

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

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

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

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

The induced dipole moment is therefore

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

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

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

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

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

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

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