

Charge storage, energy and RC time constants

Physics grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

Marks are awarded for a correct formula, correct conversion of prefixes, a clear substitution and an answer with its unit. Accept answers within rounding error and award method marks when an earlier slip is carried through consistently.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.7.4

Question 1 Defining capacitance (2 marks)

Capacitance is the **charge stored on one plate per unit potential difference**, $C = Q / V$. The unit is the farad, $1 \text{ F} = 1 \text{ C/V}$.

Marking: 1 mark for the definition, 1 mark for the unit.

Question 2 Charge and energy (3 marks)

a. $Q = CV = 220 \times 10^{-6} \times 15 = 3.3 \times 10^{-3} \text{ C}$.

b. $E = \frac{1}{2}CV^2 = 0.5 \times 220 \times 10^{-6} \times 15^2 = 0.025 \text{ J} \approx 2.5 \times 10^{-2} \text{ J}$.

Marking: (a) 1 mark. (b) 1 mark for the formula and substitution, 1 mark for the answer.

Question 3 Combining two capacitors (2 marks)

(a) $1/C = 1/8.0 + 1/8.0 = 0.25$, so **$C = 4.0 \mu\text{F}$** . (b) $C = 8.0 + 8.0 = 16 \mu\text{F}$.

Marking: 1 mark each.

Question 4 Reading a discharge graph (4 marks)

a. $V_0 = 12 \text{ V}$.

b. After one time constant $V = 0.37 \times 12 = 4.4 \text{ V}$. The graph reaches 4.4 V at about 10 s, so **$\tau = 10 \text{ s}$** .

c. $C = \tau / R = 10 / (20 \times 10^3) = 5.0 \times 10^{-4} \text{ F (500 } \mu\text{F)}$.

Marking: (a) 1 mark. (b) 1 mark for $0.37V_0$, 1 mark for τ . (c) 1 mark.

Question 5 Charging current (2 marks)

At the start the capacitor is uncharged, so all of the supply voltage is across the resistor and the current is V/R . As charge builds up, the voltage across the capacitor rises and the voltage across the resistor falls, so the current decreases. It reaches **zero when the**

capacitor voltage equals the supply voltage.

Marking: 1 mark for all the voltage across R at the start, 1 mark for the capacitor voltage rising until it equals the supply.

Question 6 Voltage after a delay (3 marks)

$$\tau = RC = 330 \times 10^3 \times 4.7 \times 10^{-6} = 1.55 \text{ s. } V = V_0 e^{-t/\tau} = 5.0 e^{-2.0/1.55} = 5.0 \times 0.275 = \mathbf{1.4 \text{ V.}}$$

Marking: 1 mark for τ , 1 mark for the substitution, 1 mark for the answer.

Question 7 Energy after one time constant (2 marks)

$E \propto V^2$. After τ the voltage is $V_0 e^{-1}$, so $E = E_0 (e^{-1})^2 = E_0 e^{-2} = 0.135 E_0$, which is **13.5 % $\approx$ 14 %**.

Marking: 1 mark for E proportional to V^2 , 1 mark for $e^{-2} = 0.135$.

Question 8 Unit of the time constant (2 marks)

$$1 \Omega = 1 \text{ V/A and } 1 \text{ F} = 1 \text{ C/V. So } 1 \Omega \times 1 \text{ F} = (\text{V/A}) \times (\text{C/V}) = \text{C/A} = \text{C}/(\text{C/s}) = \mathbf{1 \text{ s.}}$$

Marking: 1 mark for ohm and farad in base form, 1 mark for the cancellation to seconds.