PHYS 102 EXPERIMENT 3: RESISTANCE - CAPACITANCE CIRCUITS

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**Data & Results: [20]**

| *Theoretical* | | *Experimental* | | % Error |
|---|---|---|---|---|
| RC (s) | $T_{1/2}$ (s) | RC (s) | $T_{1/2}$ (s) | |
| 47.0 | 32.57 | 50.46 | 34.97 | 7.37% |

Table 1: Half life time and RC time constant of the circuit

R: 470kΩ C: 100 μF

| Time (s) | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|
| Voltage (V) | 20 | 18.46 | 17.49 | 16.52 | 15.68 | 14.14 | 13.99 | 13.28 | 12.55 | 11.88 |
| Current (A) | 0.043 | 0.039 | 0.037 | 0.035 | 0.033 | 0.030 | 0.029 | 0.028 | 0.027 | 0.025 |

$V = IR$

Table 2:a) Current change during discharge and b) RC time constant comparison

| RC (*theoretical*) | RC (from the slope) | % Error |
|---|---|---|
| 47.0 s | 52.83 s | 12.28% |

$\log_{10} I_n$ values in order → −1.37, −1.41, −1.43, −1.46, −1.48, −1.52, −1.54, −1.55, −1.57, −1.60

R: 330kΩ C: 100 μF To be more precise (in that point I can see both stopwatch and V)

| Time (s) | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|
| Voltage (V) | 18 | 16.49 | 15.20 | 13.93 | 12.82 | 11.86 | 10.87 | 9.97 | 9.22 | 8.46 |
| Current (A) | 0.055 | 0.050 | 0.046 | 0.042 | 0.039 | 0.036 | 0.033 | 0.030 | 0.028 | 0.026 |

$V = IR$

Table 3:a) Current change during discharge and b) RC time constant comparison

$\log_{10} I_n$ values in order → −1.26, −1.30, −1.34, −1.38, −1.41, −1.44, −1.48, −1.52, −1.55, −1.59

| RC (*theoretical*) | RC (experimental) | % Error |
|---|---|---|
| 33.0 s | 36.13 s | 9.48% |

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R: 220kΩ C: 100 μF

it actually started from 20 but I take 18 for making measurement error smaller

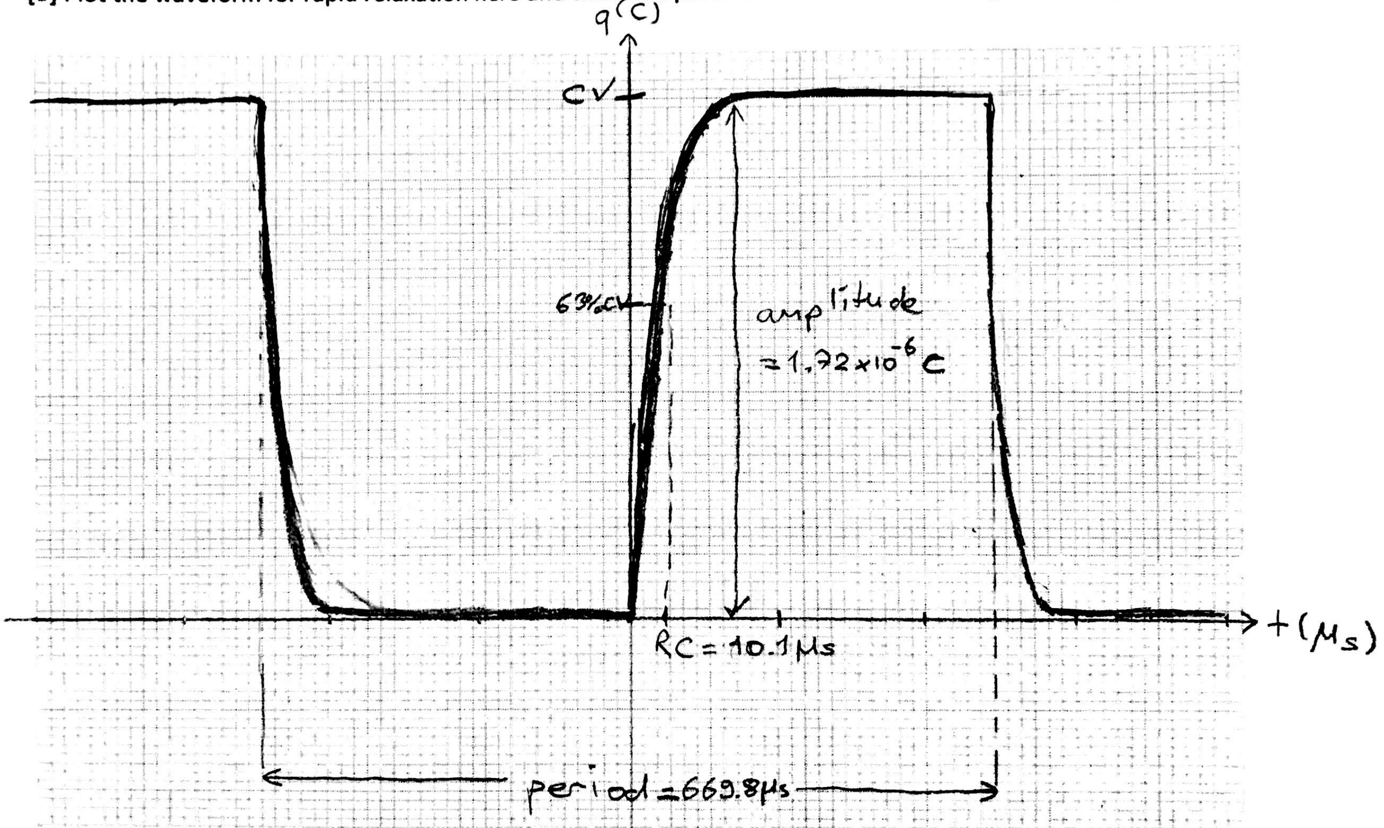
| Time (s) | 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Voltage (V) | 18 | 15.79 | 13.88 | 12.28 | 10.79 | 9.48 | 8.43 | 7.52 | 6.60 | 5.98 | 5.18 |
| Current (A) | 0.082 | 0.072 | 0.063 | 0.056 | 0.049 | 0.043 | 0.038 | 0.034 | 0.03 | 0.027 | 0.024 |

Table 4a: Current change during discharge and b) RC time constant comparison

$\log_{10} I_n$ values in order → -1.09, -1.14, -1.20, -1.25, -1.31, -1.37, -1.42, -1.47, -1.52, -1.57, -1.62

| RC (s) (*theoretical*) | RC (s) (experimental) | % Error |
|---|---|---|
| 22.0 | 24.37 | 10.77 % |

[5] Plot the waveform for rapid relaxation here and show the parameters of the waveform (period, amplitude etc.):




Freq: 1.493 kHz

C = 100 nF

R = 100 Ω

$RC_{exp}$ = 10.1 μs

PK-PK: 17.2V

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microsecond

| **RC** (μs) (***theoretical***) | **RC** (μs) (**calculated**) | **% Error** |
|---|---|---|
| 10 | 10.1 | 1% |

Table 5: RC time constant comparison for rapid relaxation

**Questions:**

**1)** [5] Why do all the three lines have different slopes? Do they also have different intercepts on the current axis? Explain.

Since we have used different resistors, $\frac{V}{R} = I$ is changed for each one of them. Their interception points are simply $\log_{10} I_0$ values. Therefore, their interception points are different since $\frac{V}{R_1}, \frac{V}{R_2}, \frac{V}{R_3}$ are diff. Their slopes gives us RC value. C is constant but R is changing. Therefore, slopes are different.

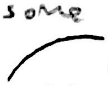
**2)** [5] Show that the capacitive time constant has units of time.

1st way → RC → Ohm. Farad $= \frac{Volt}{Amper} \cdot \frac{Coulomb}{Volt} = \frac{Coulomb}{Amper} = \frac{Amper.second}{Amper} = second$

2nd way → $Q = CV$ and $V = IR \Rightarrow Q = IRC \xrightarrow{I = Q/t} Q = \left(\frac{Q}{t}\right) RC \rightarrow RC = t$ //

**3)** [5] What happens when RC is much higher or smaller than the period of the square wave?

If RC is much smaller than the period, graphic looks like  → as change is so rapid that can't be differentiated from square at some point

If RC is much higher than the period, graph becomes  change can be more easily seen

**4)** [5] Suppose that you want to construct a parallel plate capacitor whose capacitance is 1F. If the separation between the plates is 1mm what would be the area of the plates?

$$C = \frac{\varepsilon_0 A}{d} \Rightarrow 1 = \frac{8.85 \times 10^{-12} \times A}{10^{-3}} \Rightarrow A = 11.3 \times 10^{7} m^2$$

**Conclusion: [10]** This experiment was aimed to observe how charging and uncharging of capacitor depends on RC time constant by making use of half-time $T_{1/2} = RC\ln 2 = 0.693 RC$. What is nice about that is we can easily observe $T_{1/2}$ by knowing initial voltage and discharging capacitance while keeping track of time it requires to reach $V_0/2$ volt. From that principle, we calculate table 1 experiental values and the error was 7.37%. The main source of error is one cannot be able to both pushing stopwatch and short-circuit the circuit at once. For the table 2, 3, 4: we measure voltage at every 3 seconds and finding current from V=IR, we plot $\log i$ vs $t$ graph. It turns out that slope of that gives $-(RC)^{-1} \log e$ and we find another way to calculate RC experimentally. I tried to minimize the error by taking not exactly 20V but 18V to be better able to observe both stopwatch and voltmeter and the errors of table 3 and 4 are 9.48% and 10.77% both less than table 2, 12.28% which shows that my attempt succeeded. In the last part we observe rapid relaxation and it turns out that the period of square waves and RC ratio is important for what we see in oscilloscope. I learned above formulas and especially in last part, how capacitors react in changing signal value.

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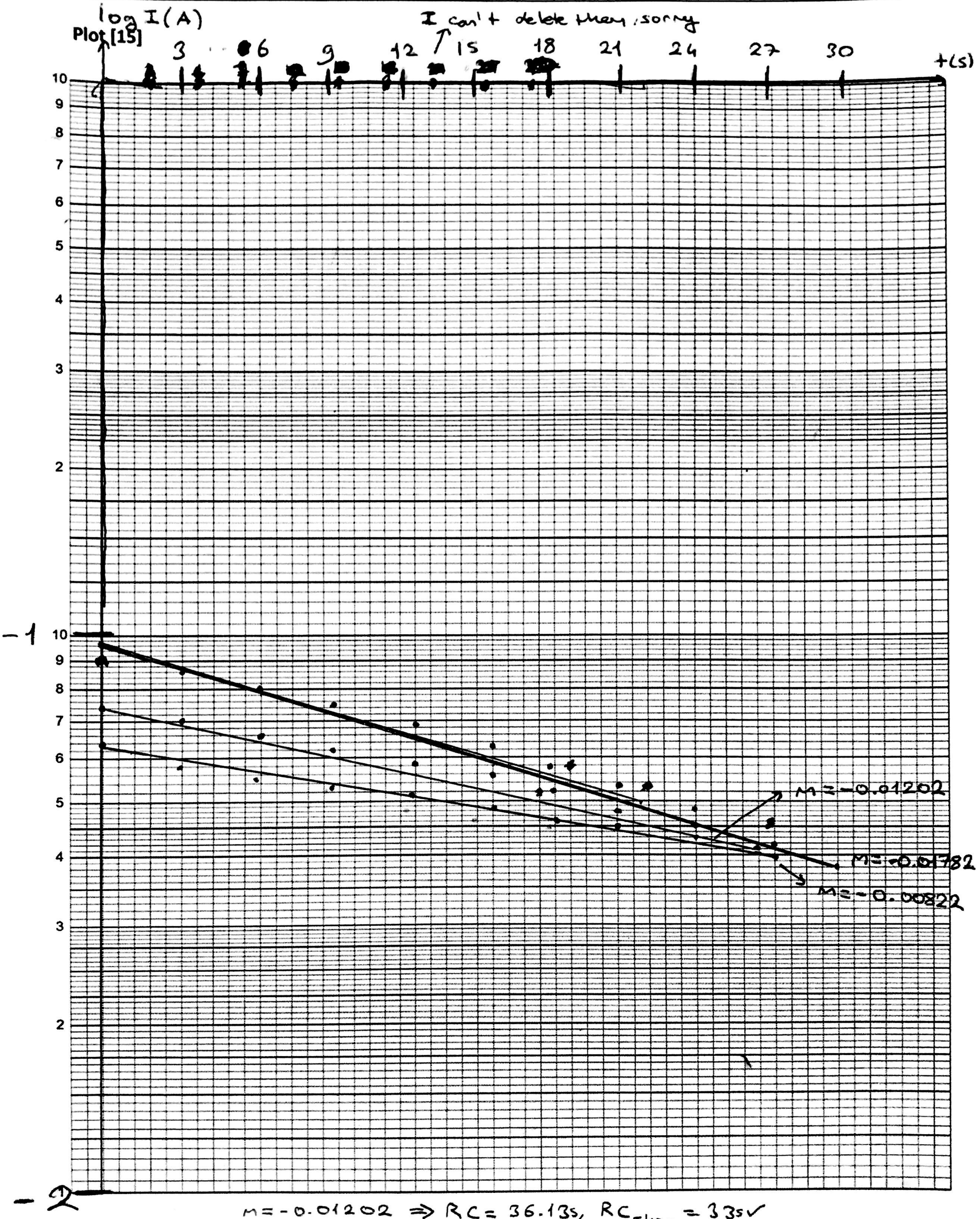
Plot [15]




$$RC = -\frac{\log e}{M} \Rightarrow \begin{array}{l} M=-0.01202 \Rightarrow RC = 36.13s,\ RC_{Theo} = 33s ✓ \\ M=-0.00822 \Rightarrow RC = 52.83s,\ RC_{Theo} = 47s ✓ \\ M=-0.01782 \Rightarrow RC = 24.37s,\ RC_{Theo} = 22s ✓ \end{array}$$

sorry for inconvenience, I wish they give normal plot as I think that scaling shouldn't be such a mess, I used it and I cannot plot again since usage of pen. But all of the lines are true and created by online linear regression calculator.