Workbook

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Electric Dipole

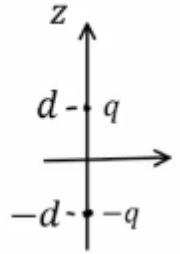## Electric Dipole

Questions

1) Two charges *q* and *-q* are placed at *x=a* and at *x=-a*.

   a. Calculate the force acting on a third charge *Q* placed at *(x, y, 0)*.
   b. Assume that the distance between *Q* and the origin is much larger than the distance between the other two charges.
       The angle between *Q* and the x-axis is 45° (see diagram).
       Use your answer to 1 to calculate the force on *Q*.
   c. Calculate the dipole moment of charges *q* and *-q*.
   d. Again calculate the force on *Q*,
       this time using the equation for a dipole field.
   How does your answer compare to that of question 2?
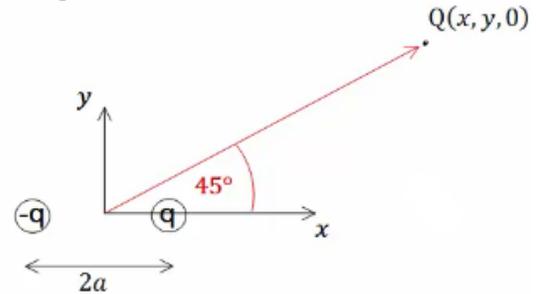
2) We are given a dipole of moment $\vec{p} = (p, 0,0)$, located at the origin.

   a. Calculate the magnitude p such that if an electron was located at $(a, 0,0)$ with a velocity of $(v, 0,0)$, it would eventually come to a stop at $(b, 0,0)$.
   b. Calculate the magnitude p such that if an electron was located at $\left(a, -\sqrt{2}a, 0\right)$ with a velocity of $(0,0, v)$, it would have circular motion.

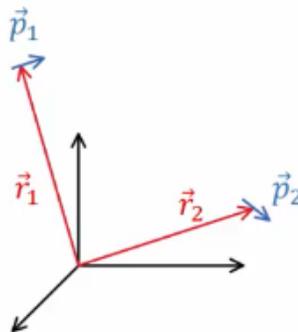**3)** Calculate the total dipole moment of the system.
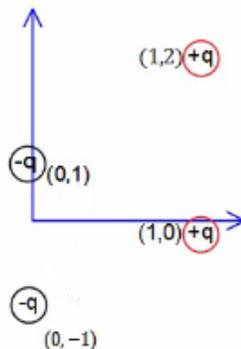
4) A charge q is located at $(0,0,d)$ and $-q$ is located at $(0,0,-d)$.

a. Calculate the exact potential at a point along the z-axis.

b. What is the minimal value of z such that the approximation of the potential at that point wont deviate more than 1% from the actual value.

c. What is the minimal value of z such that the approximation of the electric field at that point wont deviate more than 1% from the actual value.

5) An electric dipole of dipole moment $\vec{p}$ is placed at $\vec{r}$. A point charge q is at the origin.

a. What is the torque acting on the dipole?

b. What is the energy of the dipole?

c. Show that the force acting on the dipole is equal to $\vec{F} = \frac{k(\vec{p} \cdot r^2 - 3(\vec{p} \cdot \vec{r}) \cdot \vec{r})}{r^5}$
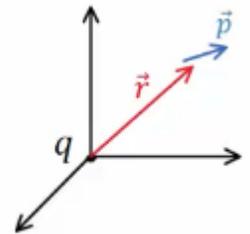
6) Dipole $\vec{p}_1$ is located at $\vec{r}_1$, and dipole $\vec{p}_2$ is located at $\vec{r}_2$.

a. Show that the energy of $\vec{p}_2$ in the field of $\vec{p}_1$ is:

b. $U = \frac{k}{\tilde{r}^3}[\vec{p}_1 \cdot \vec{p}_2 - 3(\vec{p}_1 \cdot \hat{\tilde{r}})(\vec{p}_2 \cdot \hat{\tilde{r}})]$, where $\vec{\tilde{r}} = \vec{r}_2 - \vec{r}_1$, $\hat{\tilde{r}} = \frac{\vec{\tilde{r}}}{\tilde{r}}$, $\tilde{r} = |\vec{\tilde{r}}|$.

c. This is the energy of a dipole-dipole system. Show that if we were to calculate the energy of $\vec{p}_1$ in the field of $\vec{p}_2$, we would get the same answer.

d. What is the force acting on $\vec{p}_2$ and $\vec{p}_1$?

e. What is the force on $\vec{p}_2$ if $\vec{p}_2$ were parallel to $\vec{p}_1$ and $\vec{\tilde{r}}$?

And what is the force on $\vec{p}_2$ if $\vec{p}_2$ were parallel to $\vec{p}_1$ but perpendicular to $\vec{\tilde{r}}$?

*For the solutions go see the videos

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