VP240-1 Recitation class
Week #1

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Brief introduction

- Be familiar with theorems. Many equations look similar but different. Guass's law, Faraday's law and Ampere's law, etc.
- Practice. Practice. Practice. Textbooks.
- MK's note is neat and tidy. Everything on it should be learned by heart, especially the calculation of the models.
- Try to understand. No need to recite formula. When you are familiar with it, you can use it just as your hands.
- If you feel difficult in doing homework, stick to the lecture notes and textbook and you'll find answers.
- I will give the most important parts of the lecture but not everything. And I suppose you read MK's note at least once.

1 Short Review

1. Electric force (Coulomb force) between two point charges

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2} \tag{1}$$

Info:

- the electric constant $\varepsilon_0 = 8.854 \times 10^{-12} C^2/N \cdot m^2$, it can be seen on your calculator.
- often we use the approximate value $k = 9.0 \times 10^{-9} N \cdot m^2/C^2$, be aware of the units.
- one coulomb is a huge charge. Get familiar with microcoulomb, nanocoulomb.
- compare α particle's electric repulsion and gravitational attraction.

2. Superposition principle (discrete/continuous distributions of charge)

   Principle of superposition of forces: Experiments show that when two charges exert forces simultaneously on a third charge, the total force acting on that charge is the **vector sum** of the forces that the two charges would exert individually. It holds for any number of charges.

Notice: We first consider static charges ⇒ electrostatics. Otherwise, it will cause other effects.

3. Electric field

   The field: The electric force on a charged body is exerted by the electric field created by **other** charged bodies.

$$\overrightarrow{E} = \frac{\overrightarrow{F}_0}{q_0} \tag{2}$$

Info:

- To find out experimentally whether there is an electric field at a particular point, we place a small charged body, which we call a **test charge** q_0.
- Force is a vector quantity, so electric field is also a vector quantity. The unit is 1 newton per coulomb.
- If the field $\overrightarrow{E_0}$ at a certain point is known, rearranging it gives the force $\overrightarrow{F_0}$ experienced by a point charge q_0 placed at that point.
- The electric force experienced by a test charge q_0 can vary from point to point, so the electric field can also be different at different points. For this reason, use (2) to find the electric force on a point charge only. If a charged body is large enough in size, the electric field $\overrightarrow{E}$ may be noticeably different in magnitude and direction at different points on the body, and calculating the net electric force on it can be complicated.

4. Electric field of a point charge

   If the source distribution is a point charge q, it is easy to find the electric field that it produces. We call the location of the charge the **source point**, and we call the point P where we are determining the field the **field point**.

$$\overrightarrow{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\mathbf{r}} \tag{3}$$

5. Electric dipole in an electric field (discuss the potential energy of the dipole in the electric field)

   The product of the charge q and the separation d is the magnitude of a quantity called **the electric dipole moment**, denoted by p :

$$p = qd \qquad \text{(magnitude of electric dipole moment)}$$

   discuss in class

   When a dipole changes direction in an electric field, the electric-field torque does work on it, with a corresponding change in potential energy. The work dW done by a torque τ during an infinitesimal displacement $d\phi$ is given by : $dW = \tau d\phi$. Because the torque is in the direction of decreasing ϕ, we must write the torque as $\tau = -pE\sin\phi$, and

$$dW = \tau d\phi = -pE\sin\phi d\phi$$

   In a finite displacement from ϕ_1 to ϕ_2 the total work done on the dipole is

$$\begin{aligned} W &= \int_{\phi_1}^{\phi_2}(-pE\sin\phi)d\phi \\ &= pE\cos\phi_2 - pE\cos\phi_1 \end{aligned}$$

   The work is the negative of the change of potential energy, just as in Chapter 7 : $W = U_1 - U_2$. So a suitable definition of potential energy U for this system is

$$U(\phi) = -pE\cos\phi$$

6. Electric field lines

   Field lines provide a graphical representation of electric fields. At any point on a field line, the tangent to the line is in the direction of $\vec{E}$ at that point. The number of lines per unit area (perpendicular to their direction) is proportional to the magnitude of $\vec{E}$ at the point.

2 Discussion

- the principle of the electrostatic painting process (Page 713)

  The electrostatic painting process (compare Figs. 21.7b and 21.7c). A metal object to be painted is connected to the earth ("ground"), and the paint droplets are given an electric charge as they exit the sprayer nozzle. Induced charges of the opposite sign appear in the object as the droplets approach, just as in Fig. 21.7b, and they attract the droplets to the sur- face. This process minimizes overspray from clouds of stray paint particles and gives a particularly smooth finish.

- Compare the electric force between two electrons with the force of gravitational attraction between them

3 Problems and exercises

Question 1

Positive charge Q is distributed uniformly along the y-axis between y = -a and y = +a. Find the electric field at point P on the x-axis at a distance x from the origin.

Question 2

An electric dipole is centered at the origin, with $\overrightarrow{p}$ in the direction of the +y-axis (Fig. 21.33). Derive an approximate expression for the electric field at a point P on the y-axis for which y is much larger than d.
To do this, use the binomial expansion $(1+x)^n \cong 1+n+n(n-1)x^2/2+...$ (valid for the case $|x| < 1$).

Question 3

Torque on a Dipole. An electric dipole with dipole moment $\overrightarrow{p}$ is in a uniform external electric field $\overrightarrow{E}$. (a) Find the orientations of the dipole for which the torque on the dipole is zero. (b) Which of the orientations in part (a) is stable, and which is unstable? (Hint: Consider a small rotation away from the equilibrium position and see what happens.) (c) Show that for the stable orientation in part (b), the dipole's own electric field tends to oppose the external field.

Question 4

Two thin rods of length L lie along the x-axis, one between x = $\frac{1}{2}$a and x = $\frac{1}{2}$ a + L and the other between x = $-\frac{1}{2}$ a and x = $-\frac{1}{2}a - L$. Each rod has positive charge Q distributed uniformly along its length. (a) Calculate the electric field produced by the second rod at points along the positive x-axis. (b) Show that the magnitude of the force that one rod exerts on the other is:

$$F = \frac{Q^2}{4\pi\epsilon_0 L^2} \ln\left[\frac{(a+L)^2}{a(a+2L)}\right]$$

(c)Show that if $a \gg L$, the magnitude of this force reduces to $F = Q^2/4\pi\epsilon_0 a^2$. (Hint: Use the expansion $\ln(1+z) = z - \frac{1}{2}z^2 + \frac{1}{3}z^3 - \cdots$, valid for $|z| << 1$. Carry all expansions to at least order L^2/a^2.) Interpret this result.

Question 5

$A - 3.00 - nC$ point charge is on the x -axis at $x = 1.20\mathrm{m}$. A second point charge, Q, is on the x -axis at $-0.600\mathrm{m}$. What. must be the sign and magnitude of Q for the resultant electric field at the origin to be (a) 45.0 $\mathrm{N/C}$ in the $+x$ - direction, (b) $45.0\mathrm{N/C}$ in the $-x$ -direction?