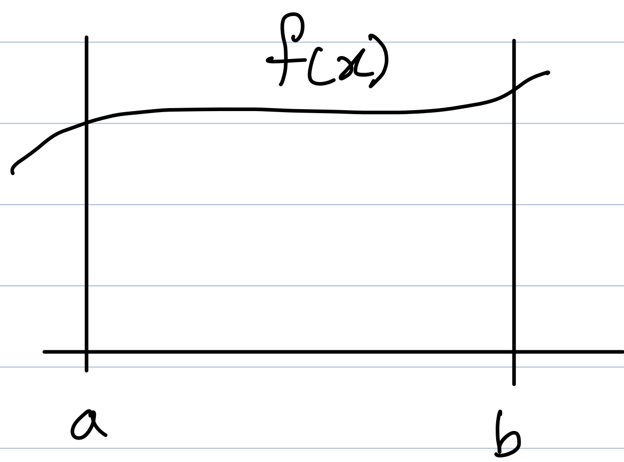
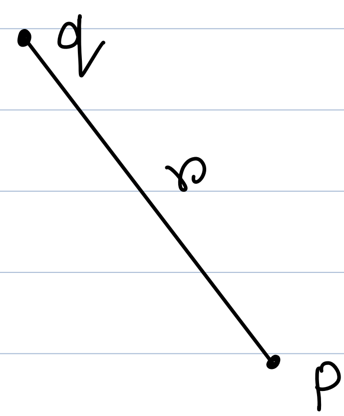
$$E = \frac{1}{4\pi\epsilon_0}\frac{qr}{R^3} \quad , r \leq R$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} \quad , r \geq R$$

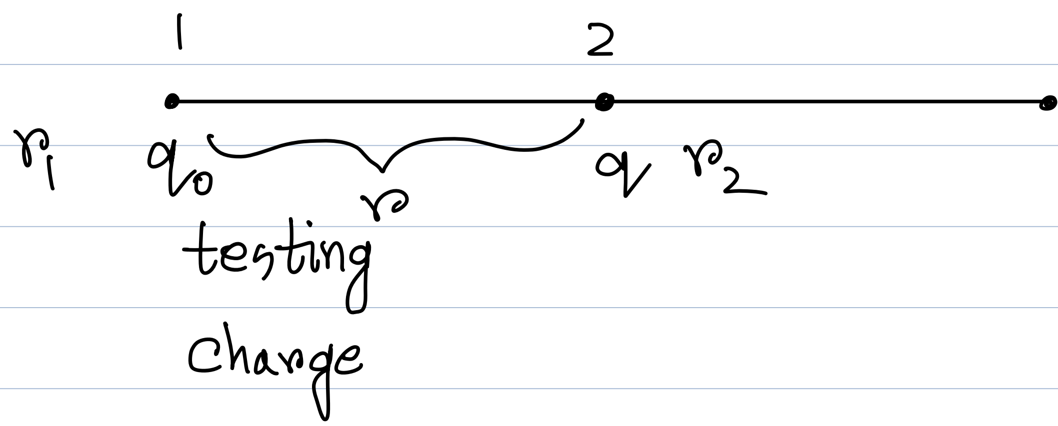


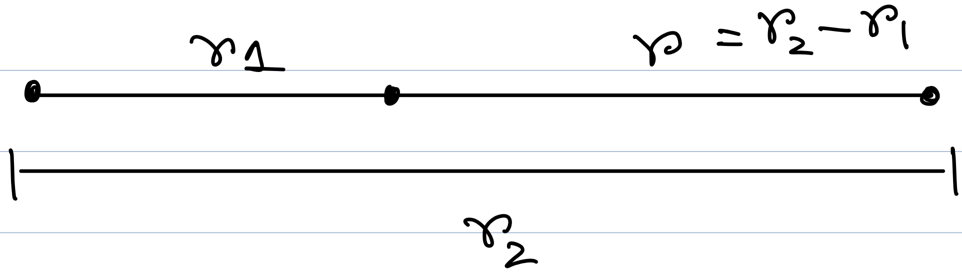

```
def f(x):
    f = x^2
    return f
def Int(f, a, b, N):
```



$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

$$U = \frac{1}{4\pi\epsilon_0}\frac{q q_0}{r}$$

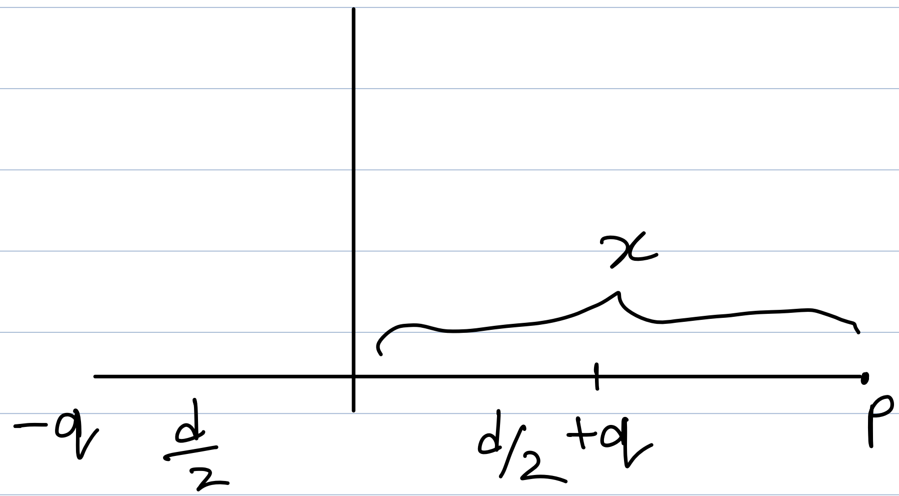




$$V_2 - V_1 = \frac{1}{4\pi\epsilon_0} q q_0 \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

q_1 $\quad$ q_2 $\quad$ q_n

$$V_{total} = V_1 + V_2 + \cdots + V_n$$



$$V_{-q} = \frac{1}{4\pi\epsilon_0} \frac{-q}{\left(x+\frac{d}{2}\right)}$$

$$V_{+q} = \frac{1}{4\pi\epsilon_0} \frac{q}{\left(x-\frac{d}{2}\right)}$$

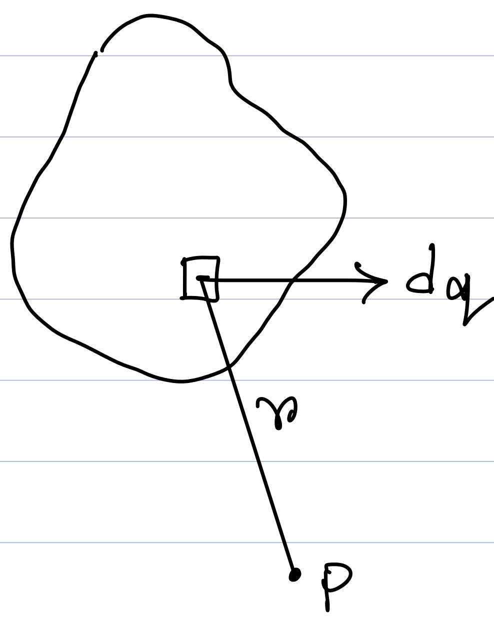
$$V_{total} = \frac{1}{4\pi\epsilon_0} q \left[-\frac{1}{x+d/2} + \frac{1}{x-d/2} \right]$$

$$= \frac{qd}{4\pi\epsilon_0} \frac{1}{x^2 - d^2/4}$$

if $x \gg d$

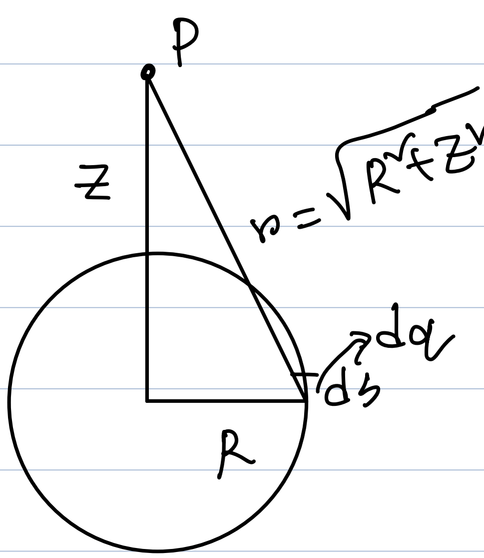
$$V_{total} = \frac{p}{4\pi\epsilon_0 x^2 \left(1 - \underbrace{\frac{d^2}{4x^2}}_{\to 0}\right)}$$

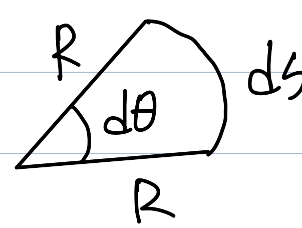
$$= \frac{p}{4\pi\epsilon_0 x^2}$$



$$dV = \frac{1}{4\pi\epsilon_0} \frac{dq}{r}$$

$$V = \int \frac{1}{4\pi\epsilon_0} \frac{dq}{r}$$





$$ds = R\,d\theta$$

$$\lambda = \frac{dq}{ds}$$

$$= \frac{dq}{R\,d\theta}$$

$$\Rightarrow dq = \lambda R\,d\theta$$

$$dV = \frac{1}{4\pi\epsilon_0} \frac{\lambda R\, d\theta}{\sqrt{R^2+z^2}}$$

$$V = \int dV$$

$$= \frac{1}{4\pi\epsilon_0} \frac{\lambda R}{\sqrt{R^2+z^2}} \int_0^{2\pi} d\theta$$

$$= \frac{2\pi\lambda R}{4\pi\epsilon_0\sqrt{R^2+z^2}}$$

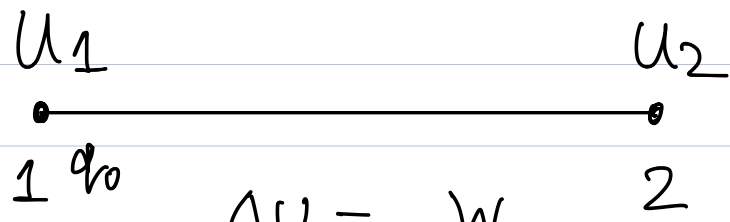
$$\lambda = \frac{q}{2\pi R}$$

$$q = 2\pi R\lambda$$

$$= \frac{q}{4\pi\epsilon_0\sqrt{R^2+z^2}}$$

$V = ?$ When $z = 0$?

$V = ?$ When $z \gg R$?



$$\Delta U = -W$$

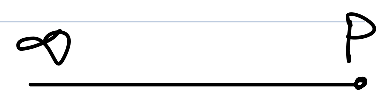
$$\Rightarrow \Delta V = \frac{\Delta U}{q_0}$$

$$\Rightarrow \Delta V\, q_0 = -W$$

$$= -\int_1^2 \vec{F} \cdot \vec{dr}$$

$$\Rightarrow q_0 \Delta V = -\int_1^2 q_0 \vec{E} \cdot \vec{dr}$$

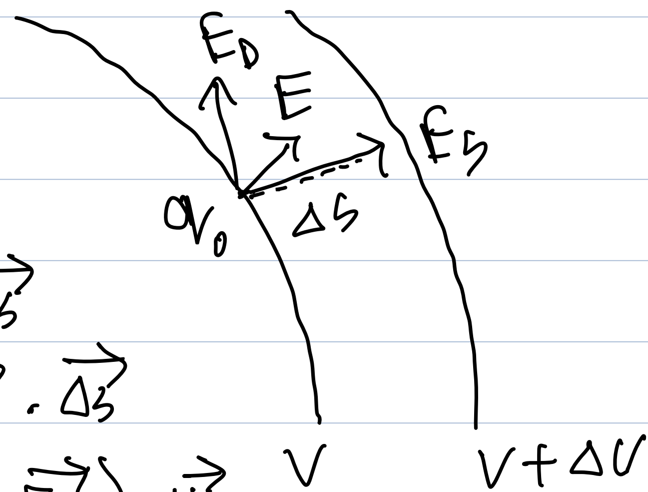
$$\Rightarrow \Delta V = -\int_1^2 \vec{E} \cdot \vec{dr}$$



$$\Rightarrow V_2 - V_1 = -\int_1^2 \vec{E} \cdot \vec{dr}$$

$$\Rightarrow V_P - \cancelto{0}{V_\infty} = -\int_\infty^P \vec{E} \cdot \vec{dr}$$

$$\boxed{\Rightarrow V_P = -\int_\infty^P \vec{E} \cdot \vec{dr}}$$



$$\Rightarrow q_0 \Delta V = -W$$

$$= -\vec{F} \cdot \vec{\Delta s}$$

$$= -q_0 \vec{E} \cdot \vec{\Delta s}$$

$$\Delta V = -(\vec{E_s} + \vec{E_p}) \cdot \vec{\Delta s}$$

$$= -\vec{E_p} \cdot \vec{\Delta s} - \vec{E_s} \cdot \vec{\Delta s}$$

$$\Delta V = -E_s \Delta s$$

$$E_s = \frac{-\Delta V}{\Delta s}$$

$$E_s = -\lim_{\Delta s \to 0} \frac{\Delta V}{\Delta s}$$

$$= -\frac{\partial V}{\partial s}$$

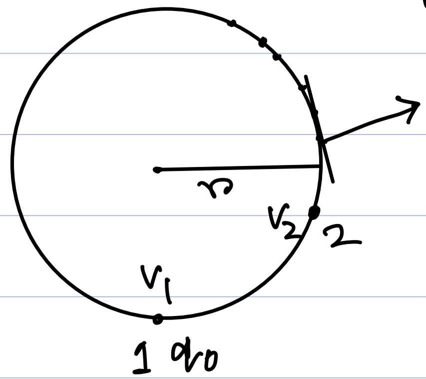
$$E_y = \frac{-\partial V}{\partial y}$$

$$E_z = \frac{-\partial V}{\partial z}$$

$V = \text{constant}$

$$\Rightarrow \frac{1}{4\pi\epsilon_0}\frac{q}{r} = \text{constant}$$

$r = \text{constant}$



$\Delta V = V_2 - V_1 = 0$

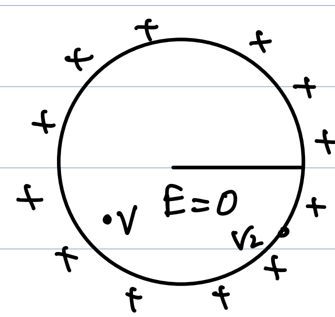
$\Delta U = q_0 \Delta V = 0 = W$

$$\Delta V = -\int \vec{E} \, d\vec{r}$$

$$\Rightarrow 0 = \vec{E} \cdot \Delta\vec{r}$$

$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R} \; ; r \leq R$

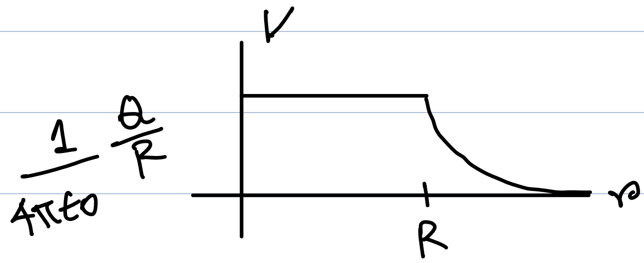
$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r} \; ; r \geq R$



$\Delta V = 0$

$\Rightarrow V_2 - V_1 = 0$

$\Rightarrow V_2 = V_1$


V
$\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$
R
r