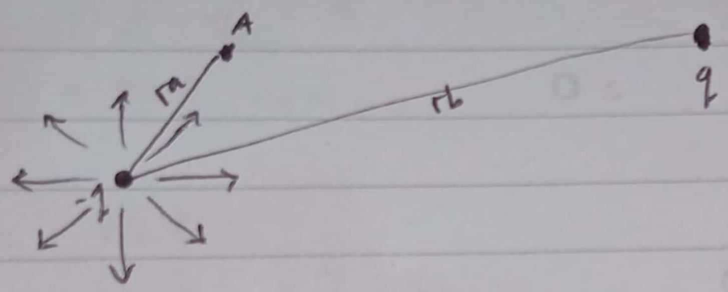
Kelistrikan dan Kemagnetan.

USAHA DAN ENERGI

- **Usaha oleh muatan titik q**



$$W = \int - \vec{F} \, dr$$

(−) negatif karena melawan muatan sumber

$$W = \int_A^B \vec{F} \, d\vec{r}$$

$$= -q \int \vec{E} \, dl$$

$$= -q \left[\int \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2} \, dr \right]$$

$$= -q \left[- \frac{q}{4\pi\varepsilon_0 r} \right]$$

↓ ganti Q

$$= Q \, [V]$$

$$= QV$$

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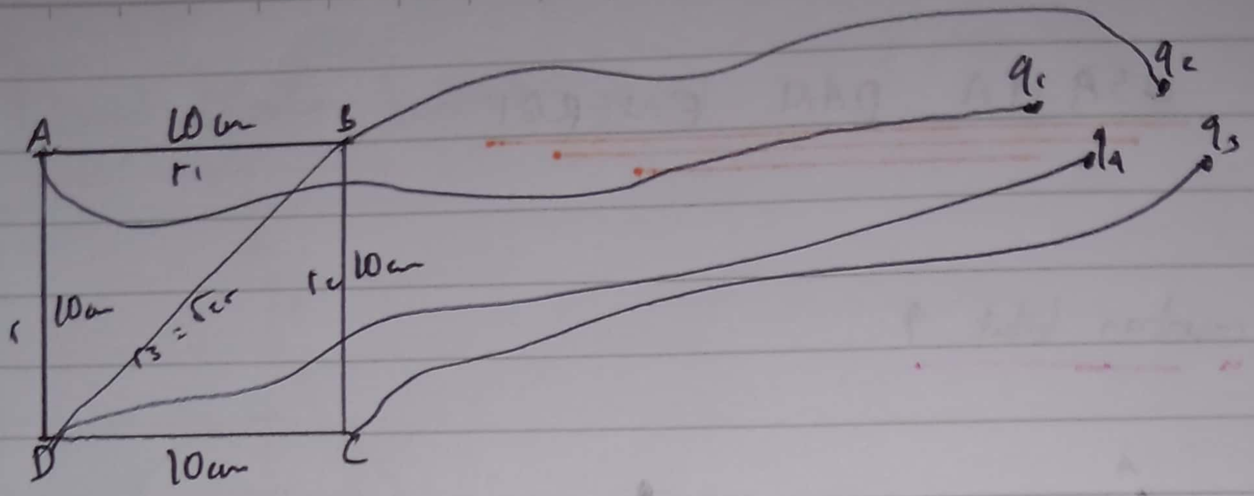

Dik : q_1 pindah ke A $= 0$

q_2 — // — B

q_3 — // — C

q_4 — // — D

Muatan : 2 μC

Panjang sisi : 10 cm

Jawab :

$W_1 = q_1 V_1 = 0$ (karena belum ada muatan).

$$W_2 = q_2 V_2$$
$$= q_2 \left[k \frac{q_1}{r} \right]$$
$$= q_2 V_2$$

$$W_3 = q_3 V_3$$
$$= q_3 \left[k \frac{q_1}{r_1} + k \frac{q_2}{r_2} \right]$$

$$W_4 = q_4 V_4$$
$$= q_4 \left[k \frac{q_1}{r_1} + k \frac{q_2}{r_2} + k \frac{q_3}{r_3} \right]$$

$$W = \frac{1}{4 \pi \varepsilon_0} \sum_{i=0}^{n} \cdot \sum_{j \neq i}^{m} \frac{q_i \cdot q_j}{r_{ij}}$$

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- $W_1 = 0$

- $W_2 = V_2 \cdot q_2$

$= k \frac{q_1}{r_{ab}} \cdot q_2$

$= 1 \cdot \frac{2}{10} \cdot 2$

$= 0{,}4$ dyne.cm

- $W_3 = V_3 q_3$

$= \left(k \frac{q_1}{r_{ac}} + k \frac{q_1}{r_{bc}}\right) q_3$

$= \left(1 \frac{2}{10} + 1 \frac{2}{10\sqrt{2}}\right) 2$

$= 0{,}683$ dyne.cm

- $W_4 = V_4 \cdot q_4$

$= \left(k \frac{q_1}{r_{ad}} + \frac{q_2}{r_{bd}} + \frac{q_3}{r_{cd}}\right)$

$= \left(1 \cdot \frac{2}{10\sqrt{2}} + 1 \frac{2}{10} + 1 \frac{2}{10}\right) 2$

$= 1{,}08$ dyne.cm.

$$W = \frac{1}{4 \pi \varepsilon_0} \sum_{i=1}^{n} \sum_{\substack{i=1 \\ j \neq i}}^{n} \frac{q_i q_j}{r_{ij}}$$

$$W = \frac{1}{8 \pi \varepsilon_0} \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} \frac{q_i q_j}{r_{ij}}$$

$$W = \frac{1}{2} \sum_{i=1}^{n} q_i V$$

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• Energi dari muatan distribusi kontinu

Garis $\rightarrow$ $\frac{1}{2}\int \lambda V \, dl$

Permukaan $\rightarrow$ $\frac{1}{2}\int \sigma V \, da$

Volume $\rightarrow$ $\frac{1}{2}\int \rho V \, d\tau$

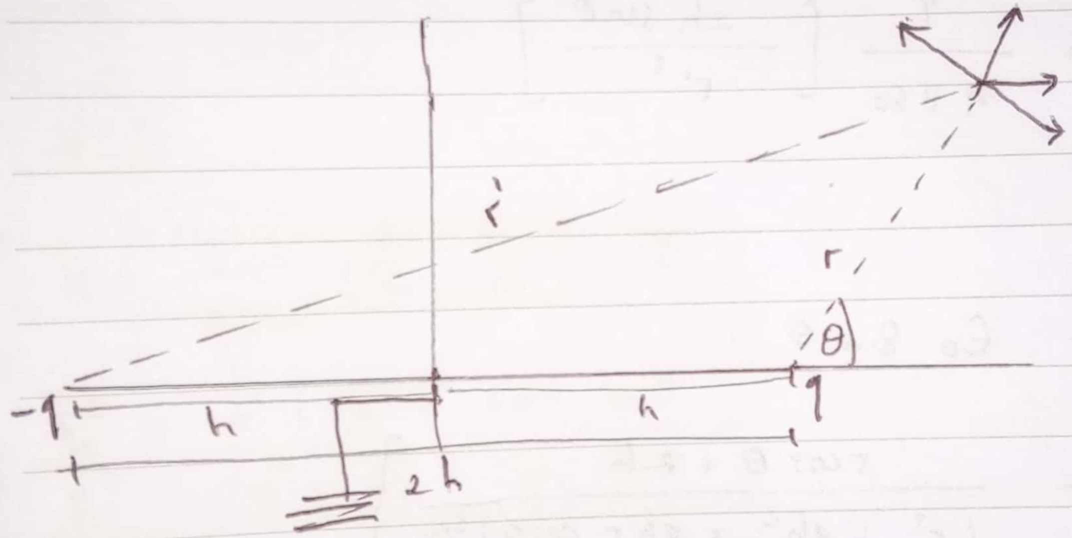
$$W = \frac{\epsilon_0}{2} \int_{surface} E^2 \, d\tau$$

~~Metoda Pu~~

BAB 3. Metoda Penentuan Potensial

Metoda Bayangan

1. Muatan titik dan batang konduktor



$$P = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

$$- \frac{q}{4\pi\epsilon_0 r'}$$

$$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{r} - \frac{1}{r'}\right]$$

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

$$= \sqrt{4h^2 + 4hr\cos\theta + r^2}$$

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$$V_P = V_{(r,\theta)} = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{(r^2 + 4h^2 + 4hr\cos\theta)^{1/2}}\right)$$

Turunkn thdp r

$$E_r = -\frac{\partial V}{\partial r} = \frac{1}{4\pi\varepsilon_0}\left[\frac{1}{r^2} - \frac{r + 2h\cos\theta}{r'^3}\right]$$

Turunk thdp θ

$$E_\theta = -\frac{1}{r}\frac{\partial V}{\partial \theta} = \frac{q}{4\pi\varepsilon_0}\left[\frac{2h\sin\theta}{r'^3}\right]$$

thdp z

$$E_z = E_r\cos\theta - E_\theta\sin\theta$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{\cos\theta}{r^2} - \frac{r\cos\theta + 2h}{(r^2 + 4h^2 + 4hr\cos\theta)^{3/2}}\right]$$

AB, $r = r' = a$

$$E_z = \frac{q}{4\pi\varepsilon_0}\left[\frac{\cos\theta}{r^2} - \frac{r\cos\theta + 2h}{(a)^3}\right]$$

$$= \frac{-q}{4\pi\varepsilon_0}\left(\frac{2h}{a^3}\right)$$

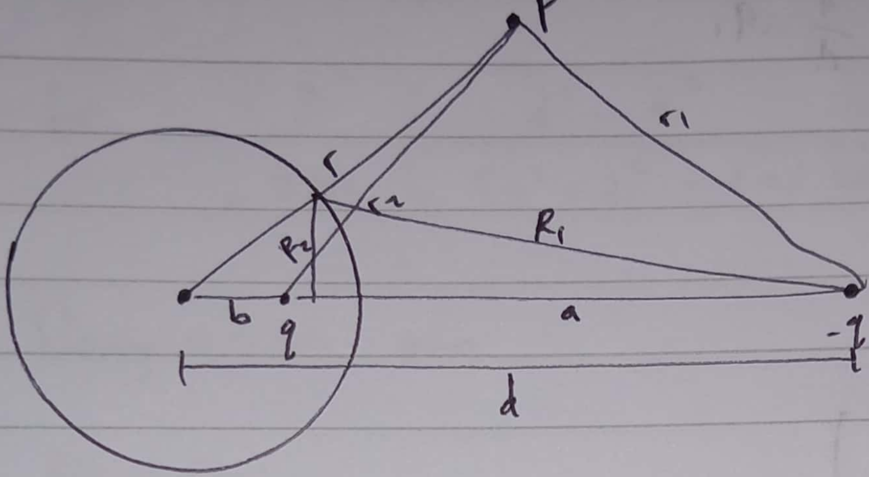
$$= \frac{-q}{2\pi\varepsilon_0}\left(\frac{h}{a^3}\right) = \frac{1}{\varepsilon_0}\sigma_{(a)}$$

$$\iint \sigma\, dA = -hq\int_0^\infty \frac{x}{a^3}\,dr$$

$$= -hq\int_h^\infty (ada)$$

$= -q$ muatan bayangan

2. Muatan titik dengan bola konduktor



$V = 0$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{R_1} - \frac{q_2}{R_2}\right) = 0$$

$$R_1^2 = a^2 + d^2 - 2ad\cos\theta$$
$$R_2^2 = a^2 + b^2 - 2ab\cos\theta$$

Untuk $V = 0$ maka

$$\frac{q_1}{R_1} = \frac{q_2}{R_2} \longrightarrow \frac{q_1^2}{q_2^2} = \frac{R_1^2}{R_2^2} = \frac{a^2 + d^2 - 2ad\cos\theta}{a^2 + b^2 - 2ab\cos\theta}$$

$$\left(\frac{q_1}{q_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^2 = \frac{d}{b}\left(\frac{a^2/d + d - 2ad\cos\theta}{a^2/b + b - 2ab\cos\theta}\right.$$

1. $a^2 = db$
2. $\left(\frac{q_1}{q_2}\right)^2 = \frac{d}{b}$ karena $d > b$ dan $q_1 > q_2$

$$\frac{q_1^2}{q_2^2} = \frac{d}{b} = -q_2 = +\sqrt{\frac{b}{d}} \cdot q_1 \quad \text{untuk} \quad b = \frac{a^2}{d}$$

$$q_2 = -\frac{a}{d} \cdot q_1$$

Jadi $V(r,\theta) = V_p$

$$V_p = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} - \frac{q_2}{r_2}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} - \frac{a/d}{r_2}\right)$$

$$r_1 = (r^2 + d^2 - 2ard\cos\theta)^{1/2}$$
$$r_2 = (r^2 + b^2 - 2arb\cos\theta)^{1/2}$$

$$V_p = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{(r^2 + d^2 - 2rd\cos\theta)^{1/2}} - \frac{a/d}{(r^2 + \frac{a^4}{d^2}(d^2/d\cos\theta)^{1/2}}\right.$$

$$E_r = -\frac{\partial V}{\partial r}$$

$$E_\theta = -\frac{1}{r}\frac{\partial V}{\partial \theta}$$

u/ permukaan bola, $r = a$

$$E_r = -\frac{q_1}{4\pi\varepsilon_0}\left[\frac{-(a - d\cos\theta)}{(a^2 + d^2 - 2ad\cos\theta)^{3/2}} + \frac{\frac{a}{d}(a - \frac{a^2}{d}\cos\theta)}{(a^2 + \frac{a^4}{d^2} - 2a(\frac{a^2}{d}\cos\theta)^{3/2}}\right.$$

$$+ \frac{\frac{d^2}{a}(1 - \frac{a}{d}\cos\theta)}{a^3/d^3(a^2 + a^2 - 2ad\cos\theta)^{3/2}}$$

$$+ \frac{d^2/a(1 - \frac{a}{d}\cos\theta)}{(a^2 + d^2 - 2ad\cos\theta)^{3/2}}$$

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$$E_r = -\frac{q_1}{4\pi\varepsilon_0}\left[\frac{-(a - d\cos\theta) + d^2/a\,(1 - a/d\cos\theta)}{(a^2 + d^2 - 2ad\cos\theta)^{3/2}}\right]$$

$$E_r = -\frac{q_1}{4\pi\varepsilon_0}\left(\frac{d^2 - a^2}{(a^2 + d^2 - 2ad\cos\theta)^{3/2}}\right)$$

Dengan cara sama

$E_\theta = 0$

Disini terjadi pergerakan listrik D

$D = \varepsilon_0 E$, $-D = \sigma_f = \sigma$

$\sigma = \varepsilon_0 E_r$

$$\sigma = -\frac{q_1}{4\pi a}\left(\frac{d^2 - a^2}{(a^2 + d^2 - 2ad\cos\theta)^{3/2}}\right)$$

σ = muatan induksi / satuan luas pd bola konduktor

F : Gaya antara bola dengan q_1

$$F = -\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{(d-b)^2}$$

$$F = -\frac{1}{4\pi\varepsilon_0}\frac{a q_1^2}{d(a-d)^2}$$

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