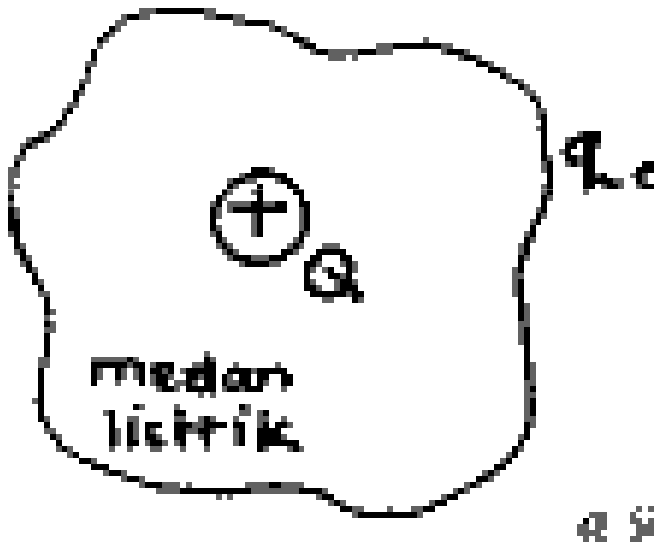
Medan Listrik

Minggu ke-2

MEDAN LISTRIK

Bagaimana mengetahui adanya medan listrik???

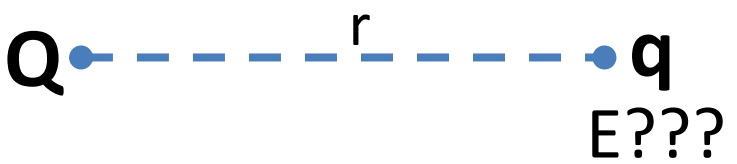


- Medan listrik, dicek dengan muatan uji qo. Bila qo mengalami gaya berarti ada medan listrik
- Muatan uji tidak boleh merubah distribusi muatan penyebab medan (sangat kecil)

Muatan ⇄ **Medan** ⇄ **Muatan**

Apa itu medan listrik?

Medan listrik : Besarnya gaya listrik yang bekerja pada tiap 1 satuan muatan listrik di titik tersebut



$$F = \frac{1}{4\pi\varepsilon_o}\frac{Qq}{r^2}$$

$$E = \frac{F}{q}$$

F = E = Vektor

q = skalar

$q >> \rightarrow F >>$

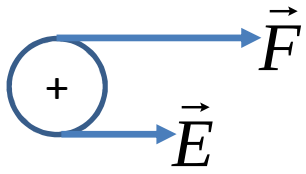
$q << \rightarrow F <<$

$$E = \frac{\frac{1}{4\pi\varepsilon_o}\frac{Qq}{r^2}}{q} = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$$

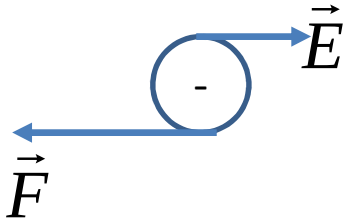
$$E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$$

Medan listrik yang ditimbulkan oleh Q pada titik sejauh r pada muatan uji q

Arah medan listrik



F dan E Searah

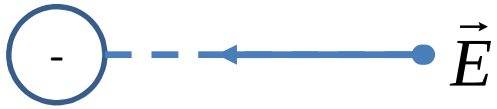


F dan E berlawanan

Bagaimana Kita tahu tentang Medan Listrik??

Medan listrik dapat kita lihat
dari : Sumber & pengaruhnya

Medan listrik yang ditimbulkan
Oleh muatan positif

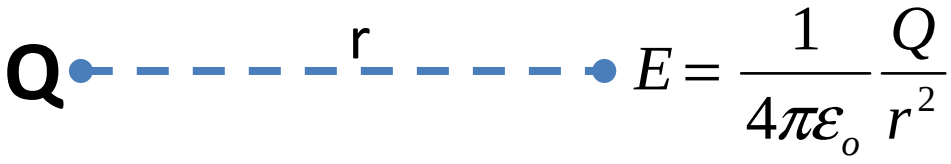


Medan listrik yang ditimbulkan
Oleh muatan negatif

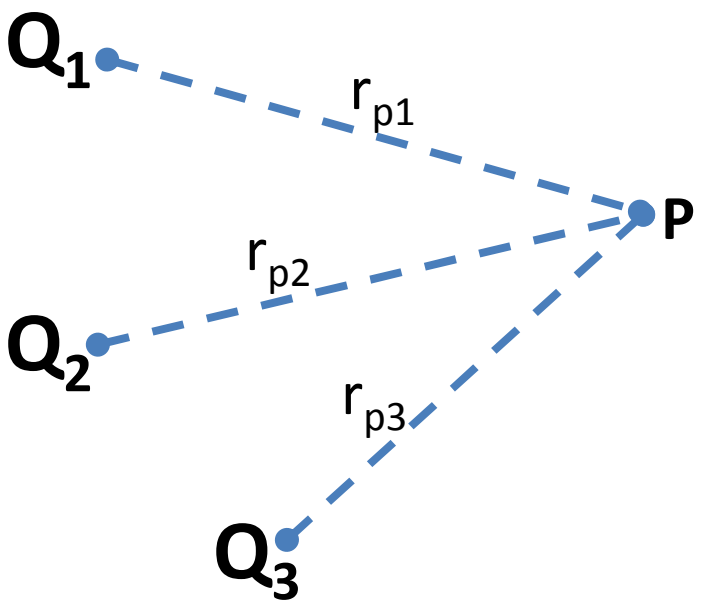
Medan listrik

- Muatan titik
- Banyak muatan titik (sistem muatan diskrit)
- Muatan listrik (dipol)
- Muatan kontinyu
  - Konduktor
  - Isolator
- Cincin muatan

Medan Listrik oleh Muatan Titik



Medan Listrik oleh Banyak Muatan Titik



$$E_{p1} = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{r_{p1}^{\,2}}\vec{r}_{p1}$$

$$E_{p2} = \frac{1}{4\pi\varepsilon_o}\frac{Q_2}{r_{p2}^{\,2}}\vec{r}_{p2}$$

$$E_{p3} = \frac{1}{4\pi\varepsilon_o}\frac{Q_3}{r_{p3}^{\,2}}\vec{r}_{p3}$$

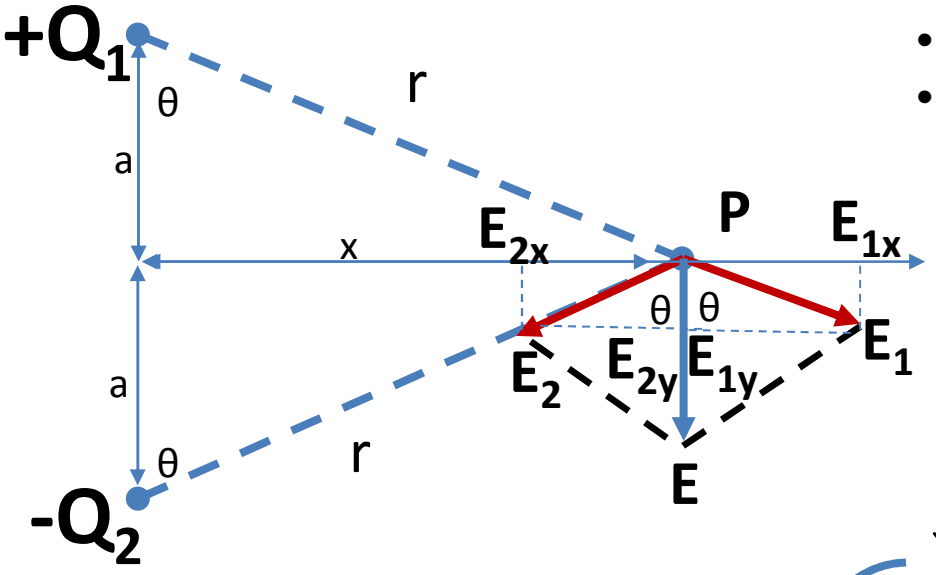
$$E_p = E_{p_1} + E_{p_2} + E_{p_3}$$

$$E_p = \frac{1}{4\pi\varepsilon_o}\left(\frac{Q_1}{r_{p1}^{\,2}}\vec{r}_{p1} + \frac{Q_2}{r_{p2}^{\,2}}\vec{r}_{p2} + \frac{Q_3}{r_{p3}^{\,2}}\vec{r}_{p3} + \ldots\right)$$

Medan Listrik oleh Dipol Listrik

Dipol listrik = Dua muatan listrik

- Tidak berjarak 0
- muatan besarnya sama
- Arahnya berlawanan
- Masing-masing muatan ≠ 0



$$\sum E_X = 0$$

$$E_{2x} = -E_{1x} \longrightarrow E_x = 0$$

$$\sum E_y = E_{1y} + E_{2y}$$

$$E_{1y} = E_{2y}$$

$$\sum E_y = 2E_{1y} = 2E_{2y}$$

$$E_{p2} = \frac{1}{4\pi\varepsilon_o}\frac{Q_2}{r_{p2}^{\,2}}\vec{r}_{p2}$$

Medan Listrik oleh Dipol Listrik

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{r_1^{\,2}}$$

Besarnya : $E_1 = \frac{1}{4\pi\varepsilon_o}\frac{Q_1}{a^2 + x^2}$

Arah Lihat gambar!!!

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_o}\frac{Q_2}{r_2^{\,2}}$$

Besarnya : $E_2 = \frac{1}{4\pi\varepsilon_o}\frac{Q_2}{a^2 + x^2}$

Arah Lihat gambar!!!

Sekarang kita hitung besar E di P : $E = 2E_y$

$$E = 2E_y$$

$$E = 2\frac{1}{4\pi\varepsilon_o}\frac{Q}{\left(a^2+x^2\right)}\cos\theta$$

$$E = 2\frac{1}{4\pi\varepsilon_o}\frac{Q}{\left(a^2+x^2\right)}\frac{a}{\left(a^2+x^2\right)^{1/2}}$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{2aQ}{\left(a^2+x^2\right)^{3/2}}$$

Momen dipol (P)

$$E = \frac{1}{4\pi\varepsilon_o}\frac{P}{\left(a^2+x^2\right)^{3/2}}$$

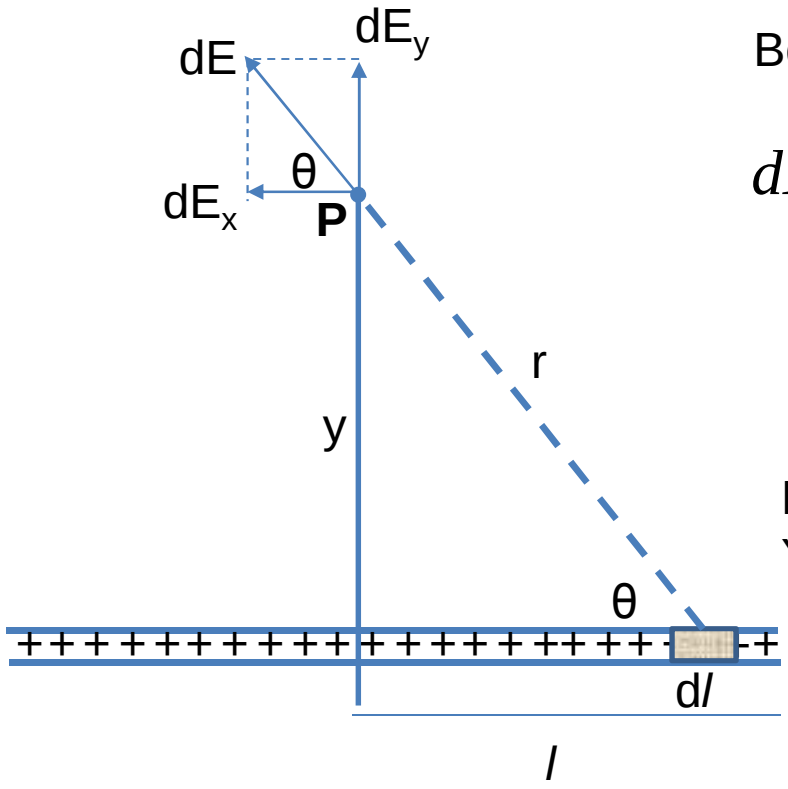
atau

$$E = \frac{1}{4\pi\varepsilon_o}\frac{P}{r^3}$$

Medan listrik oleh dipol listrik

Medan Listrik Muatan Garis Linier

- Muatan listrik yang terdistribusi dalam 1 dimensi



Berapa besarnya dE…???

$$dE = \frac{1}{4\pi\varepsilon_o}\frac{dQ}{r^2}$$

Banyaknya kontribusi medan dE
Yang berasal dari elemen muatan dq

dq =λ d*l*

λ = Rapat muatan = Jumlah muatan
pada satu satuan panjang

$$\lambda = \frac{dQ}{dl} = c/m$$

Berlawanan arah

$$dE = \frac{1}{4\pi\varepsilon_o}\frac{dQ}{r^2} \longrightarrow dE_x = dE\cos\theta \longrightarrow \int dE_x = 0$$

$$dE = \frac{1}{4\pi\varepsilon_o}\frac{\lambda dl}{r^2} \longrightarrow dE_y = dE\sin\theta \longrightarrow \int dE_y = E$$

$$E = \int \frac{1}{4\pi\varepsilon_o}\frac{\lambda dl}{r^2}\sin\theta \qquad \text{.....(1)}$$

$$\frac{y}{r} = \sin\theta \longrightarrow r = \frac{y}{\sin\theta} \longrightarrow r^2 = \frac{y^2}{\sin^2\theta} \qquad \text{.....(2)}$$

$$\frac{y}{l} = \frac{\sin\theta}{\cos\theta} \longrightarrow l = y\frac{\cos\theta}{\sin\theta} \longrightarrow \frac{dl}{d\theta} = y\frac{\left(-\sin^2\theta - \cos^2\theta\right)}{\sin^2\theta}$$

$$dl = \frac{-y}{\sin^2\theta}d\theta \qquad \text{.....(3)}$$

Persamaan (1), (2) & (3) menghasilkan:

$$E = \int \frac{1}{4\pi\varepsilon_o} \frac{\lambda\left(\frac{-y}{\sin^2\theta} d\theta\right)}{\frac{y^2}{\sin^2\theta}} \sin\theta$$

$$E = \int \frac{1}{4\pi\varepsilon_o} \frac{\lambda}{y} \sin\theta \, d\theta$$

$$E = -\frac{1}{4\pi\varepsilon_o} \frac{\lambda}{y} \int \sin\theta \, d\theta$$

$$E = \frac{\lambda}{4\pi\varepsilon_o y} \cos\theta$$

$$E = \frac{\lambda}{4\pi\varepsilon_o y} \frac{l}{r}$$

Jika *l* tidak tak berhingga :

$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\int_{\theta 1}^{\theta 2}\sin\theta\, d\theta$$

$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\left(-\cos\theta\right)\int_{\theta 1}^{\theta 2}$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\left(\cos\theta_2 - \cos\theta_1\right)$$

Jika *l* tak berhingga :

$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\int_{\theta 1=0}^{\theta 2=180}\sin\theta\, d\theta$$

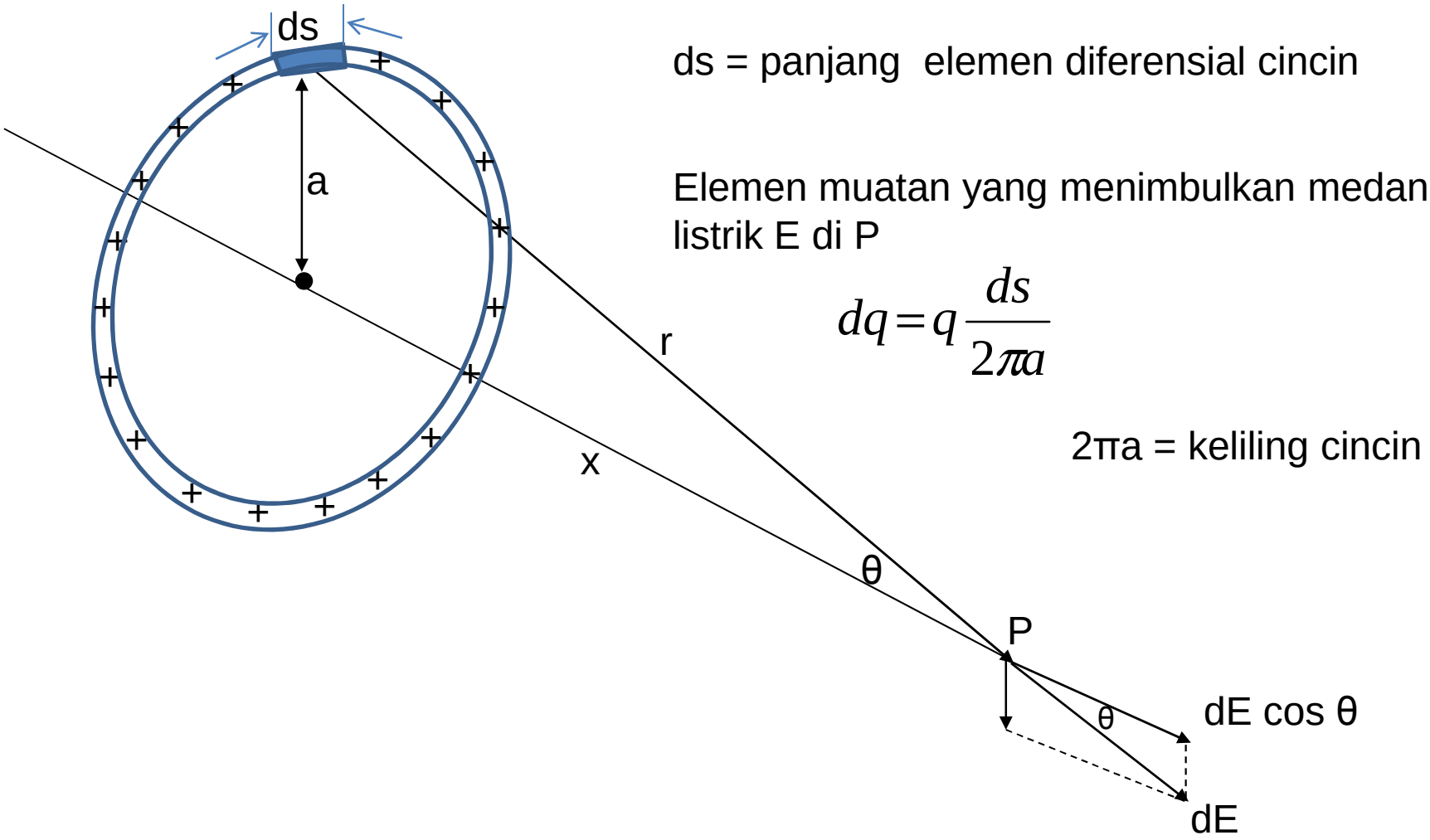
$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\left(-\cos\theta\right)\int_{\theta 1}^{\theta 2}$$

$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\left(\cos 180 - \cos 0\right)$$

$$E = -\frac{1}{4\pi\varepsilon_o}\frac{\lambda}{y}\left(-2\right)$$

$$E = \frac{\lambda}{2\pi\varepsilon_o y}$$

Medan Listrik Cincin Muatan



ds = panjang elemen diferensial cincin

Elemen muatan yang menimbulkan medan listrik E di P

$$dq = q\frac{ds}{2\pi a}$$

2πa = keliling cincin

Hanya komponen dE yang sejajar dengan sumbu cincin yang memberi kontribusi, komponen tegaklurus sumbu dihilangkan oleh komponen yang sama besar tetapi berlawanan arahnya yang, dihasilkan elemen Muatan pada sisi yang berlawanan dari cincin

$$\vec{E} = \int d\vec{E}$$ besarnya $$E = \int dE \cos\theta$$

$$dE = \frac{1}{4\pi\varepsilon_o}\frac{dq}{r^2}$$

Lihat gambar!!!

$$\cos\theta = \frac{x}{\left(a^2 + x^2\right)^{1/2}}$$

$$E = \frac{1}{4\pi\varepsilon_o}\left(\frac{qds}{2\pi a}\right)\frac{1}{a^2 + x^2}\frac{x}{\left(a^2 + x^2\right)^{1/2}}$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{qx}{(2\pi a)\left(a^2 + x^2\right)^{3/2}}\int ds$$

$$E = \frac{1}{4\pi\varepsilon_o}\frac{qx}{(2\pi a)\left(a^2 + x^2\right)^{3/2}}2\pi a \longrightarrow E = \frac{1}{4\pi\varepsilon_o}\frac{qx}{\left(a^2 + x^2\right)^{3/2}}$$

Jika x>>a $$\longrightarrow E = \frac{1}{4\pi\varepsilon_o}\frac{q}{x^2}$$