

Let a uniform surface charge density of 5 nc/m<sup>2</sup> be present at the  $z = 0$  plane, a uniform line charge density of 8 nc/m, be located at  $x = 0, z = 4$ , and a point charge of 2  $\mu\text{C}$  be present at P(2,0,0). If  $V = 0$  at M(0,0,5), find  $V$  at N(1,2,3).

(answer is 1.98 kV)

It seems to me that I need to find the electric field intensity for each of the charge configurations (the surface charge, the line charge, and the point charge), add the components (changing between coordinate systems where necessary), and then compute the integral. However, I do not understand how to find expressions for the electric field intensity or how to adjust the calculations if the zero reference potential is not at infinity. So far I have the following:

$$V_{MN} = V_M - V_N \text{ and } V_{MN} = -\int_M^N \vec{E} \cdot d\vec{L}$$

$$V_M = 0 \Rightarrow V_N = \int_M^N \vec{E} \cdot d\vec{L}$$

### Surface Charge

For the electric field intensity due to the surface charge, I have:

$$\vec{E}_s = \frac{\rho_s}{2\epsilon_0} \hat{a}_z$$

where  $\vec{E}_s$  is the electric field intensity caused by the surface charge,  $\rho_s$  is the surface charge density, and  $\epsilon_0$  is the permittivity of free space

### Line Charge

I have  $\vec{E}_L = \frac{\rho_L}{2\pi\epsilon_0} \hat{a}_r$ , but I think that this is wrong.

Please explain how to derive the expression for the electric field intensity due to an infinite line charge. I understand how to do this when the line charge extends along the z-axis (and thus possesses cylindrical symmetry), but do not understand how to do it if the charge is parallel to the x- or y-axis.

### Point Charge

I have:  $\vec{E}_p = \frac{Q}{4\pi\epsilon_0 r^2} \hat{a}_r$

where  $\vec{E}_p$  is the electric field intensity caused by the point charge,  $Q$  is the charge,  $\epsilon_0$  is the permittivity of free space,  $r$ , and  $\hat{a}_r$  is a unit vector in the  $r$  direction (spherical coordinates)

In summary, please explain:

1. How to derive the electric field intensity for each of the charge configurations (with particular emphasis on line charges that are not parallel to the z-axis)
2. What difference it makes that the zero reference is not an infinity
3. How to obtain the final answer (please show vector operations in detail as that is often where I get lost)

This problem has stumped me for a week now. Many thanks for your help.