InkPhysics

ANSWER BOOK

The time constant and exponential decay

Capacitance · Year 13

AQA 3.7.4.4 · CIE 19.3 · OCR A 6.1.3

10 questions · 30 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The time constant is $\tau = RC$. It is the time for the charge (or voltage, or current) to fall to 1/e (about 37%) of its initial value during discharge. [2]

A2 $\tau = RC = 10000 \times 100 \times 10^{-6} = 1.0$ s. [2]

A3 $Q = Q_0 e^{-t/RC}$, where Q_0 is the initial charge. [2]

SECTION B · Standard

B1 $\tau = RC = 2200 \times 470 \times 10^{-6} = 1.03$ s. After one time constant the charge has fallen to 1/e ≈ 37% of its initial value. [3]

B2 $\tau = RC = 47000 \times 100 \times 10^{-6} = 4.7$ s. $V = V_0 e^{-t/RC} = 12 \times e^{-5.0/4.7} = 4.14$ V. [4]

B3 $T_{½} = 0.69 \times 4.7 = 3.24$ s. [3]

B4 $R = \tau/C = 2.0/(220 \times 10^{-6}) = 9091\ \Omega$ (9.1 kΩ). [3]

SECTION C · Stretch

C1 $5.0 = 20e^{-t/3.0}$, so $e^{-t/3.0} = 0.25$ and $t = -3.0 \times \ln(0.25) = 4.16$ s. [4]

C2 $\tau = RC = 10000 \times 470 \times 10^{-6} = 4.7$ s. $V = 9.0 \times (1 - e^{-10/4.7}) = 7.93$ V. [4]

C3 Taking logs of $V = V_0 e^{-t/RC}$ gives $\ln V = \ln V_0 - t/RC$, a straight line. Its gradient is $-1/RC$, so $RC = -1/\text{gradient}$; the time constant is the negative reciprocal of the slope. [5]