ACTION AT A DISTANCE ANALYSIS

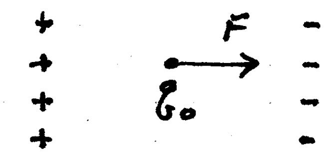
q_1 $\quad$ q_2 $\quad$ HOW DO THEY INTERACT?

ELECTRIC FIELDS

A CHARGE q SETS UP AN ELECTRIC FIELD IN THE SPACE SURROUNDING THE CHARGE. THE FIELD HAS BOTH MAGNITUDE & DIRECTION

$$\vec{E} = \frac{\vec{F}}{q_0} \quad [N/C]$$ q_0 IS A + TEST CHARGE

$+q_1$ $\quad$ $+q_0 \longrightarrow F = \dfrac{k q_1 q_0}{r^2}$

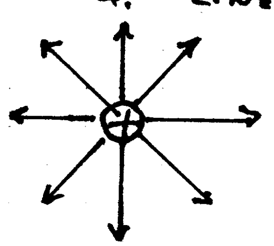


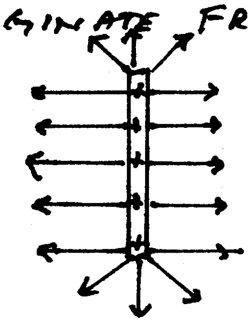
1. $\vec{E}$ exists independent of q_0

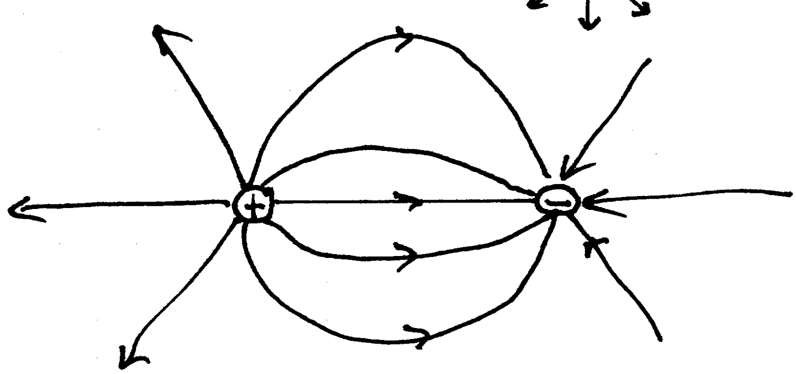
2. $\dfrac{\text{\# of E LINES}}{\text{UNIT AREA}}$ $\propto |\vec{E}|$
(⊥ TO THE LINES)

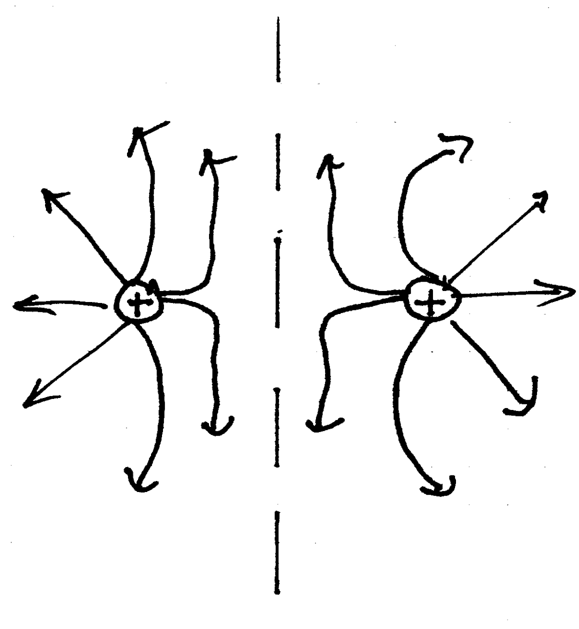
3. IF THE LINES ARE CLOSE TOGETHER $\vec{E}$ IS LARGE

4. LINES ORIGINATE FROM + CHARGE & END AT − CHARGE



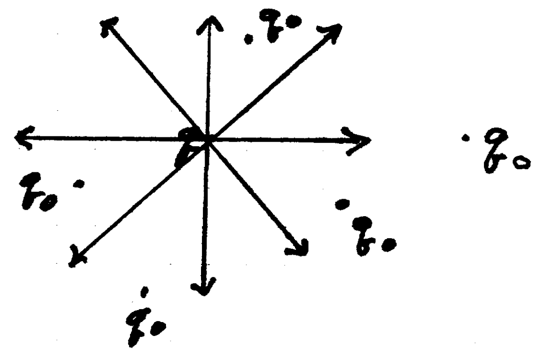






$\vec{E}$ DUE TO A POINT CHARGE

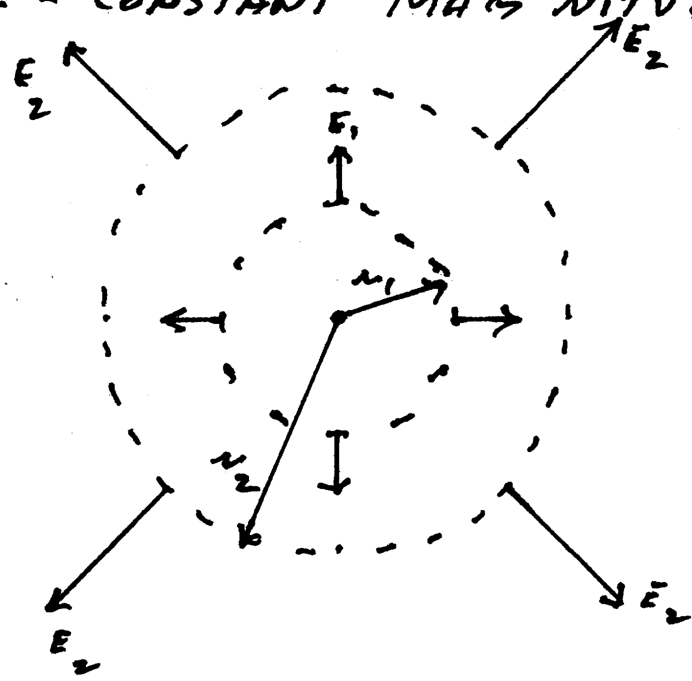
$$F = \frac{k\,q\,q_0}{r^2}$$



WE WANT TO FIND $\vec{E}$
AT ALL POINTS AROUND q
USING A SMALL TEST CHARGE q_0

$$E = \frac{F}{q_0} = \frac{k\,q}{r^2}$$

SO FOR A CONSTANT RADIUS ABOUT q WE
HAVE E = CONSTANT MAGNITUDE



$$\vec{E}_1 = \frac{k\,q}{r_1^2}$$

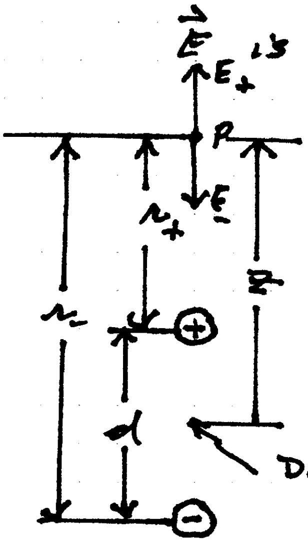
$$\vec{E}_2 = \frac{k\,q}{r_2^2}$$

THE DIRECTIONS WOULD BE REVERSED FOR $-q$

$\vec{E}$ DUE TO AN ELECTRIC DIPOLE

AN ELECTRIC DIPOLE IS A PAIR OF CHARGES OF MAGNITUDE q BUT OF OPPOSITE SIGN & SEPARATED BY A DISTANCE d

ELECTRIC DIPOLES HAVE MANY APPLICATIONS & THE $\vec{E}$ IS GIVEN AS SHOWN BELOW



$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

$$= k\frac{q}{r_+^2} - \frac{kq}{r_-^2}$$

AFTER MUCH ALGEBRA

$$\vec{E} = \frac{1}{2\pi\epsilon_0}\frac{qd}{z^3}$$ Along the z AXIS

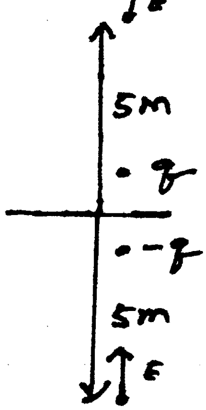
dipole moment $p = qd$

$$\vec{E} = \frac{1}{2\pi\epsilon_0}\frac{\vec{p}}{z^3}$$

p is FROM - Chg TOWARD THE + Chg

EXAMPLE I

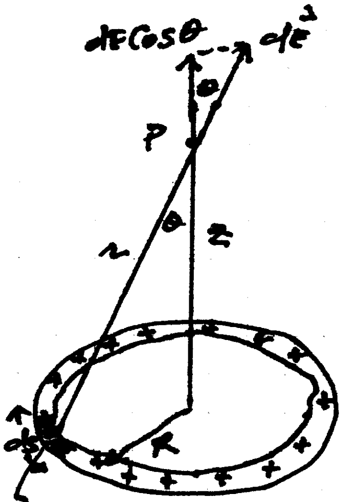
Find $\vec{E}$ AT $\pm 5m$ ON THE Dipole Axis if $q = 10^{-10}$ C & $d = 1$ mm



$$p = qd = 10^{-10}(10^{-3}m) = 10^{-13}$$

$$\vec{E} = \frac{1}{2\pi(8.85\times10^{-12})} \times \frac{10^{-13}}{5^3} = 1.4\times10^{-5}\ N/C$$

$\vec{E}$ DUE TO A LINE OF CHARGE (RING OF CHARGE)



CHARGE

$dq = \lambda\, ds$

$$\vec{E} = \frac{q\,z}{4\pi\epsilon_0 (z^2+R^2)^{3/2}}$$ $\vec{E}$ ALONG z AXIS

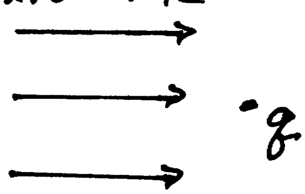
FOR LARGE $z \gg R$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{z^2}$$ $\vec{E}$ ALONG z AXIS

EXAMPLE II

POINT CHARGE IN A UNIFORM FIELD

$E = 2\times10^4\ N/C$



CALCULATE THE ACCELERATION OF THE ELECTRON

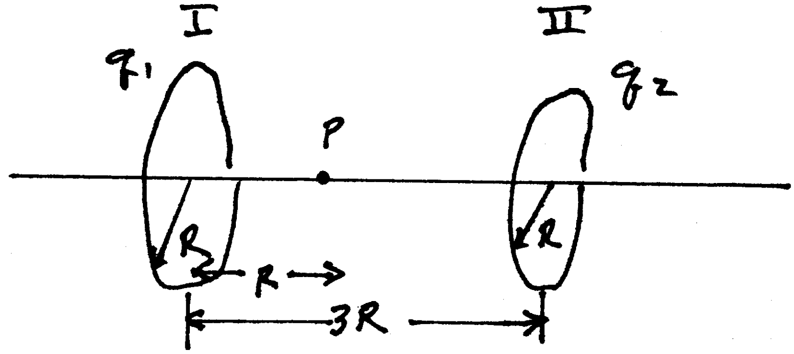
$\vec{E} = \frac{F}{q}$ $\quad F = \vec{E}q = 2\times10^4(1.6\times10^{-19})$

$= 3.2\times10^{-15}\,N$

$a = \frac{F}{m} = \frac{3.2\times10^{-15}\,N}{9.11\times10^{-31}\,kg} = 3.51\times10^{15}\,m/s^2$

EXAMPLE III

TWO ∥ NON CONDUCTING RINGS ARE ARRANGED AS SHOWN. RING 1 HAS A UNIFORM CHARGE q_1 & RADIUS R & RING 2 HAS q_2 & R. THE RINGS ARE SEPARATED BY A DISTANCE $3R$ & E_{NET} AT POINT P ON THE AXIS IS ZERO. DETERMINE THE RATIO q_1/q_2



FOR A RING OF CHARGE $E = \dfrac{qz}{2\pi\epsilon_0 (z^2+R^2)^{3/2}}$

FOR RING 1 WE REQUIRE E AT POINT P SO

$$E_1 = \frac{q_1 R}{2\pi\epsilon_0 (R^2+R^2)^{3/2}}$$

FOR RING 2 $\quad E_2 = \dfrac{-q_2 (2R)}{2\pi\epsilon_0 ((2R)^2 + R^2)^{3/2}}$

$$E_{NET} = 0 = \frac{q_1 \cancel{R}}{\cancel{2\pi\epsilon_0}(2R^2)^{3/2}} - \frac{2q_2 \cancel{R}}{\cancel{2\pi\epsilon_0}(5R^2)^{3/2}}$$

$$\frac{q_1}{\sqrt{8}\,\cancel{R^3}} = \frac{2q_2}{\sqrt{125}\,\cancel{R^3}}$$

$$\frac{q_1}{q_2} = \frac{2\sqrt{8}}{\sqrt{125}} = 0.505$$