2017 H2 Q13

Section: Electricity

Topic: Capacitors — time constant, initial current, effect of circuit on τ

An uncharged 220 μF capacitor is connected with resistors (two 6800 Ω) and switches S1 and S2 to a 12 V supply (negligible internal resistance).

(a) Initial charging current when S1 is closed (charging time ≈ 7.5 s)

For RC charging, a capacitor is effectively ‘fully charged’ after about 5 time constants (≈ 5τ). Given charging time 7.5 s, take τ ≈ 7.5/5 = 1.5 s.

τ = RC ⇒ R = τ/C = 1.5 / (220×10^-6) ≈ 6.8×10^3 Ω.

Initial charging current I0 = V/R = 12 / 6.8×10^3 ≈ 1.8×10^-3 A.

Answer: I0 ≈ 1.8 mA

(b) Why charging time is less when S2 is closed before S1

Closing S2 alters the charging path resistance (e.g. bypasses one resistor or adds a parallel path). This reduces the effective resistance in series with the capacitor, so the time constant τ = RC is smaller. Therefore the capacitor reaches full charge in less time than in part (a).

Revision tips

- Rule of thumb: ‘fully charged’ ≈ 5 time constants (5τ).
- Initial current in RC charging: $I_0 = V/R$ (at $t = 0$).
- Reducing the series resistance reduces the time constant and speeds up charging/discharging.