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Experiment 1-A.
Transient Response of RLC Circuit.

Aim: To study transient response of RLC series circuit for under damping, critical damping and over damping conditions produced by changing resistance. To study output waveform and determine the values of rise time, settling time and percentage overshoot particularly for underdamped case.

Theory: The output waveform obtained across the capacitor in an RLC series circuit depends on the normalized damping factor ζ in terms of shape.
Three-figures-of-merit for judging the transience of a step response are the rise time, percent overshoot and settling time. Percent overshoot is zero for the overdamped and critically damped cases. For the underdamped case the percent overshoot is defined as-

$$\%\text{overshoot} = \frac{\text{peak } v_{out} - v_{out}(\infty)}{v_{out}(\infty)} \times 100.$$

$$= 100 \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right) \quad \text{(theoretically)}$$

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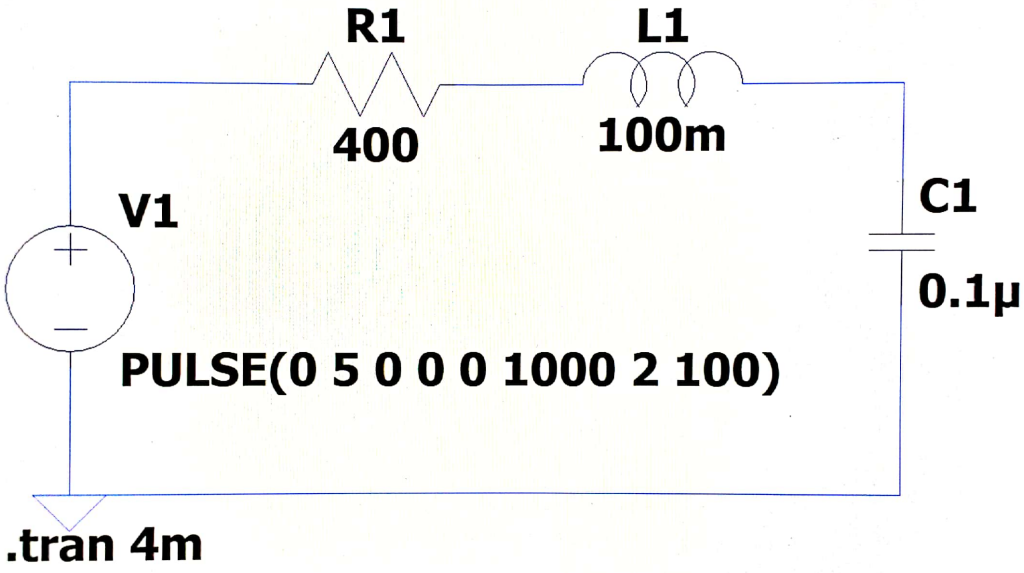
The overshoot is 0% for $\zeta = 1$. In the limit of $\zeta \to 0$ (the undamped case) the overshoot approaches 100%.

The rise time is defined as the time required for the output voltage to rise from 10% to 90% of its final steady-state value.
The settling time is the time required by an underdamped system for its output voltage to approach steady state and stay within some specified percentage.

LTSpice Circuit Diagrams:

The circuit diagrams for this experiment follow from the next page.

EXPERIMENT 2 PART A - TRANSIENT RESPONSE OF RLC CIRCUIT



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Observations:

$$\zeta_f = \frac{\alpha}{\omega_0} = \frac{R/2L}{1/\sqrt{LC}}$$

$L = 100\,mH$, $C = 0.1\,\mu F$.

① Over-damping condition -

for $\zeta_f > 1$, $R > 2000\,\Omega$

The transient response that is the voltage built up in the capacitor for $R = 3k\Omega$ is shown on the next page.

② Critical-damping condition -

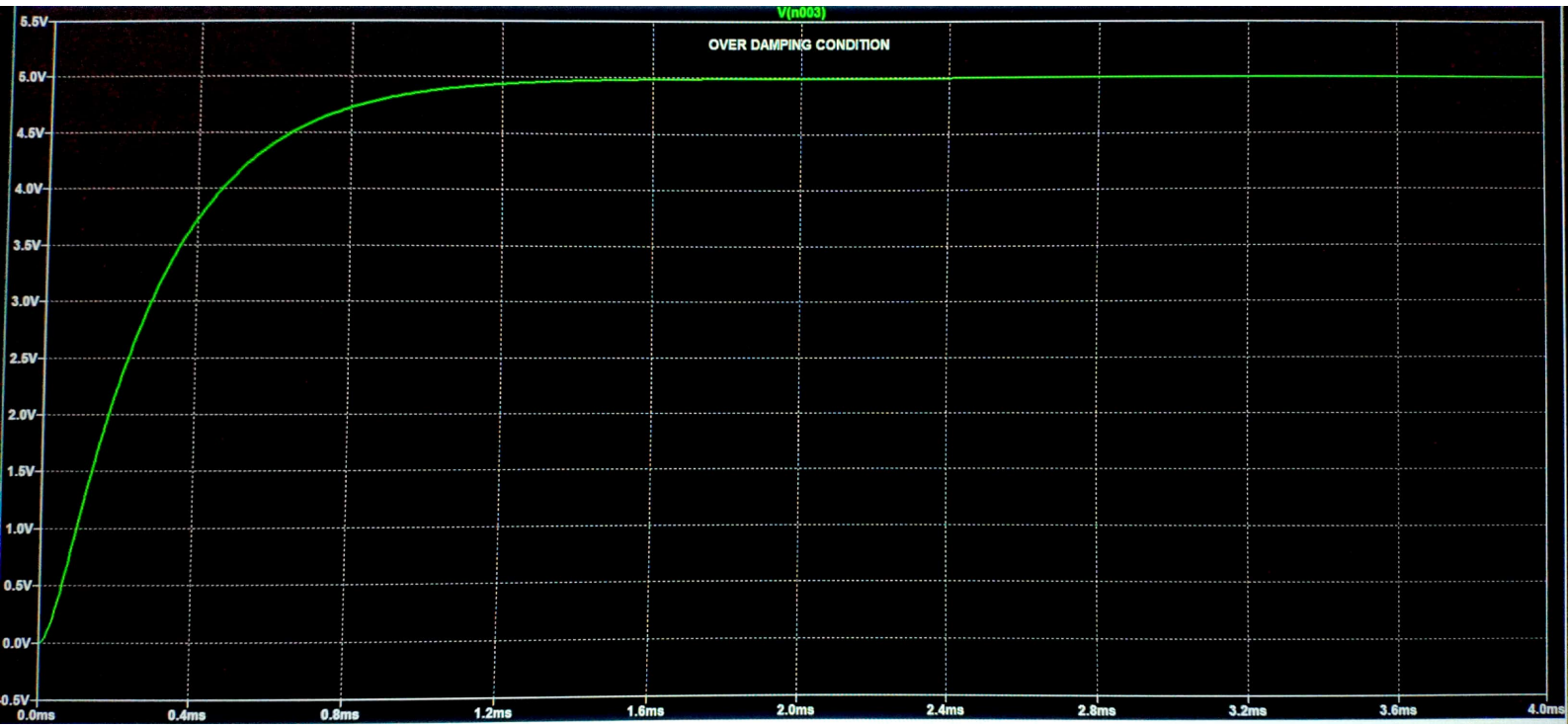
for $\zeta_f = 1$, $R = 2000\,\Omega$.

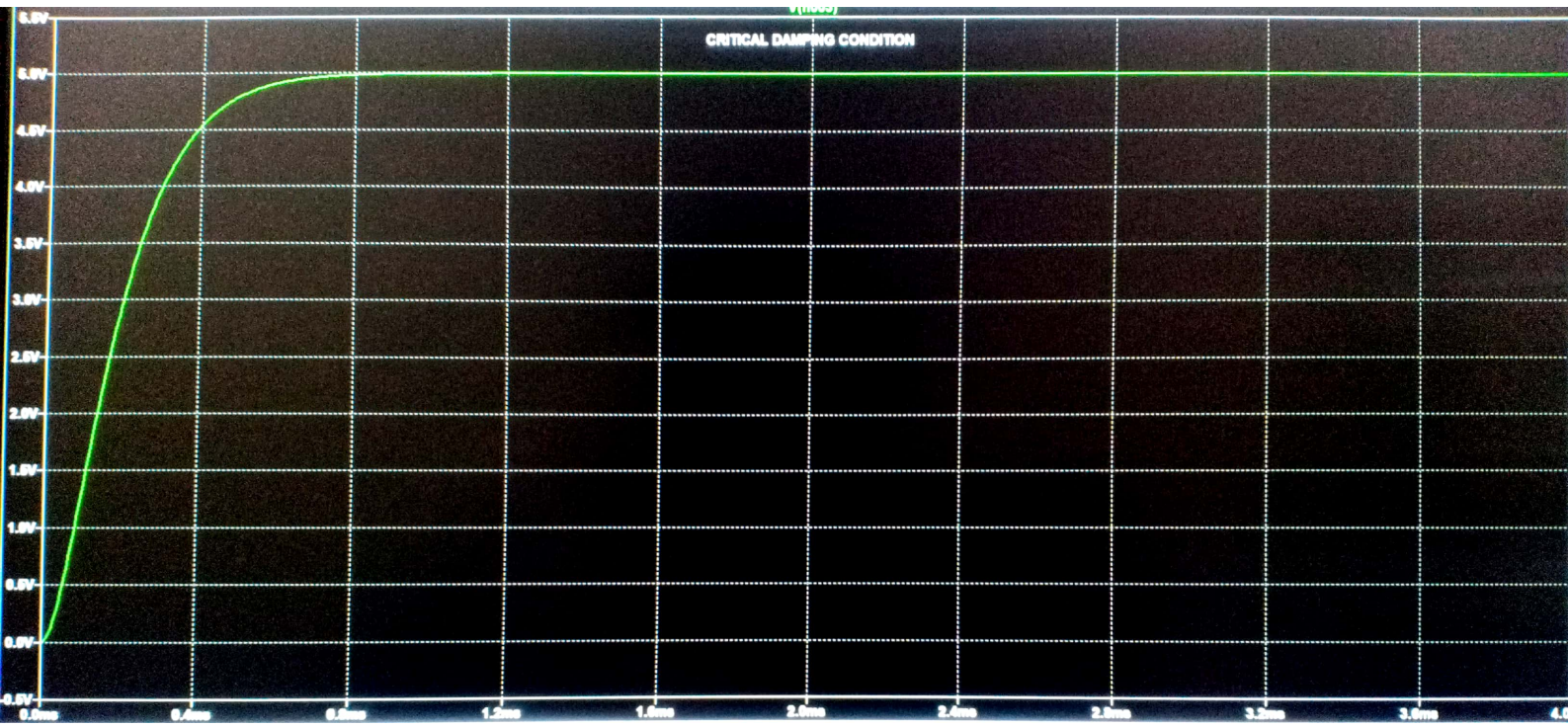
The transient responce for $R = 2k\Omega$ is shown on the next page.

③ Under-damping condition - ($R < 2000\,\Omega$)

- Rise times & Settling Times.

ζ_f	Resistance (Ω)	Rise Time	Settling Time
0.05	100	110 μs	13.34 ms
0.20	400	121 μs	7.62 ms
0.35	700	141 μs	1.73 ms
0.50	1000	164 μs	1.30 ms





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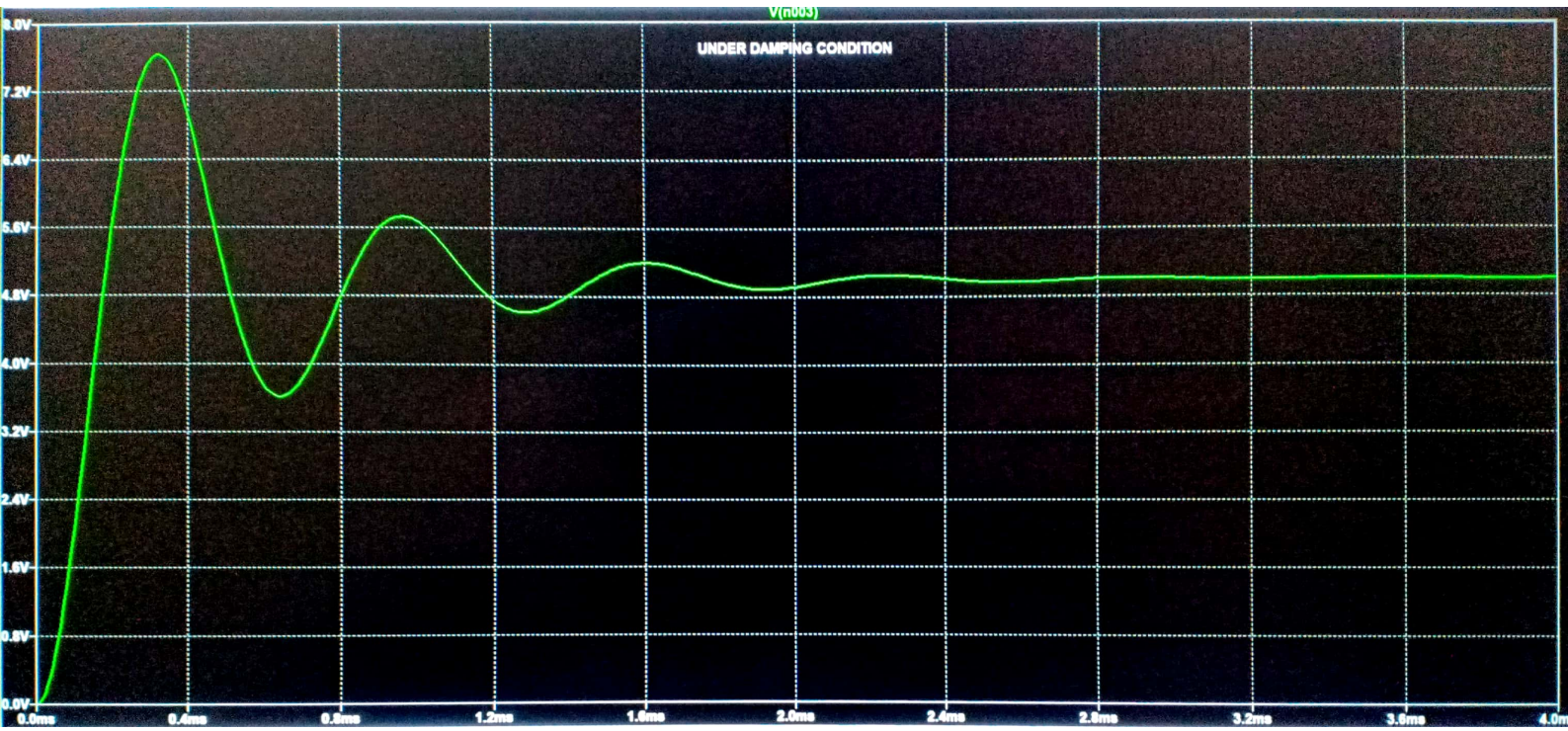
- Percentage Overshoot (for $v_{out}(\infty) = 5V$)

Eg	Resistance (in Ω)	peak v_{out} (in V)	P.O. (practical)	P.O. (theoretical)
0.1	200	8.6385	72.77 %	72.92 %
0.2	400	7.6285	52.57 %	52.66 %
0.3	600	6.8588	37.18 %	37.23 %
0.5	1000	5.8153	16.31 %	16.30 %
0.7	1400	5.2304	4.61 %	4.60 %
0.8	1600	5.0760	1.52 %	1.52 %

The transient response of the circuit for $R = 400\,\Omega$ is shown on the next page.



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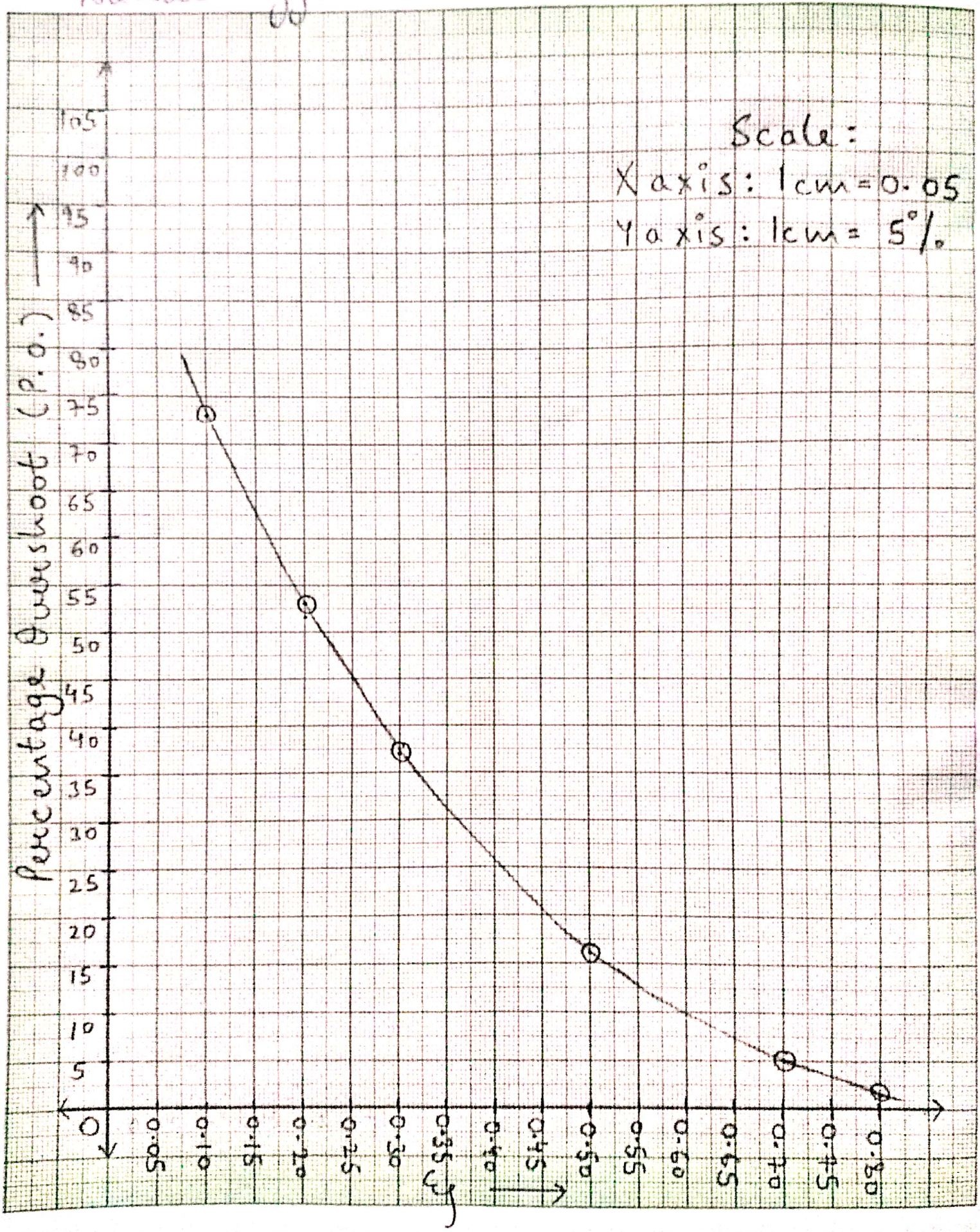

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Inference:

(1) In the transient region of the output waveform, for the over damped and critically damped cases, no oscillatory behaviour is observed.

(2) In the transient region of the output waveform, for the under-damped case, oscillatory behaviour is observed.

(3) As the normalised damping constant, or the resistance is increased, in the under-damped condition ($\zeta < 1$), the rise time is observed to increase and settling time is observed to decrease.

(4) The percentage overshoot of the step response for under-damping conditions decreases with increasing normalised damping constant. It seems to approach 0% as ζ approaches 1 and 100% as ζ approaches 0.

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Discussion: The transient response of an RLC circuit under various damping conditions was successfully studied. In the under-damping case, the values of practical and theoretical percentage overshoots were surprisingly close. The variations in the rise times and the settling times was observed to be monotonic. For very small values of ζ, the rise times were short but settling times long. The graph plotted for the practically determined values of percentage overshoot looked very similar to the graph of the theoretical formula. On varying the value of R in the circuit, the transient response changed according as when R was increased in the under-damping condition the oscillatory behaviour decreased. The experiment successfully verified all the results mentioned in the theory.