1st year Electricity and Magnetism, Tony Bell

Classwork 1 - 10th February 2005

1a) An electric dipole consists of charges Q and $-Q$ on the x-axis at $x = a/2$ and $x = -a/2$ respectively (Q is positive). What is the magnitude and direction of the dipole moment $\mathbf{M}_1$?

b) Using the expression given in the lectures for the potential due to a dipole in terms of the dipole moment, find both the potential and the electric field on the x-axis at a point $x = X$ ($X >> a$).

c) Write down expressions for the potential and the electric field at two further points on the x-axis at $x = X - b/2$ and $x = X + b/2$ respectively, where $b << X$.

d) A second dipole consists of charges q and $-q$ on the x-axis at $x = X + b/2$ and $x = X - b/2$ respectively (q is positive). Using the results from c), derive an expression for the net (total) force exerted on the second dipole in the limit that b is small. Terms proportional to b^2 can be neglected. If $\mathbf{M}_2$ is the moment of the second dipole, give the force in terms of $\mathbf{M}_1$ and $\mathbf{M}_2$. What is the direction of the force?

e) Using results from c), derive the potential energy of the second dipole in the field of the first dipole. Show that the energy is equal to $-\mathbf{E}.\mathbf{M}_2$ in the limit that b is very small and $\mathbf{E}$ is the electric field derived in b).

f) Find an expression for the energy needed to rotate the second dipole through 180° in the limit of small b. Similarly find an expression for the energy required to rotate the first dipole through 180°.

2. The so-called van der Waals force between neutral atoms and molecules arises from a 'dipole-dipole' interaction. The incessant movement of the the bound electrons means that an atom or molecule will exhibit a fluctuating dipole moment $\mathbf{M}_1$, which in turn creates an induced dipole moment $\mathbf{M}_2$ in a neighbour. Making the reasonable assumption that the magnitude of $\mathbf{M}_2$ is proportional to the field of $\mathbf{M}_1$, demonstrate that the van der Waals force varies as the inverse 7th power of the separation between them (ie force $\propto 1/r^7$ where r is the distance between the molecules). Is the van der Waals force attractive or repulsive?

adapted from a classwork by GHC New