

Solutions

Original-task marks: M1 = method, A1 = accuracy, B1 = stated reasoning point.

2.1 Convert capacitance to farads and use $Q = CV$.

$$Q = CV = 220 \times 10^{-6} \text{ F} \times 9.0 \text{ V} = 1.98 \times 10^{-3} \text{ C}$$

Charge magnitude. Use capacitor energy, not final QV .

$$W = \frac{1}{2}CV^2 = \frac{1}{2} \times 220 \times 10^{-6} \text{ F} \times (9.0 \text{ V})^2 = 8.91 \times 10^{-3} \text{ J}$$

Energy. Quoted Q is the separated-charge magnitude on either plate; the ideal plates have $+Q$ and $-Q$, not total stored charge $2Q$.

2.2 The slope is $1/C$.

$$C = \frac{1}{\text{gradient}} = \frac{1}{5000 \text{ V C}^{-1}} = 2.00 \times 10^{-4} \text{ F}$$

Capacitance $200 \mu\text{F}$. Work is the area under V against charge added, a triangle:

$$W = \frac{1}{2}QV = \frac{1}{2}CV^2$$

The factor half follows from the voltage rising from zero.

2.3 Use discharge time constant.

$$\tau = RC = 30.0 \times 10^3 \Omega \times 100 \times 10^{-6} \text{ F} = 3.00 \text{ s}$$

Time constant. Exponential discharge.

$$V = V_0 e^{-t/RC} = 10.0 \text{ V} \times e^{-6.0/3.00} = 1.35 \text{ V}$$

Voltage.

$$|I| = \frac{V}{R} = \frac{1.353 \text{ V}}{30.0 \times 10^3 \Omega} = 4.51 \times 10^{-5} \text{ A}$$

Current magnitude $45.1 \mu\text{A}$.

3.1 Initially $V_C = 0$, so the resistor has full supply p.d. and $I_0 = V_s/R$. As V_C rises, $V_R = V_s - V_C$ and current decrease. Equality gives $e^{-t/RC} = 1 - e^{-t/RC}$, hence:

$$t = RC \ln 2$$

Correct time. Smaller load resistance gives smaller RC , faster discharge between peaks and larger voltage ripple.

3.2 Divide the two exponential readings from one uninterrupted discharge.

$$R = -\frac{\Delta t}{C \ln(V_2/V_1)} = -\frac{4.0 \text{ s}}{470 \times 10^{-6} \text{ F} \times \ln(3.0/8.0)} = 8.68 \times 10^3 \Omega$$

Resistance. Allowed interval is $9.00\text{--}11.0 \text{ k}\Omega$, so it fails this test under the exact-capacitance assumption. Subtract stored energies.

$$\Delta W = \frac{1}{2}C(V_1^2 - V_2^2) = \frac{1}{2} \times 470 \times 10^{-6} \text{ F} \times (8.0^2 - 3.0^2) \text{ V}^2 = 1.29 \times 10^{-2} \text{ J}$$

Energy delivered.

3.3 Charge from a low-voltage supply then isolate it and discharge through known R , sensing p.d. across C . Record voltage/time at intervals short compared with RC . Restore the same initial voltage before repeats and keep R, C and temperature steady. Plot $\ln(V/V_0)$ vertically against t horizontally; gradient is $-1/(RC)$, so $RC = -1/\text{gradient}$. Use a sensor input resistance much larger than R ; its parallel discharge path otherwise reduces effective resistance and measured time constant. Respect capacitor polarity/rating and discharge through a resistor before reconnecting; avoid logs near zero where relative uncertainty is large.