PHY2049 Summer 2018 Exam 1 Review Questions

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Chapter 22: Electric Force and Electric Charge

1. Two charges are placed some distance apart, and exert a force F on each other. If the distance between the charges is doubled, and each charge is doubled, what would the new force exerted between the charges be?
   (a) $4F$
   (b) $2F$
   (c) F
   (d) $F/2$

2. The fundamental difference between conductors and insulators is:
   (a) Electrons are free to move in conductors, but not insulators.
   (b) Electrons are free to move in insulators, but not conductors.
   (c) Protons are free to move in conductors, but not insulators.
   (d) Protons are free to move in conductors, but not insulators.

3. A hydrogen atom is composed of an electron and proton separated by a distance of roughly 5×10^{-11}m. What is the ratio of the electric-to-gravitational force, F_e/F_G, for a hydrogen atom? Note that the mass of an electron is $m_e = 9.11 \times 10^{-31}$ kg, the mass of a proton is $m_p = 1.67 \times 10^{-27}$ kg, and the gravitational force between two masses is given by:

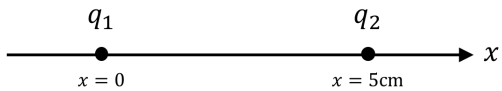
$$F_G = G\frac{m_1 m_2}{r^2}$$

   where Newton's gravitational constant is $G = 6.67 \times 10^{-11}$ Nm^2/kg^2.

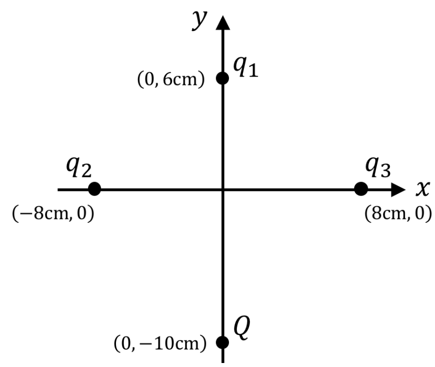
4. During a lightning strike, charge can flow between a cloud and the ground at 20,000 C/s. If a lightning strike lasts about 100μs, how many electrons are transferred during the strike?

5. A substance has a charge of $q = 3.5\mu$C. Does this substance have an excess or deficiency of electrons? How many extra or missing electrons does it have?

6. A charge $q = 15$nC, with a mass $m = 1.7 \times 10^{-20}$ kg, is released from rest a distance of 15mm from a second charge $Q = 75$nC, with a mass $M = 2.5 \times 10^{-15}$ kg. What is the initial acceleration of the released charge q? Is this acceleration constant? Assume for this problem that Q isn't allowed to move.



7. Two charges, $q_1 = 30\mu$C and $q_2 = 45\mu$C, are placed along an x-axis as shown in the figure above. Where would a third charge, $Q = -15\mu$C, have to be placed so that the net electric force on Q, due to the other two charges, would be zero?



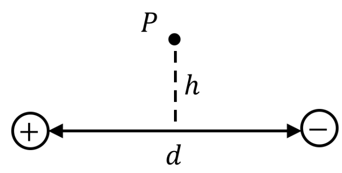
8. Consider the four charge, $q_1 = -5$nC, $q_2 = 3.5$nC, $q_3 = 3.5$nC, and $Q = -7$nC, arranged as shown in the above figure. What is the total electric force on Q due to the other three charges?

Chapter 23: The Electric Field

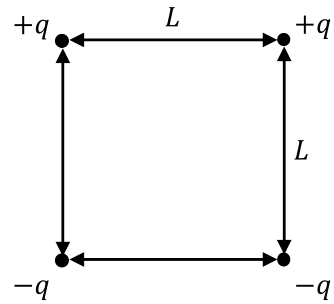
1. Which of the following is true for conductors?
   (a) Charges will be spread throughout a conductor and the electric field will be non-zero within the conductor.
   (b) Charges will move to the surface of a conductor and the electric field will be non-zero within the conductor.
   (c) Charges will spread throughout a conductor and the electric field will be zero within the conductor.
   (d) Charges will move to the surface of a conductor and the electric field will be zero within the conductor.

2. Between any separated positive and negative charges, the electric field:
   (a) Always points from the positive charges to the negative charges.
   (b) Always points from the negative charges to the positive charges.
   (c) Will be zero between the charges.
   (d) Impossible to say without knowing the specifics of the problem.

3. A charge $q = -25$nC of mass $m = 8.4\times10^{-15}$ kg is placed on a flat surface. If a vertical electric field could be produced to lift the charge up from the surface, what must the magnitude and direction of this electric field be?



4. Two charges, one $+e$ and one $-e$, are placed on an x-axis, separated by a distance $d = 12\mu$m. Exactly halfway between the two charges, and a height $h = 5\mu$m above the x-axis is a point P. What is the magnitude and direction of the net electric field at P?

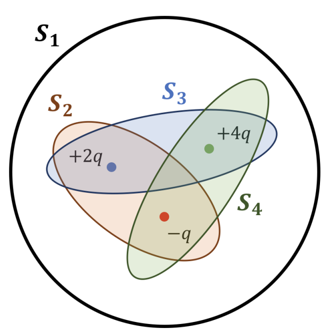


5. Imagine an $L \times L$ square with four point charges placed at the corners, as shown in the above figure. What would the net electric field be at the center of this square?

6. Using Coulomb's law, prove that for a vertical, infinitely long wire, with some positive linear charge density λ, the electric field some horizontal distance x away from the wire is:

$$E = \frac{\lambda}{2\pi\epsilon_0 x}$$

Chapter 24: Gauss' Law



1. Which of the above surfaces has the greatest total flux through it?
   (a) S_1
   (b) S_2
   (c) S_3
   (d) S_4

2. A uniform electric field can exist in a universe without **any** charges.

   (a) True

   (b) False

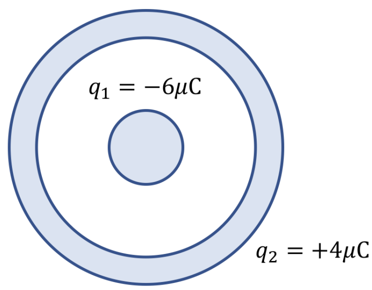
3. A charge q can be placed at the center of 3 different cubes: Cube A has a side length of L, cube B has a side length of $2L$, and cube C has a side length of $L/2$. Which cube should the charge be placed in side to produce the maximum flux through the surface?

   (a) Cube A

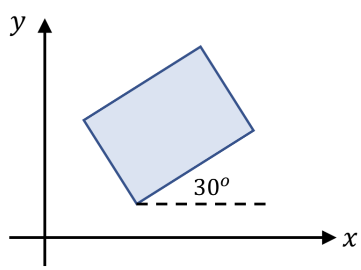
   (b) Cube B

   (c) Cube C

   (d) All cubes would have the same flux



4. A large, conducting spherical shell is placed around a small sphere such that their centers coincide, as shown in the above figure. If the charge of the small sphere is $q_1 = -6\mu$C and the charge of the large spherical shell is $q_2 = +4\mu$C, how does the charge on the large spherical shell distribute itself?

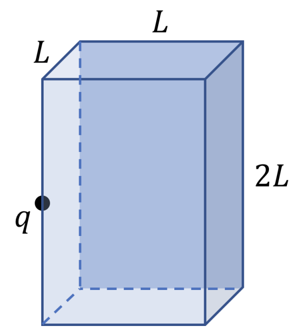


5. An electric field $\vec{E} = (3 \text{ N/C})\hat{\imath} + (4.7 \text{ N/C})\hat{\jmath} - (1.2 \text{ N/C})\hat{k}$ passes through a rectangular surface of area $A = 1.5 \times 10^{-4}$ m^2, oriented in the x, y-plane as shown in the above figure. How much flux is passing through this surface?

6. Using Gauss' law, prove that for an infinitely large sheet of charge, with some positive surface charge density σ, the electric field some distance z above the surface of the plate is:

$$E = \frac{\sigma}{2\epsilon_0}$$

   Be sure to justify your choice of Gaussian surface with some sort of symmetry argument.



7. Consider a charge q placed on the boundary of an $L \times L \times 2L$ rectangular box, as shown in the above figure. Note that q is placed such that it's exactly half-way up the $2L$ edge of the box. What is the total flux passing through the box due to the charge q?

Chapter 25: Electrostatic Potential and Energy

1. Electrons will always move towards:

   (a) High potential energy and high potential

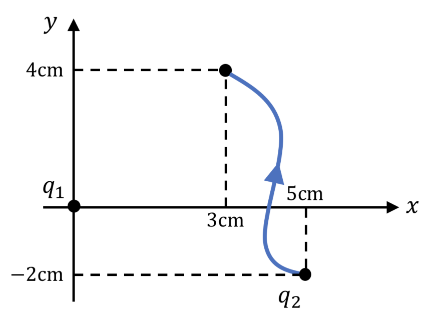
   (b) High potential energy but low potential

   (c) Low potential energy but high potential

   (d) Low potential energy and low potential

2. Using Coulomb's law, prove that the electric potential energy between two point charges, q_1 and q_2, separated by some distance x along a horizontal axis, is:

$$U = k\frac{q_1 q_2}{x}$$



3. As shown in the figure above, a charge $q_1 = 2.5\mu$C is placed at the origin of an x, y-coordinate system. A second charge, $q_2 = -3.7\mu$C is moved from its initial position to a final position along the path shown in the figure, while q_1 remains fixed in place. How much work is done by the electric force on q_2 along the path taken?

4. Consider the same set up as for the previous problem. If the charge q_2 has a mass $m_2 = 1.7 \times 10^{-20}$ kg, and was initially at rest, what is the speed of q_2 after it travels along its path?

5. Consider two points along the x-axis, points A and B, separated by $\Delta x = 2.5\text{cm}$. If the potential difference between A and B is $\Delta\phi = 60\text{V}$, what is the magnitude of the **average** electric field between A and B?

6. Imagine some charge distribution produces an electric potential:

$$\phi(x, y) = Ax^2y + B\frac{x}{y^2}$$

where A and B are constants. What would the electric field, $\vec{E}$, produced by this charge distribution be? Give the electric field in component-form, as in $\vec{E} = E_x\hat{\imath} + E_y\hat{\jmath}$.

7. Along the x-axis, there exists an electric field $\vec{E} = (3000x^2)\hat{\imath}$, where the numeric coefficient is implied to have SI units. What would the potential difference be between $x = 3\text{cm}$ and $x = 12\text{cm}$ along the x-axis?

Chapter 26: Capacitors and Dielectrics

1. Capacitance is a quantity that should depend upon:
   (a) The charge stored on the capacitor
   (b) The voltage across the capacitor
   (c) The geometry of the capacitor
   (d) Any number of these factors

2. Anytime a dielectric is placed inside of any capacitor:
   (a) Both the electric field and capacitance increase
   (b) The electric field increases and the capacitance decreases
   (c) The electric field decreases and the capacitance increases
   (d) Both the electric field and capacitance decrease

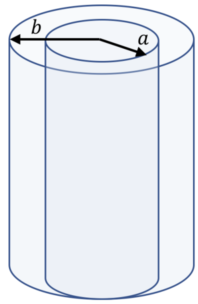
3. Assuming that the electric field produced by a very large plate is:

$$E = \frac{\sigma}{\epsilon_0}$$

prove that the capacitance of a parallel plate capacitor of some area A and plate separation d is given by:

$$C = \epsilon_0\frac{A}{d}$$

4. A variable capacitor – one whose capacitance can be changed easily – can by made by simply allowing the plate separation d to be adjustable. Imagine a variable capacitor like this to be connected to some voltage source. If you doubled the distance between the plates, how would the charge on the capacitor change? The voltage? And the energy stored by the capacitor?



5. Consider two, very long cylindrical shells with coinciding centers, as shown in the figure above, the inner shell with a radius a and the outer shell with a radius b. Prove that the capacitance **per unit length** for this capacitor is given by:

$$\frac{C}{L} = \frac{2\pi\epsilon_0}{\ln(b/a)}$$

Note that a cylindrically-symmetric charge distribution, with some charge per unit length λ, emits an electric field with a magnitude of:

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

where r is the distance away from the surface of the cylinder the electric field is being measured.

6. Consider a parallel plate capacitor with a plate area $A = 2 \times 10^{-5}$ m^2 and plate separation $d = 5$mm. A dielectric is placed between them with a strength of 36,000 V/m; this means that if the electric field between the plates exceeds this value, dielectric breakdown occurs.

   (a) What is the maximum voltage across the capacitor before breakdown occurs?

   (b) What, then, is the maximum charge that can be stored on the capacitor?

   (c) And what is the maximum potential energy that can be stored by this capacitor?

7. Imagine a capacitor were connected to some voltage source and allowed to charge up. If the voltage source were disconnected **first**, and then a dielectric were inserted into the capacitor, would the following quantities increase, decrease, or remain the same?

   (a) Capacitance

   (b) Charge stored by the capacitor

   (c) Voltage across the plates

   (d) Electric field within the capacitor

   (e) Potential energy stored by the capacitor