InkPhysics

ANSWER BOOK

Charging and discharging

Capacitance · Year 13

AQA 3.7.4.4 · CIE 19.3.1 · OCR A 6.1.1(b), 6.1.3(a)(i)

18 questions · 46 marks

NAVY EDITION

SECTION A · Warm-up

A1 Exponential decay from the initial (maximum) charge (1); the charge falls quickly at first, then ever more slowly, approaching zero without reaching it (1). [2]

A2 The current is a maximum at the instant charging begins (1); it then decreases exponentially towards zero as the capacitor charges (1). [2]

A3 The current is the magnitude of the gradient of the charge–time graph, $I = \Delta Q/\Delta t$; on discharge that gradient is negative because charge is leaving the plates (1). [1]

A4 The total charge transferred (the charge that leaves the capacitor) (1). [1]

A5 The capacitor pd equals the supply pd, 5.0 V (1); the resistor pd is zero, because the current has fallen to zero (1). [2]

A6 It starts at its maximum value, equal to the full supply pd (1); it then decreases (exponentially) towards zero as the capacitor pd rises towards the supply pd (1). [2]

SECTION B · Standard

B1 $I_0 = V/R = 12/1000$ (1) [2]
$I_0 = 0.012$ A (12 mA) (1)

B2 Initial current $I_0 = V/R = 6.0/2000 = 0.0030$ A (3.0 mA) (1) [2]
Final current = 0 when fully charged (1).

B3 The pd across the capacitor rises from zero, rapidly at first, levelling off towards the supply voltage (exponential growth towards a limit) (1). As charge builds up, the pd across the resistor (supply pd minus capacitor pd) falls, so the rate of charging decreases (1). The current starts at V/R and decays exponentially towards zero (1); because the current is driven by the pd across the resistor, which falls as the capacitor charges (1). [4]

B4 $Q = CV = 100 \times 10^{-6} \times 9.0 = 9.0 \times 10^{-4}$ C (1) [3]
$E = ½CV^2 = ½ \times 100 \times 10^{-6} \times 9.0^2$ (1)
$E = 4.050 \times 10^{-3}$ J (1)

B5 The magnitude of the initial gradient is the initial current, $I_0 = 4.0 \times 10^{-4}$ A (1) [3]
$R = V_0/I_0 = 6.0/(4.0 \times 10^{-4})$ (1)
$R = 15000\ \Omega$ (15 kΩ) (1)

B6 The area is the total charge stored, $Q = 5.4 \times 10^{-3}$ C (1) [2]
$C = Q/V = (5.4 \times 10^{-3})/9.0 = 6.0 \times 10^{-4}$ F (600 μF) (1)

B7 $V_R = 12 - 7.5 = 4.5$ V (1) [3]
$I = V_R/R = 4.5/15000$ (1)
$I = 3.0 \times 10^{-4}$ A (0.30 mA) (1)

SECTION C · Stretch

C1 $Q_0 = CV = 470 \times 10^{-6} \times 10$ (1) [4]
$Q_0 = 4.70 \times 10^{-3}$ C (1)
$I_0 = V/R = 10/2200$ (1)
$I_0 = 4.55 \times 10^{-3}$ A (4.55 mA) (1)

C2 All the stored energy is transferred to the resistor (1) [3]
$E = ½CV^2 = ½ \times 1000 \times 10^{-6} \times 12^2$ (1)
$E = 0.072$ J (1)

C3 As charge leaves the capacitor, the pd across it falls, since $V = Q/C$ (1). The same pd appears across the resistor, and $I = V/R$ (1); a smaller pd drives a smaller current, so the current keeps decreasing as the discharge proceeds (1). [3]

C4 E at 6.0 V $= ½CV^2 = ½ \times 2200 \times 10^{-6} \times 6.0^2 = 0.0396$ J (1) [3]
E at 3.0 V $= ½ \times 2200 \times 10^{-6} \times 3.0^2 = 0.0099$ J (1)
Energy transferred $= 0.0396 - 0.0099 = 0.030$ J (1)

C5 The charging current is largest at the first instant, $I_0 = V/R$ (1) [4]
With 100 Ω: $I_0 = 12/100 = 0.12$ A = 120 mA, which exceeds the 50 mA limit (1)
With 100 kΩ: $I_0 = 12/100000 = 1.2 \times 10^{-4}$ A = 0.12 mA, which is within the limit (1)
A smaller resistance charges the capacitor faster, but only the 100 kΩ resistor keeps the current below 50 mA, so the student must use 100 kΩ (1).