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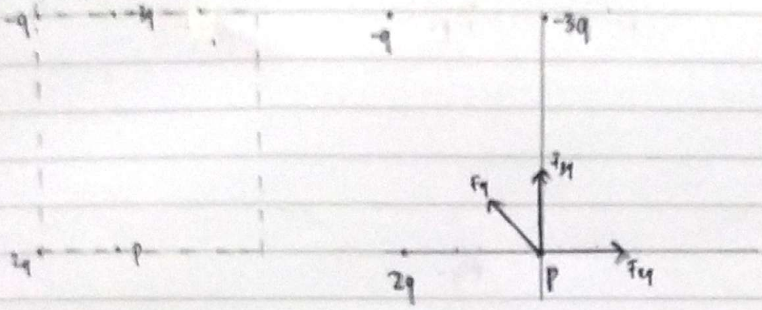
a) Gambar gaya-gaya pada titik P



b) Hitung besar gaya

$$F_p = kP \left(\frac{-3q}{3^2}(\hat{j}) + \frac{2q}{2^2}(\hat{i}) - \frac{-q}{(3,3)^2}\left(\frac{-3i+2j}{3,3}\right)\right)$$

$$F_p = kP \left(\hat{i}\left(\frac{2q}{2^2} - \frac{-q}{(3,3)^2}\left(\frac{-3}{3,3}\right)\right) + (\hat{j})\frac{-3q}{3^2} - \frac{-q}{(3,3)^2}\left(\frac{2}{3,3}\right)\right)$$

c) Hitung medan listrik pada titik tersebut

$$E_p = k\left(\frac{-3q}{3^2}(\hat{j}) + \frac{2q}{2^2}(\hat{i}) - \frac{-q}{(3,3)^2}\left(\frac{-3i+2j}{3,3}\right)\right)$$

$$= k\left((\hat{i}) \frac{-2q}{2^2} - \frac{-q}{(3,3)^2}\left(\frac{-3}{3,3}\right)\right) + \hat{j}\left(\frac{-3q}{3^2}\right) - \frac{-q}{(3,3)^2}\left(\frac{2}{3,3}\right)\Big)$$

d) Hitung besar medan listrik pada titik tsb.

$$E_p = k\left(\frac{-3q}{3^2}(\hat{j}) + \frac{2q}{2^2}(\hat{i}) - \frac{-q}{(3,3)^2}\left(\frac{-3i+2j}{3,3}\right)\right)$$

$$= k\left((\hat{i})\left(\frac{-2q}{2^2}\right) - \left(\frac{-q}{3,3^2}\left(\frac{-3}{3,3}\right)\right) + \hat{j}\left(\frac{-3q}{3^2}\right) - \frac{-q}{3,3^2}\left(\frac{2}{3,3}\right)\right)$$

e) Potensial titik tsb.

$$V_p = k\left(\frac{-3q}{3} + \frac{2q}{2} - \frac{-q}{(3,3)}\right)$$

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2) Dik: Panjang batang = L
rapat muatan linier = λ
Titik P berjarak z dari : a) ujung kawat , b) tengah-tengah kawat
Dit : a) kuat medan listrik di titik P yang berjarak z diatas ujung kawat
b) kuat medan listrik di titik P yang berjarak z diatas tengah-tengah kawat.

Penyelesaian :

$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{dq}{r^2}$$

2a) koordinat dengan kawat dari $x=0$, $x=L$, dan titik P, berada diatas titik $x=0$, sejauh z

$r = \sqrt{x^2+z^2}$

$$dE = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\lambda\, dx}{x^2+z^2} \cdot \frac{z}{\sqrt{x^2+z^2}}$$

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

Integrasi dari $x=0$, hingga $x=L$

$$E = \frac{\lambda z}{4\pi\varepsilon_0} \int_0^L \frac{dx}{(x^2+z^2)^{3/2}}$$

$$E = \frac{\lambda z}{4\pi\varepsilon_0} \left[\frac{x}{z^2\sqrt{x^2+z^2}} \right]_0^L$$

$$E = \frac{\lambda z}{4\pi\varepsilon_0} \cdot \frac{L}{z\sqrt{L^2+z^2}}$$

2b) kawat dari $x = -\frac{L}{2}$ hingga $x = \frac{L}{2}$, titik P diatas titik tengahnya.

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

Integrasi dari $-L/2$ sampai $L/2$

$$E = \frac{\lambda z}{4\pi\varepsilon_0} \int_{-L/2}^{L/2} \frac{dx}{(x^2+z^2)^{3/2}}$$

$$E = \frac{\lambda z}{4\pi\varepsilon_0} \int_0^{L/2} \frac{dx}{(x^2+z^2)^{3/2}}$$

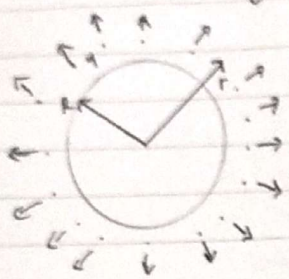
$$\int_0^{L/2} \frac{dx}{(x^2+z^2)^{3/2}} = \left[\frac{x}{z^2\sqrt{x^2+z^2}} \right]_0^{L/2} = \frac{L}{2z^2\sqrt{(\frac{L}{2})^2+z^2}}$$

$$E = \frac{\lambda}{4\pi\varepsilon_0} \cdot \frac{L}{2z\sqrt{(\frac{L}{2})^2+z^2}}$$

$$E = \frac{\lambda L}{4\pi\varepsilon_0 z\sqrt{(L^2/4)+z^2}}$$

3) Hitung medan listrik dengan rapat muatan r dengan jari-jari R

- Besar medan listrik di luar bola (r > R)



$F = k \frac{q_1 q_2}{r^2}$

$E = F/q$

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

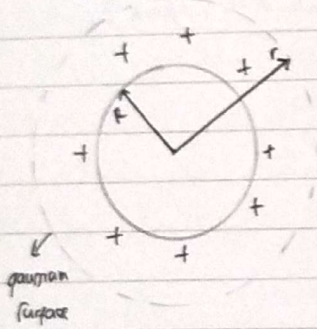
$k = \frac{1}{4\pi\varepsilon_0}$

$\sigma = \frac{Q}{4\pi R^2}$

$Q = \sigma 4\pi R^2$, $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2} \Rightarrow E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{4\pi R^2 \sigma}{r^2} \Rightarrow E = \frac{\sigma R^2}{\varepsilon_0 r^2}$

- R = jari-jari bola
- r = jari-jari permukaan gauss
- $\varepsilon_0 = 8,85 \times 10^{-12}\ C^2/Nm^2$
- Q = total muatan listrik.

- Besar medan listrik dipermukaan bola (r = R)

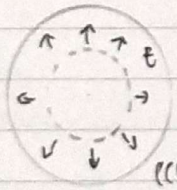


$E = \frac{\sigma}{\varepsilon_0}$

σ = rapat permukaan

$\varepsilon_0 = 8,85 \times 10^{-12}\ C^2/Nm^2$

- Besar medan listrik di dalam bola (r < R)



$E = 0$, karna muatan hanya berada di permukaan

(Muatan permukaan konduktor)

4) Dik: $\vec{E} = kr^3 \hat{r}$, ket: k = konstanta, $\hat{r}$ = faktor satuan radial dalam koordinat bola.
Dit: a. Rapat muatan (ρ)
b. Muatan total dalam bola bergari-jari (R)

4a) Rapat muatan (ρ)

Hukum gauss dalam bentuk differensial (divergensi medan listrik), medan listrik bersifat radial (hanya bergantung pada r)

$$\nabla . \vec{E} = \frac{\rho}{\varepsilon_0}$$

(Substitusikan: $\rho = \varepsilon_0 (\nabla . \vec{E})$
$\rho(r) = 5k\varepsilon_0 r^2$)

$$\nabla . \vec{E} = \frac{1}{r^2} \frac{d}{dr} (r^2 E(r))$$

$$\nabla . \vec{E} = \frac{1}{r^2} \frac{d}{dr} (kr^5)$$

$$\nabla . \vec{E} = \frac{1}{r^2} 5kr^4 \Rightarrow \nabla . \vec{E} = 5kr^2$$

4b) Hitung Muatan total dalam bola jari-jari (R)

Integralkan rapat muatan terhadap Lauma bola:

$$Q = \int_v \rho(r)\, dv, \quad dv = r^2 \sin\theta \, dr \, d\theta \, d\phi$$

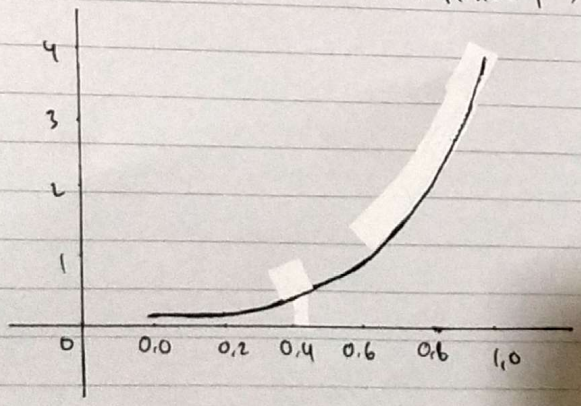
$$Q = \int_0^{2\pi} \int_0^{\pi} \int_0^{R} 5k\varepsilon_0 r^2 . r^2 \sin\theta \, dr \, d\theta \, d\phi$$

$$Q = 5k\varepsilon_0 \int_0^{2\pi} d\phi \int_0^{\pi} \sin\theta \, d\theta \int_0^{R} r^4 \, dr$$

$$Q = 5k\varepsilon_0 . 2\pi . 2 . \frac{R^5}{5}$$

$$Q = 4\pi \varepsilon_0 k R^2$$

Grafik rapat muatan $\rho(r)$ terhadap jarak r



5) Dik: · titik P berjarak z dr atas pusat persegi
· Panjang sisi kawat = 5
· Rapat muatan linear = λ
· konstanta Coulomb ke = $\frac{1}{4\pi\varepsilon_0}$

Dit. Medan listrik di titik P

Jawab: $E_z = \frac{2k\lambda x \sin\theta}{z}$

$E = 4 \cdot \frac{2k\lambda \sin\theta}{z}$

$E = \frac{8k\lambda \sin\theta}{z}$; $\theta = \tan^{-1}\left(\frac{\frac{5}{2}}{z}\right)$; $\sin(\tan^{-1}(x)) = \frac{x}{\sqrt{1+x^2}}$

$E = \frac{8k\lambda}{z} \cdot \frac{5}{2z\sqrt{1+5^2/(2z)^2}} = \frac{4k\lambda 5}{z^2\sqrt{1+5^2/4z^2}}$