4.4) A point charge q is situated a large distance r from a neutral atom of polarizability α. Find the force of attraction between them.

The charge q serves as the external field which polarizes the neutral atom. The dipole moment of the atom from this field is given as

$$p = \alpha\left(\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\right)$$

Thus, we can calculate the field produced by the induced dipole

$$E = \frac{1}{4\pi\epsilon_0}\frac{1}{r^3}\left(\frac{2\alpha q}{4\pi\epsilon_0 r^2}\right)$$

and the force on q from this field

$$\boxed{F = qE_{\text{atom}} = \frac{2\alpha q^2}{4\pi\epsilon_0 r^5}}$$

4.6) A (perfect) dipole $\vec{\mathbf{p}}$ is situated a distance z above an infinite grounded conducting plane. The dipole makes an angle θ with the perpendicular to the plane. Find the torque on $\vec{\mathbf{p}}$. If the dipole is free to rotate, in what orientation will it come to rest?

The torque on the dipole is given as

$$\vec{\mathbf{N}} = \vec{\mathbf{p}} \times \vec{\mathbf{E}}$$

We can produce an equivalent set up by placing a mirror dipole on the opposite side of the infinite conducting plane, which gives us the electric field from the plane. That is,

$$\begin{aligned}\vec{\mathbf{p}} &= p\Big[\cos\theta\hat{\boldsymbol{r}} + \sin\theta\hat{\boldsymbol{\theta}}\Big]\\ \vec{\mathbf{E}} &= \frac{p}{4\pi\epsilon_0(2z)^3}\Big(2\cos\theta\hat{\boldsymbol{r}} + \sin\theta\hat{\boldsymbol{\theta}}\Big)\end{aligned}$$

Hence, carrying out the cross product and simplifying the result,

$$\boxed{\vec{\mathbf{N}} = -\frac{p^2\sin(2\theta)}{4\pi\epsilon_0(16z^3)}\hat{\boldsymbol{\phi}}}$$

From this we can see that the dipole "attempts" to orient itself parallel to the field. If $-\pi/2 < \theta < \pi/2$ the dipole will point away from the plane. Otherwise the dipole will rotate such that it points towards the plane.