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Tugas II
Medan Elektro

① Jawab :

Diketahui :

$q_1 = 2 \times 10^{-6}$ (positif)

$q_2 = 3 \times 10^{-6}$ (positif)

$q_3 = -5 \times 10^{-6}$ (positif)

- $r_{12} = 3\ m$
- $r_{23} = 2\ m$
- $k = 9 \times 10^9\ Nm^2/C^2$

Ditanya :

Gaya elektrostika yg dialami oleh q_1 ?

Jawab :

- Gaya pada q_1 akibat q_2 (tolak menolak)

$$F_{12} = k \frac{q_1 q_2}{r_{12}^2}$$

$$F_{12} = 9 \times 10^9 \frac{(2 \times 10^{-6})(3 \times 10^{-6})}{3^2}$$

$$F_{12} = 9 \times 10^9 \frac{6 \times 10^{-12}}{9}$$

$$F_{12} = (9 \times 10^9)(6{,}67 \times 10^{-13})$$

$$F_{12} = 6 \times 10^{-3}\ N \quad \text{(menjauhi } q_2\text{)}$$

- Gaya pada q_1 akibat q_3 (tarik menarik)

$$r_{13} = r_{12} + r_{23} = 3m + 2m = 5m$$

$$F_{13} = k \frac{q_1 q_3}{r_{13}^2}$$

$$F_{13} = 9 \times 10^9 \frac{(2 \times 10^{-6})(-5 \times 10^{-6})}{}$$

$$F_{13} = 9 \times 10^9 \frac{10 \times 10^{-12}}{25}$$

$$F_{13} = (9 \times 10^9)(4 \times 10^{-13})$$

$$F_{13} = 3{,}6 \times 10^{-3}\ N \quad \text{(menuju } q_3\text{)}$$

karena kedua gaya tsb berlawanan arah maka

$$F_{net} = F_{13} - F_{12}$$
$$= 3{,}6 \times 10^{-3} - 6{,}\times 10^{-3}$$
$$= -2{,}4 \times 10^{-3}\ N$$

kekiri menuju (menjauhi q_2)

② Diketahui :

$r = 2{,}60 \times 10^{-2}$ m

$m_1 = 6{,}0 \times 10^{-6}$ kg

$a_1 = 4{,}6 \times 10^{3}$ m/s²

$a_2 = 8{,}5 \times 10^{3}$ m/s²

$k = 9{,}0 \times 10^{9}$ Nm²/C²

Jawab :

2) Besar muatan masing² partikel q

$F = m_1 a_1$

$F = (6{,}0 \times 10^{-6})(4{,}6 \times 10^{3})$

$F = 0{,}0276$ N

$q = \sqrt{\frac{Fr^2}{k}}$

$q = \sqrt{\frac{(0{,}0276)(2{,}60 \times 10^{-2})^2}{9{,}0 \times 10^{9}}}$

$q = \sqrt{\frac{(0{,}0276)(6{,}76 \times 10^{-4})}{9{,}0 \times 10^{9}}}$

$q = \sqrt{\frac{1{,}866 \times 10^{-5}}{9{,}0 \times 10^{9}}}$

$q = \sqrt{2{,}0733 \times 10^{-15}}$

$q = 4{,}55 \times 10^{-8}$ C

(untuk setiap partikel sangat besar)

b) Massa partikel 1 (m_2)

Karena Gaya sama dengan

$m_1 a_1 = \frac{m_2 \cdot a_1}{a_2}$

$m_2 = \frac{(6{,}0 \times 10^{-6}) \cdot (4{,}6 \times 10^{3})}{8{,}5 \times 10^{3}}$

$m_2 = \frac{0{,}076}{8{,}5 \times 10^{3}}$

$m_2 = 3{,}25 \times 10^{-6}$ kg

③ Diketahui :

$q_1(-4,0,0) = 5C$

$q_2(4,0,0) = 10C$

$q_3(0,5,0) = 6C$

$k = 9 \times 10^9$

Hitung gaya dari q_2 dan q_3 terhadap q_1

- $F_{12} =$

$r_{12} = 8m$

$$F_{12} = k \frac{q_2 q_2}{r_{12}}$$

$$= 9 \times 10^9 \frac{(5)(10)}{8^2}$$

$$= 9 \times 10^9 \frac{50}{64}$$

$F_{12} = 7.03 \times 10^9$ N ke kiri (menolak)

- $r_{13} = \sqrt{(0+4)^2 + (5-0)^2}$

$= \sqrt{41}$

$= 6,4 m$

$$F_{13} = k \frac{q_1 q_3}{r_{13}^2}$$

$$= 9 \times 10^9 \frac{(5)(6)}{6.4^2}$$

$$= 9 \times 10^9 \frac{30}{41}$$

$F_{13} = 6,59 \times 10^9$ N (diagonal ke kanan atas)

④ Diketahui :

$q_1\ (0,5,0) = 10C$

$q_2\ (5,5,0) = 5C$

$q_3\ (0,5,5) = -10C$

$r_{13} = 5m$

$k = 9 \times 10^9$

Ditanya = F_3 ?

$F_{13} = k \frac{q_1 q_3}{r_{13}}$

$= 9 \times 10^9 \frac{(10)(-10)}{5^2}$

$= 9 \times 10^9 \frac{-100}{25}$

$F_{13} = -3,6 \times 10^{10} N$

$\vec{r}_{23} = \vec{r}_2 - \vec{r}_3$

$= (5,0,-5)$

$r_{23} = \sqrt{(5-0)^2 + (5-5)^2 + (0-5)^2}$

$= \sqrt{50}$

$= 7,07 m$

$F_{23} = k \frac{q_2 q_3}{r^2}$

$= 9 \times 10^9 \frac{(5)(-10)}{50}$

$= 9 \times 10^9 - \frac{50}{50}$

$F_{23} = -9 \times 10^9 N$

⑤ Diketahui :

$q_1 = 2C$ di $(0,2,0)$

$q_2 = 4C$ di $(2,2,0)$

$q_3 = 5C$ di $(0,2,2)$

$q_4 = -5C$ di $(2,2,2)$

$K = 9 \times 10^9\ N.m^2/C^2$

$q = 10C$ di $(0,0,0)$

~~Diketahui~~ Ditanya = F_{tot} ?

Jawab =

- $q_1 = 2C$ di $(0,2,0)$

  $r = 2.0 m$

  $F_1 = k \frac{q q_1}{r^2}$

  $F_1 = 9 \times 10^9 \frac{(10)(2)}{2^2}$

  $F_1 = 9 \times 10^9 \frac{(20)}{4}$

  $F_1 = 9 \times 10^9 . 5$

  $F_1 = 4,5 \times 10^{10} N$

- $q_2 = 4C$ di $(2,2,0)$

  $r = \sqrt{(1-2)^2 + (-2)^2}$

  $= \sqrt{8}$

  $\approx 2,8284 m$

  $r_2 = 8,0 m$

  $F_2 = k \frac{q q_2}{r^2}$

  $= 9 \times 10^9 \frac{(10)(4)}{8}$

  $= 9 \times 10^9 . 5$

  $F_2 = 4,5 \times 10^{10} N$

• q_3 = 5C di (0,2,2)

$r = \sqrt{0^2 + (-2)^2 + (-2)^2}$

$= \sqrt{8}$

$= 2.828\ m$

$r^2 = 8.0\ m$

$F_3 = K\frac{q q_3}{r^2}$

$= 9 \times 109\ \frac{(10)(5)}{8}$

$= 9 \times 109 \cdot 6,25$

$= 5,625 \times 10^{10}\ N$

• q_4 = −5C di (2,2;2)

$r = \sqrt{(-2)^2 + (-2)^2 + (-2)^2}$

$= \sqrt{12}$

$= 3.464$

$r_2 = 12.0\ m$

$F_4 = k\ \frac{q q_4}{r^2}$

$= 9 \times 109\ \frac{(10)(-5)}{12}$

$= 3,75 \times 10^{10}\ N$

Komponen F_1 = (0, −4,50000000 × 10^{10}, 0) N

Komponen F_{2x} = −3,18198051 × 10^{10} N

F_{2y} = −3,18198051 × 10^{10} N

F_{2z} = 0

Komponen F_{3x} = 0

F_{3y} = −3,977475 × 10^{10} N

F_{3z} = −3,977475 × 10^{10} N

Komponen F_{4x} = 2,16506350 × 10^{10} N

F_{4y} = 2,16506350 × 10^{10} N

F_{4z} = 2,16506350 × 10^{10} N

Penjumlahan komponen

F_x = −1,61691700 × 10^{10} N

F_y = −9,49439265 × 10^{10} N

F_z = −1,81241213 × 10^{10} N

Faktor gaya total

F_{tot} = (−1,01691780 × 10^{10} $\hat{i}$, −9,49439265 × 10^{10} $\hat{j}$, −1,81241213 × 10^{10} $\hat{k}$)

Besar gaya

$|F| = \sqrt{F_x^2 + F_y^2 + F_z^2}$

$= 9,71917794 \times 10^{10}\ N$

⑦ Diketahui :
Panjang batang = L
rapat muatan linear = λ

a. Titik P berjarak z diatas ujung kawat
Misal batang bermuatan terletak sepanjang sumbu −x dari x = 0 sampai x = L. Titik P berada pada x = −z

$dq = \lambda\, dx$
jarak antara dq dan P =
$r = x + z$

Maka kuat medan listrik

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

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

$$E = \frac{\lambda}{4\pi\varepsilon_0}\left[-\frac{1}{x+z}\right]_0^L$$

$$E = \frac{\lambda}{4\pi\varepsilon_0}\left(\frac{1}{z} - \frac{1}{L+z}\right)$$

b. Titik P berjarak z dari tengah-tengah kawat
Misal kawat terbentang dari $x = -L/2$ sampai $x = +L/2$ titik P berada tegak lurus pada jarak z dari tengah

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

$$dE_y = dE\cos\theta = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}\frac{z}{r}$$

$$\frac{\lambda z\, dx}{(x^2+z^2)^{3/2}}$$

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

$$E_y = \frac{\lambda z}{4\pi\varepsilon_0}\left[\frac{x}{z^2\sqrt{x^2+z^2}}\right]_{-L/2}^{L/2}$$

$$E_y = \frac{\lambda z}{4\pi\varepsilon_0}\left(\frac{L/2}{z^2\sqrt{(L/2)^2+z^2}} - \frac{-L/2}{z^2\sqrt{(L/2)^2+z^2}}\right)$$

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

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

(8) Diketahui :

σ = rapatan muatan permukaan (C/m^2)

R = jari-jari bola konduktor (m)

$Q = \sigma$. luas permukaan $= \sigma \cdot 4\pi R^2$

Ditanya : $E(r)$? (muatan listrik di dalam dan di luar bola konduktor)

Jawab : $\oint_{Gauss} \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$

= untuk daerah di dalam bola konduktor ($r < R$)

$Q_{enc} = 0$

$E(r) \cdot 4\pi r^2 = \frac{Q_{enc}}{\varepsilon_0} = 0 \rightarrow E(r) = 0 \ (r < R)$

di dalam bola konduktor tidak ada medan listrik

- untuk daerah di luar bola konduktor ($r < R$)

$Q = 4\pi R^2 \sigma$

menggunakan hukum Gauss

$E(r) \cdot 4\pi R^2 \sigma = \frac{q}{\varepsilon_0}$

$E(r) = \frac{Q}{4\pi \varepsilon_0 r^2}$

$= \frac{4\pi R^2 \sigma}{4\pi \varepsilon_0 r^2}$

$= \frac{\sigma R^2}{\varepsilon_0 r^2} \ (r > R)$

Arah medan listrik radial keluar jika $\sigma > 0$

- tepat dipermukaan bola $r = R$

$E_{luas} - E_{dalam} = \frac{\sigma}{\varepsilon_0}$

$E_{dalam} = 0$

$E_{permukaan} = \frac{\sigma}{\varepsilon_0}$

Jadi $E(r) \begin{cases} 0 & r < R \\ & \text{dan } Q = 4\pi R^2 \sigma \\ \frac{\sigma R^2}{\varepsilon_0 r^2} & r > R \end{cases}$

(9) Diketahui :

$E = kr^3 \hat{r}_0$ dalam koordinat bola

k = konstanta

Ditanya = a) ρ?

b) Q_{total} ?

Jawab =

a. menggunakan hukum Gauss (divergensi) $E_r = kr^3$

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

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

$$\nabla \cdot \vec{E} = \frac{1}{r^2} \frac{d}{dr} (r^2 . kr^3)$$

$$\nabla \cdot \vec{E} = \frac{1}{r^2} \frac{d}{dr} (kr^3)$$

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

$$\nabla \cdot \vec{E} = 5kr^2$$

maka

$$\frac{\rho}{\varepsilon_0} = 5kr^2$$

$$\rho = 5\varepsilon_0 kr^2$$