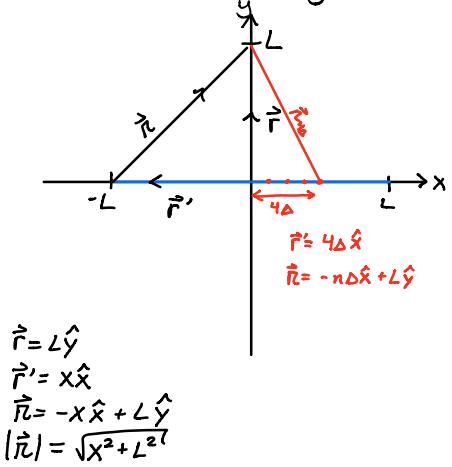


Continuous Charge Distributions



$$E = \frac{Kdq}{|r|^2} \hat{r} \quad dq \approx \lambda dl \rightarrow Q = \int \lambda dl \approx \sum_{i=1}^n \lambda(i\Delta) \approx \lambda \sum_{i=1}^n (i\Delta)$$

$$E = \frac{K\lambda_0}{l} \int_{-L}^L \frac{dl}{(x^2 + L^2)^{3/2}} \approx \lambda \sum_{i=1}^n (i\Delta)$$

$$E_x = 2K\lambda_0 \int_0^L \frac{-x dl}{(x^2 + L^2)^{3/2}} \hat{x}$$

$$E_y = 2K\lambda_0 \int_0^L \frac{L dl}{(x^2 + L^2)^{3/2}} \hat{y}$$

$$E = \frac{KQ}{n^2} \hat{r}$$

$$E_x = \int_{-L}^L \frac{K\lambda_0 (-x dl)}{(x^2 + L^2)^{3/2}}$$

$$= \lim_{n \rightarrow \infty} \sum_{i=-n}^n \frac{K\lambda_0 (x_i)(\Delta)}{(x_i^2 + L^2)^{3/2}} \quad * \quad x_i = i\Delta$$

$$= \lim_{n \rightarrow \infty} \sum_{i=-n}^n \frac{K\lambda_0 (i\Delta^2)}{((i\Delta)^2 + L^2)^{3/2}}$$

$$E_x(0, L) \approx K\lambda_0 \sum_{i=-n}^n \frac{i\Delta^2}{((i\Delta)^2 + L^2)^{3/2}}$$

$$E_y = \int_{-L}^L \frac{L dx}{(x^2 + L^2)^{3/2}}$$

$$= 2KL\lambda_0 \int_0^L \frac{dx}{(x^2 + L^2)^{3/2}}$$

$$E_{y_a} \approx 2KL\lambda_0 \sum_{i=1}^n \frac{\Delta}{((i\Delta) + L^2)^{3/2}}$$

$$E_{y_e} = \cancel{L} \frac{2K\lambda_0}{\sqrt{L^2 + L^2}} = \frac{2K\lambda_0}{\sqrt{2}L}$$

$$\sum_{i=1}^n \frac{\Delta}{((i\Delta)^2 + L^2)^{3/2}} = \frac{2K\lambda_0 L}{\sqrt{2}L^2}$$

$$\sum_{i=1}^n \frac{\Delta}{((i\Delta)^2 + L^2)^{3/2}} = \frac{1}{\sqrt{2L^4}}$$

$$\frac{\Delta}{\cancel{\Delta}} = \frac{(2L^4)^{1/2}}{\cancel{\Delta}}$$

$$1 - \frac{E_{y_a}}{E_{y_e}}$$

$$n\Delta = L$$

$$\Delta = \frac{L}{n} \rightarrow E_{y_a} = \sum_{i=1}^n \frac{\frac{L}{n}}{\left(\left(\frac{iL}{n}\right)^2 + L^2\right)^{3/2}}$$

$$dx = \lim_{n \rightarrow \infty} \frac{L}{n}$$

$$\sum_{i=1}^n \frac{L}{n} \left(\frac{i^2 L^2}{n^2} + L^2 \right)^{-3/2}$$

$$E_{y_a} = \sum_{i=1}^n \frac{\frac{2K\lambda_0}{\sqrt{2}L} \left(\left[\left(\frac{i}{n}\right)^2 + 1\right]^{-3/2}}}{\sum_{i=1}^n \frac{L}{n} \left(\left(\frac{i^2 L^2}{n^2} + L^2\right)^{-3/2}} = \sum_{i=1}^n \frac{\frac{2K\lambda_0}{\sqrt{2}L} \left(\left[\left(\frac{i}{n}\right)^2 + 1\right]^{-3/2}}}{\sum_{i=1}^n \frac{L}{n} \left(\left(\frac{i^2 L^2}{n^2} + L^2\right)^{-3/2}}$$

Excellent derivation of equations to use. Note that you could have started with the summation form (which is exact) instead of starting with the integral form (approximate) and approximating the integral (although you got the correct result).

I think that I mentioned this earlier, but I may as well emphasize it. It is important to work a bit by hand before attempting to implement in a program.

$$\frac{((\Delta)^2 + L^2)^{-\frac{1}{2}}}{(2L^4)^{\frac{1}{2}}} = \frac{E_y = \left(\sum_{i=1}^n n \lambda ((\frac{i}{n})^2 + 1)^{-\frac{1}{2}} \right)}{\frac{2K\lambda_0}{L\sqrt{2}}} \rightarrow \sum_{i=1}^n \frac{\frac{1}{\sqrt{2}}}{((\frac{i}{n})^2 + 1)^{\frac{1}{2}}}$$

where n represents the # of charges

* Exact solution by Griffiths for the electric field a distance y above the midpoint of a straight line segment

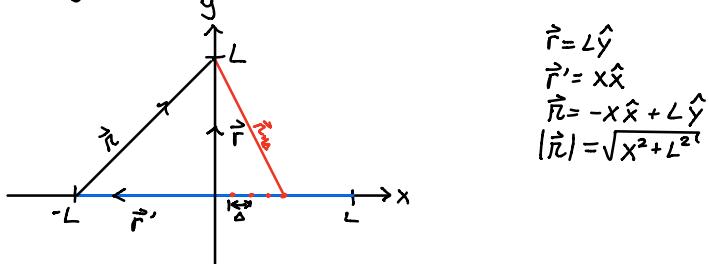
$$\vec{E}(0, y) = \frac{1}{4\pi\epsilon_0} \frac{2\lambda_0 L}{y\sqrt{y^2 + L^2}} \hat{y} \quad * K = 4\pi\epsilon_0$$

if $y = L$ then :

$$E(0, L) = \frac{2\lambda_0 K L}{L\sqrt{L^2 + L^2}}$$

$$\vec{E}_y(0, L) = \frac{2K\lambda_0}{L\sqrt{2}} \hat{y}$$

\vec{E} is originally calculated using Coulombs Law :



$$\vec{E} = \frac{Kq}{|r|^2} \hat{r}$$

$$Q = \int dq = \int \lambda_0 dl \quad * dl = dx$$

$$\therefore Q = \int_{-L}^L \lambda dx$$

$$\vec{E} = K\lambda_0 \int_{-L}^L \frac{dx (-x\hat{x} + L\hat{y})}{(x^2 + L^2)^{\frac{3}{2}}}$$

$$E_y = K\lambda_0 L \int_{-L}^L \frac{dx L}{(x^2 + L^2)^{\frac{3}{2}}} \quad * \text{an even function}$$

$$E_y = 2K\lambda_0 L \int_0^L \frac{dx}{(x^2 + L^2)^{\frac{3}{2}}}$$

$$E_y = 2K\lambda_0 L \lim_{N \rightarrow \infty} \sum_{n=0}^N \frac{\Delta}{((n\Delta)^2 + L^2)^{\frac{3}{2}}} \quad * X_i = n\Delta$$

* where N represents total amount of charges of one side
 Δ represents distance between charges

$$x_N = N\Delta = L$$

$\Delta = \frac{L}{N}$ *as the # of charges increases, distance between charges decreases

$$\begin{aligned} E_{Y_a} &= 2K\lambda_0 L \sum_{n=1}^N \frac{\frac{L}{N}}{(n(\frac{L}{N})^2 + L^2)^{3/2}} \quad * \Delta = \frac{L}{N} \\ &= 2K\lambda_0 L \sum_{n=1}^N \frac{L}{N(L^2((\frac{n}{N})^2 + 1))^{3/2}} \\ &= 2K\lambda_0 \sum_{n=1}^N \frac{1}{NL^3((\frac{n}{N})^2 + 1)^{3/2}} \\ &= \frac{2K\lambda_0}{L} \sum_{n=1}^N \frac{1}{N((\frac{n}{N})^2 + 1)^{3/2}} \end{aligned}$$

Requirement :

$$\left| \frac{E_{Y_e}(0,L) - E_{Y_a}(0,L)}{E_{Y_e}(0,L)} \right| \leq 0.01$$

$$= \left| 1 - \frac{E_{Y_a}(0,L)}{E_{Y_e}(0,L)} \right| \leq 0.01$$

* $E_{Y_a}(0,L)$ will have a finite N such that :

$$E_{Y_e}(0,L) = \frac{2K\lambda_0}{L\sqrt{2}}$$

$$E_{Y_a}(0,L) = \frac{2K\lambda_0}{L} \sum_{n=1}^N \frac{1}{N((\frac{n}{N})^2 + 1)^{3/2}}$$

$$\frac{E_{Y_a}(0,L)}{E_{Y_e}(0,L)} = \sum_{n=1}^N \frac{\sqrt{2}}{N((\frac{n}{N})^2 + 1)^{3/2}}$$

$$\therefore \left| \frac{E_{Y_e}(0,L) - E_{Y_a}(0,L)}{E_{Y_e}(0,L)} \right| \leq 0.01$$

$$\Rightarrow \left| 1 - \sum_{n=1}^N \frac{\sqrt{2}}{N((\frac{n}{N})^2 + 1)^{3/2}} \right| \leq 0.01$$

to find value, must test different N values

where $\Delta = \frac{L}{N}$ as Δ decreases approximation becomes closer to exact value

Such that a table is created.

N	$\Delta = \frac{L}{N}$	$\left \frac{E_{Y_e} - E_{Y_a}}{E_{Y_e}} \right $
1	$\frac{L}{1}$	0.99
2	$\frac{L}{2}$	0.28
3	$\frac{L}{3}$	0.013
⋮	⋮	⋮

$$Q = \lambda_0 L = N \Delta \lambda_0$$

$$\sum_{n=1}^N N \left(\left(\frac{n}{N} \right)^2 + 1 \right)^{\frac{3}{2}}$$

$$E_Y = \frac{2K\lambda_0}{\sqrt{2}L}$$

$$E_{Y_a} = 2K\lambda_0 L \lim_{N \rightarrow \infty} \sum_{i=0}^n \frac{\Delta}{((\chi_i)^2 + L^2)}$$

$$E_{Y_a} = 2K\lambda_0 L \sum_{i=0}^n \frac{\Delta}{((\Delta i)^2 + L^2)^{\frac{3}{2}}}$$

$$\frac{E_{Y_a}}{E_{Y_e}} = \frac{2K\lambda_0 L \sum \frac{\Delta}{((\Delta i)^2 + L^2)^{\frac{3}{2}}}}{\frac{2K\lambda_0}{\sqrt{2}L}}$$

$$= \sqrt{2} L^2 \sum_{i=0}^n \frac{\Delta}{((\Delta i)^2 + L^2)^{\frac{3}{2}}}$$

$$= \sqrt{2} L^2 \sum_{i=0}^n \frac{\Delta}{L^2 \left(\left(\frac{\Delta i}{L} \right)^2 + 1 \right)^{\frac{3}{2}}}$$

$$= \sqrt{2} L^2 \sum \frac{\Delta}{L^3 \left(\left(\frac{\Delta i}{L} \right)^2 + 1 \right)^{\frac{3}{2}}} \quad \Delta = \frac{L}{N}$$

$$= \frac{\sqrt{2}}{L} \sum_{i=0}^N \frac{1}{N \left(\left(\frac{i}{N} \right)^2 + 1 \right)^{\frac{3}{2}}}$$

$$= \sqrt{2} \sum_{i=1}^N \frac{1}{N \left(\left(\frac{i}{N} \right)^2 + 1 \right)^{\frac{3}{2}}}$$

$$\frac{E_{Y_a}}{E_{Y_e}} = \sum_{i=1}^N \frac{\sqrt{2}}{N \left(\left(\frac{i}{N} \right)^2 + 1 \right)^{\frac{3}{2}}}$$

$$\lambda_0 = \frac{Nq}{2L}$$

$$2K\lambda_0 L \sum_{i=0}^n \frac{\Delta}{((\Delta i)^2 + L^2)^{3/2}}$$

$$E_{Y_i} = 2K\lambda L \sum \frac{\Delta}{((\Delta i)^2 + L^2)^{3/2}} \\ = \frac{2K\lambda Nq}{2L}$$

$$E_{Y_a} = Kq \sum \frac{\Delta N}{((\Delta i)^2 + L^2)^{3/2}}$$

$$E_{Y_c} = \frac{2K\lambda}{\sqrt{2}^2 L} = \frac{2K Nq}{2L^2 \sqrt{2}^2} = \frac{KNq}{\sqrt{2}^2 L^2}$$

$$\frac{E_{Y_a}}{E_{Y_c}} = \sum_{i=1}^N \frac{\Delta \sqrt{2}^2 L^2}{((\Delta i)^2 + L^2)^{3/2}} = \frac{\frac{2L}{N} \sqrt{2}^2 L^2}{((\frac{2L}{N})^2 + L^2)^{3/2}}$$

$$E_{Y_a} = \sum_{i=1}^N \frac{2Kq}{d_i^2} = \sum_{i=0}^N \frac{2Kq}{(x_i^2 + L^2)^{3/2}} = \sum_{i=0}^N \frac{2Kq}{((x_i)^2 + L^2)^{3/2}} \quad \lambda = \frac{Nq}{2L} \\ \lambda = \frac{\text{charge}}{\text{Length}} = \frac{Nq}{2L} \mid E_{Y_a} \Rightarrow \sum_{i=0}^N \frac{2Kq}{((\Delta i)^2 + L^2)^{3/2}} \quad \alpha\Delta = \frac{N}{2L} \\ E_{Y_c} = \frac{\sqrt{2}^2 K \lambda_0}{L} = \frac{\sqrt{2}^2 K N q}{2L^2} \cdot \frac{\sqrt{2}^2}{\sqrt{2}^2} = \frac{2 K N q}{2L^2 L^2} = \frac{KNq}{\sqrt{2}^2 L^2}$$

$$\frac{E_{Y_a}}{E_{Y_c}} = \sum_{i=0}^N \frac{2Kq}{((\frac{x_i}{L})^2 + L^2)^{3/2}} \quad \frac{\sqrt{2}^2 L^2}{KNq}$$

$$= \sum_{i=0}^N \frac{2\sqrt{2}^2 L^2}{N ((\frac{x_i}{L})^2 + L^2)^{3/2}}$$

$$= \sum_{i=0}^N \frac{2\sqrt{2}^2 L^2}{N ((\frac{\Delta i}{L})^2 + 1)^{3/2}}$$

$$= \sum_{i=0}^N \frac{2\sqrt{2}^2}{N L ((\frac{\Delta i}{L})^2 + 1)^{3/2}} \quad x_i = \Delta i \quad \lambda = \frac{Nq}{2L} \rightarrow dq = \lambda dL$$

$$= \sum_{i=0}^N \frac{2\sqrt{2}^2}{N L ((\frac{2}{N} \cdot \frac{i}{L})^2 + 1)^{3/2}} \quad \Delta = \frac{N}{2L} \quad \Rightarrow q = \lambda \Delta \quad N = \Delta 2L$$

$$X_N = L = \alpha N \quad \therefore \alpha = \frac{L}{N} \\ X_i = \alpha i \rightarrow X_q = \alpha l$$

$$\sum_{i=0}^N \frac{4}{\sqrt{2}^2 N L ((\frac{N i}{2L})^2 + 1)^{3/2}} \quad \Delta = \frac{N}{2L} \\ \frac{4}{\sqrt{2}^2 N L ((\frac{N i}{2L})^2 + 1)^{3/2}}$$

$$E_{Y_a} = \sum_{i=0}^N \frac{2Kq}{((\frac{N i}{2L})^2 + L^2)^{3/2}} \\ = \sum_{i=0}^N \frac{2Kq}{((\frac{N^2 i^2}{4L^2}) + L^2)^{3/2}}$$

$$\sqrt{2}^2 K \lambda \quad \sqrt{2}^2 K N q \quad \sqrt{2}^2 K N q \quad \rightarrow \quad \dots \quad \dots$$

$$E_{y_c} = \frac{1}{L} = \frac{1}{L} \frac{2L}{2L} = \frac{1}{2L^2} \frac{K}{\sqrt{2}} = \frac{K \cdot K N q}{2L^2} = \frac{K N q}{\sqrt{2} L^2}$$

$$\frac{E_{y_c}}{E_y} = \sum_{i=0}^N \frac{2Kq}{L((\frac{i}{N})^2 + 1)^{3/2}} \frac{\sqrt{2} L^2}{KNq} \quad E_{y_c} = \frac{\sqrt{2} K}{\Delta L}$$

$$= \sum_{i=0}^N \frac{2\sqrt{2}}{NL((\frac{i}{N})^2 + 1)^{3/2}} \quad \lambda = \frac{Nq}{2L} = \frac{q}{\Delta}$$

$$\Delta = \frac{q}{\lambda} = \frac{2L}{N} \quad \Delta = \frac{q}{\lambda}$$

$$N = \frac{2L}{\Delta} = \sum_{i=0}^N \frac{2^{3/2}}{LN((\frac{i}{N})^2 + 1)^{3/2}}$$

$$= \sum_{i=0}^N \frac{1}{LN} \left(\frac{2}{(\frac{i}{N})^2 + 1} \right)^{3/2}$$

$$L = \frac{\Delta N}{2} = \sum_{i=0}^N \frac{2}{N^2 \Delta} \left(\frac{2}{(\frac{i}{N})^2 + 1} \right)^{3/2}$$

$$N = \frac{2L}{\Delta}$$

$$\Delta = \frac{2L}{N}$$

$$L = \frac{N\Delta}{2}$$

Coulomb's Law :

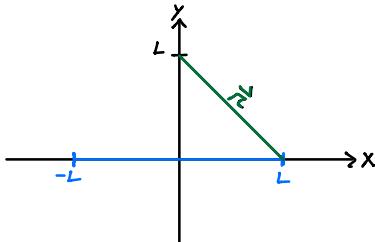
$$\vec{E} = \frac{Kq}{r^2} \hat{r}$$

When dealing with N charges

$$\vec{E}_i = \frac{Kq_i}{r_i^3} \hat{r}_i$$

Now let $q_i = q$ for all i and distributed evenly across a line of $2L$

Where the \vec{E} field is to be calculated L above the midpoint



Using Griffiths pg. 64

$$\vec{E}(0, y) = \frac{1}{4\pi\epsilon_0} \frac{2\lambda_0 L}{y\sqrt{y^2 + L^2}} \hat{y} \quad * K = \frac{1}{4\pi\epsilon_0}$$

when a distance L from the midpoint:

$$\vec{E}(0, L) = \frac{2K\lambda_0}{L\sqrt{L^2 + L^2}} \hat{y}$$

$$= \frac{2K\lambda_0}{L\sqrt{2}} \hat{y}$$

$$E_y(0, L) = \frac{\sqrt{2} K \lambda_0}{L} \quad * \text{exact solution}$$

For approximate solution N charges exist

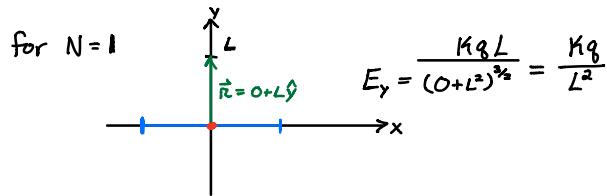
$$* \lambda = \frac{\text{Total charge}}{\text{Total Length}}$$

$$\lambda = \frac{Nq}{2L}$$

$$E_y(0, L) = \frac{\sqrt{2} K}{L} \frac{Nq}{2L} \left(\frac{\sqrt{2}}{\sqrt{2}} \right)$$

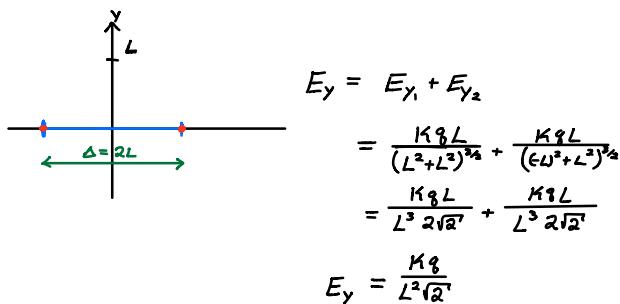
$$E_y(0, L) = \frac{KNq}{\sqrt{2} L^2}$$

For N charges spread evenly over $2L$:

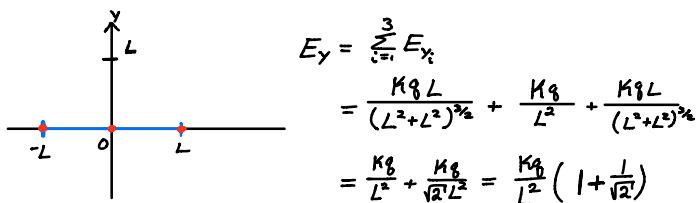


* where $\vec{r} = L\hat{y}$

for $N=2$



for $N=3$



for $N=4$

$$E_Y = \sum_{i=1}^4 E_{Y_i} = \frac{2KqL}{(L^2 + (\frac{L}{3})^2)^{3/2}} + \frac{2KqL}{(L^2 + L^2)^{3/2}}$$

$$= \frac{2Kq}{L^2 (1 + (\frac{1}{3})^2)^{3/2}} + \frac{Kq}{L^2 \sqrt{2}}$$

$$= \frac{Kq}{L^2 \sqrt{2}} + \frac{Kq}{L^2} \frac{2}{(\frac{10}{9})^{3/2}}$$

$$= \frac{Kq}{L^2} \left(\frac{1}{\sqrt{2}} + \left(\frac{2}{9} \right)^{3/2} \right)$$

$$E_{Y_i} = \frac{KqL}{(\chi_i^2 + L^2)^{3/2}}$$

$$\chi_i = x_0 + i\Delta \quad \text{where } i=1, 2, \dots, N-1$$

$$x_0 = \begin{cases} \frac{\Delta}{2} & \text{for } N=\text{even} \\ 0 & \text{for } N=\text{odd} \end{cases}$$

$$\therefore E_{Y_a} = \sum_{i=0}^{\frac{N-1}{2}} \frac{2KqL}{((x_0 + i\Delta)^2 + L^2)^{3/2}} \quad \Delta = \frac{2L}{(N-1)}$$

$$= \sum_{i=0}^{\frac{N-1}{2}} \frac{2KqL}{\left(\left(\frac{x_0 + i\Delta}{L} \right)^2 + 1 \right)^{3/2}}$$

for $N=\text{odd}$ and $N>1$

$$E_Y = E_o + \sum_{i=1}^{\frac{N-1}{2}} \frac{2KqL}{\left(L^2 \left[\left(\frac{x_0 + i\Delta}{L} \right)^2 + 1 \right] \right)^{3/2}}$$

$$E_{Y_a} = \frac{Kq}{L^2} + \sum_{i=1}^{\frac{N-1}{2}} \frac{2Kq}{L^2 \left(\left[\frac{x_0 + i\Delta}{L} \right]^2 + 1 \right)^{3/2}} \quad * \quad x_0 = 0, \Delta = \frac{2L}{(N-1)}$$

$$E_{Y_a} = \frac{Kq}{L^2} \left(1 + \sum_{i=1}^{\frac{N-1}{2}} \frac{2}{\left[\left(\frac{2i}{N-1} \right)^2 + 1 \right]^{3/2}} \right)$$

$$E_{Y_a} = \frac{Kq}{L^2} \left(1 + \sum_{i=1}^{\frac{N-1}{2}} \frac{2}{\left[\left(\frac{2i}{N-1} \right)^2 + 1 \right]^{3/2}} \right) \quad E_{Y_e}(0, L) = \frac{Kq}{\sqrt{2} L^2}$$

Let $N=3$

$$E_{Y_a} = \frac{Kq}{L^2} + \frac{2Kq}{L^2} \left(\frac{1}{\left[\left(\frac{2}{2}(1) \right)^2 + 1 \right]^{3/2}} \right)$$

$$= \frac{Kq}{L^2} + \frac{2Kq}{L^2} \frac{1}{2\sqrt{2}}$$

$$= \frac{Kq}{L^2} + \frac{Kq}{L^2 \sqrt{2}} = \frac{Kq}{L^2} \left(1 + \frac{1}{\sqrt{2}} \right)$$

For $N=\text{even}$

$$E_{Y_a} = \sum_{i=0}^{\frac{N}{2}} \frac{2Kq}{L^2 \left(\left(\frac{x_0 + i\Delta}{L} \right)^2 + 1 \right)^{3/2}} = \frac{2Kq}{L^2} \sum_{i=0}^{\frac{(N-2)}{2}} \frac{1}{\left(\left(\frac{\Delta}{2} + i\Delta \right)^2 + 1 \right)^{3/2}} \quad \Delta = \frac{2L}{N-1} \rightarrow \frac{\Delta}{L} = \frac{2}{N-1}$$

$$= \frac{2Kq}{L^2} \sum_{i=0}^{\frac{(N-2)}{2}} \frac{1}{\left(\left(\frac{1}{2} + i \right)^2 + 1 \right)^{3/2}}$$

def N=4

$$\begin{aligned}
 &= \frac{2Kg}{L^2} \sum_{i=0}^{\frac{1}{2}} \frac{1}{\left(\left(\frac{2}{3}\right)^2 \left(\frac{1}{2}+i\right)^2 + 1\right)^{\frac{3}{2}}} \\
 &= \frac{2Kg}{L^2} \left(\frac{1}{\left(\frac{1}{9}\left(\frac{1}{4}\right) + 1\right)^{\frac{3}{2}}} + \frac{1}{\left(\left(\frac{2}{3}\right)^2 \left(\frac{3}{2}\right)^2 + 1\right)^{\frac{3}{2}}} \right) \\
 &= \frac{2Kg}{L^2} \left[\left(\frac{1}{9} + 1\right)^{-\frac{3}{2}} + \left(\left(\frac{4}{9}\right)\left(\frac{9}{4}\right) + 1\right)^{-\frac{3}{2}} \right] \\
 &= \frac{2Kg}{L^2} \left[\frac{1}{\left(\frac{10}{9}\right)^{\frac{3}{2}}} + \frac{1}{(2)^{\frac{3}{2}}} \right] \\
 &= \frac{Kg}{L^2} \left[\frac{2}{\left(\frac{10}{9}\right)^{\frac{3}{2}}} + \frac{1}{\sqrt{2}} \right] \quad * \text{ works}
 \end{aligned}$$

$$\therefore E_{\gamma_a} = \begin{cases} \frac{Kg}{L^2} \left[\sum_{i=0}^{\frac{N-1}{2}} \frac{2}{\left(\frac{1}{N-1}(1+2i)^2 + 1\right)^{\frac{3}{2}}} \right] & \text{for } N = \text{even} \\ \frac{Kg}{L^2} \left(1 + \sum_{i=1}^{\frac{N-1}{2}} \frac{2}{\left[\left(\frac{2i}{N-1}\right)^2 + 1\right]^{\frac{3}{2}}} \right) & \text{for } N = \text{odd} \end{cases}$$

$$* E_{\gamma_e}(0, L) = \frac{KNg}{\sqrt{2}L^2}$$

$$\frac{E_K}{E_{\gamma_e}} = \frac{\sqrt{2}}{N} \sum_l (\text{odd or even})$$

$$0.01 \geq |1 - \frac{E_{\gamma_a}}{E_{\gamma_e}}| ?$$

* determine N such that the above ratio holds true

$$\Delta = \frac{2}{(N-1)} L$$

$$\Delta = \frac{2L}{(N-1)}$$

* found N = 51

$$\therefore \Delta = \frac{1}{50} \cdot 2L$$

$$\Delta = 0.04L$$

For N=1:

$$E_{Y_0} = \frac{Kq}{L^2}$$

$$\left|1 - \frac{E_{Y_0}}{E_{Y_e}}\right| = |1 - \sqrt{2}| = 0.4142$$

For N=2:

$$E_{Y_0} = \frac{Kq}{\sqrt{2}^1 L^2}$$

$$E_{Y_e} = \frac{KNq}{\sqrt{2}^1 L^2} = \frac{2Kq}{\sqrt{2}^1 L^2} = \frac{\sqrt{2}^1 Kq}{L^2}$$

$$\left|1 - \frac{E_{Y_0}}{E_{Y_e}}\right| = 0.5$$