Nama : Sihfa Zhainita
NPM : 2013022062
Prodi : Pendidikan Fisika
Kelas : B

Metode Penentuan Potensial

1). Persamaan laplace

$\oint \vec{E} \cdot d\vec{e} = 0$, untuk $\vec{E}$ konservatif

$\oint \vec{E} \cdot d\vec{p} = \int \nabla \times \vec{E} \cdot d\vec{A} = 0$

$\nabla \times \vec{E} = 0$,

$\nabla E = \rho / c_0$

$E = - \nabla V$

$\nabla \vec{E} = - \nabla \cdot \nabla V$

$\frac{1}{\varepsilon_0} \rho = - \nabla^2 V.$

$\nabla^2 V = - \frac{1}{\varepsilon_0} \rho$ (Hukum Poisson)

$\nabla^2 V = 0$ => Persamaan laplace

$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$

$\frac{\partial^2 V}{\partial x^2} = 0$; $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = 0$;

$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$

Persamaan laplace 1 dimensi, untuk menghitung potensial listrik dari rumus poisson.

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$$\nabla^2 V = \frac{1}{\varepsilon_0} \rho$$

* Dalam persamaan laplace $\rho = 0$, ε_0 = konstan

$\nabla^2 V = 0$ (untuk 1 dimensi), maka =

$\frac{\partial^2 V_x}{\partial x^2} = 0$ karena V fungsi dari x, maka:

$\frac{d^2 V_x}{dx^2} = \frac{d}{dx}\left(\frac{dv}{dx}\right) = 0$

$\frac{dV_x}{dx} = k$, k = konstan

.) $dV_x = t\,dx$

.) $V_x = tx + b$

.) b = bil. konstan

* Untuk koordinat bola, maka persamaan laplace satu dimensi $\nabla^2 V = 0$

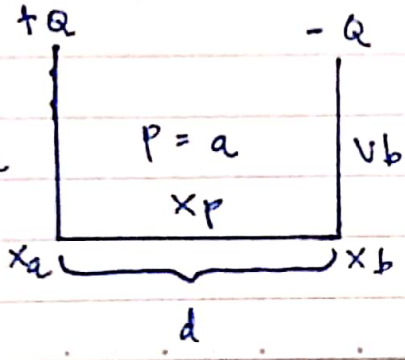
$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial v}{\partial r}\right) = 0$$

$$r^2 \frac{\partial v}{\partial r} = r^2 \frac{dv}{dr} = k$$

$$dr = \frac{1}{r^2} k\,dr$$

$$v(r) = -\frac{1}{r} k + c$$

Contoh: $V_a = 10$ V, $V_b = 20$ V, $x_a = 0$, $x_b = 10$, $x_p = s$



$V(xp) = ?$

$V(x) = kxp + b$

$Va = k(xa) + b$

$Vb = k(xb) + b$ $-$

$Va - Vb = k(xa - xb)$

$xa = 0$

$xb = 10$

$$k = \frac{Va - Vb}{xa - xb}$$

$$Vx = \left(\frac{Va - Vb}{xa - xb}\right) k\,a + b = \left[\frac{10 - 0}{10 - 0}\right]$$

$$b = Va - \left(\frac{Va - Vb}{xa - xb}\right) \cdot xa^2 - 1$$

$$Vx = \left(\frac{Va - Vb}{xa - xb}\right) xa \cdot x + \left(Va - \left(\frac{Va - Vb}{xa - xb}\right) \cdot xa\right)$$

$$= xa\left[\left(\frac{Va - Vb}{xa - xb}\right) \cdot x + \left(\frac{Va}{xa} - \left(\frac{Va - Vb}{xa - xb}\right)\right)\right]$$

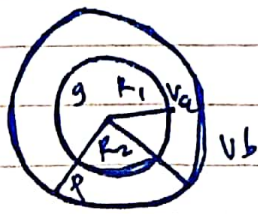
$$Vxp = xa\left[\left(\frac{Va - Vb}{xa - xb}\right) \cdot xa + \left(\frac{Va}{ka} - \left(\frac{Va - Vb}{xa - xb}\right)\right)\right]$$

Solusi

$$Vx = \left[\frac{(Va - Vb)}{(xa - xb)} x + \left(Va - \left(\frac{Va - Vb}{xa - xb}\right) xa\right)\right]$$

$V(p) = \ldots ?$

$$V(r) = -\frac{1}{r} k + c, \quad Va = -\frac{1}{r_1} k + c$$



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$$V_a = -\frac{1}{R_1} k + c$$

$$V_b = -\frac{1}{R_2} k + c$$

$$V_a - V_b = k\left(\frac{1}{R_2} - \frac{1}{R_1}\right)$$

$$V_a - V_b = k\left(\frac{R_1 - R_2}{R_2 - R_1}\right)$$

$$k = \frac{R_2 R_1 (V_a - V_b)}{(R_1 - R_2)}$$

$$V_a = -\frac{1}{K_1}\left[\frac{R_2 R_1 (V_a - V_b)}{(R_1 - R_2}\right] + c$$

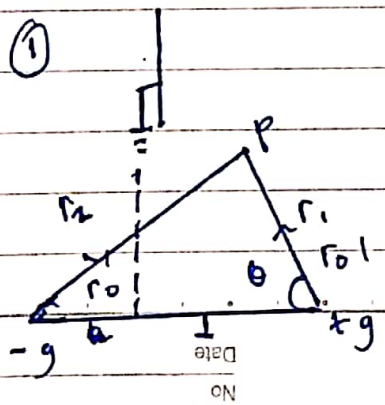
$$c = V_a + \frac{1}{k_1}\left[\frac{R_2 R_1 (V_a - V_b)}{(R_1 - R_2)}\right]$$

$$V(rp) = -\frac{1}{r_p}\frac{R_2 R_1 (V_a - V_b)}{(R_1 - R_2)} + \left[V_a + \frac{1}{R_1}\left(\frac{R_2 R_1}{R_1 - \frac{(V_a - V_b}{R_2}}\right)\right]$$

$$V(p) = \frac{R_2 - R_1 (V_a - V_b)}{R_1 - R_2}\left(-\frac{1}{H} + \frac{1}{R_1}\right) + V_a$$

※ Metode bayangan dengan

a). Muatan titik batang konduktor



$V_p = ?$ $E_A = -\frac{\partial V}{\partial r}$;

$E\theta = \frac{2V}{dr}$.

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$$V_p = \frac{1}{4\pi\varepsilon_0} + \frac{q}{r_1} + \frac{(-q)}{4\pi\varepsilon_0 r_2}$$

$$= \frac{q}{4\pi\varepsilon_0}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$$

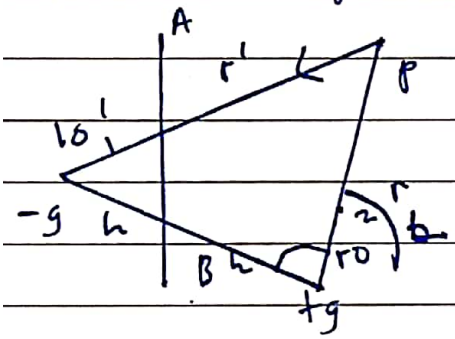
or penjumlahan biasa

$$V_p = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{r_1}\right)$$

$$V_p = \frac{q}{4\pi\varepsilon_0}\left(\frac{r' - r}{r \cdot r'}\right)$$

$$= V(AE)$$

Perbaikan gambar



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

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

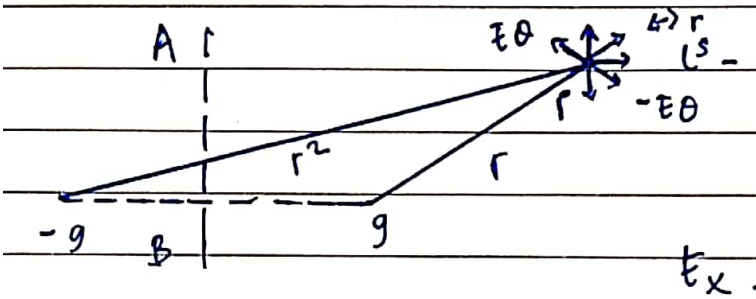
$$= \frac{\partial}{\partial r}\left(\frac{1}{r} - \frac{1}{r^2 + 4h^2 + 4h + (\cos\theta)^{1/2}}\right)$$

$$= -\frac{1}{l^2} + \frac{1}{2}\frac{(r^2 + 4h^2 + 4hr\cos\theta)^{-1/2}(2r + 4h\cos\theta)}{(r^2 + 4h^2 + 4hr\cos\theta)}$$

$$= -\frac{1}{r^2} + \frac{(r + 2h\cos\theta)}{(r^2 + 4h^2 + 4h + \cos\theta)^{3/2}}$$

$$E_r = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r^2} - \frac{(r + 2h\cos\theta)}{(r^2 + 4h^2 + 4h + \cos\theta)^{3/2}}\right]$$

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



$$E_x = E_r (\omega b - E_b \sin b)$$

$$E_z = \frac{g}{4\pi\varepsilon_0}\left[\frac{\cos\theta}{r^2} - \frac{r\cos b + 2b}{r^{13}}\right]$$

untuk setiap titik pada bidang AB, $r = r' = a$, sehingga

$$E_z(a) = \frac{g}{4\pi\varepsilon_0}\left(\frac{\cos\theta}{a^2} - \frac{a\cos\theta + 2h}{a^1}\right)$$

$$= -\frac{g}{4\pi\varepsilon_0}\left(\frac{2b}{a^2}\right) -$$

$$= -\frac{gh}{2\pi\varepsilon_0 a^3}$$

$$= \frac{1}{\varepsilon_0}\,\sigma(A)$$

$$T(A) = \frac{-gh}{2\pi a^5}$$

$\sigma(A)$ = muatan indeks luas pada pelat konduktor AB.