University Physics A(1) 2014

Name (名字):　　　　　　　　　　　　　　　Student number (学号):

New words: Write the Chinese next to these words as you learn them.

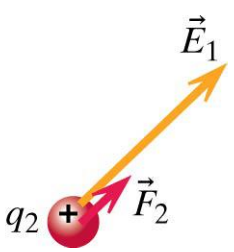
electric field	neutral
magnetic field	superposition
charge	dipole
quantized	dipole moment

Problems Show all working.

(1) (a) [14.X.15] What is the relationship between the concepts "field" and "force"? What are their units?

(b) [14.X.21] An electron in a region in which there is an electric field (有电场的区域) experiences a force of $\langle 8.0 \times 10^{-17}, -3.2 \times 10^{-16}, -4.8 \times 10^{-16} \rangle$ N. What is the electric field at the location of the electron?

(c) [14.X.20] If the particle in the figure below is a proton, and the electric field has the value $\langle 2 \times 10^4, 2 \times 10^4, 0 \rangle$ N/C, what is the force on the proton?



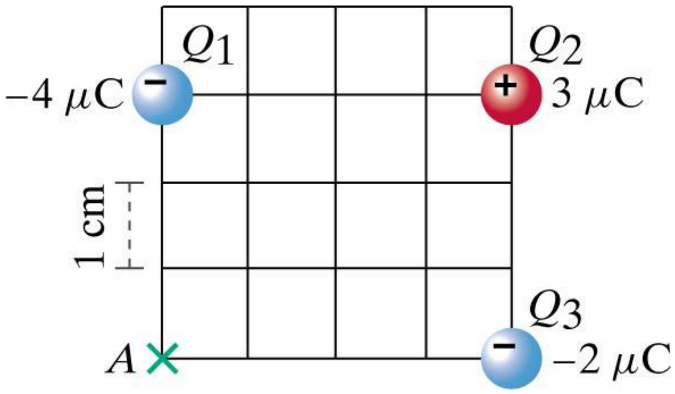
(d) [14.P.26] You are the captain (船长) of a spaceship. You need to measure the electric field at a specified location P in space outside your ship. You send a crew member (船员) outside with a meter stick (米尺), a stopwatch (跑表), and a small ball of known mass M and net charge $+Q$.

(i) Write down the instructions (指示) you will give to the crew member, explaining what observations (监测) to make.

(ii) Explain how you will analyze (分析) the data (数据) that the crew member brings you to determine the magnitude and direction of the electric field at location P.

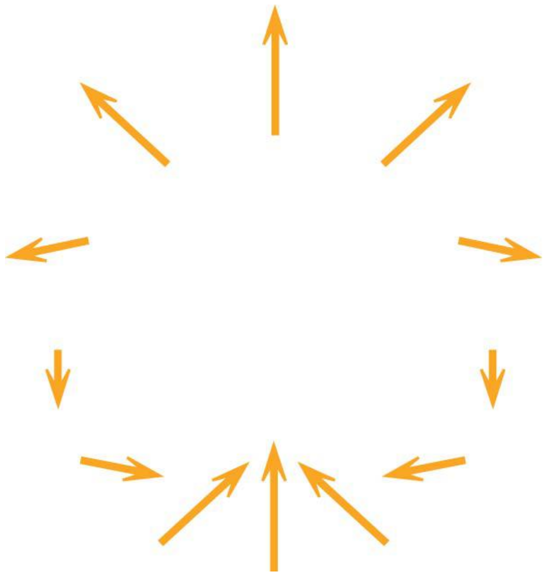
(2) (a) [14.X.29] What is the electric field at a location $\langle -0.1, -0.1, 0 \rangle$ m, due to a particle with charge +4 nC located at the origin? (1 nC $= 1 \times 10^{-9}$ C.)

(b) [14.P.50] At a particular moment, three charged particles are located as shown in the figure below. Your answers to the following questions should be vectors. (1 $\mu C = 1 \times 10^{-6}$ C.)



(i) Find the electric field at the location of Q_1, due to Q_2 and Q_3.
(ii) Use the electric field you calculated in part (i) to find the force on Q_1.
(iii) Find the electric field at location A, due to all three charges.
(iv) An alpha particle (He^{2+}, containing two protons and two neutrons) is released from rest at location A. Use your answer from the previous part to determine the initial acceleration of the alpha particle.

(3) (a) [14.X.56] Where could you place one positive charge and one negative charge to produce the pattern of electric field shown in the figure below? (The tails of the arrows are placed at the location where the electric field was measured.) Briefly explain your choices.



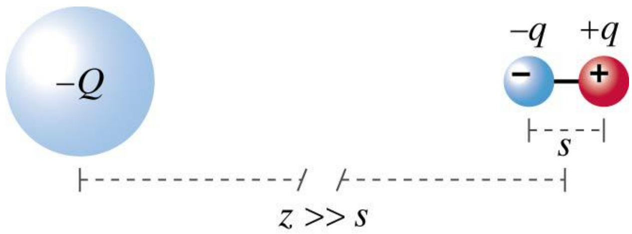
(b) [14.X.67] On the diagram below, draw (只要画，不用算):

(i) The electric field of the dipole at the location of the negatively charged ball

(ii) The net force on the ball due to the dipole

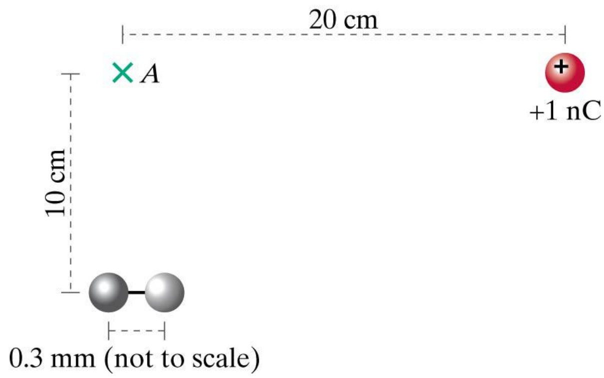
(iii) The electric field of the ball at the center of the dipole

(iv) The net force on the dipole due to the ball



(c) [14.X.68] If the distance between the ball and the dipole in the figure above were doubled (距离增加一倍), what change would there be in the force on the ball due to the dipole?

(d) [14.P.75] A charge of +1 nC and a dipole with charges $+q$ and $-q$ separated by 0.3 mm contribute a net field at location A that is zero, as shown in the figure below (A 处的电场强度为零).



("not to scale" = 不按比例)

(i) Which end of the dipole is positively charged? Draw + and − signs at the appropriate ends of the dipole.
(ii) What is the value of the charge q?

第八周作业

(1) (a) $\vec{F} = q\vec{E}$ $\vec{F}$单位为N，$\vec{E}$单位为N/C.

(b) $\vec{E} = \frac{\vec{F}}{q} = \frac{(8.0\times10^{-17}, -3.2\times10^{-16}, -4.8\times10^{-16})N}{-1.602\times10^{-19}C} = (-500, 2000, 3000)N/C$

(c) $\vec{F_2} = q_2\vec{E_1} = (1.602\times10^{-19}C)\cdot(2\times10^4, 2\times10^4, 0)N/C = (3.2\times10^{-15}, 3.2\times10^{-15}, 0)N$

(d) (i) 在P处释放小球，记录小球移动1m所用时间Δt，还有运动方向.

(ii) 假设球受力为$\vec{F}$，初速度为$\vec{V_i}$，末速度为$\vec{V_f}$，由动量守恒定律有：

$\vec{P_f} = \vec{P_i} + \vec{F}\cdot\Delta t$ 即 $MV_f = MV_i + F\Delta t$ 得：$V_f = V_i + \frac{F}{M}\cdot\Delta t$

因为 $\frac{V_i+V_f}{2} = \frac{\Delta x}{\Delta t}$，又$V_i=0$ 则 $\frac{F}{2M}\cdot\Delta t = \frac{\Delta x}{\Delta t}$ 所以 $F = \frac{2M\Delta x}{\Delta t^2} = Q|\vec{E}|$

则 $|\vec{E}| = \frac{F}{Q} = \frac{2M\Delta x}{Q\cdot\Delta t^2}$，$Q>0$时，电场方向与球运动方向相同，$Q<0$时，方向相反

(2) (a) $|\vec{r}| = \sqrt{(-0.1)^2+(-0.1)^2+0^2}\ m = 0.141m$，$\hat{r} = \frac{\vec{r}}{|\vec{r}|} = (-0.707, -0.707, 0)$

$|\vec{E}| = \frac{1}{4\pi\varepsilon_0}\cdot\frac{|Q|}{|\vec{r}|^2} = 9\times10^9 \times \frac{4\times10^{-9}}{(0.141)^2} = 1811N/C$

则 $\vec{E} = |\vec{E}|\cdot\hat{E} = |\vec{E}|\cdot\hat{r} = 1811\cdot(-0.707, -0.707, 0)N/C = (-1280, -1280, 0)N/C$

(b) (i) $\vec{r}_{2\to1} = \vec{r_1} - \vec{r_2} = (0, 0.03, 0) - (0.04, 0.03, 0) = (-0.04, 0, 0)m$

$|\vec{r}_{2\to1}| = 0.04$. $\hat{r}_{2\to1} = \frac{\vec{r}_{2\to1}}{|\vec{r}_{2\to1}|} = (-1, 0, 0)$，$\vec{E_2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_2}{|\vec{r}_{2\to1}|^2}\cdot\hat{r}_{2\to1} = (-1.688\times10^7, 0, 0)N/C$

同理得：$\vec{r}_{3\to1} = (-0.8, 0.6, 0)$. $|\vec{r}_{3\to1}| = 0.05m$. 则 $\vec{E_3} = (5.76\times10^6, -4.32\times10^6, 0)N/C$

所以 $\vec{E_0} = \vec{E_2} + \vec{E_3} = (-1.1\times10^7, -4.3\times10^6, 0)N/C$

(ii) $\vec{F_1} = Q_1\cdot\vec{E_0} = (-4\times10^{-6}C)\cdot(-1.1\times10^7, -4.3\times10^6, 0)N/C = (44, 17, 0)N$

(iii) $\vec{r_1} = (0, -0.03, 0)m$. $|\vec{r_1}| = 0.03m$，$\hat{r_1} = (0, -1, 0)$

$\vec{r_2} = (-0.04, -0.03, 0)m$. $|\vec{r_2}| = 0.05m$ $\hat{r_2} = (-0.8, -0.6, 0)$

$\vec{r_3} = (-0.04, 0, 0)m$ $|\vec{r_3}| = 0.04m$ $\hat{r_3} = (-1, 0, 0)$

则 $\vec{E_1} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1}{|\vec{r_1}|^2}\cdot\hat{r_1} = 9\times10^9\times\frac{(-4\times10^{-6})}{(0.03)^2}\cdot(0, -1, 0) = (0, 4\times10^7, 0)N/C$

同理得：$\vec{E_2} = (-8.6\times10^6, -6.5\times10^6, 0)N/C$ $\vec{E_3} = (1.13\times10^7, 0, 0)N/C$

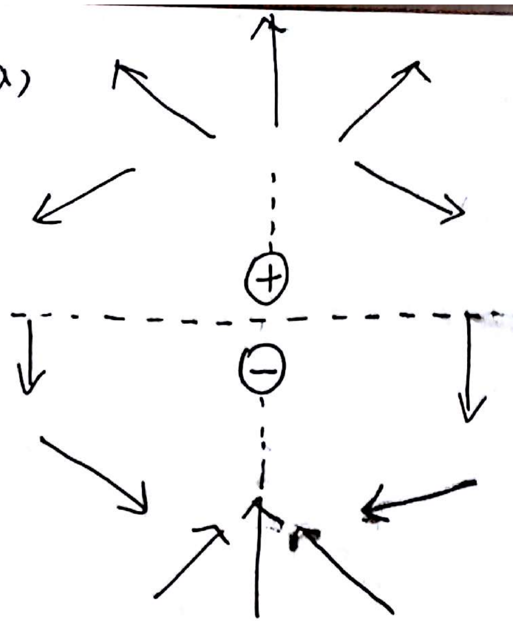
则 $\vec{E}_{总} = \vec{E_1} + \vec{E_2} + \vec{E_3} = (2.7\times10^6, 3.4\times10^7, 0)N/C$

(iv) $Q = 2e$，$M = 2M_{质子} + 2M_{中子} \approx 4M_{质子} = 4\times1.7\times10^{-27}kg = 6.8\times10^{-27}kg$

$\vec{F} = Q\cdot\vec{E}_{总} = 2\times1.6\times10^{-19}\cdot(2.7\times10^6, 3.4\times10^7, 0)N/C = (8.6\times10^{-13}, 1.1\times10^{-11}, 0)N$

则 $\vec{a} = \frac{\vec{F}}{M} = (1.3\times10^{14}, 1.6\times10^{15}, 0)m/s^2$

(3) (a)

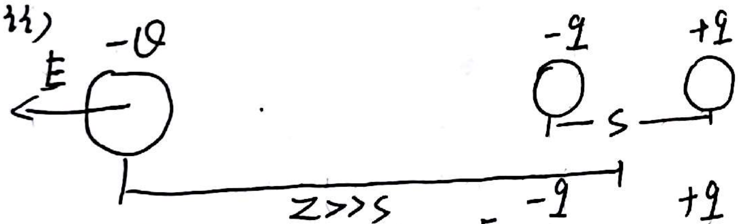


背向离正电荷远处

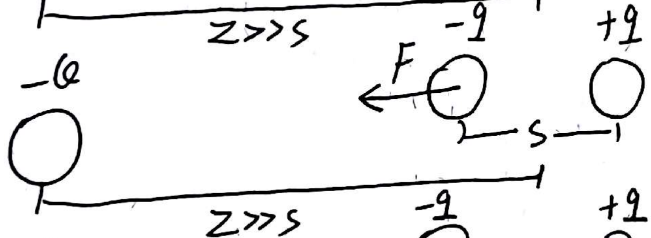
指向靠近负电荷

(b) (i)

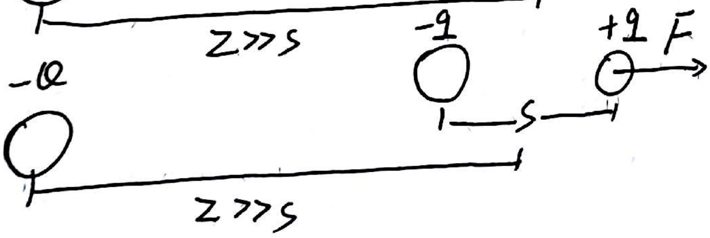
(ii)



(iii)



(iv)



(c) 因为 $z \gg s$，$E \propto \frac{1}{z^3}$ 当 $z = 2z$ 时，$E \times \frac{1}{2^3} = \frac{E}{8}$，又 $F = qE$.
则 F 为原来的 $\frac{1}{8}$

(d). (i) 左端 (ii) $|q| = \frac{Qd^3}{s|\vec{r}|^2} = 8.3 \times 10^{-8}\,C$