VP240-1 Recitation class
Week #3

Bicheng Gan
ganbicheng@sjtu.edu.cn

SJTU - UMJI — September 29, 2019

Brief introduction

- Remember why the charges on conductors in an electrostatic situation (in which there is no net motion of charge) the electric field at every point within a conductor is zero and any excess charge on a solid conductor is located entirely on its surface. The reason behind is that the $\overrightarrow{E}=0$ inside.
- Remember the Gaussian surface is not a 2-D form. It must be a **closed** surface in 3-D situation.
- Please use the **term** just as I mentioned in the last week. Such as outer surface of charged conductor...... If you are not sure about the term, please turn to the textbook instead of inventing it.
- Remember to hand in the homework after the National Day. Please be tidy.
- Be prepare for your exam. Surely you should cover everything you learn till now. You should calculate every model at least once.

1 Short Review

1. Electric potential field

   First, when a force $\vec{F}$ acts on a particle that moves from point a to point b , the work $W_{at}=b$, done by the force is given by a line integral:

   $$W_{a,b}=\int_{a}^{b} F \cdot dl=\int_{\mathrm{u}}^{b} F \cos \phi dl \quad \text{(work done hy a force)}$$

   Second, if the force $\vec{F}$ is conservative, the work done by F wan always be expressed in terms ol a pulential energy U . When the particle moves from a point where the potential cncrgy is U_a to a point where it is U_b , the change in potential energy is $\Delta U=U_b-U_a$ and

   $$W_{a \rightarrow b}=U_a-U_b=-\Delta U$$

   Info:

   - Whether the test charge is positive or negative, the following general rules apply: U increases if the test charge q_0 moves in the direction opposite the electric force $\overrightarrow{F}=q_0\vec{E}; U$ decreases if q_0 moves in the same direction as $\overrightarrow{\boldsymbol{F}}=q_0\overrightarrow{\boldsymbol{E}}$.

2. Three methods to find electric potential

   Emphasize that we can use three methods to find electric potential, (1) by adding contributions from small charges dq regarded as point charges; (2) by integrating the electric field $V(\mathbf{r})=\int_{\mathbf{r}}^{\mathbf{r0}} \mathbf{E} \mathrm{d} \mathrm{r}$, where $V\left(\mathbf{r}_0\right)=0$ with $\mathbf{r}_0$ being a reference point; (3) by solving a PDE (the Poisson's equation).

Info:

- Electric Potential Energy of two Point charges: $U = \frac{1}{4\pi\epsilon_0}\frac{qq_0}{r}$. It is valid no matter what the signs of the charges q and q_0. The potential energy is positive if the charges q and q_0 have the same sign.
- Potential energy is always defined relative to some reference point where $U = 0$. and negative if they have opposite signs.
- The total electric field at each point is the vector sum of the fields due to the individual charges, and the total work done on q_0 during any displacement is the sum of the contributions from the individual charges.
- From the equation above we conclude that the potential energy associated with the test charge q_0 at point a is the **algebraic sum (not a vector sum)**:

$$U = \frac{40}{4\pi\epsilon_0}\left(\frac{41}{r_1} + \frac{42}{r_2} + \frac{4_3}{r_3} + \dots\right) = \frac{q_0}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$$

- It follows that **for every electric field due to a static charge distribution, the force exerted by that field is conservative**.

3. Interpreting electric potential field

   The potential-energy difference $U_a - U_b$ equals the work that is done by the electric force when the particle moves from a to b.

   The potential energy difference $U_a - U_b$ is then defined as the work that must be done by an external force to move the particle slowly from b to a against the electric force.

4. Electric potential

   Potential is potential energy per unit charge.

$$V_a - V_b = \int_a^b \vec{E}\vec{dl} = \int_a^b E\cos\phi dl$$

Info:

- V_{ab}, the potential (in $\mathbf{V}$) of a with respect to b , equals the work (in J) done by the clectric force when a UNIT $(1-C)$ charge moves from a to b.
- V_{ab}, , the potential (in V) of a with respect to b, equals the work (in J) that must be done to move a UNIT (1-C) charge slowly from b to a against the electric force.
- Calculating the electric potential: $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$,$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$,$V = \frac{1}{4\pi\epsilon_0}\int \frac{dq}{r}$
- Finding electric potential from electric field: Moving with the direction of $\overrightarrow{E}$ means moving in the direction of decreasing V, and moving against the direction of $\overrightarrow{E}$ means moving in the direction of increasing V.

5. Calculating electric potential

   Whenever possible, solve problems by means of an energy approach (using electric potential and electric potential energy) rather than a dynamics approach (using electric fields and electric forces).

2 Discussion

- Is it possible to have an arrangement of two point charges separated by a finite distance such that the electric potential energy of the arrangement is the same as if the two charges were infinitely far apart? Why or why not? What if there are three charges? Explain.

- If $\overrightarrow{E}$ is zero throughout a certain region of space, is the potential necessarily also zero in this region? Why or why not? If not, what can be said about the potential?
- It is easy to produce a potential difference of several thousand volts between your body and the floor by scuffing your shoes across a nylon carpet. When you touch a metal doorknob, you get a mild shock. Yet contact with a power line of comparable voltage would probably be fatal. Why is there a difference?
- Imagine we place a conductor in the electric field of a charge configuration, so that its surface coincides with an equipotential surface in that field. Can the potential distribution in space change?
- More discussed in RC......

3 Problems and exercises

Question 1

A very large plastic sheet carries a uniform charge density of -6.00 nC/m^2 on one face. (a) As you move away from the sheet along a line perpendicular to it, does the potential increase or decrease? How do you know, without doing any calculations? Does your answer depend on where you choose the reference point for potential? (b) Find the spacing between equipotential surfaces that differ from each other by 1.00 V. What type of surfaces are these?

Question 2

A small sphere with mass 2.50 g hangs by a thread between two very large parallel vertical plates 5.00 cm apart. The plates are insulating and have uniform surface charge densities $+\sigma$ and -σ. The charge on the sphere is q = $7.10 * 10^6 C$. What potential difference between the plates will cause the thread to assume an angle of 30.0 degrees with the vertical?

Question 3

A point charge $q_1 = 4.05\mathrm{nC}$ is placed at the origin, and a second point charge $q_2 = -2.95\mathrm{nC}$ is placed on the x -axis at $x = +21.0\mathrm{cm}$. A third point charge $q_3 - 2.05\mathrm{nC}$ is to be placed on the x -axis between q_1 and q_2. (Take as zero the potential energy of the three charges when they are infinitely far apart. (a) What is the potential energy of the system of the three charges if q_3 is placed at $x = +11.0\mathrm{cm}$? (b) Where should q_3 be placed to make the potential energy of the system equal to zero?

Question 4

Two plastic spheres, carrying charge uniformly distributed throughout its interior, are initially placed in contact and then released. One sphere is 65.0 cm in diameter, has mass 50.0 g, and contains $-10.0\mu\mathrm{C}$ of charge. The other sphere is 42.0 cm in diameter, has mass 160.0 g , and contains $-25.0\mu\mathrm{C}$ of charge. Find the maximum acceleration and the maximum speed achieved by each sphere (relative to the fixed point of their initial location in space), assuming that no other forces are are acting on them. (Hint: The uniformly distributed charges behave as though they were concentrated at the centers of the two spheres.)