Lab 4: Measurement of the EMF from a source and the RC time constant of a series RC circuit

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Abstract:

This lab exercise provides a brief investigation of the EMF from a battery and the time dependence of a series RC circuit. These concepts become evident as internal resistance of the battery is calculated and a time constant is computed for both charging and discharging RC circuits. The results for today's lab reveal fairly linear time dependence.

Introduction:

This lab provides an opportunity to examine specific characteristics of the EMF from a battery and allows the time dependence of a series RC circuit to be studied. The experiment makes clear the distinction between a potential source and an EMF. Using a battery as an EMF source, terminal voltage and internal resistance of the battery can be determined. In addition, today's lab focuses on the time constant that can be measured as a series RC circuit is charged and discharged. The theory at play here can be expressed by $V(t) = V_{max}\left(1 - e^{-t/\tau}\right); V_{max} = \mathcal{E}; \tau = RC$ for a charging circuit, and $V(t) = V_0 e^{-t/\tau}; V_0 = \mathcal{E}; \tau = RC$ for a discharging circuit.

Materials and Methods:

In Part I, the internal resistance of a battery was measured. The circuit was assembled as shown in Figure 4.1.

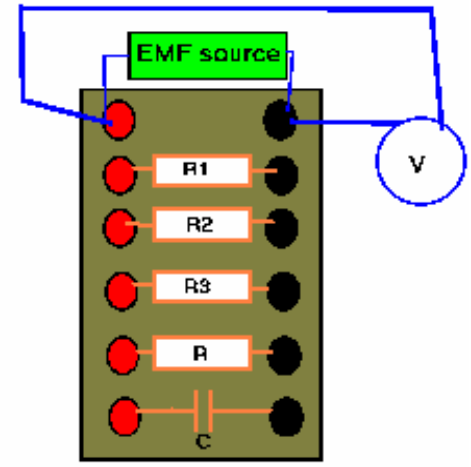

Figure 4.1 Part I Apparatus

The emf of the battery was directly measured, as were the values of R1, R2, R3, R, and C. Next, the connection as shown in Figure 4.2 was made, with the ammeter placed into the circuit. Terminal voltage and the current for each resistor was measured, allowing internal resistance to be calculated.

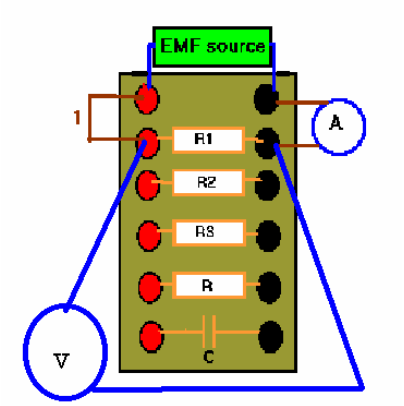

Figure 4.2 Part I Additional Connection

In Part II, the time constant of a series RC circuit was measured. Voltage across the capacitor was measured for the circuit as shown in Figure 4.3. A red lead was connected, and then the two battery leads were connected, as shown in Figures 4.4 and 4.5, respectively.

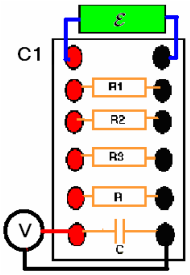

Figure 4.3 Circuit

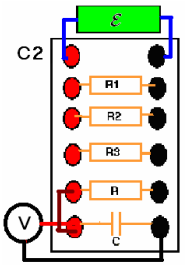

Figure 4.4 Circuit

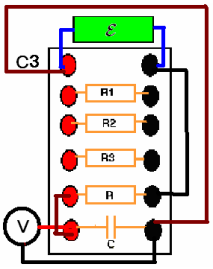

Figure 4.5 Circuit

A shorting lead was connected to short out the capacitor, so that it is discharged, as shown in Figure 4.6.

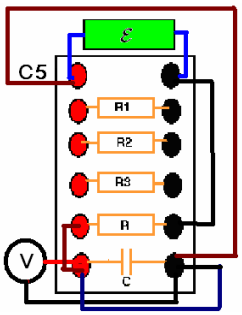

Figure 4.6 Discharging the Capacitor

After discharging the capacitor, the shorting lead was removed, and a voltmeter was used to measure the voltage at 9 increments in time, as the RC circuit charged.

Next, the circuit was assembled as shown in Figure 4.4. The black terminal from the capacitor was then connected to the resistor leg, as shown in Figure 4.7. The red terminal was connected to the RC circuit, as shown in Figure 4.8, to charge the capacitor. Another lead is connected as shown in Figure 4.9 to charge the capacitor to its maximum potential. After charging the capacitor, the end of the lead was removed, and the voltage was measured at 9 increments in time, as the RC circuit discharged.

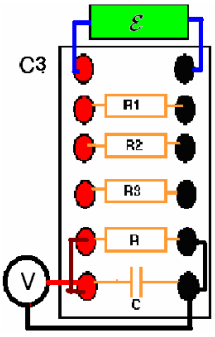

Figure 4.7 Circuit

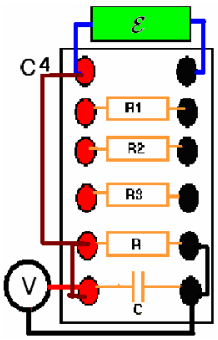

Figure 4.8 Circuit

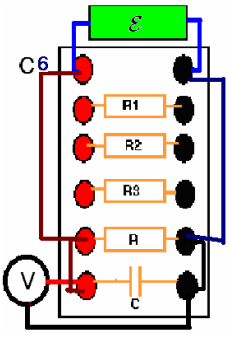

Figure 4.9 Circuit

Results / Discussion:

The EMF of the battery was measured to be 1.515 V. The capacitance was measured to be 28.1µf. Figure 4.10 displays the results for Part I of the experiment. Here, Resistance=V/I, and Internal Resistance= (E-V)/I.

	Resistors	Terminal Voltage [Volts]	Currents [Amps]	Measured Resistance [Ohms]	Internal Resistances [Ohms]
R1	5	1.030E+00	3.500E-01	2.943E+00	1.386E+00
R2	20	1.289E+00	6.260E-02	2.059E+01	3.610E+00
R3	1000	1.484E+00	1.490E-03	9.960E+02	2.081E+01
R4	1.4 Meg	1.505E+00	1.000E-06	1.505E+06	1.000E+04

Figure 4.10 Part I Results

Figure 4.11 shows the results for Part II of the experiment, in which the RC circuit was charged. The plotted data displays a slope of –0.0185. The graph reveals a time dependence, with the time constant calculated as 54.1s.

Time [s]	V1	V/Vmax	ln(1-(V/Vm))
0	0	0	0
1	0.014	0.009241	-0.0092839
2.7	0.053	0.034983	-0.0356101
4.5	0.09	0.059406	-0.0612436
7.4	0.156	0.10297	-0.1086663
12.2	0.252	0.166337	-0.1819256
20.1	0.39	0.257426	-0.2976324
33.1	0.576	0.380198	-0.4783552
54.6	0.799	0.527393	-0.7494906

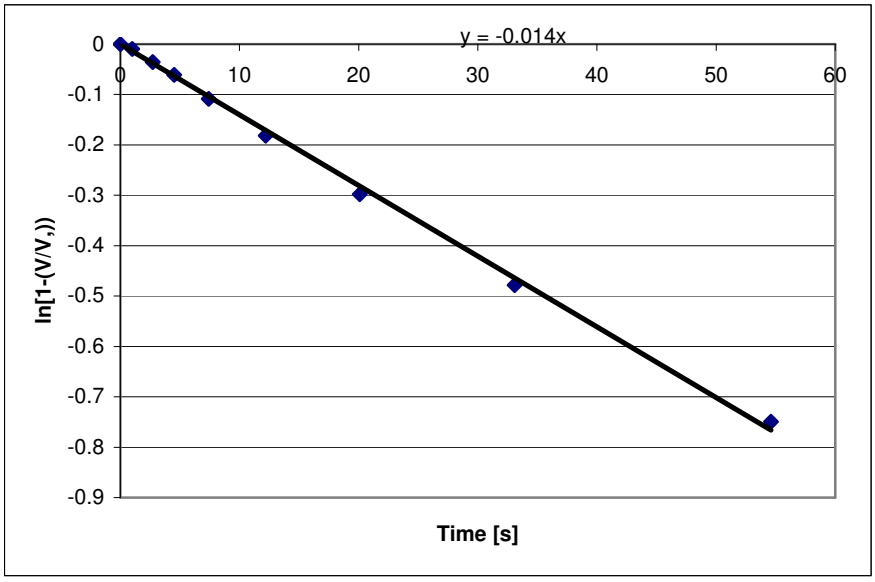

Figure 4.11 Part II Results – Charging RC Circuit

Figure 4.12 shows the results for Part II of the experiment, in which the RC circuit was discharged. The plotted data displays a slope of –0.0231. The time constant was calculated as 43.29s.

Time [s]	V1	V/Vmax	ln(V/Vmax)
0	1.498	0.988779	-0.0112846
1	1.489	0.982838	-0.0173107
2.7	1.444	0.953135	-0.0479984
4.5	1.389	0.916832	-0.0868314
7.4	1.322	0.872607	-0.1362697
12.2	1.198	0.790759	-0.2347619
20.1	1.031	0.680528	-0.3848862
33.1	0.808	0.533333	-0.6286087
54.6	0.547	0.361056	-1.0187219

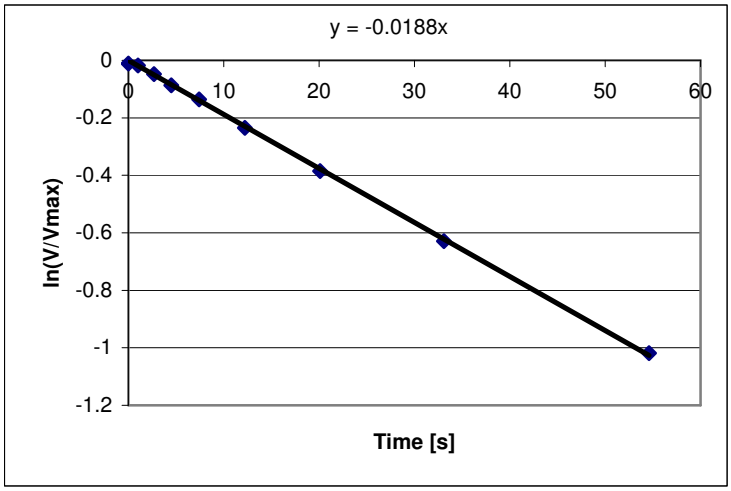

Figure 4.12 Part II Results – Discharging RC Circuit

Literature Cited:

1. Hutton, S. “Measurement of the EMF from a source and the RC time constant of a series RC circuit.” Revised Spring 2005. Retrieved from http://www.lyon.edu/webdata/users/shutton/physics251-spring2005/lab4.doc