

Kirchhoff's rules and RC transients

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: _____ Date: _____ Class: _____

How quickly does a capacitor lose its charge through a resistor, and does the time constant equal RC ? You will discharge a large capacitor through a fixed resistor, record the voltage with a stopwatch, and use a log graph to find τ and compare the capacitance with its label.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 11

Aim

Measure how the voltage across a discharging capacitor falls with time, find the time constant from a logarithmic graph, and test the relation $\tau = RC$.

Equipment

- Electrolytic capacitor, nominal 1000 μF , rated at least 10 V
- Resistor 22 k Ω
- Four 1.5 V cells and holder (6.0 V)
- Digital voltmeter and leads
- Stopwatch or phone timer
- Single-pole switch or a loose lead

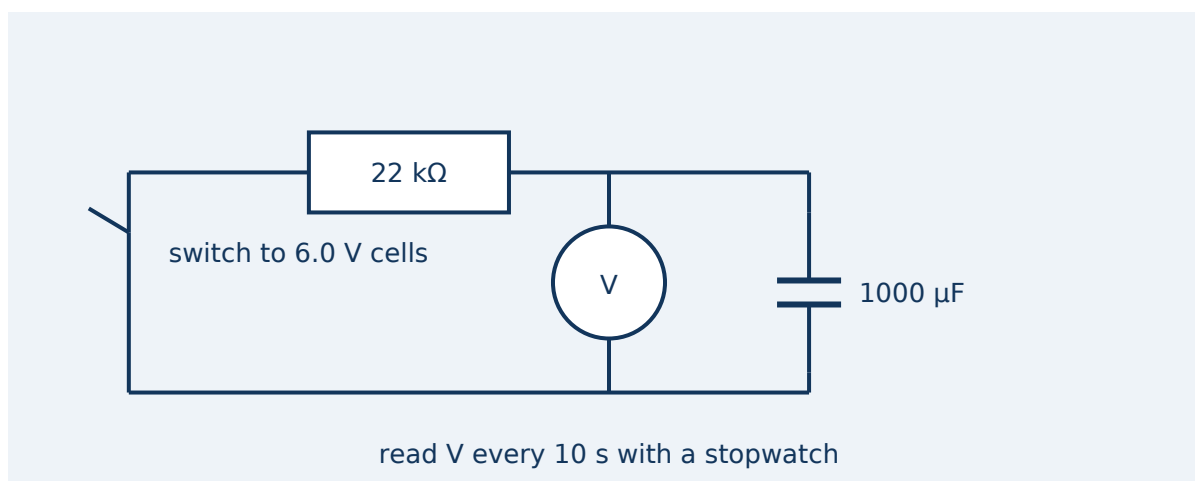
Safety

Safety

Connect the electrolytic capacitor with the correct polarity (long lead to +) and never exceed its rated voltage. Use only the 6.0 V cells. Short the capacitor through the resistor after the lab so that it is fully discharged.

Method

1. Connect the capacitor across the 6.0 V cells for 2 minutes so it is fully charged.
2. Connect the voltmeter across the capacitor and disconnect the cells.
3. Connect the resistor across the capacitor and start the stopwatch at the same moment.
4. Record the voltage every 10 s for 60 s.
5. Repeat the whole run and average the readings at each time.
6. Calculate $\ln V$ for each reading.



Set-up: the charged capacitor discharges through the resistor while a voltmeter records V against time.

Results

Sample measurements (voltmeter resistance $10\text{ M}\Omega$, negligible compared with $22\text{ k}\Omega$):

$t\text{ (s)}$	0	10	20	30	40	50	60
$V\text{ (V)}$	6.0	3.5	2.1	1.2	0.73	0.43	0.26
$\ln(V/V_0)$	1.79	1.25	0.74	0.18	-0.31	-0.84	-1.35

Analysis questions

Question 1 Plot $\ln V$ against t

Explain why $\ln V$ against t should be a straight line and plot it.

Question 2 Gradient

Calculate the gradient of the graph from the first and last points.

Question 3 Time constant

Use the gradient to find τ .

Question 4 Capacitance

Calculate the capacitance from τ and compare it with the nominal $1000\text{ }\mu\text{F}$.

Question 5 Half-time check

Use τ to predict the time for V to halve and compare it with the table.

Question 6 Uncertainty

The voltmeter reads to ± 0.01 V and the timing to ± 0.5 s. State which reading affects τ most and estimate the percentage uncertainty.

Question 7 Reducing error

Suggest two ways to get a more accurate time constant.