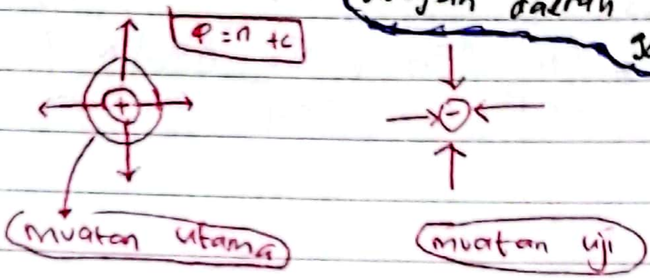
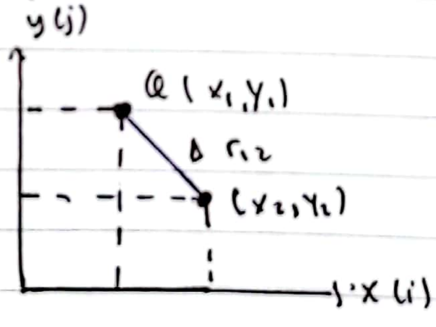
MEDAN LISTRIK ⇒ Daerah dimana sebuah muatan yang didekatkan dengan daerah tsb masih dipengaruhi oleh gaya listriknya.



Jika besarnya medan listrik dihasilkan muatan Q_1 pada posisi muatan Q_2 dinyatakan sebagai $\vec{E}_{2.1}$. Maka gaya yang dilakukan oleh muatan Q_1 pada muatan Q_2 memenuhi persamaan :

$$\boxed{\vec{F}_{21} = Q_2 \vec{E}_{21}}$$

Kuat medan listrik yang dihasilkan muatan Q_1 (muatan utama) pada posisi muatan Q_2 (muatan uji) memenuhi persamaan:



$$F_{Qq} = q \cdot E_Q$$

$$F_q = 0$$

$$F_{Qq} = \frac{1}{4\pi\varepsilon_0} \frac{Q \cdot q}{r^2_{Qq}} \hat{r}_{Qq}$$

$$E_q = \frac{1}{4\pi\varepsilon_0} \frac{Q_q}{r^2_{Qq}} \hat{r}_{Qq}$$

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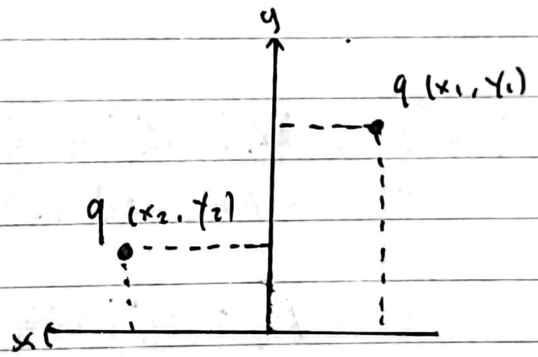
$$E_Q = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2_{Qq}}\hat{r}_{Qq}$$

$$\hat{r}_{Qq} = \frac{\Delta x\hat{i} + \Delta y\hat{j}}{\sqrt{\Delta x^2 + \Delta y^2}} = \overline{|\vec{r}_{Qq}|}$$

$$|\hat{r}_{Qq}| = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^3_{Qq}}\vec{r}_{Qq}$$



$$\vec{E}_{q_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2_{12}}\cdot\hat{r}_{1,2}$$

$$\vec{E}_{q_2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r^2_{21}}\cdot\hat{r}_{21}$$

- Medan listrik yang dihasilkan oleh Banyak Muatan
  ↳ (Besaran vektor)

Jika terdapat sejumlah muatan yang tersebar pada sistem koordinat, maka besar medan listrik total pada muatan q' (muatan uji) adalah ~~juga~~ jumlah vektor medan listrik yang dilakukan oleh sejumlah muatan banyaq.

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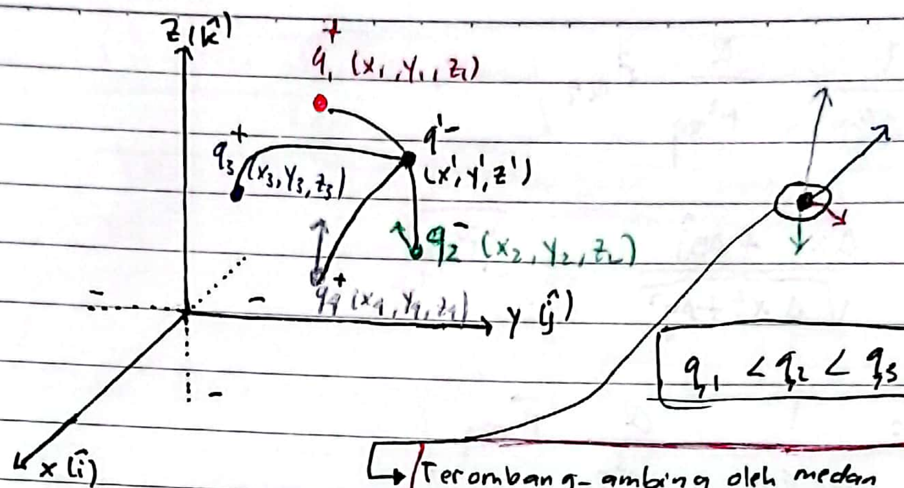

$q_1 < q_2 < q_3 < q_4$

Terombang-ambing oleh medan listrik yg berada pada q_1, q_2, q_3 dan q_4

$$E_{total} = E_{q'} = E_{q_1} + E_{q_2} + E_{q_3} + E_{q_4}$$

$$E_{q_1} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{r_1'^2} \hat{r}_1'$$

$$E_{q_2} = \frac{1}{4\pi\varepsilon_0} \frac{q_2}{r_2'^2} \hat{r}_2'$$

$$E_{q_3} = \frac{1}{4\pi\varepsilon_0} \frac{q_3}{r_3'^2} \hat{r}_3'$$

$$E_{q_4} = \frac{1}{4\pi\varepsilon_0} \frac{q_4}{r_4'^2} \hat{r}_4'$$

$$\hat{r}_1' = \frac{\vec{r}_1'}{|\vec{r}_1'|} = \frac{\Delta x_1' \hat{i} + \Delta y_1' \hat{j} + \Delta z_1' \hat{k}}{\sqrt{\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2}}$$

$$\vec{r}_1' = \Delta x_1' \hat{i} + \Delta y_1' \hat{j} + \Delta z_1' \hat{k}$$

$$\downarrow$$

$$(x' - x_1) \quad (y' - y_1) \quad (z' - z_1)$$

$$E_{q_1} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{r_1'^2} \hat{r}_1$$

$$E_{q_1} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{\left(\left[\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2\right]^2\right)^{1/2}} \cdot \frac{\Delta x_1' \hat{i} + \Delta y_1' \hat{j} + \Delta z_1' \hat{k}}{(\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)^{1/2}}$$

$$E_{q_1} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{(\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)(\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)^{1/2}} \cdot \Delta x_1' \hat{i} + \Delta y_1' \hat{j} + \Delta z_1' \hat{k}$$

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$$\cdot E_{q_1} = \frac{1}{4\pi\epsilon_0} \frac{q_1}{(\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)(\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)^{1/2}} \cdot \Delta x_1'\hat{j} + \Delta y_1'\hat{j} + \Delta z_1'\hat{k}$$

$$\cdot E_{q_2} = \frac{1}{4\pi\epsilon_0} \frac{q_2}{r_2'^2} \cdot \hat{r}_2'$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_2}{|(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)^2|^{1/2}} \cdot \frac{\Delta x_2'\hat{i} + \Delta y_1'\hat{j} + \Delta z_2'\hat{k}}{(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)^{1/2}}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_2}{(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z'^2)^{1/2}} \cdot \Delta x_2'\hat{i} + \Delta y_2'\hat{j} + \Delta z_2'\hat{k}$$

$$\cdot E_{q_3} = \frac{1}{4\pi\epsilon_0} \frac{q_3}{r_3'^2} \cdot \hat{r}_3'$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q_3}{|(\Delta x_3'^2 + \Delta y_3'^2 + \Delta z_3'^2)^2|^{1/2}} \cdot \frac{\Delta x_3'\hat{i} + \Delta y_3'\hat{j} + \Delta z_3'\hat{k}}{(\Delta x_3'^2 + \Delta y_3'^2 + \Delta z_3'^2)^{1/2}}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q_3}{(\Delta x_3'^2 + \Delta y_3'^2 + \Delta z_3'^2)(\Delta x_3'^2 + \Delta y_3'^2 + \Delta z_8'^2)^{1/2}} \cdot \Delta x_3'\hat{i} + \Delta y_3'\hat{j} + \Delta z_3'\hat{k}$$

$$\cdot E_{q_4} = \frac{1}{4\pi\epsilon_0} \frac{q_4}{r_4'^2} \cdot \hat{r}_4'$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_4}{|(\Delta x_4'^2 + \Delta y_4'^2 + \Delta z_4'^2)^2|^{1/2}} \cdot \frac{\Delta x_4'\hat{i} + \Delta y_4'\hat{j} + \Delta z_4'\hat{k}}{(\Delta x_4'^2 + \Delta y_4'^2 + \Delta z_4'^2)^{1/2}}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_3}{(\Delta x_4'^2 + \Delta y_4'^2 + \Delta z_4'^2)(\Delta x_4'^2 + \Delta y_4'^2 + \Delta z_4'^2)^{1/2}} \cdot \Delta x_4'\hat{i} + \Delta y_4'\hat{j} + \Delta z_4'\hat{z}$$

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$$E_{q'} = \left(\frac{1}{4\pi\epsilon_0}\frac{q_1}{(\Delta x_1'^2+\Delta y_1'^2+\Delta z_1'^2)(\Delta x_1'^2+\Delta y_1'^2+\Delta z_1'^2)^{1/2}}(\Delta x_1'\hat{i}+\Delta y_1'\hat{j}+\Delta z_1'\hat{k})\right)+$$

$$\left(\frac{1}{4\pi\epsilon_0}\frac{q_2}{(\Delta x_2'^2+\Delta y_2'^2+\Delta z_2'^2)(\Delta x_2'^2+\Delta y_2'^2+\Delta z_2'^2)^{1/2}}(\Delta x_2'\hat{i}+\Delta y_2'\hat{j}+\Delta z_2'\hat{k})\right)+$$

$$\left(\frac{1}{4\pi\epsilon_0}\frac{q_3}{(\Delta x_3'^2+\Delta y_3'^2+\Delta z_3'^2)(\Delta x_3'^2+\Delta y_3'^2+\Delta z_3'^2)^{1/2}}(\Delta x_3'\hat{i}+\Delta y_3'\hat{j}+\Delta z_3'\hat{k})\right)+$$

$$\left(\frac{1}{4\pi\epsilon_0}\frac{q_4}{(\Delta x_4'^2+\Delta y_4'^2+\Delta z_3'^2)(\Delta x_4'^2+\Delta y_4'^2+\Delta z_4'^2)^{1/2}}(\Delta x_4'\hat{i}+\Delta y_4'\hat{j}+\Delta z_4'\hat{k})\right)$$

$$E_{q'} = \frac{1}{4\pi\epsilon_0}\left(\left(\frac{q_1}{(\Delta x_1'^2+\Delta y_1'^2+\Delta z_1'^2)(\Delta x_1'^2+\Delta y_1'^2+\Delta z_1'^2)^{1/2}}(\Delta x_1'\hat{i}+\Delta y_1'\hat{j}+\Delta z_1'\hat{k})\right)+\right.$$

$$\left(\frac{q_2}{(\Delta x_2'^2+\Delta y_2'^2+\Delta z_2'^2)(\Delta x_2'^2+\Delta y_2'^2+\Delta z_2'^2)^{1/2}}(\Delta x_2'\hat{i}+\Delta y_2'\hat{j}+\Delta z_2'\hat{k})\right)+$$

$$\left(\frac{q_3}{(\Delta x_3'^2+\Delta y_3'^2+\Delta z_3'^2)(\Delta x_3'^2+\Delta y_3'^2+\Delta z_3'^2)^{1/2}}(\Delta x_3'\hat{i}+\Delta y_3'\hat{j}+\Delta z_3'\hat{k})\right)+$$

$$\left.\left(\frac{q_4}{(\Delta x_4'^2+\Delta y_4'^2+\Delta z_4'^2)(\Delta x_4'^2+\Delta y_4'^2+\Delta z_4'^2)^{1/2}}(\Delta x_4'\hat{i}+\Delta y_4'\hat{j}+\Delta z_4'\hat{k})\right)\right)$$

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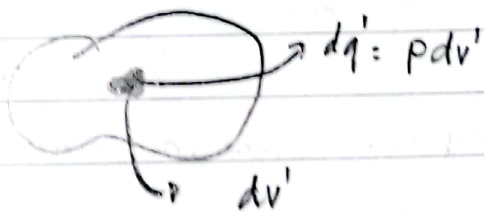
• Medan listrik yang dihasilkan Distribusi Muatan.

	Cartesian (x, y, z)	Cylindrical (ρ, φ, z)	Spherical (r, θ, ϕ)
dl (Panjang)	dx, dy, dz	$d\rho, \rho d\phi, dz$	$dr, r d\theta, r \sin\theta\, d\phi$
dA (luas)	$dx\,dy, dy\,dz, dz\,dx$	$d\rho\,dz, \rho d\phi\,dz, \rho d\phi\,d\rho$	$r\,dr\,d\theta, r\sin\theta\, dr\,d\phi$ $r^2 \sin\theta, d\theta\,d\phi$
dv (volume)	$dx\; dy\; dz$	$\rho d\; \rho d\phi\; dz$	$r^2 \sin\theta\, dr\, d\theta\, d\phi$

- Rapat Muatan
  ↳ kuantitas banyak muatan yang terdistribusikan garis bidang ruang (tertentu).

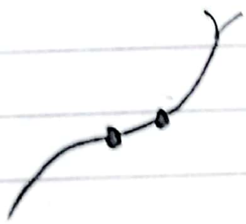
a.) Rapat Muatan Volume (dv)

$$\boxed{\rho = \frac{\partial q_1}{\partial v}}$$



b.) Rapat Muatan Panjang (ds') atau (dl') (λ lambang)

$$\boxed{\lambda = \frac{\partial q'}{\partial l'}} \quad \text{atau} \quad \boxed{\lambda = \frac{\partial q}{\partial s}}$$



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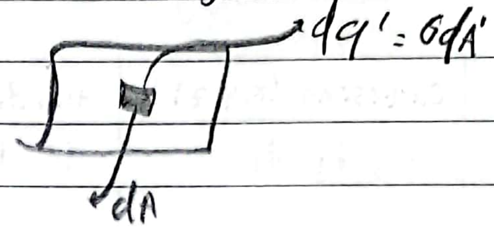
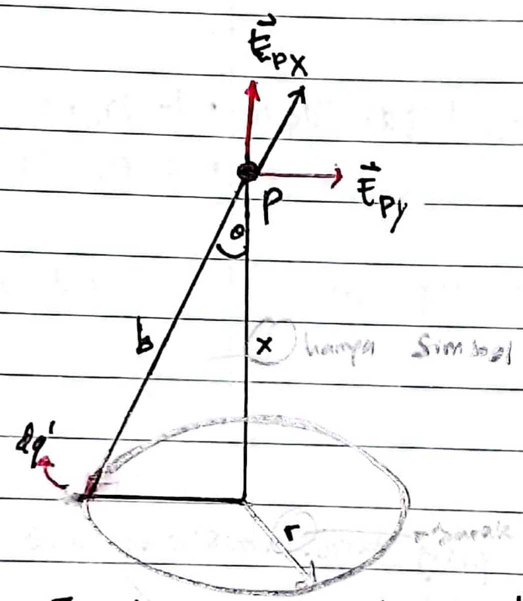
C.) Rapat Muatan luas (dA) (lambang σ)

$$\boxed{\sigma = \frac{\partial q}{\partial A}}$$





Gambar medan listrik di sumbu

Keliling cincin :

$$k = 2\pi r$$

kerapatan muatan cincin (muatan per panjang) :

$$\boxed{\lambda = \frac{q}{l}}$$ l = panjang lintasan

$$\boxed{\lambda = \frac{q}{k}}$$

$$\boxed{\lambda = \frac{q}{2\pi r}}$$

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- Kita bagi cincin atau bagian² kecil sejumlah N buah sebagai sampel. Panjang tiap bagian adalah

$$ds' = \frac{s}{N} \quad , \quad ds' = 2\pi dr$$

atau

$$L = 2\pi r \quad , \quad \partial L = 2\pi \partial r$$

$$\boxed{\begin{aligned} E_Q &= \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2} \\ E_{\partial p'} &= \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{b^2} \\ &= \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{(r^2+x^2)} \end{aligned}}$$

$$\sin\theta = \frac{r}{(r^2+x^2)}$$

$$\cos\theta = \frac{x}{(r^2+x^2)}$$

- $$E_{\partial p_y} = E_{\partial p_y} \sin\theta = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{(r^2+x^2)} \sin\theta$$

$$= \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{(r^2+x^2)} \cdot \frac{r}{(r^2+x^2)^{1/2}}$$

- $$E_{\partial p_x} = E_{\partial p_x} \cos\theta = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{(r^2+x^2} \cdot \cos\theta$$

$$= \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \cdot \partial l}{(r^2+x^2)} \cdot \frac{x}{(r^2+x^2)^{1/2}}$$

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$$\vec{E_P} = \vec{E_{Px}} = \frac{1}{4\pi\varepsilon_0}\int \frac{\lambda\, dl}{(r^2+x^2)} \cos\theta$$

$$\vec{E_P} = \frac{1}{4\pi\varepsilon_0}\int \frac{\lambda\, dl}{(r^2+x^2)} \cdot \frac{x}{(r^2+x^2)^{1/2}}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}} \int dl$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}} \int 2\pi\, dr$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}}\, 2\pi \int_0^r dr$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}}\, 2\pi (r)$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{(\lambda 2\pi r)\, x}{(r^2+x^2)^{3/2}}$$

$$\boxed{\vec{E_P} = \frac{1}{4\pi\varepsilon_0} \frac{q x}{(r^2+x^2)^{3/2}}}$$

$= \int \left(\frac{1}{x^2}\right) dx$

$= \int (x^{-2}) dx$

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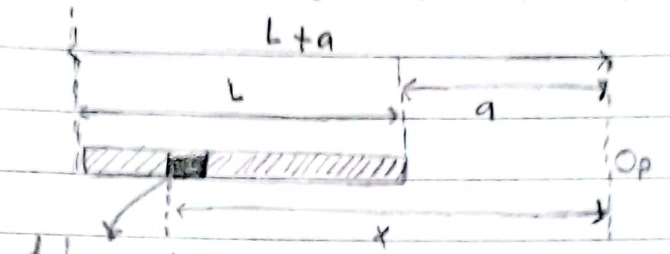
$= (-1\, x^{-1}) \Big|_a^{L+a}$

$= \left(-\frac{1}{x}\right]_a^{L+a}$

$dq' = \lambda dx$



$dq' = \lambda dl'$

• Medan listrik ŷ dihasilkan oleh batang

Medan yang dihasilkan elemen tersebut pada titik p adalah :

$$\vec{E}_p = k \int \frac{dq'}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda dl'}{x^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \int_a^{l+a} \frac{dx}{x^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \int_a^{l+a} \left(\frac{1}{x^2}\right) dx$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left[-\frac{1}{x}\right]_a^{l+a}$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left[\left\{-\frac{1}{l+a}\right\} - \left\{-\frac{1}{a}\right\}\right]$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left[\left\{\frac{1}{a}\right\} - \left\{\frac{1}{l+a}\right\}\right]$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left[\left\{\frac{l+a}{a(l+a)}\right\} - \left\{\frac{a}{a(l+a)}\right\}\right]$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left\{\frac{(l+a) - a}{a(l+a)}\right\}$$

$$= \frac{1}{4\pi\varepsilon_0} \lambda \left\{\frac{l}{a(l+a)}\right\}$$

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$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{\lambda l}{(al+a^2)}$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{q}{(al+a^2)}$$

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