PHY2049 Summer 2019 Exam 1 Review Questions

Prof. Douglas H. Laurence

Department of Physical Sciences, Broward College

Chapter 21: Electric Charge and Electric Field

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) $F/2$

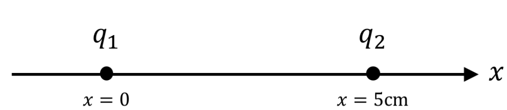
2. A hydrogen atom is composed of an electron and proton separated by a distance of roughly 5×10^{-11}m. What is the ratio of the electric-to-gravitational force, F_e/F_G, for a hydrogen atom? Note that the mass of an electron is $m_e = 9.11 \times 10^{-31}$ kg, the mass of a proton is $m_p = 1.67 \times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

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

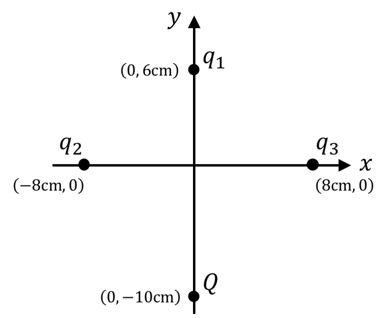
   where Newton's gravitational constant is $G = 6.67 \times 10^{-11}$ Nm^2/kg^2.

3. 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?

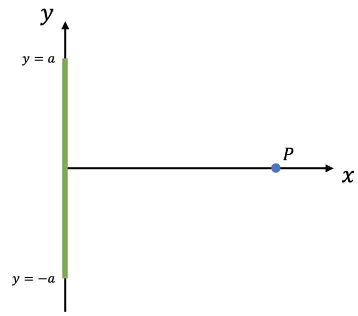
4. A substance has a charge of $q = 3.5\mu$C. Does this substance have an excess or deficiency of electrons? How many extra or missing electrons does it have?



5. 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?



6. Consider the four charge, $q_1 = -5\text{nC}$, $q_2 = 3.5\text{nC}$, $q_3 = 3.5\text{nC}$, and $Q = -7\text{nC}$, arranged as shown in the above figure. What is the net electric field at the location of Q? What is the net electric force on Q?



7. Consider a thin wire with a charge per unit length of λ. The wire is a length $2a$, arranged such that it stretches from $y = +a$ to $y = -a$, as shown in the coordinate system above. A point P is located a distance x away from the wire along the x-axis.

   (a) Argue using the symmetry of the wire that the electric field at point P points only in the x-direction – that is, that the y-component E_y is zero.

   (b) Show that the magnitude of the electric field is given by:

$$E = \frac{2ak\lambda}{x\sqrt{x^2 + a^2}}$$

   Note that the following integral is useful:

$$\int_{-a}^{a} \frac{dy}{(x^2 + y^2)^{3/2}} = \frac{2a}{x^2\sqrt{x^2 + a^2}}$$

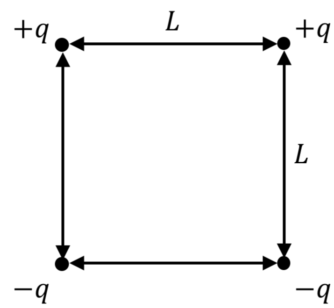
   (c) Show that in the limit $x \gg a$, the electric field becomes:

$$E = k\frac{Q}{x^2}$$

   where Q is the total charge of the wire. What is the significance of this result?

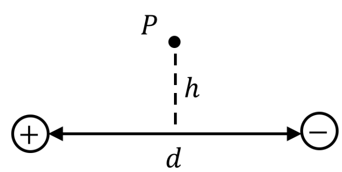
   (d) Show that in the limit $a \gg x$, the electric field becomes:

$$E = 2k\frac{\lambda}{x}$$



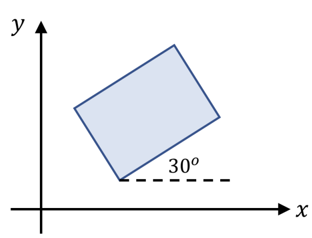
8. Imagine a square with four point charges placed at the corners, as shown in the above figure. What would the net electric field, magnitude and direction, be at the center of this square?

9. A charge $q = -25\text{nC}$ of mass $m = 8.4 \times 10^{-15}$ 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?



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

Chapter 22: Gauss' Law



1. 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 $A = 1.5 \times 10^{-4}\text{ m}^2$, oriented in the x, y-plane as shown in the above figure. How much flux is passing through this surface?

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. Which of the following is true for charges within a conductor?

   (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.

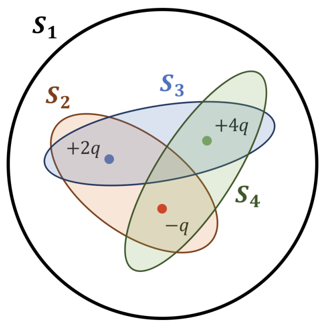
4. Between any separated positive and negative charges, the electric field:

   (a) Always points from the negative charges to the positive charges.

   (b) Always points from the positive charges to the negative charges.

   (c) Will be zero between the charges.

   (d) Impossible to say without knowing the specifics of the problem.



5. Which of the above surfaces has the greatest total flux through it?

   (a) S_1

   (b) S_2

   (c) S_3

   (d) S_4

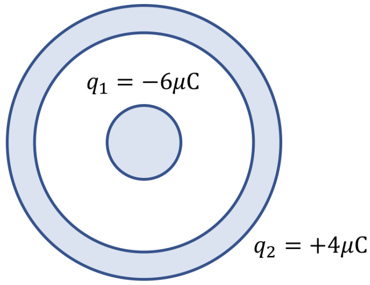
6. A charge q can be placed at the center of 3 different cubes: Cube A has a side length of L, cube B has a side length of $2L$, and cube C has a side length of $L/2$. Inside which cube should the charge be placed to produce the maximum flux through the surface?

   (a) Cube A

   (b) Cube B

   (c) Cube C

   (d) All cubes would have the same flux



7. 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?

8. 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:

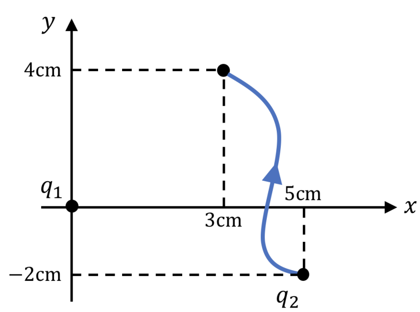
$$E = \frac{\sigma}{2\epsilon_0}$$

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

Chapter 23: Electric Potential

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. 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?

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

4. 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?

5. 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 $\vec{E} = E_x\hat{\imath} + E_y\hat{\jmath}$.

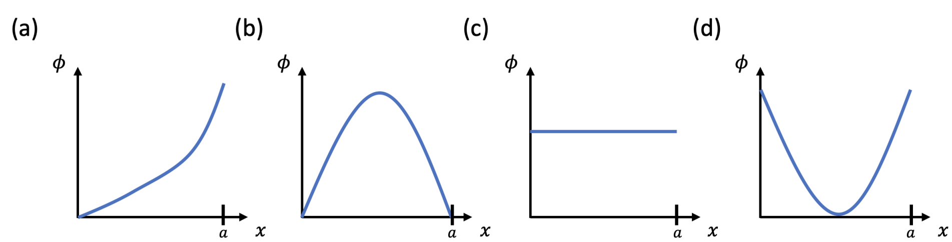
6. Assuming the same electric potential as in the previous problem, what is the force on a charge $q = 5\mu\text{C}$ at $x = 10\text{cm}$ and $y = 3\text{cm}$ if $A = 1000\ \text{V/m}^3$ and $B = -0.05\ \text{Vm}$? Give the force in component form, as in $\vec{F} = F_x\hat{\imath} + F_y\hat{\jmath}$.

7. In a region of space, the electric field points in the x-direction, obeying the following function:

$$\vec{E} = (3000x^2)\hat{\imath}$$

where the units of the coefficient, 3000, are understood to be SI units. Given this electric field, what is the potential difference between $x = 5\text{cm}$ and $x = 10\text{cm}$? *Hint: for a vector field $\vec{A}$ in 1-dimension, the following simplification can be made,*

$$\int \vec{A}\cdot d\vec{x} = \int A dx$$

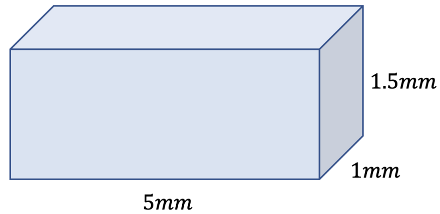


8. Imagine a thin, conducting wire extending from $x = 0$ to $x = a$. In the figure above, four possible graphs of potential vs. x are shown for this wire. Which graph is the only one that could be correct? *Hint: recall what the electric field must be inside a conductor.*

Chapter 25: Current, Resistance, and Electromotive Force

1. In the case of electrostatics, the slope of potential ϕ vs. position x in a 1-dimensional conductor would be:

   (a) Zero
   (b) Positive
   (c) Negative
   (d) Not enough information to solve the problem



2. A conductor with a resistivity of 1.2×10^{-6} Ωm is shaped as shown in the above figure. Wires can be placed across any two, opposing faces of the conductor, producing different values of resistance. What is the maximum possible resistance of the above conductor?

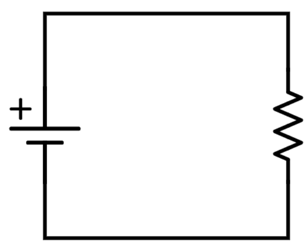
3. Imagine a cylindrical copper wire, of length $L = 1$m and radius $R = 1$mm. Inside the copper wire, there exists an electric field $E = 1$ N/C. Note that copper has a density of 9000 kg/m^3, and each copper atom has a mass of 1.055×10^{-25} kg.

   (a) If each copper atom contributes 1 conduction electron, what is the density n of conduction electrons in the wire?

   (b) If the average time between collisions τ in copper is 2.4×10^{-14} s at room temperature, what is the conductivity σ of copper at room temperature? Note the mass of an electron is 9.11×10^{-31} kg.

   (c) What would be the current carried by the copper wire at room temperature?

   (d) What would be the resistance of the copper wire at room temperature?



4. In the above circuit, in what direction does the current flow, and in what directions do the electrons move?

   (a) The current flows clockwise, the electrons move clockwise

   (b) The current flows clockwise, the electrons move counterclockwise

   (c) The current flows counterclockwise, the electrons move clockwise

   (d) The current flows counterclockwise, the electrons move counterclockwise

5. A 5Ω resistor is connected to a 10V battery. What is the voltage across the resistor?

   (a) 0.5V

   (b) 2V

   (c) 5V

   (d) 10V

6. A 5Ω resistor is connected to a 10V battery. What is the current flowing through the resistor?

   (a) 0.5A
   (b) 2A
   (c) 10A
   (d) 50A

7. A 5Ω resistor is connected to a 10V battery. How much heat, per unit time, is produced by the resistor?

   (a) 2W
   (b) 5W
   (c) 10W
   (d) 20W

Answers

Ch 21

1. (c)
2. 2.27×10^{39}
3. 1.25×10^{19} electrons
4. A deficiency of 2.19×10^{13} electrons
5. $x = 2.25$cm
6. $\sum E = 1246$ N/C in the $-y$-direction, and $\sum F = 8.72 \times 10^{-6}$ N in the $+y$-direction
7. Look through class notes for derivation
8. $4\sqrt{2}k\dfrac{q}{L^2}$
9. $E = 3.36 \times 10^{-6}$ N/C, downward
10. $E = 0.000282$ N/C, to the right

Ch 22

1. 1.8×10^{-4} Tm^2
2. (a)
3. (d)
4. (b)
5. (c)
6. (d)
7. $+6\mu$C is on the inner surface of the shell, while -2μC is on the outer surface of the shell
8. Look through class notes for derivation

Ch 23

1. (c)
2. 0.118J
3. 37,259 m/s
4. 2400 V/m
5. $\vec{E} = \left(2Axy + \dfrac{B}{y^2}\right)\hat{\imath} + \left(Ax^2 - 2B\dfrac{x}{y^3}\right)\hat{\jmath}$
6. $\vec{F} = (-49.6\text{N})\hat{\imath} + (-175\text{N})\hat{\jmath}$
7. $\Delta\phi = 0.875$ V
8. (c)

Ch 25

1. (a)
2. 0.004Ω
3. (a) 8.53×10^{-25} electrons/m^3; (b) 5.75×10^7 $1/\Omega$m; (c) 180A; (d) 0.0055Ω
4. (b)
5. (d)
6. (b)
7. (d)