(d) Potential due to a charged disk:

Start from ring - potential due to a ring of charge is: $V = \frac{Q}{4pe_0\sqrt{R^2 + x^2}}$

Integrate over R. to get:

$$dV = \frac{Q}{4pe_0\sqrt{r^2 + x^2}} = \frac{2p\,s\,r dr}{4pe_0\sqrt{r^2 + x^2}}$$

OR

$V = \frac{sr}{2e_0}\int_0^R \frac{rdr}{\sqrt{r^2 + x^2}} = \frac{sr}{2e_0}(\sqrt{R^2 + x^2} - x)$ for disk. Therefore,

$\frac{\partial V}{\partial x} = \frac{s}{2e_0}\left(\frac{2x}{\sqrt{R^2 + x^2}} - 1\right)$ When R$\rightarrow\infty$ we recover:

$$E_x = -\frac{\partial V}{\partial x} = \frac{s}{2e_0}$$