

Charge storage, energy and RC time constants

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The sample readings give a time constant near 23 s, compared with a nominal RC of 22 s. The answers below show the calculations from the sample data, so your own results should have the same pattern but slightly different numbers.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.7.4

Question 1 Shape of the curve

The voltage falls steeply at first and then more and more gradually, approaching zero without reaching it. The rate of fall is proportional to the voltage still on the capacitor, so **the decay is exponential**.

Question 2 Half the voltage

4.5 V is reached between 10 s (5.9 V) and 20 s (3.9 V); a smooth curve through the points gives about 16 s (straight-line interpolation would overestimate). Since $t^{1/2} = \tau \ln 2$, $\tau = 16 / 0.693 = \mathbf{23\ s}$.

Question 3 Logarithm table

$\ln V = 2.20, 1.77, 1.36, 0.96, 0.53, 0.10, -0.36$ for 9.0, 5.9, 3.9, 2.6, 1.7, 1.1 and 0.7 V. From $V = V_0 e^{-t/\tau}$, $\ln V = \ln V_0 - t/\tau$, so **$\ln V$ is linear in t** with gradient $-1/\tau$.

Question 4 Gradient and τ

Gradient = $(-0.36 - 2.20) / 60 = -0.0426\ \text{s}^{-1}$. $\tau = -1 / \text{gradient} = \mathbf{23\ s}$. (A least-squares fit of all seven points gives $\tau = 23.6\ \text{s}$.)

Question 5 Comparing with RC

$RC = 22 \times 10^3 \times 1000 \times 10^{-6} = 22\ \text{s}$. Difference = $(23 - 22) / 22 \times 100 = \mathbf{7\ \%}$.

Question 6 Capacitor tolerance

Yes. A difference of about 7 % lies inside the $-20\ \%$ to $+50\ \%$ tolerance, so the measured value is **consistent with the nominal value**. The capacitor is probably slightly above 1000 μF .

Question 7 Initial current

$$I_0 = V_0 / R = 9.0 / (22 \times 10^3) = \mathbf{4.1 \times 10^{-4} \text{ A (0.41 mA)}}.$$

Question 8 Improving the method

Any two of: record more readings, especially in the first 30 s; use a datalogger to remove timing errors; repeat the run and average τ ; use a capacitor measured on a capacitance meter; use a voltmeter with a larger input resistance. **Any two sensible changes.**