Step 2 $V = 0$ @ ∞

We know V at the surface from part a:

$$V_S = \frac{Q}{4\pi\varepsilon_0 R}$$

Step 3

$$\Delta V = \underbrace{V_B}_{V(r)} - \underbrace{V_A}_{\text{at surface, } r=R} = -\int_{\underbrace{A}_{\text{radial path}}}^{B} \underbrace{\vec{E}}_{\text{from step 1}} \cdot d\vec{s}$$

$$\Delta V = V(r) - V_S = -\int_R^r \vec{E} \cdot d\vec{s}$$

Step 4

Plug in $E(r)$

$$= -\int_R^r \frac{Q}{4\pi\varepsilon_0 R^3} r'\,dr'$$

$$= \frac{-Q}{4\pi\varepsilon_0 R^3} \left.\frac{r'^2}{2}\right|_R^r$$

$$V(r) - V_S = \frac{Q}{4\pi\varepsilon_0 R^3} \frac{1}{2}\left[R^2 - r^2\right]$$

Step 5

Solve for $V(r)$

$$V(r) = \frac{Q}{4\pi\varepsilon_0 R^3} \frac{1}{2}\left[R^2 - r^2\right] + \frac{Q}{4\pi\varepsilon_0 R}$$