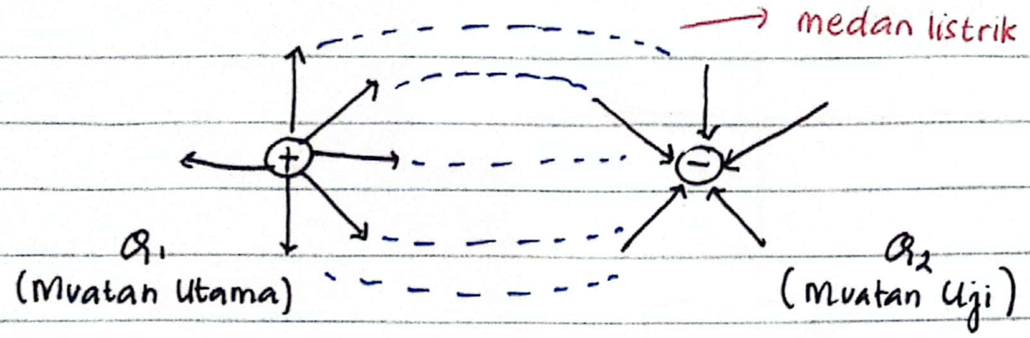
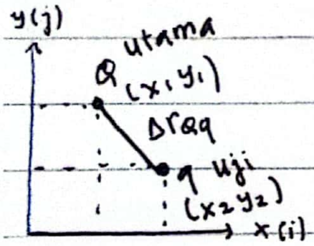
Medan Listrik

↳ Daerah yang masih dipengaruhi oleh gaya listrik / gaya colomb



* Muatan utama menghasilkan medan listrik pada muatan uji

Persamaan.



$$\vec{F}_{21} = Q_2 \vec{E}_{21} \quad \rightarrow \vec{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{Q_1}{r_{21}^2} \hat{r}_{21}$$

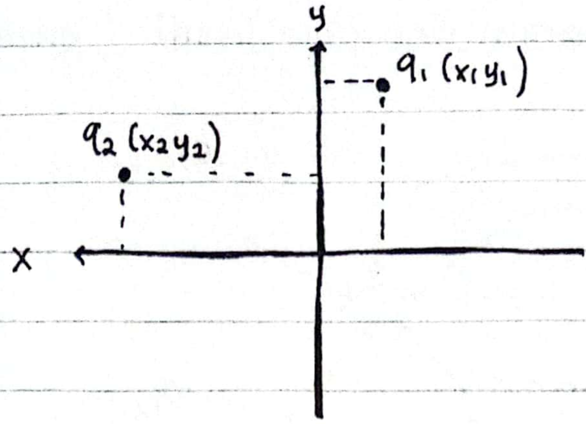
$$\vec{E}_{21} = Q_2 \frac{1}{4\pi\varepsilon_0} \frac{Q_1}{r_{21}^2} \hat{r}_{21}$$

$$\boxed{\vec{E}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{Q_1}{r_{21}^2} \hat{r}_{21}} \quad \rightarrow \hat{r}_{21} = \frac{\Delta x \hat{i} + \Delta y \hat{j}}{\sqrt{\Delta x^2 + \Delta y^2}} = \frac{\vec{r}_{21}}{|\vec{r}_{21}|}$$

$$|\vec{r}_{21}| = r_{12} = \sqrt{\Delta x^2 + \Delta y^2}$$

$$\boxed{\vec{E}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{Q_1}{r_{21}^3} \cdot \vec{r}_{21}}$$

Misalkan :



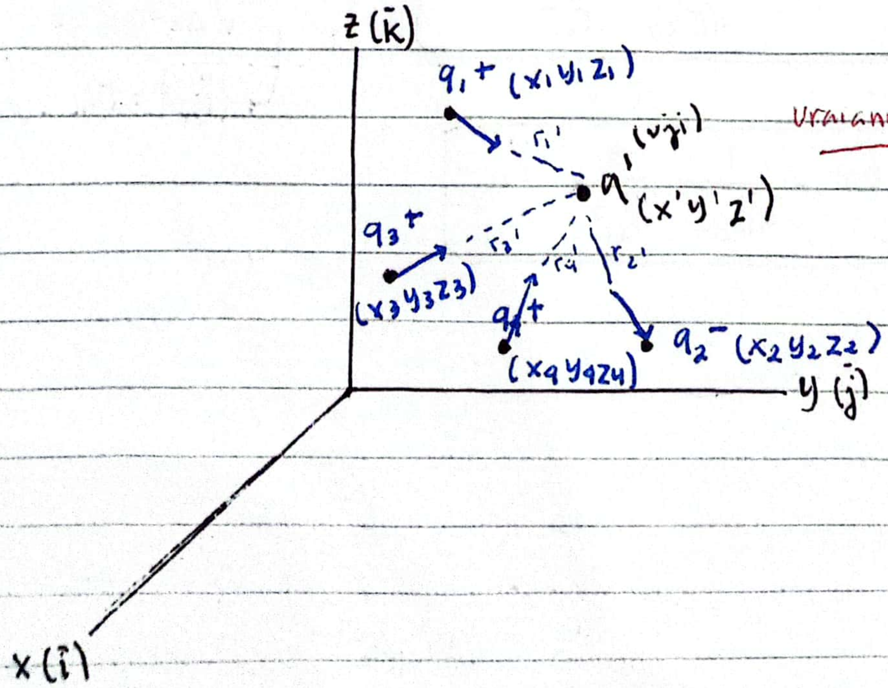
$$\boxed{\vec{E}_{q_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{12}^2}\hat{r}_{12}}$$

→ jika yg ditanya q_1, maka jadikan q_1 sebagai muatan utama

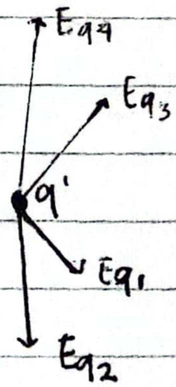
$$\boxed{\vec{E}_{q_2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{21}^2}\hat{r}_{21}}$$

→ jika yg ditanya q_2, maka jadikan q_2 sebagai muatan utama

Medan Listrik pada Banyak Muatan



Uraiannya →



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

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

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

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

$$r_1' = |\vec{r}_1'| = (\Delta x_1'^2 + \Delta y_1'^2 + \Delta z_1'^2)^{\frac{1}{2}}$$

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

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

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

Sehingga menjadi,

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

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

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

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

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_2}{\left((\Delta x_2'^2 + \Delta y_2'^2 + \Delta z'^2)^{\frac{1}{2}}\right)^2} \cdot \frac{\Delta x_2' \hat{i} + \Delta y_2' \hat{j} + \Delta z_2' \hat{k}}{(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)^{\frac{1}{2}}}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_2}{(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)(\Delta x_2'^2 + \Delta y_2'^2 + \Delta z_2'^2)^{\frac{1}{2}}}(\Delta x_2' \hat{i} + \Delta y_2' \hat{j} + \Delta z_2' \hat{k})$$

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$$* \; E_{q_3} = \frac{1}{4\pi\varepsilon_0} \frac{q_3}{r_{3'}^2} \hat{r}_{3'}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q_3}{\left((\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)^{\frac{1}{2}}\right)^2} \cdot \frac{\Delta x_{3'}\hat{i} + \Delta y_{3'}\hat{j} + \Delta z_{3'}\hat{k}}{(\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)^{1/2}}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q_3}{(\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)(\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)^{1/2}} \cdot \Delta x_{3'}\hat{i} + \Delta y_{3'}\hat{j} + \Delta z_{3'}\hat{k}$$

$$* \; E_{q_4} = \frac{1}{4\pi\varepsilon_0} \frac{q_4}{r_{4'}^2} \hat{r}_{4'}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q_4}{\left((\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)^{1/2}\right)^2} \cdot \frac{\Delta x_{4'}\hat{i} + \Delta y_{4'}\hat{j} + \Delta z_{4'}\hat{k}}{(\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)^{1/2}}$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{q_4}{(\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)(\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)^{1/2}} \cdot \Delta x_{4'}\hat{i} + \Delta y_{4'}\hat{j} + \Delta z_{4'}\hat{k}$$

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

$$E_{q'} = \left(\frac{1}{4\pi\varepsilon_0} \frac{q_1}{(\Delta x_{1'}^2 + \Delta y_{1'}^2 + \Delta z_{1'}^2)(\Delta x_{1'}^2 + \Delta y_{1'}^2 + \Delta z_{1'}^2)^{1/2}} (\Delta x_{1'}\hat{i} + \Delta y_{1'}\hat{j} + \Delta z_{1'}\hat{k})\right) + \left(\frac{1}{4\pi\varepsilon_0} \frac{q_2}{(\Delta x_{2'}^2 + \Delta y_{2'}^2 + \Delta z_{2'}^2)(\Delta x_{2'}^2 + \Delta y_{2'}^2 + \Delta z_{2'}^2)^{1/2}} (\Delta x_{2'}\hat{i} + \Delta y_{2'}\hat{j} + \Delta z_{2'}\hat{k})\right) + \left(\frac{1}{4\pi\varepsilon_0} \frac{q_3}{(\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)(\Delta x_{3'}^2 + \Delta y_{3'}^2 + \Delta z_{3'}^2)^{1/2}} (\Delta x_{3'}\hat{i} + \Delta y_{3'}\hat{j} + \Delta z_{3'}\hat{k})\right) + \left(\frac{1}{4\pi\varepsilon_0} \frac{q_4}{(\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)(\Delta x_{4'}^2 + \Delta y_{4'}^2 + \Delta z_{4'}^2)^{1/2}} (\Delta x_{4'}\hat{i} + \Delta y_{4'}\hat{j} + \Delta z_{4'}\hat{k})\right)$$

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

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

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

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

Medan Listrik yg dihasilkan Distribusi Muatan

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

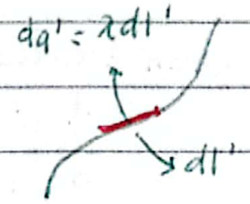
a. Rapat Muatan

↳ Kuantitas muatan yg didistribusikan pada bidang tertentu (space tertentu)

a) Rapat muatan panjang (ds') atau (dl')

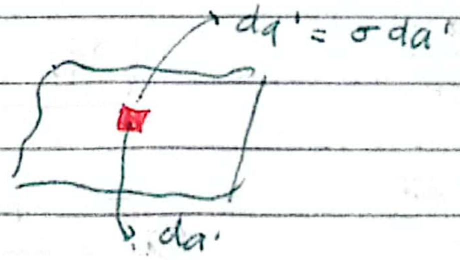
$$\lambda = \frac{dq'}{dl'}$$

$$\lambda = \frac{dq'}{ds'}$$



b) Rapat muatan luas (da')

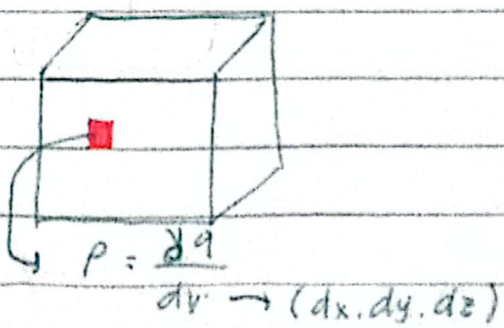
$$\sigma = \frac{dq'}{da'}$$



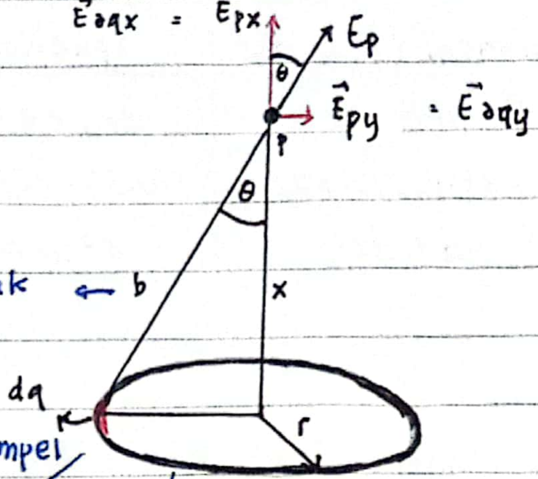
c) Rapat Muatan Volume $(d\tau')$ atau (dV')

$$\rho = \frac{dq'}{dv'}$$

$$\rho = \frac{dq'}{dv'}$$



Medan Listrik pada Muatan Cincin



$\sin\theta = \dfrac{r}{(r^2+x^2)^{1/2}}$

$\boxed{b = \sqrt{r^2+x^2}}$

jarak ← b

$\cos\theta = \dfrac{x}{(r^2+x^2)^{1/2}}$

Jika cincin diambil sampel

$\boxed{dl = 2\pi \partial r}$

↳ muatannya di sekitar cincin

$ds' = 2\pi \partial r$

Kerapatan muatan cincin (muatan per satuan panjang)

$$\lambda = \frac{q}{l} \rightarrow \lambda = \frac{q}{k}$$

$$\lambda = \frac{dq'}{2\pi r} \rightarrow \text{kel. lingkaran}$$

$$\lambda = \frac{q}{l} \qquad \boxed{\lambda = \frac{\partial q}{\partial l}}$$

$$\lambda = \frac{q}{2\pi r} \qquad \boxed{\partial q = \lambda \cdot \partial l}$$

$$q = \lambda\, 2\pi r$$

$$E_{\partial q} = \frac{1}{4\pi\varepsilon_0} \frac{\partial q}{b^2}$$

$$\boxed{E_{\partial q} = \frac{1}{4\pi\varepsilon_0} \frac{\lambda\, \partial l}{r^2+x^2}}$$

$$\vec{E}_{\partial qy} = E_{\partial q} \cdot \sin\theta = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda\, \partial l}{(r^2 + x^2)} \sin\theta$$

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

$$\vec{E}_{\partial qx} : E_{\partial q} \cos\theta = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda\, \partial l}{(r^2 + x^2)} \cos\theta$$

$$\vec{E}_{px} = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda\, \partial l}{(r^2+x^2)} \frac{x}{(r^2+x^2)^{1/2}}$$

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

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

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}} 2\pi \int_0^r \partial r$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{\lambda x}{(r^2+x^2)^{3/2}} 2\pi \left(r\right]_0^r$$

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

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

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{qx}{(r^2+x^2)^{3/2}}$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{qx}{\left((r^2+x^2)^{1/2}\right)^3}$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{qx}{b^3}$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} q \frac{1}{b^2} \frac{x}{b}$$

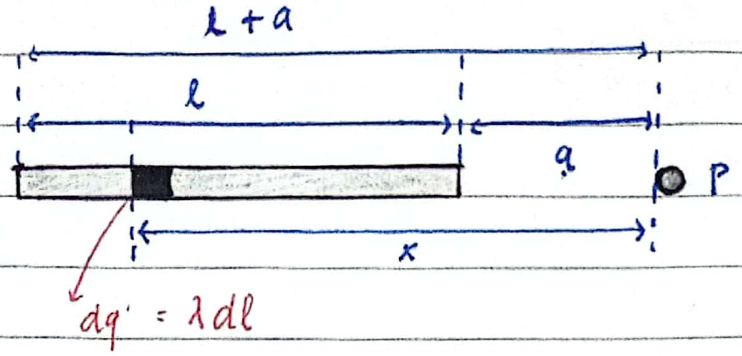
$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} q \frac{1}{b^2} \frac{x}{b} \frac{r^2}{r^2}$$

$$\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \frac{r^2}{b^2} \frac{x}{b}$$ $\rightarrow$ $\sin\theta = \frac{r}{b}$; $\cos\theta = \frac{x}{b}$.

$\sin^2\theta = \frac{r^2}{b^2}$

$$\boxed{\vec{E}_p = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \sin^2\theta \cos\theta}$$

Medan Listrik oleh Muatan Batang



$$\vec{E_p} = k \int \frac{\partial q}{r^2}$$

$$\vec{E_p} = \frac{1}{4\pi\varepsilon_0} \int \frac{\lambda \partial l}{x^2}$$

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

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

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

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

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

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

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

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

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