Key Concepts

Chapter 8

Capacitance

$C = \frac{\varepsilon_0 A}{d}$

$Q = VC$

Takeaways

When solving electrostatics questions, stop to ask yourself what quantities you have and what quantities you need. In this case, we were presented with a capacitor but asked for voltage. At that point, ask yourself how you can get voltage from capacitance and capacitance from the given information. This is a common strategy that can be applied to many physics-related questions on the MCAT.

Things to Watch Out For

This type of question can be asked in several different ways, but the biggest mistake that most people will make on Test Day is whether the voltage, charge, or capacitance should be held constant. Many students make the mistake of keeping voltage constant in this problem.

Use these facts to guide you: (1) Charge must be supplied by something (generally a battery), (2) a battery will hold a capacitor at a set voltage, and (3) capacitance is determined by the structure of the capacitor.

Parallel Plate Capacitor

A parallel plate air-gap capacitor is constructed from two square plates of side length 100 cm. The separation between the plates is 20 cm. The capacitor is attached to a battery of voltage 10 V. After the capacitor is fully charged, the battery is disconnected, and the separation of the plates is doubled. Afterwards, what is the voltage across the capacitor? ($\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N·m^2)

1) Find the capacitance of the capacitor.

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85 \times 10^{-12})(1)^2}{0.2} = 4.4 \times 10^{-11}\ \text{F} = 44\ \text{pF}$$

The capacitance is calculated using the physical dimensions of the capacitor. Keep everything in meters because ε_0 is given in terms of meters.

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2) Find the initial charge on the capacitor.

$Q = VC = (10\ \text{V})(44\ \text{pF}) = 440\ \text{pC}$

This is the general formula relating capacitance, charge, and voltage.

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3) Find the new capacitance of the capacitor.

$$C = \frac{\varepsilon_0 A}{d} = \frac{(8.85 \times 10^{-12})(1)^2}{0.4} = 2.2 \times 10^{-11}\ \text{F} = 22\ \text{pF}$$

The separation is doubled, so the capacitance is cut in half.

Remember: *The capacitance of a capacitor can only be altered by changes in the physical structure of the capacitor itself: plate size, separation, or gap material.*

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4) Find the new voltage across the capacitor.

$$V = \frac{Q}{C} = \frac{440\ \text{pC}}{22\ \text{pF}} = 20\ \text{V}$$

It is very important to understand that because the battery is no longer connected to the capacitor, the charge stored on the capacitor must remain the same—there is nowhere for new charges to come from, nor is there anywhere for excess charge to go! Likewise, the voltage is allowed to change because the battery is no longer holding the capacitor at a set voltage.

Similar Questions

1) A fully charged capacitor is connected to a 120 V power source and holds a charge of 1 μC. What is the charge stored on the capacitor if the voltage is doubled?
2) A 1 μF capacitor holds a charge of 2 μC and is not connected to a battery. Another initially uncharged, 1 μF capacitor is connected in parallel to this capacitor. What is the total charge stored by the second capacitor?
3) A 25 nC parallel plate capacitor is connected to a 12 V battery. By what factor should the separation between the plates be changed so that the charge stored by the capacitor is 30 nC?