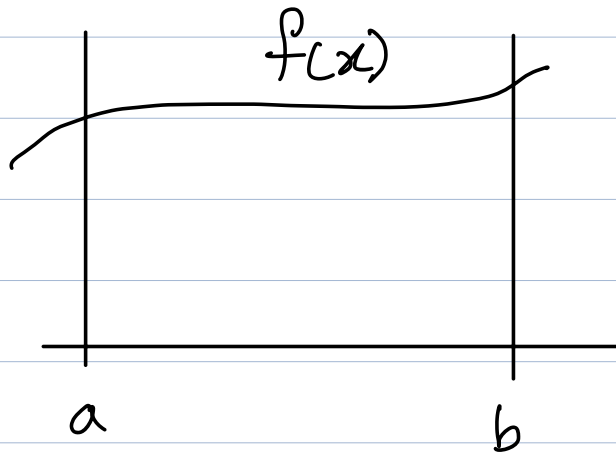


$$E = \frac{1}{4\pi\epsilon_0} \frac{qr}{R^3}, \quad r \leq R$$

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

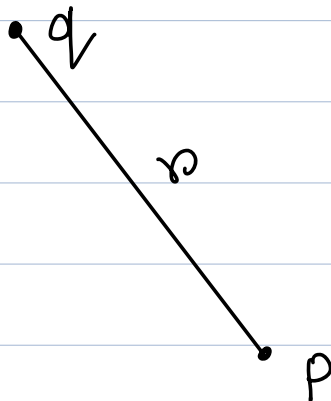


def f(x):

$f = x^2$

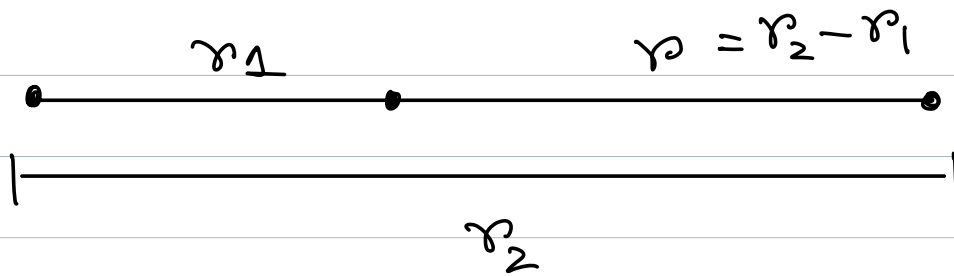
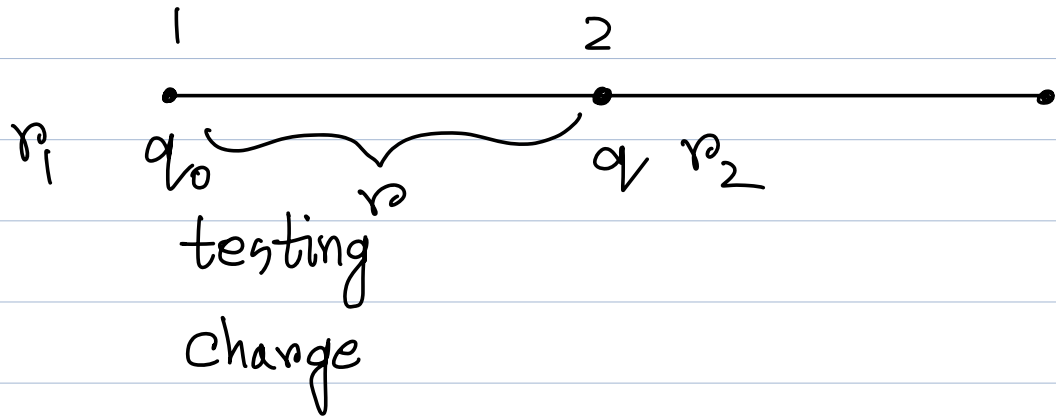
return f

def Int(f, a, b, N):



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

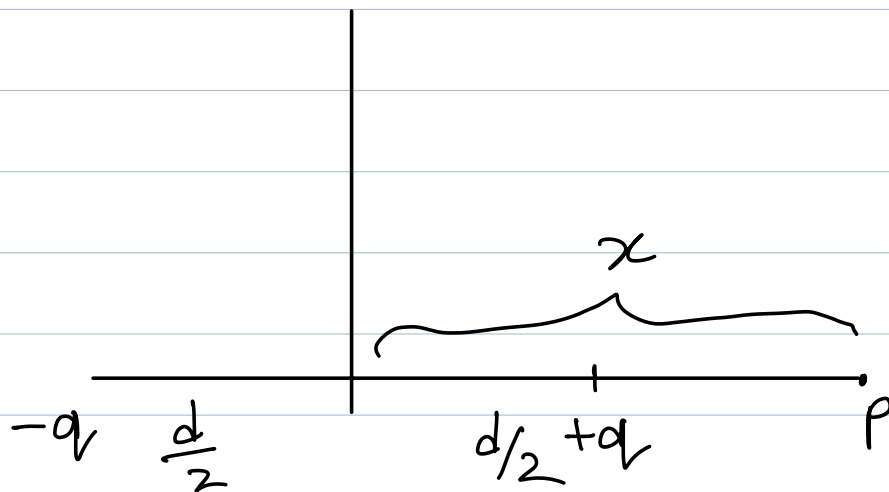
$$U = \frac{1}{4\pi\epsilon_0} \frac{qq_0}{r}$$



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

$$q_1 \quad q_2 \quad q_n$$

$$V_{\text{total}} = V_1 + V_2 + \dots + V_n$$



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

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

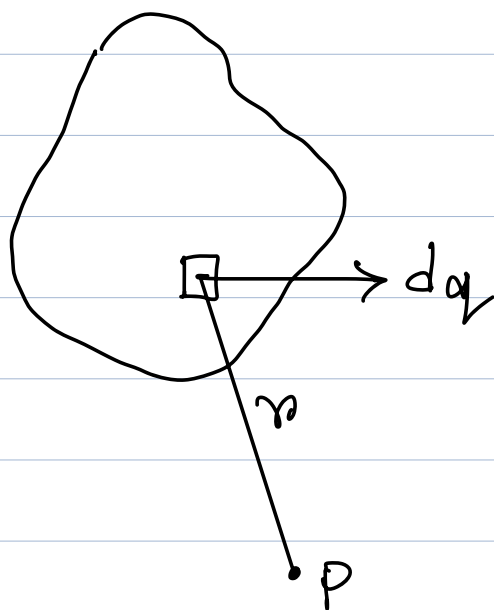
$$V_{\text{total}} = \frac{1}{4\pi\epsilon_0} q \left[ -\frac{1}{x + d/2} + \frac{1}{x - d/2} \right]$$

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

if  $x \gg d$

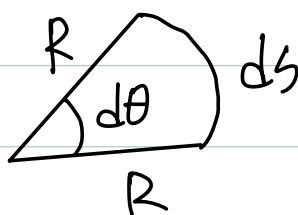
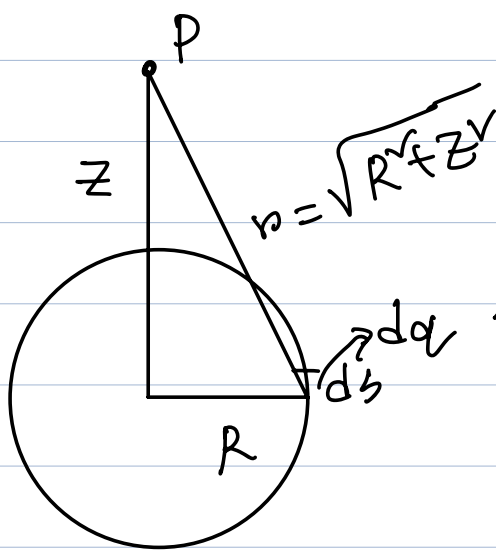
$$V_{total} = \frac{P}{4\pi\epsilon_0 r^2 \left(1 - \frac{dr}{4\pi r}\right)} \rightarrow 0$$

$$= \frac{P}{4\pi\epsilon_0 r^2}$$



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

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



$$ds = R d\theta$$

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

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

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

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

$$V = \int dv$$

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

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

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

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

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

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

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

$$\begin{array}{ccc}
 U_1 & & U_2 \\
 \bullet & \text{---} & \bullet \\
 1 \quad q_0 & & 2
 \end{array}
 \quad \Delta U = -W$$

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

$$\begin{aligned}
 \Rightarrow \Delta V q_0 &= -W \\
 &= - \int_1^2 \vec{F} \cdot d\vec{r}
 \end{aligned}$$

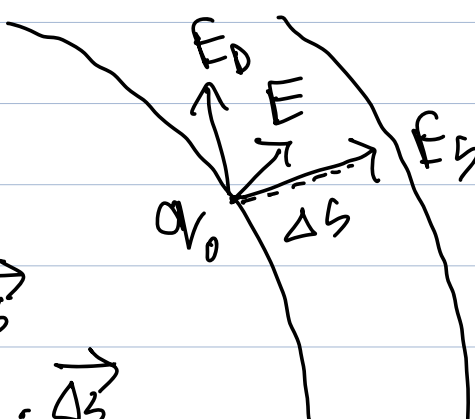
$$\Rightarrow q_0 \Delta V = - \int_1^2 q_0 \vec{E} \cdot d\vec{r}$$

$$\Rightarrow \Delta V = - \int_1^2 \vec{E} \cdot d\vec{r} \quad \infty \quad P$$

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

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

$$\Rightarrow V_P = - \int_\infty^P \vec{E} \cdot d\vec{r}$$



The diagram shows a curved path. At a point on the path, a vector  $\vec{E}_D$  points upwards, and a vector  $\vec{E}$  points along the path. A displacement vector  $\Delta \vec{s}$  is shown tangent to the path. A charge  $q_0$  is indicated at the point. The path starts at a point labeled  $V$  and ends at a point labeled  $V + \Delta V$ .

$$\begin{aligned} \Rightarrow q_0 \Delta V &= -W \\ &= -\vec{F} \cdot \Delta \vec{s} \\ &= -q_0 \vec{E} \cdot \Delta \vec{s} \\ \Delta V &= -(\vec{E}_s + \vec{E}_p) \cdot \Delta \vec{s} \\ &= -\vec{E}_p \cdot \Delta \vec{s} - \vec{E}_s \cdot \Delta \vec{s} \end{aligned}$$

$$\Delta V = -E_s \Delta s \quad E_y = \frac{-\partial V}{\partial y}$$

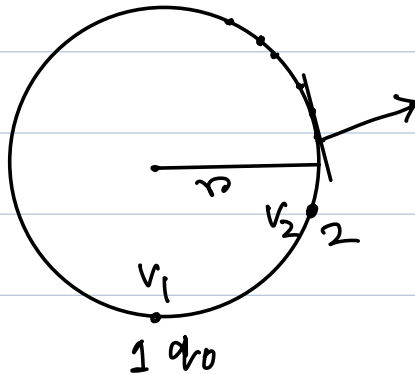
$$E_s = \frac{-\Delta V}{\Delta s} \quad E_z = \frac{-\partial V}{\partial z}$$

$$\begin{aligned} E_s &= -\lim_{\Delta s \rightarrow 0} \frac{\Delta V}{\Delta s} \\ &= -\frac{\partial V}{\partial s} \end{aligned}$$

$$V = \text{constant}$$

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

$$r = \text{constant}$$



$$\Delta V = V_2 - V_1 = 0$$

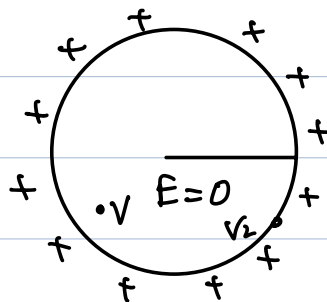
$$\Delta U = q_0 \Delta V = 0 = W$$

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

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

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

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



$$\Delta V = 0$$

$$\Rightarrow V_2 - V_1 = 0$$

$$\Rightarrow V_2 = V_1$$



