CHARGING AND DISCHARGING OF A CAPACITOR THROUGH THE RESISTANCE

(Characteristics of Series RC circuit)

Object: To Study the charging and discharging of a capacitor through the resistor

Related Concepts: Charging, Discharging, Time Constant, Exponential Function and Half Life

Object Problem: To measure the charging current oven time.

(i) Using different capacitance values C, with constant voltage V d. c. & constant resistance R.

(ii) Using different resistance values R, with constant voltage V d. c. & constant capacitance C.

Principle: A capacitor is charged by way of a resistor. The current is measured as a function of time and the effect of capacitance resistance and voltage are determined.

When a capacitor 'C' is charges through a resistance 'R' and a d.c. voltage 'V', the charge Q on the capacitor 'C' at any time t is given by

$$Q = Q_0 \left(1 - e^{-\frac{t}{RC}}\right)$$

Where $Q_0 = V . C$ is the charge on the capacitor in its fully charged state. The product R C has the dimensions of the time and is known as the time constant of the circuit.

The charging current as a function of time is given by

$$I = -\frac{dQ}{dt} = \frac{Q_0}{RC} e^{-\frac{t}{RC}} = \frac{V_0}{R} e^{-\frac{t}{RC}}$$

Or

$$I = I_0 e^{-\frac{t}{RC}}$$

Where I_0 is the current at $t = 0$

When a fully charged capacitor is discharged through a resistor R, then Q varies as

$$Q = Q_0 \left(1 - e^{-\frac{t}{RC}}\right)$$

And the discharge current is given by

$$I = -\frac{dQ}{dt} = -\frac{Q_0}{RC} e^{-\frac{t}{RC}} = I_0 e^{-\frac{t}{RC}}$$

Graphical variations of Q and I are shown in Fig. (1) and (2) respectively

From graph it is clear that the current flows in opposite directions during charging and discharging processes.

Experimental Set-up:

The experimental set-up is designed on the sunmica decorated bakelite board with

(a) Complete experimental circuit diagram drawn on the board.

(b) Digital Galvanometer 0 - ± 1000 uA. to read charging and discharging currents.

(c) D.C. power supply : 6 V d.c.

(d) Set of Resistance R : R_1 = 6.8 Kohm, R_2 = 8.2 Kohm and R_3 = 12 Kohm

(e) Set of Capacitors C : C_1 = 1000 uF & C_2 = 2200 uF

Extra accessories required: Stop watch

METHOD:

1. Make the circuit as shown in **Fig. 1** (on layout diagram Fig. 2)or also shown on the set-up with the negative end of the capacitor must be connected to the negative terminal of the d.c. power supply.

2. Put R_1 and C_1 in the circuit by connecting A to open end of R_1 and T to open end of R_1

3. Put switch S_2 at charging position.

4. Switch 'ON' S_1 and simultaneously start the stop watch.

5. Note down the maximum initial deflection in the galvanometer at time t = 0 sec. As the time passes the galvanometer deflection goes on decreasing. Read this deflection corresponding to different time interval say 10 sec. , 20 sec. .... so on till the deflection goes to nearly zero. Note all these readings in table as shown below.

6. When the galvanometer deflection goes to nearly zero, change the switch S_2 at discharge position and simultaneously start the stop watch. Note down the maximum initial deflection in the galvanometer at time t = 0 sec. In this case as the time passes the galvanometer deflection goes on decreasing. Note the deflection corresponding to different time interval say 10 sec., 20 sec. ... so on till the deflection goes on nearly to zero. Put all these observations in table as shown below.

   NOTE: - A few trials will give you sufficient practice to take the observations accurately

7. Repeat the experiment for other combination of R and C and note your observations in table-1.

8. Plot the graph between deflection and time for charging and discharging process in all the cases.

9. Find the value of time constant from different curves.

   "The time constant is defined as the time during which the current falls to 37% (1/e) of its maximum value" and compare these value with the product R x C.

9. Take logarithm on both sides of the equation

$$I = I_0\, e^{-\frac{t}{RC}}$$

$$\log I = \log I_0 - (t/RC) \log_{10} e$$

$$\log I = \log I_0 - (0.43/RC)\, t$$

A plot of log I Vs t should yield a straight line.

Plot this graph for one of the sets of observations of table - 1 and find the value of time constant ( ) from the slop of the line.

Table-1 Observations and Tabulations

(i) For Resistance R = 12 K ohm

S.No.	Time t Sec.	For C = 1000 uF		For C = 2200 uF	
		Charging 'Q'	Discharging 'Q'	Charging 'Q'	Discharging 'Q'

Q : represents the deflection of the galvanometer at time **'t'**

Results:

1. Graph shows the charging and discharging curve of a capacitors for different values of R

Discussion:

1. Looking at one set of curves, say for the charging process, why does the current value differ initially. Why do the curves have different shapes. In which case the charging process faster.
2. What does the area under the curve represent
3. Should this area be same for two curves, If yes why
4. Why is the direction of the current during charging opposite to that during the discharging?

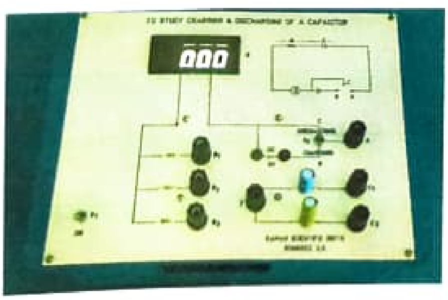
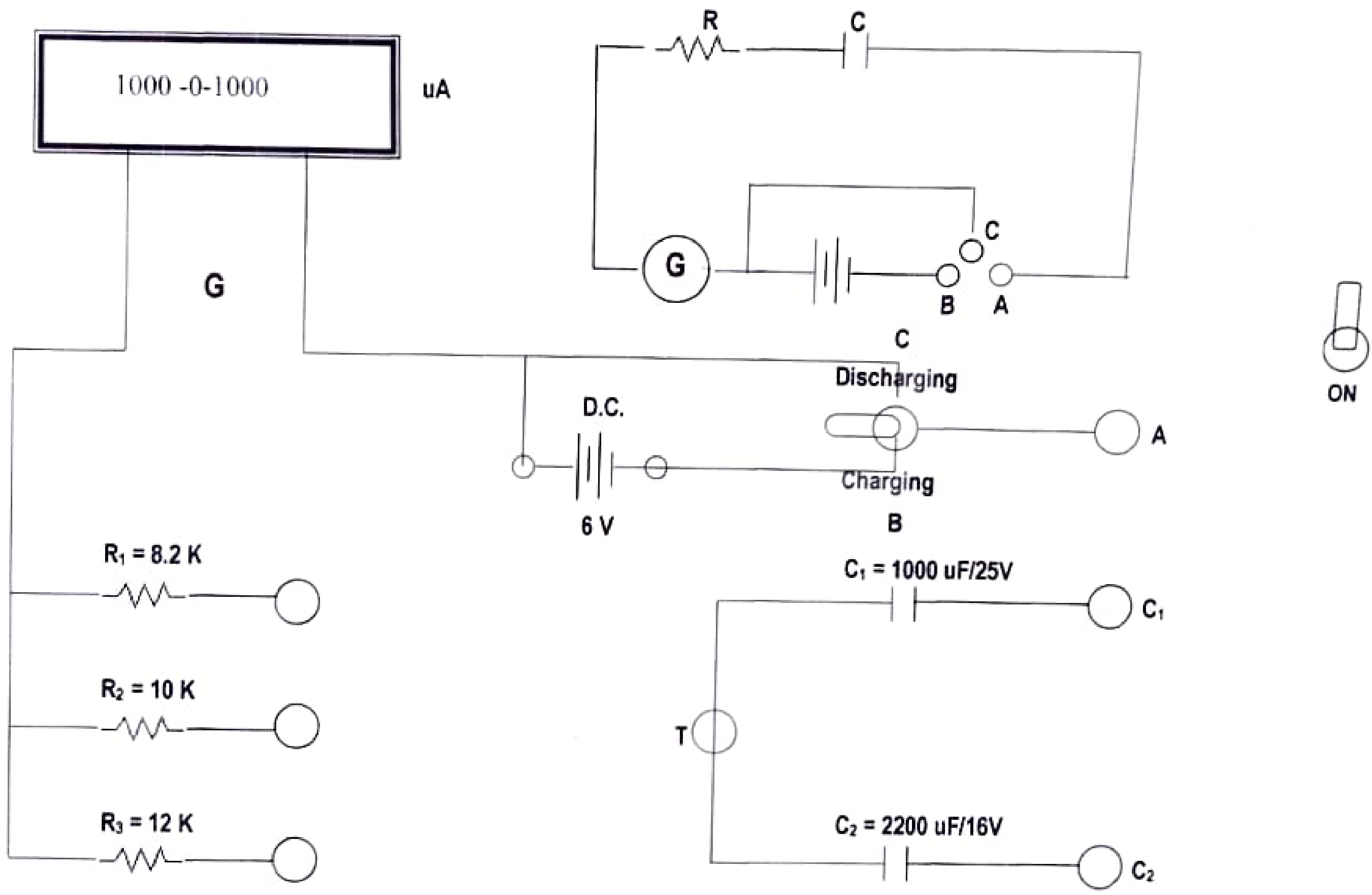


Fig. 2 Layout Diagram

TO STUDY THE CHARGING AND DISCHARGING OF A CAPACITOR USING RESISTOR



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