Calculate the potential due to a charged thick disk of radius a along the symmetry axis.

$$V\left(\vec{r}_p\right)=\int_{\substack{\text{all}\\ q}}\frac{kdq_i}{\left|\vec{r}_{ip}\right|}$$

coordinates:

$$\vec{r}_i=x_i\hat{x}+y_i\hat{y}:\vec{r}_p=z_p\hat{z}:\vec{r}_{ip}=-x_i\hat{x}-y_i\hat{y}+z_p\hat{z}:\left|\vec{r}_{ip}\right|=\sqrt{x_i^2+y_i^2+z_p^2}=\sqrt{s_i^2+z_p^2}$$

dq:

$$dq_i=\rho s ds\, d\varphi\, dz_i$$

Then:

$$V\left(\vec{r}_p\right)=\int_{z=0}^{z=h}\int_{s=0}^{s=a}\int_{\varphi=0}^{\varphi=2\pi}\frac{ksds\,d\varphi dz_i}{\sqrt{s^2+\left(z_p-z_i\right)^2}}=2\pi k\rho\int_{z_i=0}^{z_i=h}\left\{\sqrt{a^2+\left(z_p-z_i\right)^2}-\sqrt{\left(z_p-z_i\right)^2}\right\}dz_i$$

Consider only (here) the case for $z_p>z_i$

$$V\left(\vec{r}_p\right)=2\pi k\rho\int_{z_i=0}^{z_i=h}\left\{\sqrt{a^2+\left(z_p-z_i\right)^2}-\left(z_p-z_i\right)\right\}dz_i$$

It's probably easiest to see this by changing variables:

$$\text{let }u\equiv z_p-z_i:du=-dz_i:z_i=0\Rightarrow u=z_p:z_i=h\Rightarrow u=z_p-h$$

$$V\left(\vec{r}_p\right)=2\pi k\rho\left[-\int_{u=z_p}^{u=z_p-h}\sqrt{a^2+u^2}\,du+\int_{u=z_p}^{u=z_p-h}udu\right]=$$

$$=\left\{2\pi k\rho\left[-\tfrac{1}{2}\left(\ln a^2\left[u+\sqrt{a^2+u^2}\right]+u\sqrt{a^2+u^2}\right)\right]+2\pi k\rho\tfrac{u^2}{2}\right\}\Bigg|_{u=z_p}^{u=z_p-h}$$

The unbeautiful result is:

$$V\left(\vec{r}_p\right)=\pi k\rho\left\{\left[\left(\ln\frac{z_p+\sqrt{a^2+z_p^2}}{z_p-h+\sqrt{a^2+\left(z_p-h\right)^2}}+z_p\sqrt{a^2+z_p^2}-\left(z_p-h\right)\sqrt{a^2+\left(z_p-h\right)^2}\right)\right]+\left[-2z_ph+h^2\right]\right\}$$