POINT CHARGE AND NEUTRAL ATOM

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Reference: Griffiths, David J. (2007) Introduction to Electrodynamics, 3rd Edition; Prentice Hall - Problem 4.4.

In an earlier post, we saw that placing a neutral atom in an external field induces a dipole moment p where for small fields the experimentally determined relation is

$$\mathbf{p}=\alpha\mathbf{E} \tag{0.1}$$

where α is the atomic polarizability.

If this external field is due to a point charge q at a distance r from the atom then the field at the atom due to the charge is

$$E=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \tag{0.2}$$

The induced dipole moment is therefore

$$p=\frac{\alpha}{4\pi\varepsilon_0}\frac{q}{r^2} \tag{0.3}$$

We've seen that the electric field due to a dipole is (in spherical coordinates):

$$\mathbf{E}=\frac{p}{4\pi\varepsilon_0 r^3}\left[2\cos\theta\hat{\mathbf{r}}+\sin\theta\hat{\theta}\right] \tag{0.4}$$

The field from the dipole induced by the point charge is therefore

$$\mathbf{E}=\frac{\alpha q}{(4\pi\varepsilon_0)^2 r^5}\left[2\cos\theta\hat{\mathbf{r}}+\sin\theta\hat{\theta}\right] \tag{0.5}$$

where $\hat{\mathbf{r}}$ points along the line from the atom to the point charge. The point charge is thus located at $\theta=0$ so the force on the charge due to the dipole is

$$F = \frac{2\alpha q^2}{(4\pi\varepsilon_0)^2 r^5} \tag{0.6}$$