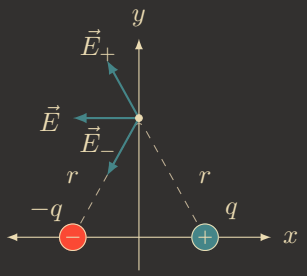
Example: Electric Dipole - Modeling a Molecule

A molecule may be approximately modeled as a positive charge q at $x = a$ and a negative charge $-a$ at $x = -a$. Evaluate the electric field on the y-axis, and find an approximate expression valid at large distances ($|y| \gg a$).



The individual unit vectors point from the two charges toward the field point. The negative charge contributes a field opposite its unit vector; individual fields are indicated. Symmetry makes the y-components cancel, giving a field in the $-x$ direction, so only the x-components of the unit vectors are needed.

These are $\hat{r}_{x^-} = {}^{a}/_{r}$ for the negative charge at $x = -a$ and $\hat{r}_{x^+} = -{}^{a}/_{r}$ for the positive charge at $x = a$.
When evaluated using equation 4:

$$\vec{E} = \frac{k_e(-q)}{r^2}\left(\frac{a}{r}\right)\hat{\imath} + \frac{k_e q}{r^2}\left(-\frac{a}{r}\right)\hat{\imath} = -\frac{2k_e q a}{(a^2+y^2)^{3/2}}$$

In the last step the substitution $r = \sqrt{a^2+y^2}$ is used. For $|y| \gg a$, a^2 can be neglected compared with y^2, giving

$$\vec{E} = -\frac{2k_e q a}{|y|^3}\hat{\imath} \quad (|y| \gg a)$$