ELECTRIC CHARGE AND FIELD

DIPOLE IN A UNIFORM EXTERNAL FIELD

DIPOLE IN A UNIFORM EXTERNAL FIELD:

Consider a permanent dipole of dipole moment p in a uniform external field E, as shown in (By permanent dipole, we mean that p exists irrespective of E; it has not been induced by E.)
There is a force qE on q and a force –qE on –q. The net force on the dipole is zero, since E is uniform. However, the charges are separated, so the forces act at different points, resulting in a torque on the dipole. When the net force is zero, the torque (couple) is independent of the origin. Its magnitude equals the magnitude of each force multiplied by the arm of the couple (perpendicular distance between the two antiparallel forces).

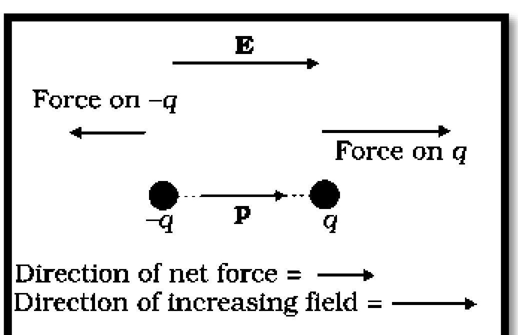
Magnitude of torque = $q\,E \times 2\,a \sin\theta$

$= 2\,q\,a\,E \sin\theta$

Its direction is normal to the plane of the paper, coming out of it. The magnitude of $p \times E$ is also $p\,E \sin\theta$ and its direction is normal to the paper, coming out of it. Thus, $\tau = p \times E$

This torque will tend to align the dipole with the field E. When p is aligned with E, the torque is zero.

What happens if the field is not uniform? In that case, the net force will evidently be non-zero. In addition, there will, in general, be a torque on the system as before. The general case is involved, so let us consider the simpler situations when p is parallel to E or antiparallel to E. In either case, the net torque is zero, but there is a net force on the dipole



(a)

if E is not uniform.

is self-explanatory. It is easily seen that when p is parallel to E, the dipole has a net force in the direction of increasing field. When p is antiparallel to E, the net force on the dipole is in the direction of decreasing field. In general, the force depends on the orientation of p with respect to E

This brings us to a common observation in frictional electricity. A comb run through dry hair attracts pieces of paper. The comb, as we know, acquires charge through friction. But the paper is not charged. What then explains the attractive force? Taking the clue from the preceding discussion, the charged comb 'polarizes' the piece of paper, i.e., induces a net dipole moment in the direction of field. Further, the electric field due to the comb is not uniform. This non-uniformity of the field makes a dipole to experience a net force on it. In this situation, it is easily seen that the paper should move in the direction of the comb!