University of Anbar
College of Engineering
Dept. of Electrical Engineering

Electric physics II

Electric dipole moment , torque, potential energy

By

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1.Electric dipole moment

- An electric dipole is a pair of point charges with equal magnitude and opposite sign (a positive charge q and a negative charge –q) separated by a distance (d = 2a) which is the dipole axis as shown in figure (3-1) .

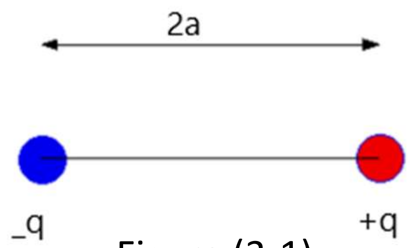


Figure (3-1)

- Definition of electric moment:-

In physics, the electric dipole moment
(or electric dipole for short) is a measure of
the polarity of a system of electric charges.
In figure(3-2) r =2a =d, In the simple case of two point
one with charge +q and one with charge –q

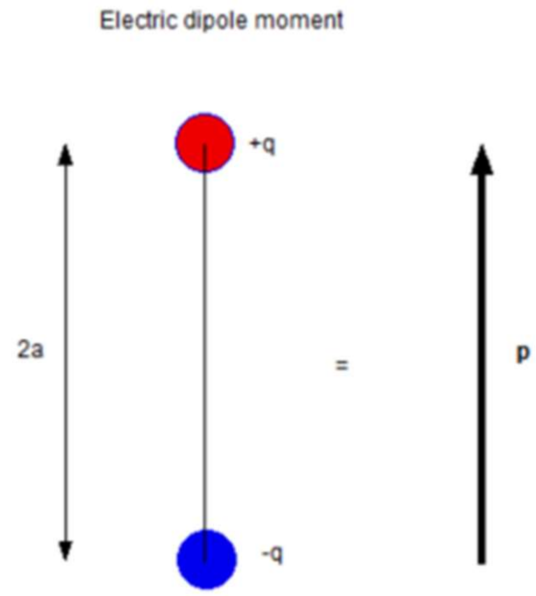


Figure (3-2)

- the electric dipole moment is:
- $p = r \times q$ .... (3-1) (the magnitude of dipole moment)
- The unite of dipole moment is Coulomb. meter (C. m)
- where r is the displacement vector pointing from the negative charge to the positive charge ($r = 2a = d$). This implies that the electric dipole moment vector points from the negative charge to the positive charge.
- What happen if we put a dipole in electric field?
- If the dipole is parallel to the electric field as shown in figure (3-3 (a),(b)
- The +ve charge produces a force accelerated in the direction of E, while the –ve charge produces a force accelerated opposite to the direction of E.
- In this case there are two forces having the same magnitude but opposite in their direction, then the resultant force acting on dipole=0

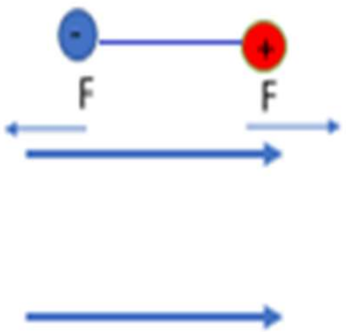


figure 3-3(a)

the electric field parallel to the dipole axis, the forces having the same magnitude but opposite direction , The resultant force acting on dipole =0

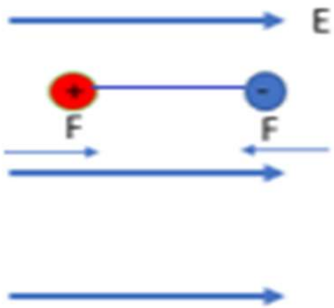


Figure 3-3(b)

the electric field parallel to the dipole axis, the forces having the same magnitude but opposite direction , The resultant force acting on dipole =0

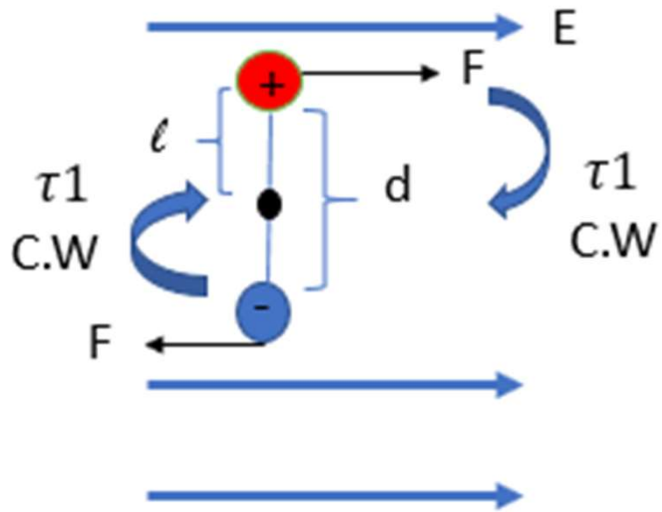


Figure 3-3 (c)

the electric field perpendicular to the dipole axis, the forces having the same magnitude but opposite direction , The resultant force acting on dipole generate a torque

- Figure 3-3c represent the dipole axis vertical to the electric field (E) . In this case there is a torque will be produces
- $\tau = f \times l$ .... *(3-2)*
- Where τ represent the torque and ℓ the arm of the acting force
- $\tau_{net} = \tau_1 + \tau_2$ becuse the two force in clock wise (C.W) direction
- $= f \times \ell + f \times \ell$
- $= f \times \frac{d}{2} + f \times \frac{d}{2}$
- $\tau_{net} = f \times \mathrm{d}$
- $\mathrm{F} = \mathrm{q} \times \mathrm{E}$
- $\tau_{net} = q \times E \times \mathrm{d}$ .... *(3-3)*

*

2. Torque

- We consider the behavior of the electric dipole moment in the presence of an electric field
- An electric dipole is a pair of point charges with

equal magnitude and opposite sign
(a positive charge q and a negative charge –q)
separated by a distance d (= 2a) as in figure (3-4).

- The electric dipole moment is defined by

- P=2aq ………….. (3-4)

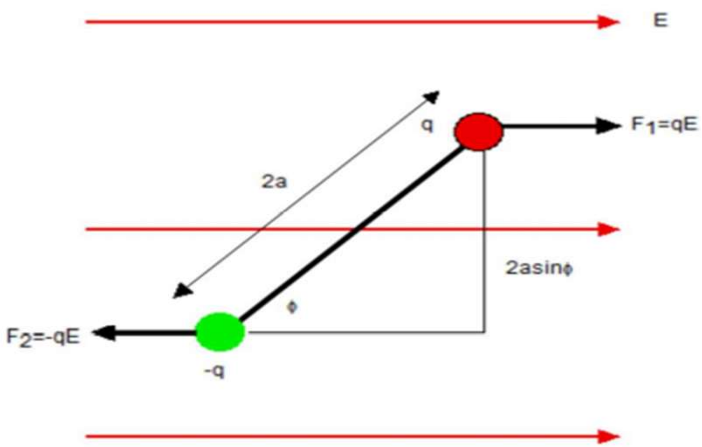


Figure (3-4)

- The unit of p is C m. The magnitude of

the torque τ exerted by the field E is according to equation (3-3):

- $\tau = (qE)(2a)sin\emptyset = pEsin\emptyset$ ………….(3-5)

where ∅ is the angle between E and the dipole axis

The torque directed to clock –wise
Figure (3-5) represent the vector form of the torque (τ)

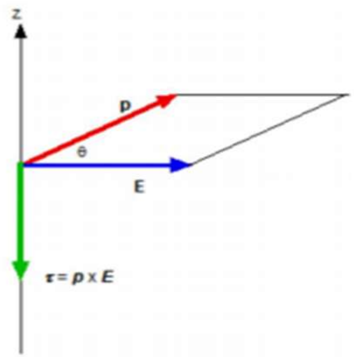
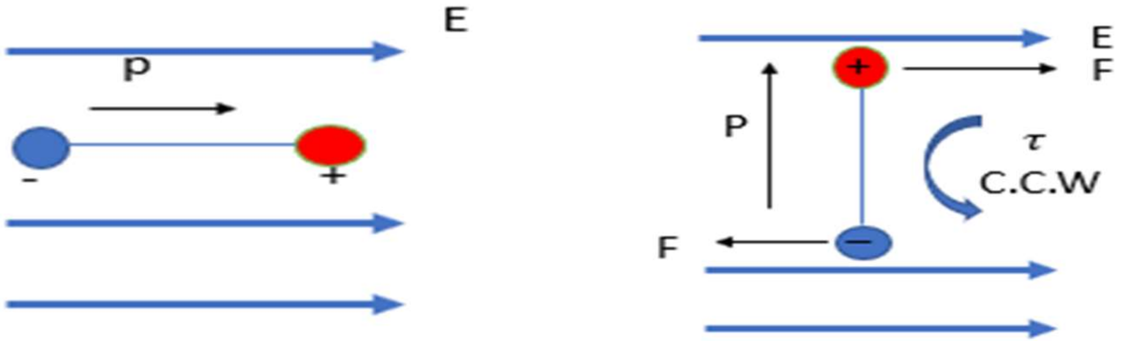


Figure (3-5)

3-Potential energy of electric dipole

- The work done on the electric dipole moment (p) by the electric field (E) is given by $\omega = \tau\emptyset$ ……………………(3-6)
- *Where* τ *is the torque ,* $\emptyset$ *is the angular displacement*
- $d\omega = \tau\, d\emptyset$, $\tau = -p\, E\, sin\emptyset$
- Not that This torque (- τ) is the counterclockwise direction and in the direction of increasing $\emptyset$ as shown in

figure (3-6)(a),(b).



$a)\ (p)\ in\ \ the\ same\ diraction\ of\ E$, $\emptyset$=0
$\tau = p\ E\ sin\emptyset$=0, The minimum value

$b)(p)\ perpendiculer\ to\ E$, $\emptyset$=90
$\tau = p\ E\ sin\emptyset$ = maximum value ,

Figure (3-6)

- When Ø is increases from 0 ° to 90 ° then the torque will be negative sign ($-\tau$)
- $\int dw = -\int pE\, sin\emptyset = -p\, E \int sin\emptyset$ d Ø

  W=$p\ E\ cos\emptyset$

W=-U=$p\ E\ cos\emptyset$

- Since ΔU=- Δ W , we have the expression for the potential energy (U) (in units of J)
- U =- p E
- Note-1 Work-energy theorem; Δ K= Δ W =- ΔU,

  Where Δ K is the kinetic energy
- note-2) The kinetic energy work theorem; W= $+\Delta$ K
- Note-3)) The potential energy has its minimum value where p and E are parallel (Ø = 0). The potential energy has its maximum value where p and E are antiparallel (Ø = π)

Example: -

An electric dipole has a charge of +/- 3.2×10^{-19} and separation distance of 0.25nm, the electric field is (4×10^{6}N/C).

A) What is the magnitude and the direction of the electric dipole moment? b) what is the force on each charge and the net force on the entire dipole? C) calculate the potential energy at an angle of 90° and 30°? d) calculate the work required to move the dipole from 90° to 30°? e) what is the magnitude of the net torque at 90° ?

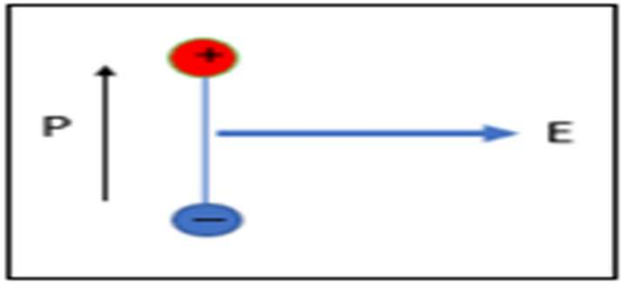
Solution: -

a) What is the magnitude and the direction of the electric dipole moment?

$$p = q \times d$$

P= $3.2\times 10^{-19} \times o.25 \times 10^{-9}$= 8×10^{-29}C.m

the direction of p in y_ direction + according to the figure



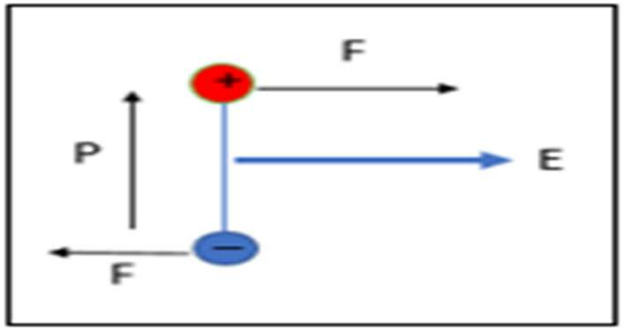
b) what is the force on each charge and the net force on the entire dipole?

$$f = q \times E$$

F= $3.2\times 10^{-19} \times 4 \times 10^{6}$=$1.28 \times 10^{-12}$N the force on each charge

The two force have the same magnitude but in the opposite direction, then the net force =0

$$f_{net} = 0$$



c) calculate the potential energy at an angle of 90° and 30°?

$U = -P \times E \cos\emptyset$

$U1 = -(8 \times 10^{-29}) \times (4 \times 10^{6}) \cos 90° = \ 0J$

$U2 = -(8 \times 10^{-29}) \times (4 \times 10^{6}) \cos 30 = \quad -2.771 \times 10^{-22} J$

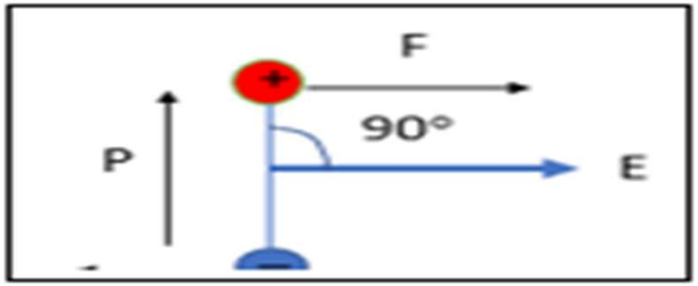
d) calculate the work required to move the dipole from 90° to 30°?

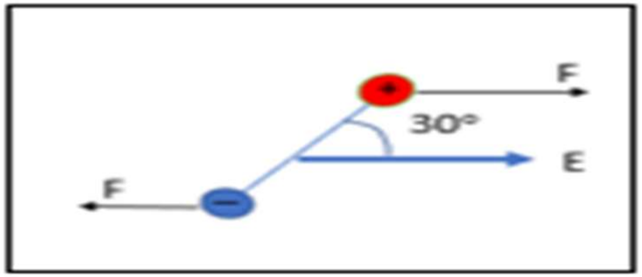
$W = P \times E(\cos\emptyset_2 - \cos\emptyset_1)$

$W = (8 \times 10^{-29}) \times (4 \times 10^{6})(\cos 30 - \cos 90)$

$W = 2.771 \times 10^{-22}$

This mean $W = -\Delta U$





e) what is the magnitude of the net torque at 90°?

$\tau = P \times E \sin\emptyset$

$\tau = (8 \times 10^{-29}) \times (4 \times 10^{6}) \sin 90$

$\tau = 3.2 \times 10^{-22}$N.m