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# Capacitance a review mastering physics

1 Capacity Energy - Dielectrics in V E and V E 2 Today... Overview of elements from the last lecture: Capacitors (series and parallel) Calculate energy, stored in the capacitor Calculate the energy density in the electric field Determine Dielectric Permanent Change of the Gauss Act to include Dielectrics 3 Summary of important geometry capacitor Determining capacity refers to V via C: Capacity depends on geometry: b cylindrical d Parallel plates In the SYSTEM of the SI unit: C has a unit Farads or F (1F and 1C/V) ACT 1 V0 V Conductor (a) V (2/3)V0 (b) v V0What is the link between V0 and V in systems, shown below? Issue (Region A) (Region A) d/3 V0 V d Conductor d/3 - q (a) V (2/3)V0 (b) v v v v (c) V (c) V (3/2)V0 5 Lecture 8, ACT 1 V0 V Conductor (a) V (2/3)V0 (b) V and V0What is the relationship between V0 and V in the systems shown below? (Region A) (Area A) d/3 V0 V d conductor d/3 -z (a) V (2/3)V0 (b) V v v v (c) V (c) V (3/2)V0 Electric field in conductor No 0. Electric field everywhere: E q/(Ae0) To find a potential difference, integrate the electric field: 6 Lecture 8, ACT 1, Another wayWhat is the relationship between V0 and V in the systems shown below? Conductor (Area A) (Area A) V - d/3 V0 d -a) V (2/3)V0 (b) V (c) V (c) V (3/2)V0 Location on the right is equivalent to capacitors (each with division No d/3) in SERIES!! conductor d/3 (Region A) V - 7 Capacitor Energy How much energy is stored in a charged capacitor? Calculate the work provided (usually by the battery) to charge the capacitor up to q/- : Calculate the incremental work dW needed to add the dq charge to the capacitor at V voltage (there is a trick here!): In terms of voltage V: The overall work of W to charge to q is then given: Look at this! Two ways to write W 8 capacitor variables Total work on charging up q equals the U energy stored in the capacitor: Look at this! Two ways to write U In terms of Voltage V: You can do one of two things to a capacitor: connect it to the battery to specify the V and should put some charge on it to indicate and the V follows the 9 question! A.J. - - - - - - : C: E: V: U: Suppose the capacitor shown here is charged on th, and then the battery shuts down. Now suppose I pull the plates further apart, so the final division is d1. How do the numbers of q, C, E, V, U change? The question: C: E: V: U: remains the same. There is no way to charge to get away. Decreases.. Since the capacity depends on the geometry remains the same ... depends only on increasing the density of the charge. since C ̄, but q remains the same (or d but E same) increases. add energy to the system by dividing how many of these amounts change?.. Exercise for the student!! Answers: 10 Related question A. - No v d - - - - - - - - C: V: : E: U: Suppose the battery (V) is kept attached to Pull the plates apart from d to d1. Now, what's changing? C: V: E: U: decreases (capacity depends only on geometry) should remain the same - the battery forces it to be v should decrease, the CV charge flowing from the plate should decrease ( , ) should decrease ( ) How many of these quantities vary?.. Exercise for the student!! Answers: 11 2) What is the connection between the charges against the two capacitors? Pre-flight 8: Two identical parallel plate capacitors are connected to the battery, as shown. The C1 is then disconnected from the battery, and the separation between the plates of both capacitors doubles. 2) What is the connection between the charges against the two capacitors? (a) No.1 b) No.1 - c) No.1 qlt; No2 3) How does the electric field between C2 plates change as the separation between plates increases? Electric field: a) increases b) decreases c) does not change 12 5) What is the connection between the voltages on the two capacitors?Preliminary Flight 8: Two identical parallel capacitors are connected to the battery, battery, as shown in the picture. The C1 is then disconnected from the battery, and the separation between the plates of both caps doubles. 5) What is the connection between the voltages on the two capacitors? (a) V1 qgt; v b) V1 and V c) V1 zlt; V2 13 Lecture 8, ACT 2 (a) U1 (b) U1 and U2 (c) U1,1)gt; U2Two identical parallel plate capacitors connected to the battery. The C1 is then disconnected from the battery, and the separation between the plates of both capacitors doubles. 2d v C1 C2 d V d What is the connection between U1, the energy stored in C1, and U2, the energy stored in C2? a) U1 zlt; U2 (b) U1 (c) U2 (c) U1 qgt; U2 14 Lecture 8, ACT 2 (a) U1 (b) U1 and U2 (c) U1's U1's U2Two identical parallel plate capacitors are connected to the battery. The C1 is then disconnected from the battery, and the separation between the plates of both capacitors doubles. 2d v C1 C2 d V d What is the connection between U1, the energy stored in C1, and U2, the energy stored in C2? (a) U1 (b) U1 and U2 (c) U1 ,u1,U2 What is the difference between the final states of the two capacitors? The fee for C1 has not changed. The tension on C2 has not changed. The energy stored in C1 has definitely increased, as it is necessary to work out the work of separating plates with a fixed charge, they attract each other. The energy in the C2 will actually decrease, as the charge must go away to reduce the electric field, so that the potential remains the same. Originally: Later: 15 Where is the energy stored? Claim: Energy is stored in the electric field itself. Think of the energy needed to charge the capacitor as the energy needed to create a field. To calculate the density of energy in the field, first consider the constant field generated by the parallel capacitor of the plate, where - - This is the density of energy, u, electric field.... The electric field is given: Field given: Units: 16 Energy density is common and is not limited to a special case of a permanent field in a parallel capacitor plate. Claim: Expressing the Energy Density of the Electrostatic Field Example (and another exercise for the student!) consider the E-field between the surfaces of the cylindrical capacitor: Calculate the energy in the capacitor area, integrating the aforementioned energy density over the amount of space between the cylinders. Compare this value with what you would expect from the general expression: 17 Lecture 8, ACT 3 Consider two cylindrical capacitors, 1 C1 1.1 Consider two cylindrical capacitors, each of the L. C1 lengths has an internal radius of 1 cm and an external radius of 1.1 cm. C2 has an internal radius of 1 cm, and an external radius of 1.2 cm 1 C2 1.2 If both capacitors are given the same amount of charge, what is the connection between U1, the energy stored in C1, and U2, the energy stored in C2? a) U2 zlt; U1 (b) U2 and U1 (c) U2 zgt; U1 18 Lecture 8, ACT 3 Consider two cylindrical capacitors,1 C1 1.1 Consider two cylindrical capacitors, each of the L. C1 lengths have an internal radius of 1 cm and an external radius of 1.1 cm. C2 has an internal radius of 1 cm, and an external radius of 1.2 cm 1 C2 1.2 If both capacitors are given the same amount of charge, what is the connection between U1, the energy stored in C1, and U2, the energy stored in C2? a) U2 zlt; U1 (b) U2 and U1 (c) U2 ,U1 Electric Field Size from r 1 to 1.1 cm is the same for C1 and C2. But C2 also has an electrical energy density of 1.1 to 1.2 cm. In formulas: 19 Dielectrics Empirical Observation: The insertion of not swiping material between capacitor plates alters value capacity. Definition: The dielectric constant of the material is the ratio of capacity when filled with a dielectric, what's without it: k values always zgt;1 (e.g. glass No. 5.6; water No. 78) They increase capacitor capacity (usually good, as it's hard to make a large capacitors) They allow more energy to be stored on a given capacitor than otherwise with a vacuum (i.e. air): 20 Parallel Plate Example Deposit Charge on parallel plates filled with vacuum (air)-capacitance C0. Disconnecting from battery Potential difference is that of V0 and C0. E V V E - Now insert the material with a dielectric constant k. Charging remains a constant Capacity increases C and K0 Tension decreases from V0 to: Electric field decreases also: Note: The field only decreases when the charge stays constant! 21 Parallel Plate Example, Assuming That Permanent How About GAUSS' LAW? How can the field shrink if the charge stays the same? Answer: Dielectric becomes polarized in the presence of the field due to the Z. Molecules are partially aligned with the field so that their negative charge tends to be a positive plate. The field because of this inside the dielectric (a la dipole) confronts the original field field it is therefore responsible for reducing the effective area. Some of the original field lines now run out on charges in dielectric - V E v E 4 change the Gauss Act, see Appendix 22 7) Compare the voltages of the two capacitors. Two identical parallel plate capacitors receive the same charge, after which they are disconnected from the battery. Once the C2 has been charged and disconnected, it is filled with dielectric. Pre-flight 8: 7) Compare the voltage of the two capacitors. (a) V1 (b) V1 and V (c) V1 and V2 8) Compare electric fields between the plates of both capacitors. a) E1 qgt; E b) E1 and E c) E1 qlt; E2 23 10) When we insert a dielectric in the C2 capacitor we do: Pre-flight 8: 10) When we insert a dielectric in the capacitor C2 we do: a) positive work b) do not work Recall the meaning of negative operation the energy of the system decreases. The dielectric is absorbed into the capacitor. When the charge is constant, the total energy of the capacitor decreases because the presence of dielectric increases the capacity. It turns out that the dielectric is drawn even if the voltage remains constant, for example, through the battery. On a microscopic scale, the force on the dielectric is caused by transfixing fields at the edges of the capacitor. 24 Lecture 8, ACT 4 k (a) E1 zlt; E2 (b) E1 and E2 (c) E1's E2' - Two parallel capacitors plates are identical (same A, same d), except that C1 has half the space between plates filled with dielectric permanent K material as shown in the photo. If both capacitors are given the same amount of charge, what is the relationship between E1, the electric field in the air C1 and E2, the electric field in the air C2 (a) E1 and E2 (b) E1 and E2 (c) E1 qgt; E2 25 Lecture 8, ACT 4 k (a) E1 and E2 (b) E2 (c) E1 and E2 - Two parallel capacitors plates (same as A) , the same d), except that the C1 has half the space between the plates filled with the material of the dielectric constant K, as shown in the photo. If both capacitors receive the same amount of charge, what is the relationship between E1, the electric field in the air C1 and E2, the electric field in the air C2 (a) E1 (b) E2 (c) E1 zgt; E2 The key here is to understand that the electric field in the air in C1 should be equal to the electric field in the dielectric B1! Why? The upper plane is the conductor; so it's an equipical surface. The lower plane is the conductor; so it is also an eccipity surface. To do this, the charge density on each plane should not be homogeneous to create equal electric fields!! With C1, for the same fee, the V1 is a V2. Consequently, E1 is e2. NOTE: If the tension was constant, E wouldn't change!! 26 Note: This should leave a lot In waterWhy salt dissolves usually NaCl is in a rigid crystalline structure, supported by electrostatic attraction between Na Na Ions. Water has a very high dielectric constant (78). This reduces

the field between the atoms, hence their attraction to each other. The crystal lattice falls apart and dissolves. Note: This should leave a lot of ions in the water 27 Summary of capacitors parallel and in seriesenergy stored in the charged capacitor work done to assemble the charges on the energy plates stored in the electric capacitor field example of the density of the J/m3 field energy of the electrical reaction of the dielectric materials of the atomic vision: polarized atoms - 28 Changed law Gauss (in the presence of dielectric)In the vacuum, the Law of Gauss: In the dielectric, the field decreases: Rewrite the law gauss: Rethink if in the presence of dielectric: Replace ! This form of Gauss Law can be used in vacuum or dielectric, so where q represents only a free charge. - Free fee you can move around