ELECTRICITY (Physics 2)

Electric Potential :

We saw in dynamics that Potential energy refer to the energy stored in a body that can be converted to a kinematic energy

Here we apply the same context in electricity

So the Electric potential the electrical potential , the energy neede to move a point charge tought a distance r and it is calculated by

$\mathbf{V}= \frac{W}{q} = k\,\frac{q}{r}$ $\qquad W=-q \cdot E \cdot r$

W: Work done to move the charge
q: the electrical charge
k: coulomb's constant

Interaction Energy between two points charges : The Interaction Energy between two points charges can be calculated using coulomb's law equation Ep = K $\frac{q_1 q_2}{r}$

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Relationship between Electrical field and Electrostatic Potential:

The relationship between electrical field and electrostatic potential can be expressed by the following

$$\vec{E} = -\overrightarrow{grad}(V) \qquad -dV = -\vec{E}.\vec{dl}$$

Superposition Principal:

The same principal apply as with force, and electrical field the potential in a field is the equal to the sum of all electrical potentials of all charges

$$V = V_1 + V_2 + V_3 + \text{..........} \text{ etc.}$$

➢ Electrific field created by a continuous charge distribution

Sometimes when we have a great number of point charges we treat them as if their number is infinite and **continuously distributed in the field**

In this case we talk about **continuous distribution**

The continuous distribution can be :

Linear distribution: if the charges are distributed along a line

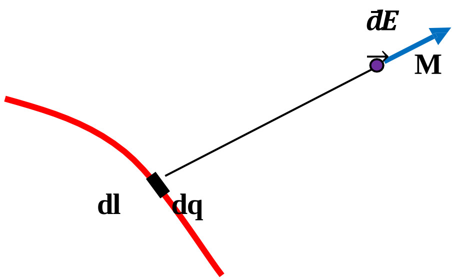
Surface distribution: if the charges are distributed along a surface

Volume distribution: if the charges are distributed along a volume

Linear charges Density λ

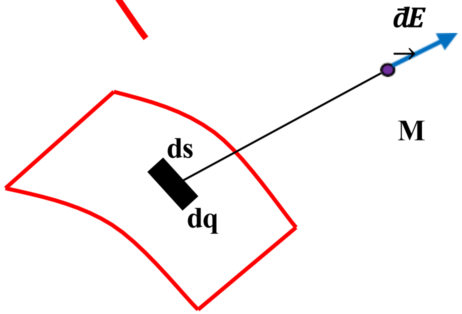
It is defined as the charge density by unit of length. This is the case with an electrical wire.

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



Areal Charges Density σ:

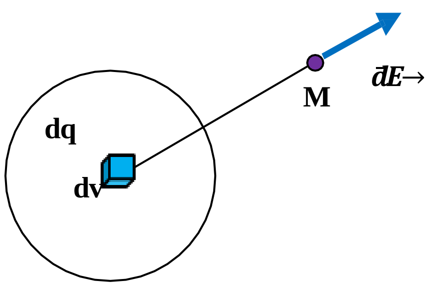
This is the charge density per unit area.
It is found in a flat object; Exampel . A disk.



$$\sigma = \frac{dq}{dS}$$

Volume Charges Density ρ:

This is the charge density per unit volume. It is used when the object has these three dimensions;
Example: Charged sphere.



$$\rho = \frac{dq}{dV}$$

Electric field created by continuous charge distribution:

If the loads are spread in a continuous distribution (per unit of the volume dq = ρ.dV, per unit of area dq = σ.dS ou per unit of length dq = λ.dl), the summation becomes an integral, and the expression of the field becomes:

1. Volume charge density, $\rho = \frac{dq}{dV}$
2. Surface charge density, $\sigma = \frac{dq}{ds}$
3. Linear charge density, $\lambda = \frac{dq}{dL}$
4. Force exerted on a charge q_0 due to a continuous charge distribution,

$$\vec{F} = \frac{q_0}{4\pi\varepsilon_0} \int \frac{dq}{r^2}\,\hat{r}$$

5. Electric field due to a continuous charge distribution,

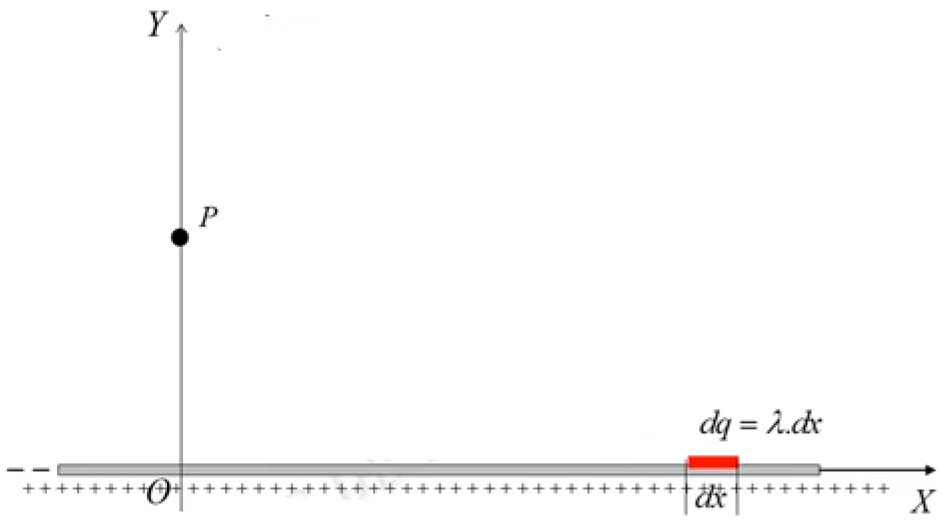
$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \int \frac{dq}{r^2}\,\hat{r}$$

Units Used

ρ is in Cm^{-3}, σ in Cm^{-2}, λ in Cm^{-1} and E in NC^{-1}.

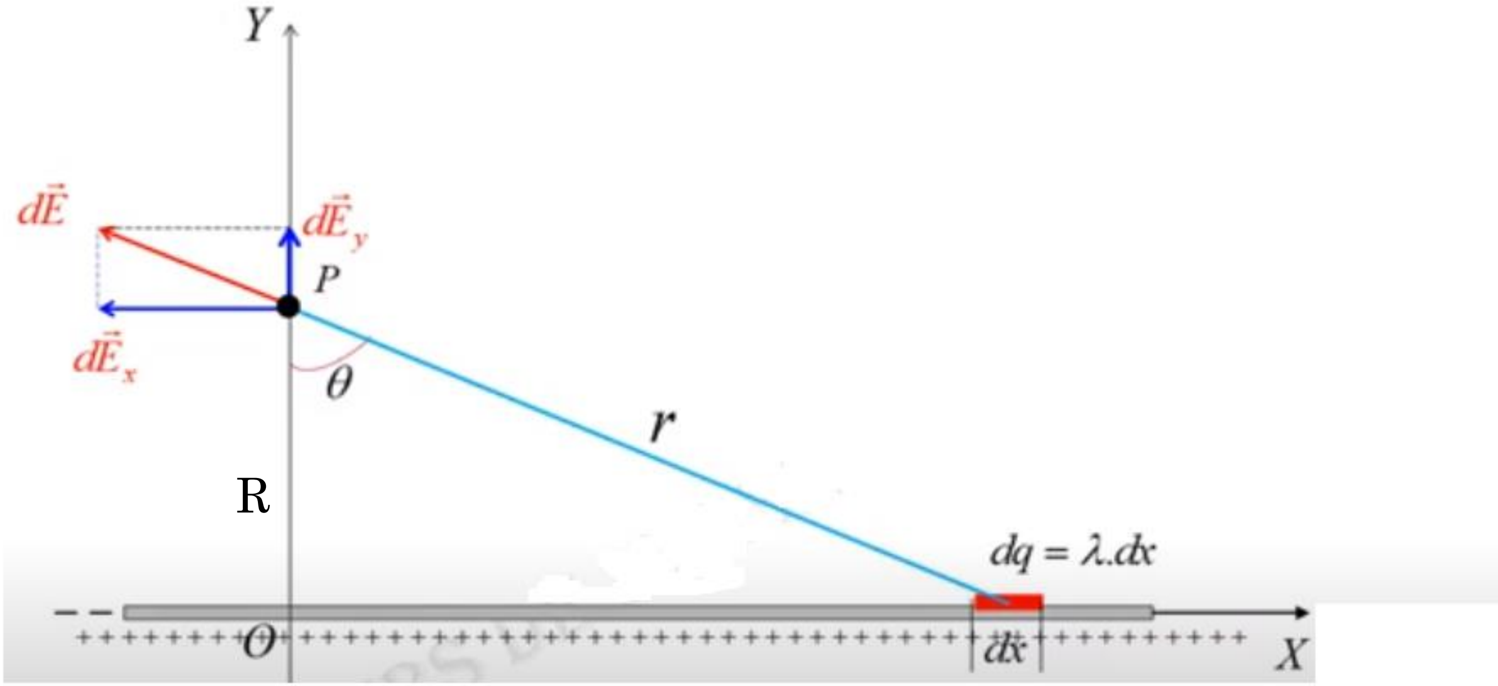
Example of linear Distribution

- The electrostatic field produced by a fine wire of infinite length et have a linear positive constant charge density λ
- Let's calculate the electrostatic field produced by those charges on a point P



Here we take the rectilinear segment dx that has a charge $dq = \lambda.dx$

Here, the elementary field is located on the extension of the rectilinear segment of length r and connecting p to dq



Y
$d\vec{E}$
$d\vec{E}_y$
P
$d\vec{E}_x$
θ
r
R
$dq = \lambda.dx$
O
dx
X

- Here when we project the field dE on the X and Y axis we find:
- $\overrightarrow{dE} = d\overrightarrow{E_x} + d\overrightarrow{E_y}$
- We have : dE_x = dE.cosθ dE_y = dE.sinθ
- $dE = k\frac{dq}{r^2} = k.\ \frac{\lambda.dx}{r^2}$
- So $E_x = k \int \frac{dx}{r^2} \cos\theta$ and $E_y = k \int \frac{dx}{r^2} \sin\theta$
- Geometrically x = R.tanθ → $dx = R.\frac{1}{cos^2\theta} d\theta$
- $r = \frac{R}{cos\theta}$

- $E_x = \lambda.\mathrm{k} \int \frac{dx}{r^2} \cos\theta = \lambda.\mathrm{k} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \frac{(R/cos^2\theta\ )}{R/cos^2\theta} d\theta.\ \mathrm{Sin}\theta$

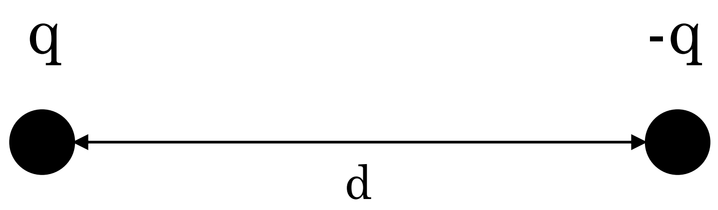
- $E_x = \frac{1}{R} \lambda.\mathrm{k} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} sin\,\theta\ d\theta = \frac{1}{R} \lambda.\mathrm{k}\ [-cos\theta\ ]_{\frac{-\pi}{2}}^{\frac{\pi}{2}}$
- $E_x = 0$

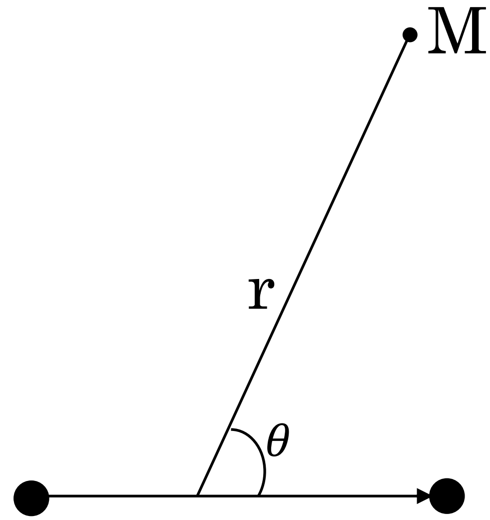
$-$

- $E_y = \lambda.\mathrm{k} \int \frac{dx}{r^2} \cos\theta = \lambda.\mathrm{k} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} \frac{(R/cos^2\theta\ )}{R/cos^2\theta} d\theta.\ \cos\theta$
- $E_y = \frac{1}{R} \lambda.\mathrm{k} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} cos\,\theta\ d\theta = \frac{1}{R} \lambda.\mathrm{k}\ [sin\theta\ ]_{\frac{-\pi}{2}}^{\frac{\pi}{2}}$
- $E_y = \frac{1}{R} \lambda.\mathrm{k}\ [1\ -\ \ -\ 1] = \frac{2}{R} \lambda.\mathrm{k}\ = \frac{1}{2\pi\varepsilon_0} \frac{1}{R}$
- $E_y = \frac{1}{2\pi\varepsilon_0} \frac{1}{R}$

Electrical dipole

- It's a system created by two points charges with opposites signs and separated by a distance d





Electric potential

The electric potential created by a dipole on a point M, spotted by it's polar coordinates by is given by:

$$V = \frac{kdcos\theta}{r^2}$$

- The electrical field created by this dipole is given by :
- $\mathrm{E} = -\ \overrightarrow{\mathrm{grad}}(\mathrm{V})$ $\Rightarrow$ $$\begin{cases} E_r = -\dfrac{\partial y}{\partial r} = \dfrac{2kd\cos\theta}{r^3} \\ E_\theta = -\dfrac{1}{r}\dfrac{\partial y}{\partial \theta} = \dfrac{kd\cos\theta}{r^3} \end{cases}$$

Good luck


Van de Graaff generator