2019 Ph H2 Q13

Section: Electricity

Topic: Capacitor charging, energy and analogy

A 47 μF capacitor is charged from a 6.0 V supply via a resistor. The current is monitored with time as it charges. (a) Calculate the maximum charge stored. (b) Sketch how current vs time graph changes if resistor is increased. (c) Suggest how to increase maximum energy stored. (d) Comment on the car park analogy for capacitor charging.

Worked solution

(a) Maximum charge is given by Q = CV.
= $47\times10^{-6} \times 6.0$ = 2.82e-04 C.

Answer: 2.8×10^{-4} C

(b) Increasing resistance increases the time constant τ = RC.
This makes the current fall more slowly with time. The initial current is smaller, and the curve is shallower, but the capacitor still charges to the same final value. So the I–t curve lies below the original and decays more gradually.

(c) Maximum energy stored = ½CV^2.
To increase energy: either increase C (use bigger capacitor) or increase V (higher supply voltage).

(d) Analogy: Cars entering a car park represent charge flowing onto a capacitor.
• At first many spaces are empty → cars enter quickly (large initial current).
• As spaces fill → cars must slow and wait (current decreases).
• Eventually full → no more cars enter (current = 0).
The analogy helps illustrate decreasing current. However, cars slow because of congestion, whereas in a capacitor charging current falls because potential difference across capacitor increases. So it is helpful but not exact.

Final answers

(a) $Q_{max} \approx 2.8\times10^{-4}$ C

(b) Current falls more slowly with higher R

(c) Increase C or increase V

(d) Analogy shows decreasing current, but physical reasons differ

Revision tips

- $Q = CV$ for maximum charge.
- Energy stored: $\frac{1}{2}CV^2$.
- Time constant $\tau = RC$: bigger R → slower charge/discharge.

- Analogy useful: cars = charge, spaces = capacity, congestion = rising voltage.
- Capacitor charging: I falls exponentially as capacitor charges.