AQA, Edexcel

A Level

A Level Physics

Capacitors (Answers)

Name:

MME

Mathsmadeeasy.co.uk

Total Marks: /30

1. George wishes to explore the rules for multiple capacitors. To do this, he constructs a circuit using three: C_1 is connected in series with C_2; these are both connected in parallel with C_3. All are connected to a 6 V power supply. $C_1 = 10\ \mu F, C_2 = 20\ \mu F$ and $C_3 = 50\ \mu F$.

Total for Question 1: 13

(a) Explain in terms of the flow of electrons how a potential difference is built up across a capacitor. [3]

Solution: Initially, electrons flow from the cell. They cannot travel between the plates of the capacitor because of the dielectric insulator. However, the initial current removes electrons from the 'positive' side of the capacitor and builds up a surfeit them on the 'negative' side. Since current must be the same everywhere, the charge on one side is of equal magnitude but opposite polarity to that on the other side. Thus, there is a potential difference across the capacitor. The current will fall to zero when the PD equals the EMF.

(b) Which of the following is correct? For two capacitors in series, irrespective of their capacitances, the charge stored by the first will be... [1]

i. Half of that stored by the second.
ii. The same as that stored by the second.
iii. Twice that stored by the second.

Solution: 2

(c) In any circuit, charge is conserved. Use this, in combination with Kirchoff's laws, to show that the total capacitance of two capacitors in series is given by $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2}$. [3]

Solution: According to Kirchoff's second law, $V_{total} = V_1 + V_2$.
Charge stored by each is the same.
Since $Q = VC$, $\frac{Q}{C_{total}} = \frac{Q}{C_1} + \frac{Q}{C_2}$.
This simplifies to give the required result.

(d) Using similar techniques, it can be shown that $C_{total} = C_1 + C_2$. For George's circuit, calculate the following:

i. The total capacitance of the circuit. [3]

Solution: 57 μF

ii. The reading on a voltmeter placed across capacitor 1. [3]

Solution: 4 V

2. Total for Question 2: 6

(a) What is represented by the area underneath a graph of the potential difference across a resistor against the charge stored by it? [1]

Solution: Stored energy.

(b) From the equation $W = \frac{1}{2}QV$, derive two other equations for the energy stored in capacitor. One should not include the term V and one should not include the term Q. [3]

Solution: $\frac{Q^2}{2C}$ and $\frac{1}{2}V^2C$

(c) State the effect of each of the following on the energy stored by a capacitor. [2]

i. Doubling the potential difference across it.

Solution: $\times 4$

ii. Halving the capacitance.

Solution: $\times \frac{1}{2}$

3. Ella charges a 50 μF capacitor using a 6 V power supply. She then discharges it through a resistor of resistance R (connected in parallel).

Total for Question 3: 11

(a) Outline an experiment that Ella could perform to demonstrate the discharge characteristics of a capacitor when it is discharging through a resistor. Include a circuit diagram. [3]

Solution: Circuit should have a capacitor, a resistor and a data logger all in parallel (i.e. 3 circuit loops). In addition, there should be a power supply and a switch.
When the switch is closed, the data logger will record the current and potential difference across the resistor.
The proportion by which these decrease should be constant for a given time interval i.e. $V_{1s}/V_{2s} = V_{5s}/V_{6s}$ etc..

(b) After 10 s, the charge has reduced by 99 μC from its initial value of 300 μC. Calculate R. [2]

Solution: 50 kΩ

(c) Calculate the current in the circuit 2τ after the switch has been turned on. [2]

Solution: 1.6×10^{-5} A

(d) Once it has completely discharged, Ella recharges the capacitor using the same 6 V power supply. Calculate the potential difference across the capacitor after 5 s. [2]

Solution: 5.2 V

(e) Sketch, on a single set of axes, the variation of V_c, V_R and V_0 with time during charging. V_C, V_R and V_0 are the potential differences across the capacitor, the resistor and the power supply respectively. [2]

Solution: Should show a constant line for V_0. V_C should have the form $1 - \exp(-x)$ and V_R should decrease exponentially.
The sum $V_C + V_R$ should always be equal to V_0.