

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

$$\mathbf{p} = \alpha \mathbf{E} \quad (1)$$

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

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \quad (2)$$

The induced dipole moment is therefore

$$p = \frac{\alpha}{4\pi\epsilon_0} \frac{q}{r^2} \quad (3)$$

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

$$\mathbf{E} = \frac{p}{4\pi\epsilon_0 r^3} [2\cos\theta\hat{\mathbf{r}} + \sin\theta\hat{\boldsymbol{\theta}}] \quad (4)$$

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

$$\mathbf{E} = \frac{\alpha q}{(4\pi\epsilon_0)^2 r^5} [2\cos\theta\hat{\mathbf{r}} + \sin\theta\hat{\boldsymbol{\theta}}] \quad (5)$$

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

$$F = \frac{2\alpha q^2}{(4\pi\epsilon_0)^2 r^5} \quad (6)$$