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MK : Medan Elektromagnetik

1.) Tiga buah muatan titik q_1, q_2 dan q_3 yang masing-masing bermuatan 2.10^{-6} C (Positif), 3.10^{-6} C (Positif) dan 5.10^{-6} C (negatif) terletak pada sebuah garis lurus. Jika jarak q_1 dan q_2 adalah 3m dan q_2 dan q_3 adalah 2m, hitung gaya elektrostatika yang dialami oleh q_1!

→ Diket : · Muatan $q_1 = +2.10^{-6}$ C · Jarak $r_{12} = 3m$
· Muatan $q_2 = +3.10^{-6}$ C · Jarak $r_{23} = 2m$
· Muatan $q_3 = -5.10^{-6}$ C · Konstanta Coulomb $k = 9 \times 10^9 \, N\,m^2/C^2$

Ditanya : Gaya elektrostatika yang dialami oleh q_1

Jawab :

$q_1 \xleftarrow{3m} q_2 \xrightarrow{2m} q_3$

• Tentukan jarak r_{13}

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

• Hitung besar gaya F_{21}
Karena q_1 dan q_2 sama-sama positif gayanya adalah tolak-menolak. Arah kiri

$$F_{21} = k\frac{|q_1 q_2|}{r_{12}^2}$$

$$F_{21} = (9 \times 10^9)\frac{(2.10^{-6})(3.10^{-6})}{(3)^2}$$

$$F_2 = (9 \times 10^9)\frac{6.10^{-12}}{9}$$

$F_2 = 6.10^{-3}$ N (Negatif

• Hitung besar gaya F_{31}
Karena q_1 positif dan q_3 negatif, gayanya tarik-menarik, arah ke kanan.

$$F_{31} = k\frac{|q_1 q_3|}{r_{13}^2}$$

$$F_{31} = (9 \times 10^9)\frac{(2.10^{-6})(5.10^{-6})}{(5)^2}$$

$$F_{31} = (9 \times 10^9)\frac{10.10^{-12}}{25}$$

$F_{31} = 9 \times 10^9 \times 0.4$
$F_{31} = 3.6 \times 10^{-3}$ N (Positif)

• Hitung gaya total F_1

$F_1 = -F_{21} + F_{31}$
$F_1 = (-6.10^{-3}) + (3.6.10^{-3})$
$F_1 = -2.4.10^{-3}$ N

2.) Dua buah partikel bermuatan positif dan sama besar terpisah pada jarak $2,60.10^{-2}$ m dilepaskan dari keadaan diam. Sesaat setelah dilepas, partikel 1 yang bermassa $6,0.10^{-6}$ kg bergerak dengan percepatan $4,6.10^3 \, ms^{-2}$, sedangkan partikel 2 bergerak dengan percepatan $8,5.10^3 \, ms^3$. Tentukan
a.) Besar muatan masing-masing partikel

b. Massa Partikel 2

→ Diketahui : • q_1 (Positif) • $m_1 = 6.0 \times 10^{-6}$ kg
• q_2 (Positif) • $a_1 = 4.6 \times 10^{3}$ m/s²
• $|q_1| = |q_2| = q$ • $a_2 = 8.5 \times 10^{3}$ m/s²
• $r = 2.60 \times 10^{-2}$ m

Karena kedua muatan positif dan dilepaskan, gaya yang terjadi adalah tolak - menolak ($F_{12} = F_{21} = F$)

Jawab :

a.) Besar muatan masing - masing partikel

• Hitung Besar gaya F

$F = m_1 a_1$

$F = (6.0 \times 10^{-6}\ kg) \times (4.6 \cdot 10^{3}\ m/s)$

$F = (6.0 \times 46) \times 10^{(-6+3)}\ N$

$F = 27.6 \times 10^{-3}\ N = 0.0276\ N$

• Hitung besar muatan q

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

$q^2 = \frac{F \cdot r^2}{k}$

$q^2 = \frac{(27.6 \times 10^{-3}) \cdot (2.60 \times 10^{-2})^2}{(9 \times 10^{9})}$

$q^2 = \frac{(27.6 \times 10^{-3}) \cdot (6.67 \times 10^{-4})}{(9 \times 10^{9})}$

$q^2 = \frac{186.576 \times 10^{-7}}{9 \times 10^{9}}$

$q^2 \approx 20.73 \times 10^{(-7-9)}$

$q^2 \approx 20.73 \times 10^{-16}\ C^2$

$q = \sqrt{20.73 \times 10^{-16}\ C}$

$q \approx 4.55 \times 10^{-8}\ C$

b.) Massa Partikel 2

$F = m_2 a_2$

$m_2 = \frac{F}{a_2}$

$m_2 = \frac{27.6 \times 10^{-3}\ N}{8.5 \times 10^{3}\ m/s^2}$

$m_2 = \frac{27.6}{8.5} \times 10^{(-3-3)}\ kg$

$m_2 \approx 3.247 \times 10^{-6}\ kg$

3.) Tentukan gaya yang dialami q_1, jika :

q_1 (−4,0,0) : 5C

q_2 (4,0,0) : 10 C

q_3 (0,5,0) : 6C

→ Diketahui : • $q_1 = -5$ C Pada posisi $r_1 = (-4,0,0)$ m • $q_3 = +6$ C Pada
• $q_2 = +10$ C Pada Posisi $r_2 = (4,0,0)$ m Posisi: $r_3 = (0,5,0)$ m

Ditanya : Gaya yang dialami q_1

$F_1 = F_{21} + F_{31}$

Jawab :

• Tentukan vektor jarak dan besar jarak

+ Jarak q_1 dan q_2 (r_{21})

$r_{21} = r_1 - r_2$

$= (-4,0,0) - (4,0,0)$

$= (-8,0,0)\ m$

$r_{21} = \sqrt{(-8)^2 + 0^2 + 0^2}$

$r_{21} = 8\ m$

+ Jarak q_1 dan q_3 (r_{31})

$r_{31} = r_1 - r_3$

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

$= (-4,-5,0)\ m$

$r_{31} = \sqrt{(-4)^2 + (-5)^2 + 0}$

$= \sqrt{16 + 25}$

$r_{31} = \sqrt{41}\ m$

• Hitung F_{21}

$+q_1$ dan $-q_2$ akan tarik - menarik, arah sumbu x positif

$F_{21} = k \frac{|q_1 q_2|}{r_{21}^2}$

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

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

$F_{21} = 9\times 10^9 \times 0.78125$

$F_{21} = 7.03125 \times 10^9\ N$

→ Vektor $F_{21} = 7.03125 \times 10^9\ \hat{i}\ N$

• Hitung gaya F_{31}

$+q_1$ dan $+q_3$ akan tarik - menarik

+ Besar gaya F_{31}

$F_{31} = k \frac{|q_1 q_3|}{r_{31}^2}$

$= (9\times 10^9) \frac{(5)(6)}{(\sqrt{41})^2} = 9\times 10^9 \frac{30}{41}$

$F_{31} \approx 9\times 10^9 \times 0.7317 \approx 6.5853 \times 10^9\ N$

+ Vektor F_{31}

$F_{31} = F_{31} \cdot \hat{r}_{31}$

$= (6.5853\times 10^9) \cdot \frac{(-4\hat{i} - 5\hat{j})}{\sqrt{41}}$

$F_{31} \approx 6.5853 \times 10^9 \cdot (-0.6246\ \hat{i} - 0.7809\ \hat{j})$

$F_{31} \approx (-4.113 \times 10^9\ \hat{i}) + (-5.143 \times 10^9\ \hat{j})\ N$

• Hitung Gaya total F_1

$F_1 = F_{21} + F_{31}$

$F_1 \approx (7.03125 \times 10^9\ \hat{i}) + (-4.113 \times 10^9\ \hat{i} - 5.143 \times 10^9\ \hat{j})$

$\approx (7.03125 - 4.113) \times 10^9\ \hat{i} - 5.143 \times 10^9\ \hat{j}$

$F_1 \approx 2.918 \times 10^9\ \hat{i} - 5.143 \times 10^9\ \hat{j}\ N$

• Besar gaya total F_1

$F_1 = \sqrt{F_{1x}^2 + F_{1y}^2}$

$= \sqrt{(2.918 \times 10^9)^2 + (-5.143 \times 10^9)^2}$

$= 10^9 \sqrt{8.51 + 26.45}$

$= 10^9 \sqrt{34.96}$

$F_1 = 5.91 \times 10^9\ N$

4.) Tiga partikel bermuatan terdistribusi sebagai berikut :

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

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

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

Tentukan gaya yang dialami oleh q_3

→ Diket : $q_1 = +10\ c$ pada posisi $r_1 = (0,5,0)\ m$

- q_2 : + 5c Pada Posisi r_2 : (5, 5, 0) m
- q_3 : - 10c Pada Posisi r_3 : (0, 5, 5) m

Ditanya : Gaya yang dialami oleh q_3

$F_3 = F_{13} + F_{23}$

Jawab :

- Jarak antara q_3 dan q_1 (r_{13})

$r_{13} = r_3 - r_1$

$= (0,5,5) - (0,5,0)$

$= (0,0,5)$ m

$r_{13} = \sqrt{0^2 + 0^2 + 5^2} = 5$ m

Vektor Satuan $\hat{r}_{13} = (0,0,1) = \hat{k}$

- Jarak antara q_3 dan q_2 (r_{23})

$r_{23} = r_3 - r_2$

$= (0,5,5) - (5,5,0) = (-5,0,5)$ m

$r_{23} = \sqrt{(-5)^2 + 0^2 + 5^3} = \sqrt{50}$ m

Vektor satuan $\hat{r}_{23} = \left(-\frac{\sqrt{2}}{2}, 0, \frac{\sqrt{2}}{2}\right)$

- Hitung gaya F_{13} (Gaya pada q_3 oleh q_1)

$-q_3$ dan $+q_1$ akan tarik - menarik

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

$= (9 \times 10^9) \frac{(10)(10)}{(5)^2} = 9 \times 10^9 \frac{100}{25}$

$F_{13} = 9 \times 10^9 \times 4 = 36 \times 10^9$ N

Vektor gaya $F_{13} = F_{13} \cdot (-\hat{k}) = -36 \times 10^9 \hat{k}$ N

- Hitung gaya F_{23} (gaya pada q_3 oleh q_2)

$-q_3$ dan $+q_2$ akan tarik - menarik

$F_{23} = F_{23} \cdot (-\hat{r}_{23})$

Besar F_{23}

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

$= (9 \times 10^9) \frac{(5)(10)}{(\sqrt{50})^2} = 9 \times 10^9 \frac{50}{50}$

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

+ Vektor F_{23}

$F_{23} = 9 \times 10^9 \cdot (-\hat{r}_{23}) = 9 \times 10^9 \cdot \left(\frac{\sqrt{2}}{2}\hat{i} - \frac{\sqrt{2}}{2}\hat{k}\right)$

$\approx 9 \times 10^9 \cdot (0.707\hat{i} - 0.707\hat{k})$

$F_{23} \approx 6.363 \times 10^9 \hat{i} - 6.363 \times 10^9 \hat{k}$ N

- Gaya total F_3

$F_3 = F_{13} + F_{23}$

$\approx (0\hat{i} + 0\hat{j} - 36 \times 10^9 \hat{k}) + (6.363 \times 10^9 \hat{i} + 0\hat{j} - 6.363 \times 10^9 \hat{k})$

$F_3 \approx 6.363 \times 10^9 \hat{i} + 0\hat{j} + (-36 - 6.363) \times 10^9 \hat{k}$

$F_3 \approx 6.363 \times 10^9 \hat{i} - 42.363 \times 10^9 \hat{k}$ N

- Besar Gaya total F_3

$F_3 = \sqrt{F_{3x}^2 + F_{3z}^2}$

$F_3 = \sqrt{(6.363 \times 10^9)^2 + (-42.363 \times 10^9)^2}$

$= 10^9 \sqrt{40.49 + 1794.6}$

$= 10^9 \sqrt{1835.09}$

$F_3 = 42.84 \times 10^9$ N

5.) Berapa gaya yang dialami muatan q = 10c di (0,0,0) karena pengaruh muatan

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)

- Hitung Besar F_i

$F_i = k\frac{|qq_i|}{r_i^2} \rightarrow k \cdot k \cdot q = (9\times10^9)\cdot 10 = 90\times10^9\ N\ m^2/c$

- $F_1 = k\frac{qq_1}{r_1^2} = k\frac{2}{2^2} = 0.5k$
- $F_2 = k\frac{qq_2}{r_2^2} = k\frac{4}{(\sqrt{8})^2} = 0.5k$
- $F_3 = k\frac{qq_3}{r_3^2} = k\frac{5}{(\sqrt{8})^2} = 0.625k$
- $F_4 = k\frac{qq_4}{r_4^2} = k\frac{5}{(\sqrt{12})^2} = 0.4167k$

- Hitung vektor F_i

$F_i = F_i \cdot \frac{r_i}{r_i}$

- $+q, +q_1 \rightarrow$ tolak. arah $F_1 = -\hat{r}_1$

$F_1 = 0.5k \cdot (-\hat{j}) = -0.5k\hat{j}$

- $+q, +q_2 \rightarrow$ tolak. arah $F_2 = -\hat{r}_2$

$F_2 = 0.5k \cdot \left(\frac{1}{\sqrt{8}}(2,2,0)\right) = 0.5k \cdot \left(\frac{2}{2\sqrt{2}}\hat{i} + \frac{2}{2\sqrt{2}}\hat{j}\right) = \frac{0.5k}{\sqrt{2}}(\hat{i}+\hat{j})$

- $+q, +q_3 \rightarrow$ tolak. arah $F_3 = -\hat{r}_3$

$F_3 = 0.625k\left(\frac{1}{\sqrt{8}}(0,2,2)\right) = 0.625k \cdot \left(\frac{2}{2\sqrt{2}}\hat{j} + \frac{2}{2\sqrt{2}}\hat{k}\right) = \frac{0.625k}{\sqrt{2}}(\hat{j}+\hat{k})$

- $+q, -q_4 \rightarrow$ tarik. arah $F_4 = \hat{r}_4$

$F_4 = 0.4167k \cdot \left(\frac{1}{\sqrt{12}}(-2,-2,-2)\right) = 0.4167k \cdot \left(-\frac{2}{\sqrt{12}}(\hat{i}+\hat{j}+\hat{k})\right)$

$= -0.4167k \cdot \frac{2}{2\sqrt{3}}(\hat{i}+\hat{j}+\hat{k}) = -\frac{0.4167k}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})$

- Hitung gaya total F

$F = F_1 + F_2 + F_3 + F_4$

$F = k\left[\left(\frac{0.5}{\sqrt{2}} - \frac{0.4167}{\sqrt{3}}\right)\hat{i} + \left(-0.5 + \frac{0.5}{\sqrt{2}} + \frac{0.625}{\sqrt{2}} - \frac{0.4167}{\sqrt{3}}\right)\hat{j} + \left(\frac{0.625}{\sqrt{2}} - \frac{0.4167}{\sqrt{3}}\right)\hat{k}\right]$

dengan $\rightarrow \frac{1}{\sqrt{2}} = 0.7071$ dan $\frac{1}{\sqrt{3}} = 0.5774$

$F = 90\times10^9\left[(0.3536-0.2403)\hat{i} + (-0.5+0.5336+0.4419-0.2403)\hat{j} + (0.4419-0.2403)\right]$

$= 90\times10^9\left[0.1133\hat{i} + 0.0552\hat{j} + 0.2016\hat{k}\right) N$

$F = (10.197\hat{i} + 4.968\hat{j} + 18.144\hat{k})\times10^9\ N$

- Besar gaya total yang dialami muatan q

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

$= 10^9\sqrt{(10.197)^2 + (4.968)^2 + (18.144)^2}$

$= 10^9\sqrt{104.0 + 27.7 + 329.2}$

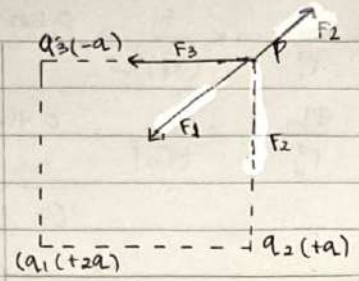
$F = 10^9\sqrt{457.9}$

$= 21.399\times10^9\ N$

$F = 21.4\times10^9\ N$

6) a. Gambar Gaya - Gaya pada muatan 3q

- F_1 (+2q) : tolak - menolak, arah diagonal ke kiri bawah
- F_2 (+q) : tolak - menolak, arah ke atas $(+\hat{j})$
- F_3 (-q) : tarik - menarik, arah ke kiri $(-\hat{i})$



6.) Hitung besar gaya

- Hitung vektor gaya
  - F_2 (Jarak s, arah $+\hat{j}$)

$$F_2 = k\frac{|(3q)(q)|}{s^2} \cdot 3k' \cdot 3k'\hat{j}$$

  - F_3 (Jarak s, arah $-\hat{i}$)

$$F_3 = k\frac{|(3q)(-q)|}{s^2} = 3k' = 3k'\hat{j}$$

  - F_1 (Jarak $s\sqrt{2}$, arah $-\hat{i}, -\hat{j}$)

$$F_1 = k\frac{|(3q)(2q)|}{(s\sqrt{2})^2} = k\frac{6q^2}{2s^2} = 3k'$$

$$= 3k' \cdot \frac{1}{\sqrt{2}}(-\hat{i}, -\hat{j}) = -\frac{3k'}{\sqrt{2}}\hat{i}, -\frac{3k'}{\sqrt{2}}\hat{j}$$

$$F_{total} = F_1 + F_2 + F_3$$

$$= \left(-3k' - \frac{3k'}{\sqrt{2}}\right)\hat{i} + \left(3k' - \frac{3k'}{\sqrt{2}}\right)\hat{j}$$

- Besar gaya total

$$F_{total} = \sqrt{F_x^2 + F_y^2}$$

$$= 3k'\sqrt{\left(-1 - \frac{1}{\sqrt{2}}\right)^2 + \left(1 - \frac{1}{\sqrt{2}}\right)^2}$$

$$= 3k\sqrt{1+1+\frac{1}{2}+\frac{1}{2}} = 3k'\sqrt{3} = 3\sqrt{3} \cdot k\frac{q^2}{s^2}$$

c.) Hitung ~~Vektor~~ medan listrik

$$E_{total} = \frac{F_{total}}{3q} = \frac{3k\frac{q^2}{s^2}\left[\left(-1-\frac{1}{\sqrt{2}}\right)\hat{i} + \left(1-\frac{1}{\sqrt{2}}\right)\hat{j}\right]}{3q}$$

$$= k\frac{q}{s^2}\left[\left(-1-\frac{1}{\sqrt{2}}\right)\hat{i} + \left(1-\frac{1}{\sqrt{2}}\right)\hat{j}\right]$$

d.) Hitung Besar Medan Listrik

$$\vec{E} = \frac{F_{total}}{3q} = \frac{3\sqrt{3} \cdot k\frac{q^2}{s^2}}{3q} = \sqrt{3} \cdot k\frac{q}{s^2}$$

e.) Hitung pula potensial listrik pada titik itu

$$V = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + k\frac{q_3}{r_3}$$

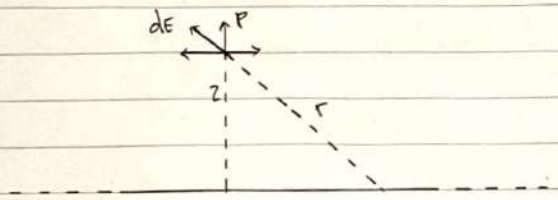
- $V_1 = k\frac{2q}{s\sqrt{2}} = k\frac{q}{s}\sqrt{2}$
- $V_3 = k\frac{-q}{s} = -k\frac{q}{s}$
- $V_2 = k\frac{q}{s}$

$$\vec{V} = V_1 + V_2 + V_3$$
$$= k\frac{q}{s}\sqrt{2} + k\frac{q}{s} - k\frac{q}{s}$$
$$= k\frac{q}{s}\sqrt{2}$$
$$\vec{V} = \sqrt{2} \cdot k\frac{q}{s}$$

~~7.) Sebuah batang panjang dititi P yang berjarak z dari~~

7.) Sebuah batang panjangnya L, rapat muatan per satuan panjang adalah λ. Hitung :

a.) kuat medan listrik dititik P yang berjarak z diatas ujung kawat.



$x = 0$ hingga $x = L$

P : $x = L + z$

$$d\vec{E} = k\frac{dq}{r^2} = k\frac{\lambda dx'}{((L+z) - x')^2}$$

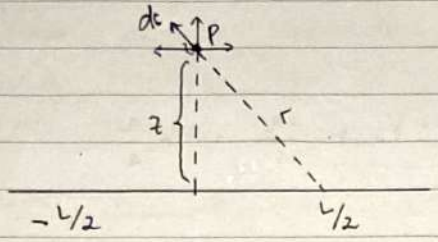
$$\vec{E} = \int_0^L k\lambda \frac{dx'}{((L+z) - x')^2}$$

Gunakan $u = (L+z) - x'$, maka $du = -dx'$, batas integral berubah

- untuk $x' = 0$, $u = L+z$
- untuk $x' = L$, $u = z$

$$\vec{E} = k\lambda \int_{L+z}^{z} \frac{-du}{u^2} = -k\lambda \left[-\frac{1}{u}\right]_{L+z}^{z} = k\lambda \left[\frac{1}{u}\right]_{L+z}^{z}$$
$$= k\lambda \left(\frac{1}{z} - \frac{1}{L+z}\right)$$
$$= k\lambda \left(\frac{(L+z) - z}{z(L+z)}\right)$$
$$\vec{E} = k\lambda \frac{L}{z(L+z)}$$

b.) Kuat medan listrik dititik p yang berjarak z ditengah - tengah kawat



$$d\vec{E} = k\frac{\lambda dx'}{(z-x')^2}$$

$$\vec{E} = \int_{-L/2}^{L/2} k\lambda \frac{dx}{(z-x')^2}$$

Gunakan substitusi $u = z - x'$; maka $du = -dx'$

- Untuk $x' = -L/2$, $u = z + L/2$
- Untuk $x' = L/2$, $u = z - L/2$

$$\vec{E} = k\lambda \int_{z+L/2}^{z-L/2} \frac{-du}{u^2} = -k\lambda \left[-\frac{1}{u}\right]_{z+L/2}^{z-L/2} = k\lambda \left[\frac{1}{u}\right]_{z+L/2}^{z-L/2}$$

$$= k\lambda \left(\frac{1}{z-L/2} - \frac{1}{z+L/2}\right)$$

$$= k\lambda \left(\frac{(z+L/2) - (z-L/2)}{(z-L/2)(z+L/2)}\right)$$

$$\vec{E} = k\lambda \frac{L}{z^2 - (L/2)^2}$$

8.) Hitung medan listrik pada bola konduktor dengan rapat muatan σ dan jari-jari R

Hukum Gauss → $\oint E \cdot dA = \frac{Q_{enclosed}}{\varepsilon_0}$

Total muatan pada permukaan bola $Q = \sigma \cdot A = \sigma(4\pi R^2)$

$$\oint E \cdot dA = \frac{0}{\varepsilon_0} = E(4\pi r^2) = 0 \rightarrow E = 0$$

↳ medan listrik dalam bola konduktor

- Medan listrik dalam bola konduktor

$$\oint E \cdot dA = \frac{Q_{enclosed}}{\varepsilon_0}$$

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

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

$$E = \frac{\sigma R^2}{\varepsilon_0 r^2}\hat{r}$$

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

9.) a.) Hitung rapat muatan (ρ)

$$\nabla \cdot E = \frac{\rho}{\varepsilon_0} \rightarrow \nabla \cdot E = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 E_r)$$

- Hitung Divergensi

$E_r = kr^3$

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

$$= \frac{1}{r^2}\frac{\partial}{\partial r}(kr^5)$$

$$= \frac{1}{r^2}(5kr^4)$$

$$\nabla \cdot E = 5kr^{4-2}$$

- Hitung rapat muatan (ρ)

$$\rho = \varepsilon_0(\nabla \cdot E)$$

$$\rho = \varepsilon_0(5kr^2) \rightarrow \rho = 5k\varepsilon_0 r^2$$

b.) Cari muatan total yang terdapat dalam suatu bola dengan jari - jari R

$$Q_{total} = \int_{Volume} \rho \, dV$$

dalam koordinat bola, volume $dv = r^2 \sin\theta \, dr \, d\theta \, d\phi$

$$Q_{total} = \int_0^{2\pi}\int_0^{\pi}\int_0^{R} (5k\varepsilon_0 r^2)(r^2 \sin\theta \, dr \, d\theta \, d\phi)$$

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

$$\int_0^R \sin\theta \, d\theta = [-\cos\theta]_0^{\pi} = -(\cos\pi - \cos 0) = -(-1-1) = 2$$

$$\int_0^{2\pi} d\phi = 2\pi$$

$$\int_0^R r^4 dr = \left[\frac{1}{5}r^5\right]_0^R = \frac{1}{5}R^5$$

→ muatan total

$$Q_{total} = 5k\varepsilon_0\left(\frac{1}{5}R^5\right)(2)(2\pi)$$

$$= 4\pi k\varepsilon_0 R^5$$