



ANSWER BOOK

Capacitors and energy stored

Capacitance · Year 13

AQA 3.7.4.1, 3.7.4.2, 3.7.4.3 · CIE 19.1.1, 19.1.2, 19.1.3, 19.1.4, 19.2.1, 19.2.2
OCR A 6.1.1(a), 6.1.1(c), 6.1.1(d), 6.1.1(e)(i), 6.1.2(a), 6.1.2(b), 6.1.2(c), 6.2.3(b)

19 questions · 56 marks

NAVY EDITION

SECTION A · Warm-up

- A1** Charge stored per unit potential difference, $C = Q/V$ (1); unit: farad (F), equal to one coulomb per volt (1). [2]
- A2** $C = Q/V = (6.0 \times 10^{-3})/12$ (1) [2]
 $C = 5.0 \times 10^{-4} \text{ F}$ (500 μF) (1)
- A3** $E = \frac{1}{2}QV$ (1); $E = \frac{1}{2}CV^2$ (1); $E = \frac{1}{2}Q^2/C$ (1). [3]
- A4** The capacitance of the capacitor, since the gradient is $Q/V = C$ (1). [1]
- A5** $C = Q/V = 0.36/1800$ (1) [2]
 $C = 2.0 \times 10^{-4} \text{ F}$ (200 μF) (1)
- A6** $V = Q/C = (4.0 \times 10^{-3})/(50 \times 10^{-6})$ (1) [2]
 $V = 80 \text{ V}$ (1)

SECTION B · Standard

- B1** $Q = CV = 100 \times 10^{-6} \times 20 = 2.0 \times 10^{-3} \text{ C}$ (1) [3]
 $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 100 \times 10^{-6} \times 20^2$ (1)
 $E = 0.020 \text{ J}$ (1)
- B2** $E = \frac{1}{2}QV = \frac{1}{2} \times 5.0 \times 10^{-3} \times 8.0$ (1) [2]
 $E = 0.020 \text{ J}$ (1)
- B3** $C = \epsilon_0 A/d = (8.85 \times 10^{-12} \times 0.020)/(1.0 \times 10^{-3})$ (1) [2]
 $C = 1.77 \times 10^{-10} \text{ F}$ (177 pF) (1)
- B4** $Q = CV = 470 \times 10^{-6} \times 9.0 = 4.23 \times 10^{-3} \text{ C}$ (1) [3]
 $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 470 \times 10^{-6} \times 9.0^2$ (1)
 $E = 0.019 \text{ J}$ (1)
- B5** $A = 4.0 \times 10^{-4} \text{ m}^2$ and $d = 1.0 \times 10^{-4} \text{ m}$ (1) [3]
 $C = \epsilon_0 \epsilon_r A/d = (8.85 \times 10^{-12} \times 5.0 \times 4.0 \times 10^{-4})/(1.0 \times 10^{-4})$ (1)
 $C = 1.77 \times 10^{-10} \text{ F}$ (177 pF) (1)

B6 The gradient is $V/Q = 1/C$, so $C = Q/V = (3.6 \times 10^{-3})/12$ (1) [4]
 $C = 3.0 \times 10^{-4} \text{ F}$ (300 μF) (1)
 Energy = area under the line = $\frac{1}{2}QV = \frac{1}{2} \times 3.6 \times 10^{-3} \times 12$ (1)
 $E = 0.022 \text{ J}$ (1)

B7 $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 1500 \times 10^{-6} \times 6.0^2$ (1) [3]
 $E = 0.027 \text{ J} = 27 \text{ mJ}$ (1)
 $P = E/t = 0.027/0.30 = 0.090 \text{ W}$ (1)

SECTION C · Stretch

C1 $C = \epsilon_0 \epsilon_r A/d$, so C increases by a factor of 4.0 (1) [3]
 $C = 4.0 \times 177 = 708 \text{ pF}$ (1)
 At fixed V , $E = \frac{1}{2}CV^2$, so the energy stored also increases by a factor of 4.0 (1).

C2 $E = \frac{1}{2}Q^2/C = \frac{1}{2} \times (3.3 \times 10^{-3})^2 / (220 \times 10^{-6})$ (1) [4]
 $E = 0.0247 \text{ J}$ (1)
 $V = Q/C = (3.3 \times 10^{-3}) / (220 \times 10^{-6})$ (1)
 $V = 15 \text{ V}$ (1)

C3 The polar molecules rotate to align with the electric field between the plates [3]
 (1); the aligned molecules produce a field that opposes the applied field, reducing the net field and hence the potential difference for a given charge (1); since $C = Q/V$, more charge is stored per volt, so the capacitance increases (1).

C4 Use of $E = \frac{1}{2}CV^2$ at the maximum rated pd (1) [4]
 $E_P = \frac{1}{2} \times 0.10 \times 6.3^2 = 1.98 \text{ J}$ (1)
 $E_Q = \frac{1}{2} \times 0.022 \times 16^2 = 2.82 \text{ J}$ (1)
 Only Q stores more than 2.5 J; P falls short, so the designer should choose Q (1).

C5 $C = \epsilon_0 \epsilon_r A/d$, so removing the dielectric reduces the capacitance by a factor of [4]
 2.5 (1). The charge is unchanged: the capacitor is disconnected, so there is no path for charge to leave the plates (1). $V = Q/C$, so the pd increases by a factor of 2.5 (1). $E = \frac{1}{2}Q^2/C$ increases by a factor of 2.5; the extra energy is the work done against the attraction of the plates in withdrawing the sheet (1).

- C6** The first charge transferred arrives when the capacitor pd is (almost) zero, so [6]
it needs (almost) no work (1); as charge builds up the pd rises (in proportion, since $V = Q/C$), so each successive amount of charge is moved through a larger pd (1); the average pd during charging is $V/2$, so the energy stored is $Q \times V/2 = \frac{1}{2}QV$, the area under the graph of pd against charge (1). The capacitor can release its whole store in a very short time (about a millisecond) (1); this gives a very large power, $P = E/t$, far greater than the battery could deliver directly (1); the battery instead recharges the capacitor slowly at low power between flashes (1).
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