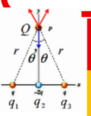
$$F = k\frac{q1q2}{r^2}$$

$$tan\theta = sin\theta$$

$$F = -\frac{3Qqa^2}{y^4}$$



If y>>a

$$\vec{F}_B = q\,\vec{v}\times\vec{B}$$
$$F_B = |q|vB\sin\theta$$

$$B = \frac{F_B}{|q|v}$$

$$qvB = \frac{mv^2}{r}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

$$qE = qvB$$

$$v = \frac{E}{B}$$

$$\vec{\mu} = i\vec{A}$$

$$\vec{F}_B = (q\vec{v}_d\times\vec{B})nAL$$

$$i = nqv_dA$$

For current carrying conduct-

$$\oint_C \vec{B}\bullet d\vec{l} = \mu_0 i_{encl}$$

$$J = i/\pi R^2$$

$$\vec{F}_B = i\vec{L}\times\vec{B}$$

$$B = \frac{\mu_0 ir}{2\pi R^2}$$ Inside wire

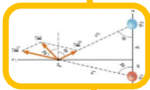
$$B = \frac{\mu_0 i}{2\pi r}$$ Outside wire

$$\bar{E} = \frac{\vec{F}}{q_0}$$

$$\vec{E} = k\frac{q}{r^2}\hat{r}$$

$$\Phi_E = \vec{E}\bullet\vec{A}$$

$$\Phi_E = \frac{q_{enclosed}}{\varepsilon_0}$$



$$E_1 = k\frac{|q_2|}{a^2+y^2}, E_2 = k\frac{|q_2|}{b^2+y^2}$$

Make components then add them to get the components for (E)

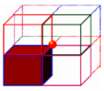
$$E_x = k\frac{2qa}{(a^2+y^2)^{3/2}}$$

If y>>a

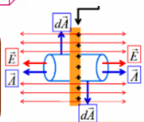
$$E = k\frac{2qa}{y^3}$$

$$\Phi_{face} = \frac{q}{6\varepsilon_o}$$

$$\Phi_{face} = \frac{q}{24\varepsilon_o}$$



$$E = \frac{\sigma}{2\varepsilon_o}$$

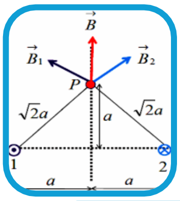


$$\vec{\tau} = iA\hat{n}\times\vec{B}$$
$$\tau(\theta) = iAB\sin\theta$$

$$\vec{\tau} = \vec{\mu}\times\vec{B}$$

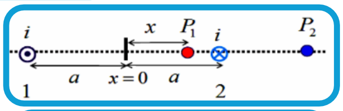
$$U = -\vec{\mu}\bullet\vec{B}$$

$$\tau = NiAB\sin\theta$$



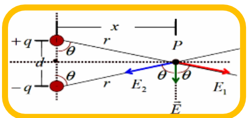
$$= \frac{\mu_o i}{2\pi a}\hat{j}$$

	Electric Dipole	Magnetic Dipole
Moment	$\vec{p} = q\vec{d}$	$\vec{\mu} = i\vec{A}$
Torque	$\vec{\tau} = \vec{p}\times\vec{E}$	$\vec{\tau} = \vec{\mu}\times\vec{B}$
Potential Energy	$U = -\vec{p}\cdot\vec{E}$	$U = -\vec{\mu}\cdot\vec{B}$



$$B_{p1} = \frac{\mu_o ia}{\pi(a^2-x^2)}\hat{j}$$

$$B_{p2} = -\frac{\mu_o ia}{\pi(x^2-a^2)}\hat{j}$$



$p = qd$ (electric dipole moment)

$$E_1 = E_2 = k\frac{q}{x^2+(d/2)^2}$$

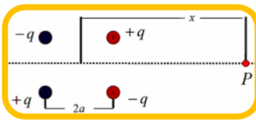
$$E = 2E_1 cos\theta$$

$$E = 2k\frac{q}{x^2+(d/2)^2}\frac{d}{2\sqrt{x^2+(d/2)^2}}$$

$$\bar{E} = -k\frac{p}{x^3}\hat{j}$$

If x>>a

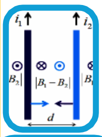
$$E = \frac{kp}{\left(x^2+(d/2)^2\right)^{3/2}}$$



$$\bar{E} = -k\frac{6(2qa^2)}{x^4}\hat{j}$$

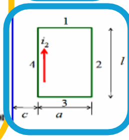
Typical Electric Field Calculations Using Gauss's Law

Charge Distribution	Electric Field	Location
Insulating sphere of radius R, uniform charge density, and total charge Q	$k_e\frac{Q}{r^2}$	$r > R$
	$k_e\frac{Q}{R^3}r$	$r < R$
Thin spherical shell of radius R and total charge Q	$k_e\frac{Q}{r^2}$	$r > R$
	0	$r < R$
Line charge of infinite length and charge per unit length λ	$2k_e\frac{\lambda}{r}$	Outside the line
Nonconducting, infinite charged plane having surface charge density σ	$\frac{\sigma}{2\epsilon_0}$	Everywhere outside the plane
Conductor having surface charge density σ	$\frac{\sigma}{\epsilon_0}$	Just outside the conductor
	0	Inside the conductor



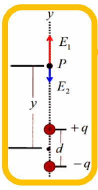
$$F_{21} = \frac{\mu_o i_1 i_2 L}{2\pi d}$$

$$\vec{F}_{21} = -\vec{F}_{12}$$



$$F_1 = \frac{\mu_o i_1 i_2}{2\pi}\ln\frac{c+a}{a}\hat{j}$$

$$\vec{F}_3 = -\frac{\mu_o i_1 i_2}{2\pi}\ln\frac{c+a}{a}\hat{j}$$



$$= \frac{kq}{y^2}\left[\left(1-\frac{d}{2y}\right)^{-2} - \left(1+\frac{d}{2y}\right)^{-2}\right]\hat{j}$$

If dipole moment along y axis and r>>d

If y>>d

$$\vec{E} = \frac{3kpyx}{(x^2+y^2)^{5/2}}\hat{i} + \frac{kp(2y^2-x^2)}{(x^2+y^2)^{5/2}}\hat{j}$$

$$\vec{F}_2 = \frac{\mu_o i_1 i_2 l}{2\pi(c+a)}\hat{i}$$

$$\vec{F}_4 = -\frac{\mu_o i_1 i_2 l}{2\pi c}\hat{i}$$

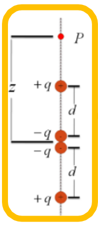
$$\vec{F} = \cancel{\vec{F}_1} + \vec{F}_2 + \cancel{\vec{F}_3} + \vec{F}_4$$

$$i_{encl} = nih$$

$$\bar{E} = \frac{2kp}{y^3}\hat{j}$$

$\vec{E} = -(kp/r^3)\hat{j}$ At perpendicular Bisector

$\vec{E} = (2kp/r^3)\hat{j}$ At axis of dipole

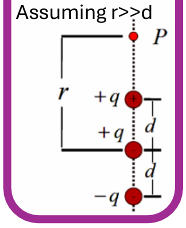


$$E = \frac{3(2qd^2)}{4\pi\varepsilon_0 z^4}$$

Line	Surface	Volume
$dq = \lambda\ dl$	$dq = \sigma da$	$dq = \rho dv$

$$V = \frac{kq}{r}\left(1+\frac{2d}{r}\right)$$

Assuming r>>d



$$E_s = -\frac{\Delta V}{\Delta s}$$

$$E_s = -\frac{dV}{ds}$$

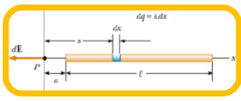
$$\oint\vec{B}\bullet d\vec{l} = Bh$$

$$n = N/l$$

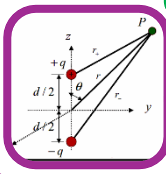
$$Bh = \mu_o nih \Rightarrow B = \mu_o ni$$

$$B = \frac{\mu_0 Ni}{2\pi r}$$

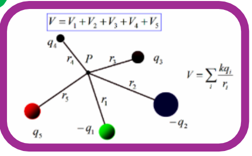
$$W = F_s\Delta s = q_o E_s\Delta s$$

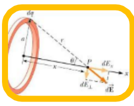


$$E = k_e\frac{Q}{a(l+a)}$$



$$V = \frac{kp\cos\theta}{r^2}$$





E_x $k_e\frac{Qx}{(a^2+x^2)^{3/2}}$

$$F = ma = qE$$

For dipoles

kq/r OUTSIDE

$$\frac{kqr^2}{2R^3}$$ INSIDE

$$E_{out} = \frac{kq}{r^2}$$

$$E_{in} = \frac{kq}{R^3}r$$

For Sphere with radius R

$$V = -\int_{ref}^{P}\vec{E}\bullet d\vec{s}$$

Reference point is infinity

$$= pE(\cos\theta - \cos\theta_o)$$

$$W = \int_{\theta_o}^{\theta}\vec{\tau}\bullet d\vec{\theta}$$

$$\tau = pE\sin\theta$$
$$\vec{\tau} = \vec{p}\times\vec{E}$$

$$U = -pE\cos\theta$$
$$U = -\vec{p}\bullet\vec{E}$$

$$w = -2pE\cos\theta_o$$

$$\Delta U = U_f - U_i = -W$$

$$W_{if} = q_0\int_i^f\vec{E}\bullet d\vec{s}$$

$$\Delta V = V_f - V_i \equiv \frac{U_f - U_i}{q_0} = -\frac{W_{if}}{q_0}$$
$$V_f - V_i = -\int_i^f\vec{E}\bullet d\vec{s}$$

$$V = \frac{kq}{r}$$