
110				220				330		

Part II

Repeat the same procedure in Part I when switch B is closed and switch A is opened. It is called as discharging of the capacitor.

Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)
5				115				225		
10				120				230		
15				125				235		
20				130				240		
25				135				245		
30				140				250		
35				145				255		
40				150				260		
45				155				265		
50				160				270		
55				165				275		
60				170				280		
65				175				285		
70				180				290		
75				185				295		
80				190				300		
85				195				305		
90				200				310		
95				205				315		
100				210				320		
105				215				325		
110				220				330		

Part III

By using the multimeter and the chronometer, record the experimental voltage value of the capacitor and current passing through the circuit as a function of time using the capacitor $C_2 = 2200\ \mu$F or make parallel connection of two capacitors of 1000 μF where the equivalent capacitance will doubled as 2000 μF and the resistance R = 10 kΩ. Set the voltage source to V_s = 10V. (In the case of charging that means switch A is closed when switch B is opened)

Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)
5				115				225		
10				120				230		
15				125				235		
20				130				240		
25				135				245		
30				140				250		
35				145				255		
40				150				260		
45				155				265		
50				160				270		
55				165				275		
60				170				280		
65				175				285		
70				180				290		
75				185				295		
80				190				300		
85				195				305		
90				200				310		
95				205				315		
100				210				320		
105				215				325		
110				220				330		

Part IV

By using the multimeter and the chronometer, record the experimental voltage value of the capacitor and current passing through the circuit as a function of time using the capacitor $C_1 = 1000\ \mu$F and the resistance R = 10 kΩ. Set the voltage source to $V_s =$ 5V. (In the case of charging that means switch A is closed when switch B is opened)

Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)		Time (s)	Iexp (mA)	Vc (Volt)
5				115				225		
10				120				230		
15				125				235		
20				130				240		
25				135				245		
30				140				250		
35				145				255		
40				150				260		
45				155				265		
50				160				270		
55				165				275		
60				170				280		
65				175				285		
70				180				290		
75				185				295		
80				190				300		
85				195				305		
90				200				310		
95				205				315		
100				210				320		
105				215				325		
110				220				330		

4. Plot voltage vs time graph. How does the volage across the capacitor change with the time for all cases?

5. Plot (I_{exp}) vs time graph. How does the current change with the time for all cases?

6. Calculate the theoretical values of the time constants *(RC)* for all cases. Determine the experimental values of the time constants by drawing the ln (I_{exp}) vs time graph. In order to do that, calculate the ln() values with calculator first. The slope of the graph will be (-1/RC) which is shown in Equation 5. After mathematical manipulation, determine the percentage error in time constant.

graph paper

Time constant for		Theoretical	Experimental
C_1	:	....	....
C_2	:	....	....

% percentage error for C_1 ....
C_2 ....

7. How does the time constant change as the capacitance in the circuit increases?