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

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

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:

$$dq_i=\sigma s\,ds\,d\varphi$$

Then:

$$V\left(\vec{r}_p\right)=\int_{s=0}^{s=a}\int_{\varphi=0}^{\varphi=2\pi}\frac{k s\,ds\,d\varphi}{\sqrt{s^2+z_p^2}}=\int_{s=0}^{a}\frac{2\pi\sigma k}{\sqrt{s^2+z_p^2}}\,s\,ds=2\pi k\sigma\sqrt{s^2+z_p^2}\Big|_0^a=2\pi k\sigma\left\{\sqrt{a^2+z_p^2}-z_p\right\}$$

In the limit of large z, this should look like a point charge potential:

$$\sqrt{a^2+z_p^2}=z_p\sqrt{1+\left(\frac{a}{z_p}\right)^2}\approx z_p\left\{1+\frac{1}{2}\left(\frac{a}{z_p}\right)^2\right\}\Rightarrow V\left(\vec{r}_p\right)\approx 2\pi k\sigma\left\{\frac{a^2}{2z_p}\right\}\approx k\,\frac{\pi a^2}{z_p}=k\,\frac{Q}{z_p}$$