UNIVERSITATEA TEHNICĂ
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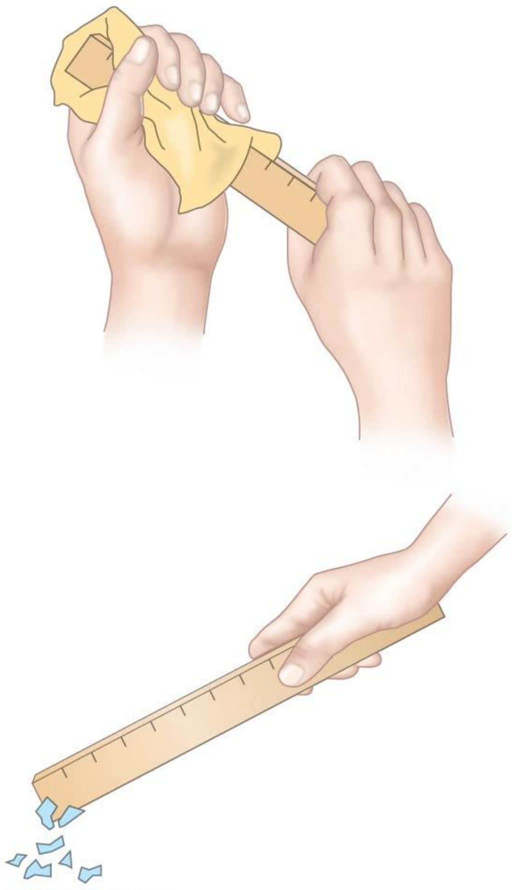
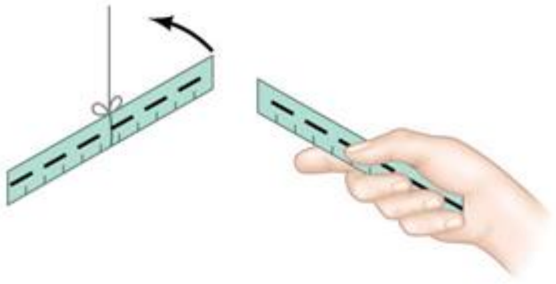
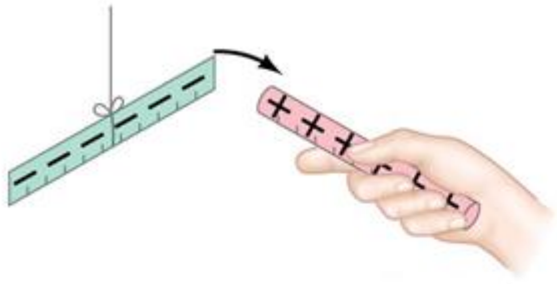
3a Electrostatic field I

Electric charge

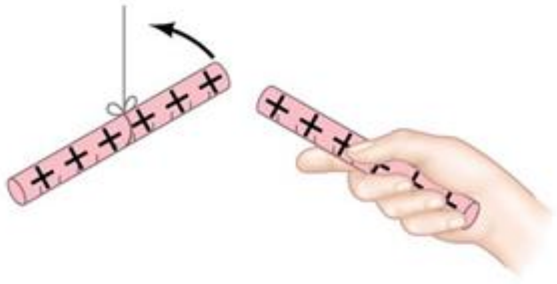




Two plastic rulers repulse

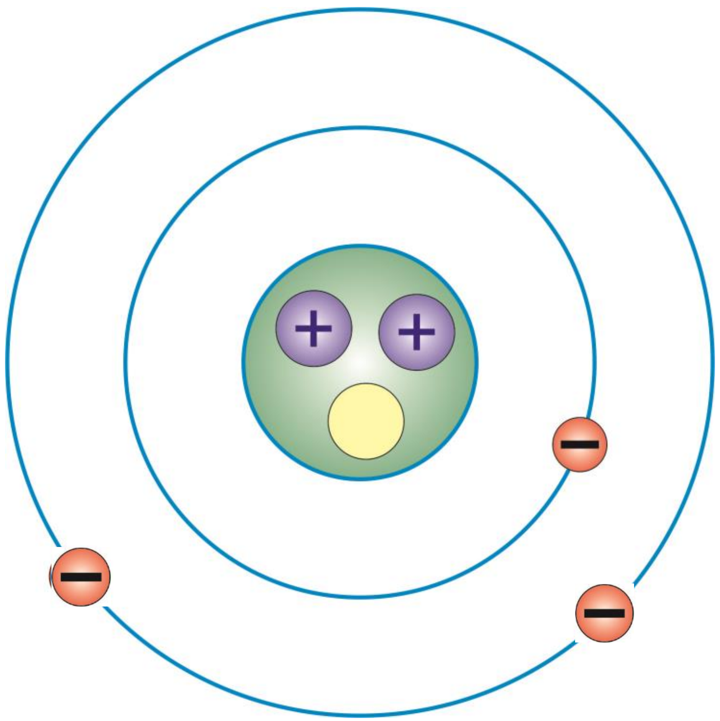


Plastic ruler and glass stick attract



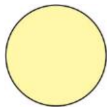
Two glass sticks are repulse

Particles carring charges



 Electron

 Proton

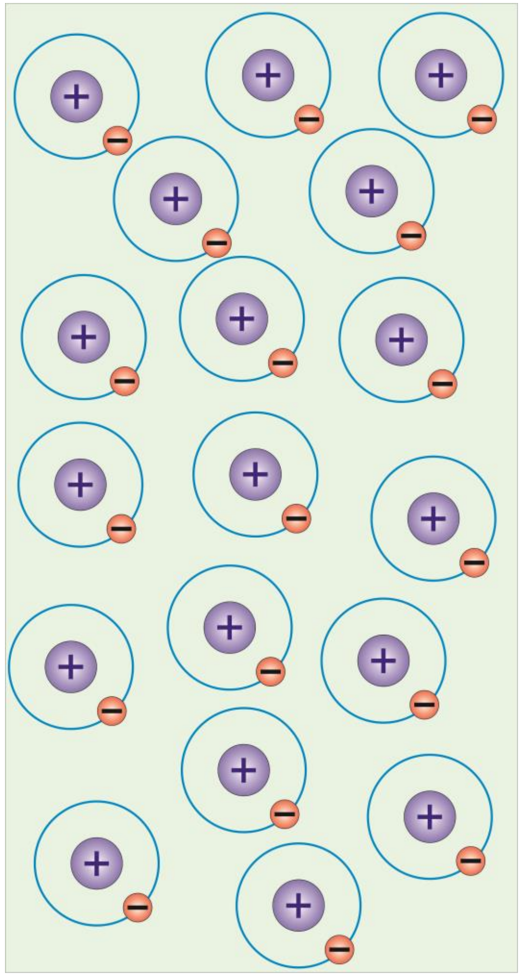
 Neutron

Elementary charge

$$|q_e| = |q_p| = 1{,}6\cdot10^{-19}\ \mathrm{C}$$

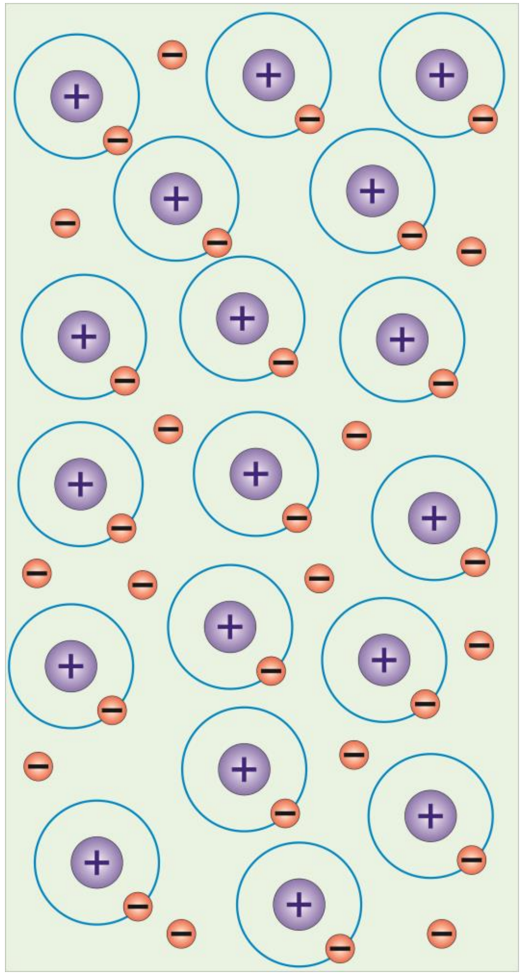
$[q]$ = C (Coulomb)

Charged body

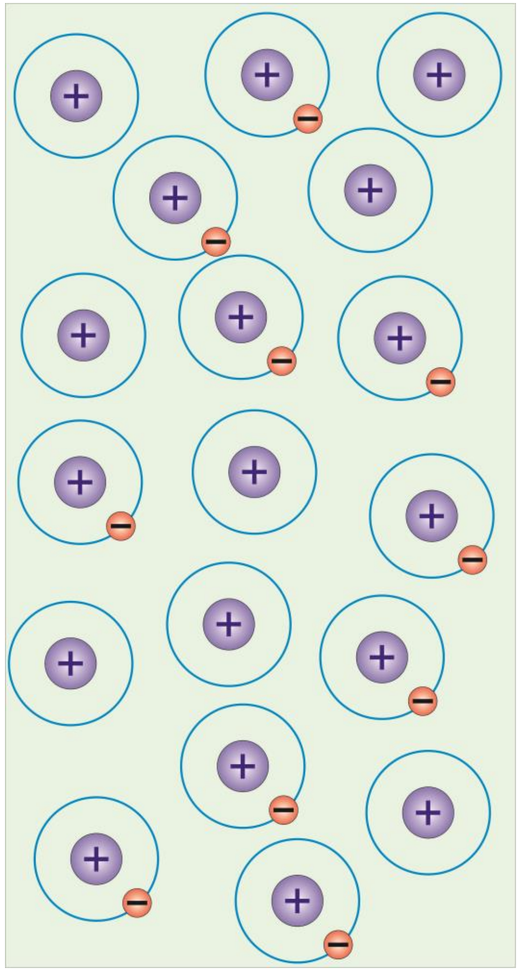


neutral

The algebraic sum of the charges equils zero

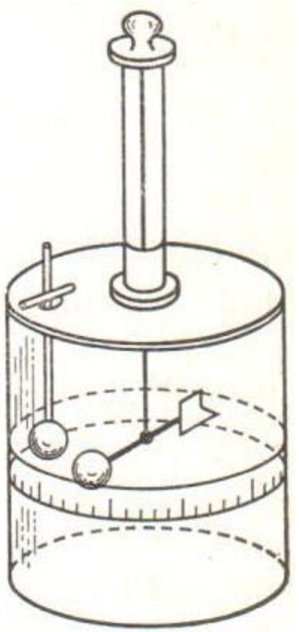


negativ

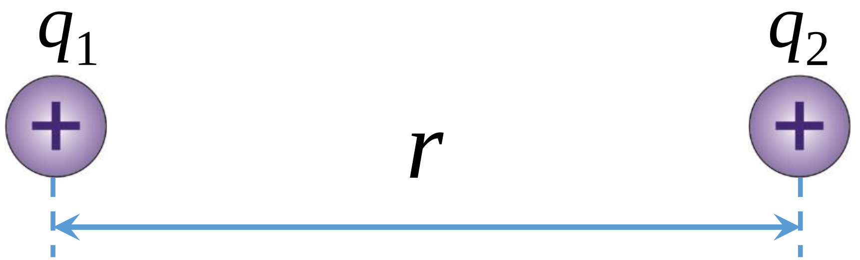


pozitiv

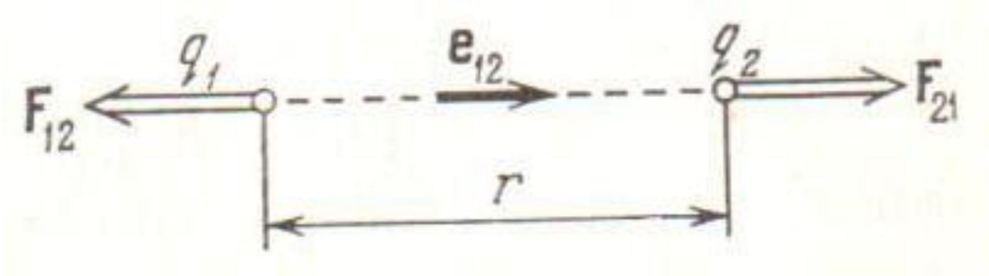
Coulomb law



$$F = k\frac{q_1 q_2}{r^2}$$



$$k = \frac{1}{4\pi\varepsilon_0} = 9 \cdot 10^9\ \mathrm{N \cdot m^2/C^2}$$

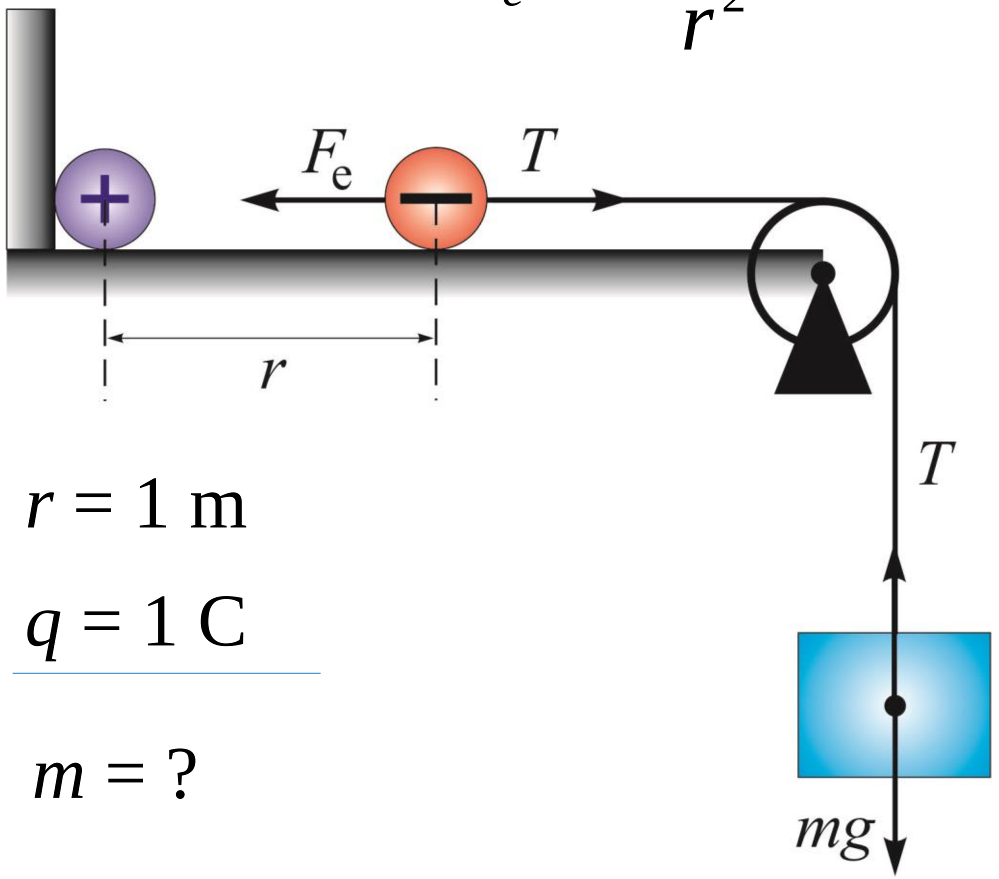


$$\varepsilon_0 = 8{,}86 \cdot 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$$

the force of interaction between two stationary point charges is proportional to the magnitude of each of them and inversely proportional to the square of the distance between them.

Coulomb law

$$T = F_e = k\frac{q^2}{r^2} \quad T = mg \qquad mg = k\frac{q^2}{r^2} \qquad m = k\frac{q^2}{gr^2}$$



$$m = 9\cdot 10^9\frac{1}{9{,}8} \approx 10^9\ \text{kg} = 10^6\ \text{t}!!!$$

10 000 wagons

$r = 1$ m

$q = 1$ C

$m = ?$

Electric and gravitational forces

Electric force

$$F_e = k\frac{q_1 q_2}{r^2}$$

$q = 1{,}6 \cdot 10^{-19}$ C

$r = 5{,}3 \cdot 10^{-11}$ m

$k = 9 \cdot 10^{9}$ N·m²/C²

$F_{\mathbf{e}} = 8{,}2 \cdot 10^{-8}$ N

Gravitational force

$$F_g = G\frac{m_1 m_2}{r^2}$$

$m_{\mathbf{e}} = 9{,}1 \cdot 10^{-31}$ kg

$m_p = 1{,}7 \cdot 10^{-27}$ kg

$r = 5{,}3 \cdot 10^{-11}$ m

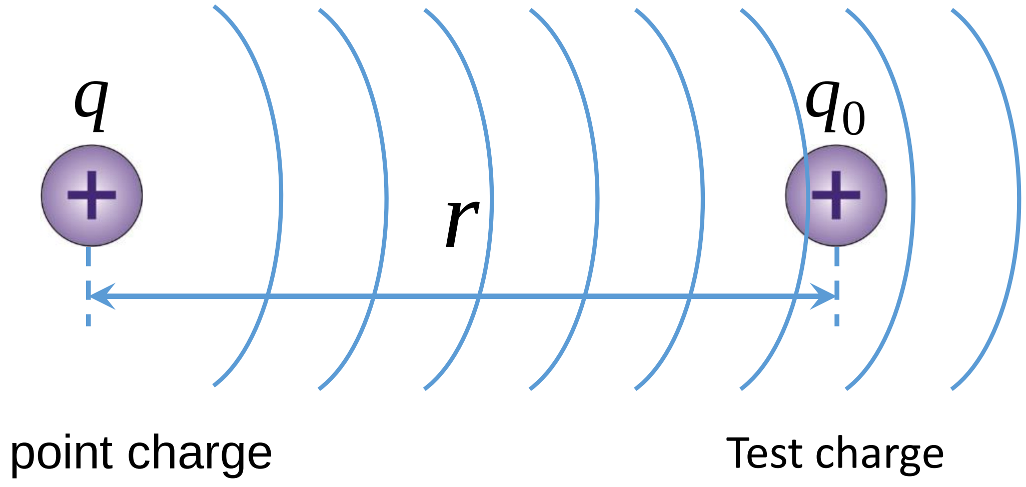
$G = 6{,}67 \cdot 10^{-11}$ N·m²/kg²

$F_{\mathbf{g}} = 3{,}67 \cdot 10^{-47}$ N

In the hidrogen atom the elecftric force is $\approx 10^{39}$!!! times greater than the gravitational force

Electric field strength or intensity

$$F = k\frac{qq_0}{r^2} \qquad \frac{F}{q_0} = \text{const} \qquad E = \frac{F}{q_0}$$

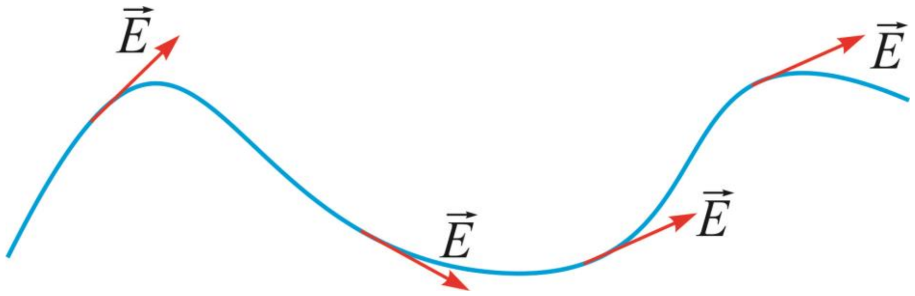


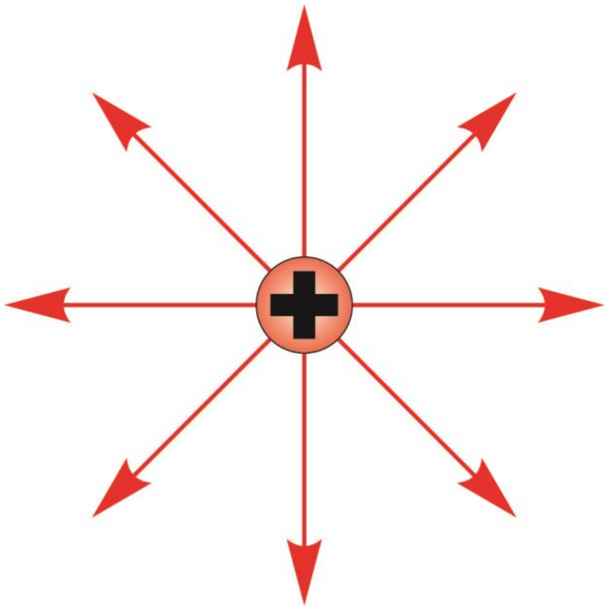
$$\boxed{\vec{E} = \frac{\vec{F}}{q_0}}$$ Electrostatic field strength

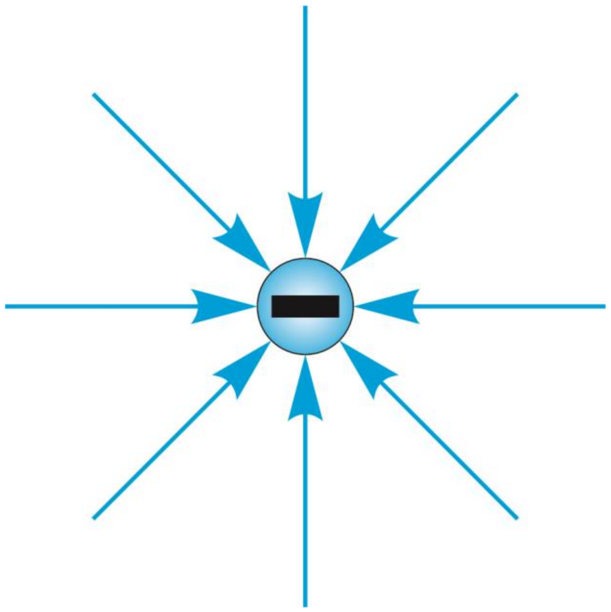
$$E = k\frac{qq_0}{q_0 r^2}$$

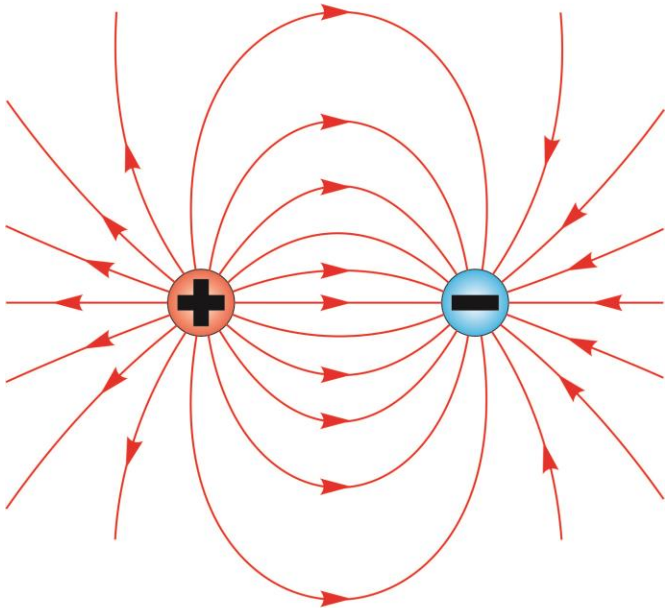
$$\boxed{E = k\frac{q}{r^2}}$$ Electrostatic field strength created by the point charge

Lines of force



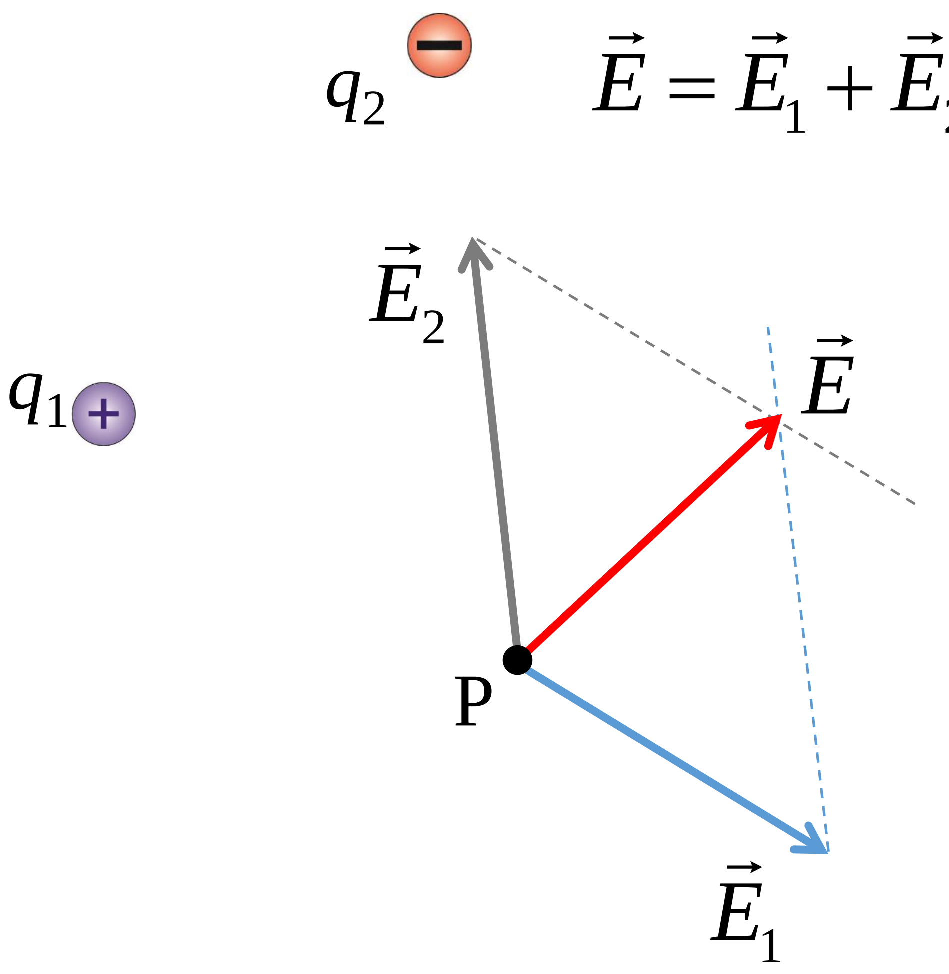






Line of force is a straight of curved line whose tangent at each point coincides with the direction of the field strength vector.

Principle of electric field superposition



$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

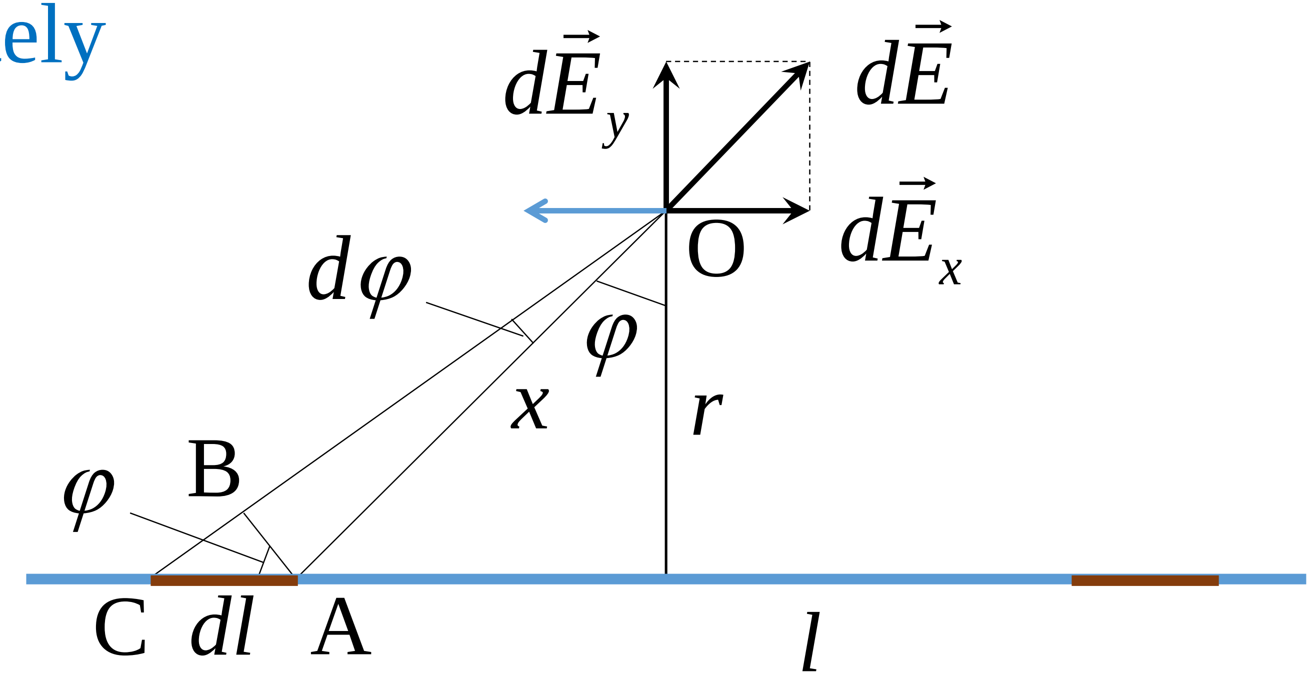
$$\boxed{\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots + \vec{E}_n}$$

Principle of superposition

the field strength of a system of charges equals the vector sum of the field strengths that would be produced by each of the charges of the system separately

The application of principle of superposition

The field created by an infinitely long rectilinear wire charged with the linear density τ.



Linear density of charge :

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

$$\vec{E} = \int d\vec{E} = \int d\vec{E}_x + \int d\vec{E}_y$$

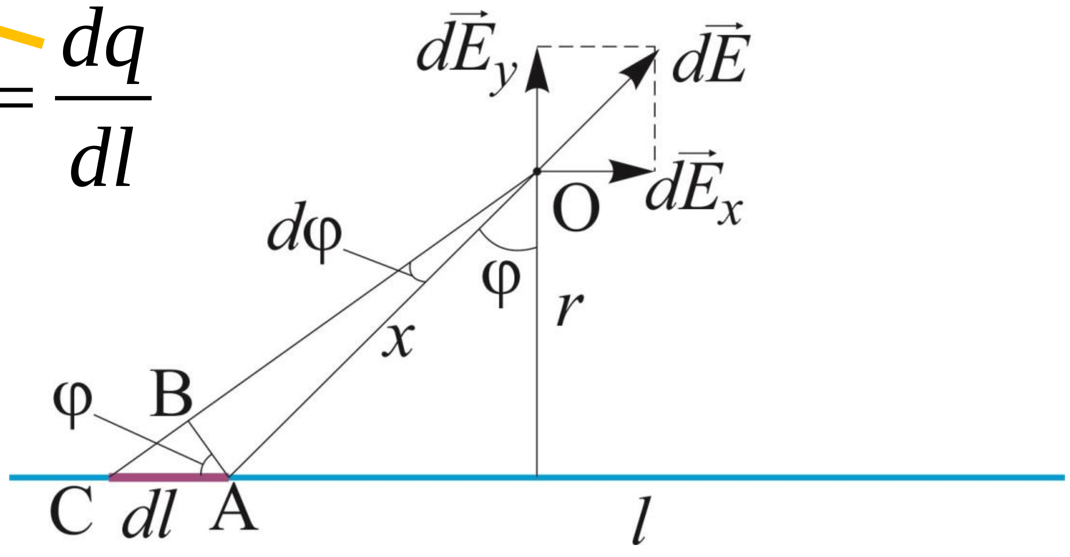
$$E = k\frac{q}{x^2}$$

$$\int d\vec{E}_x = 0 \qquad \vec{E} = \int d\vec{E}_y$$

$$E = \int dE_y = \int dE \cos\varphi$$

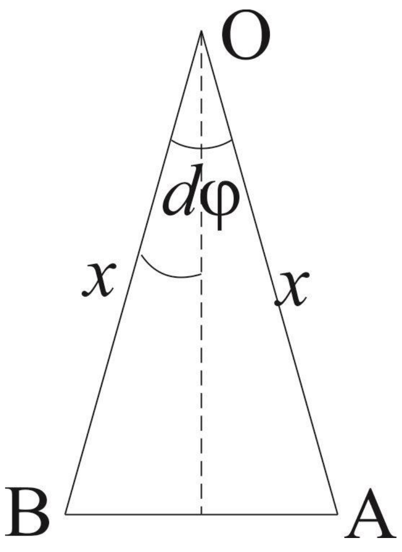
The application of principle of superposition

$$E = \int k \frac{dq}{x^2} \cos\varphi = \int k \frac{\tau dl}{x^2} \cos\varphi \qquad \tau = \frac{dq}{dl}$$



$$dl = \frac{AB}{\cos\varphi} \qquad \frac{1}{2}AB = x\sin\frac{d\varphi}{2}$$

$$\frac{1}{2}AB = x\frac{d\varphi}{2} \qquad AB = xd\varphi$$



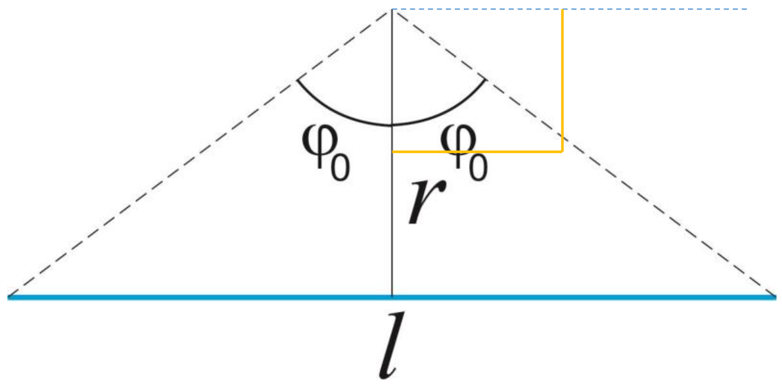
$$dl = \frac{xd\varphi}{\cos\varphi} \qquad E = \int k \frac{\tau \cancel{x} d\varphi}{\cancel{\cos}\varphi x^{\cancel{2}}} \cancel{\cos}\varphi$$

The application of principle of superposition

$$E = \int k \frac{\tau d\varphi}{x} = \int k \frac{\tau d\varphi}{r} \cos\varphi$$

$$E = k \frac{\tau}{r} \int_{-\varphi_0}^{\varphi_0} \cos\varphi d\varphi$$

$$E = k \frac{\tau}{r} \left(\sin\varphi_0 - \sin(-\varphi_0) \right)$$



$$E = k \frac{\tau}{r} 2 \sin\varphi_0$$

For infinit wire $\varphi_0 = 90^0$

$$\boxed{E = \frac{2k\tau}{r}}$$

Vector flux of electrostatic field

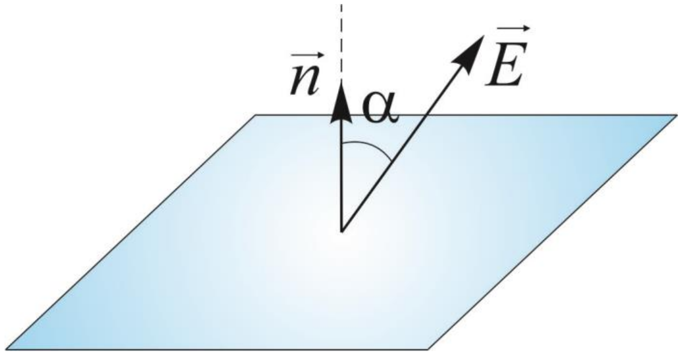
$$\Phi = ES\cos\alpha$$

$\vec{n}$ – the unit vector of the normal

$\vec{S} = S \cdot \vec{n}$ – surface vector

$$\vec{a} \cdot \vec{b} = ab\cos\alpha$$

$$\Phi = \vec{E} \cdot \vec{S}$$



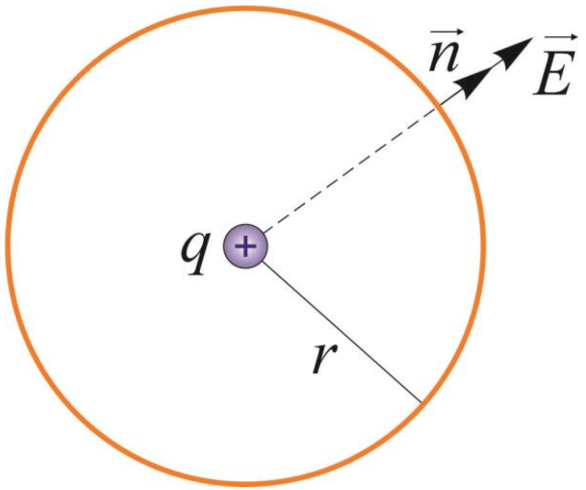
$$d\Phi = \vec{E} \cdot d\vec{S}$$

$$\Phi = \int_S \vec{E} \cdot d\vec{S}$$

Gauss theorem

The Gauss theorem allows us to calculate the flux of the intensity vector through a closed surface, called the Gaussian surface.

$$\Phi = \int_S \vec{E}\cdot d\vec{S} = \oint_S EdS\cos\alpha$$



$$\alpha = 0,\quad \cos\alpha = 1 \qquad \Phi = \oint_S EdS = ES$$

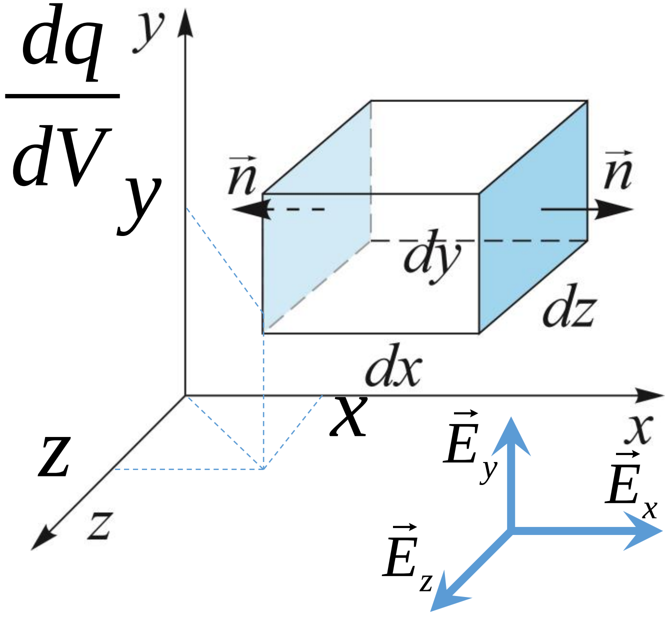
$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2} \qquad S = 4\pi r^2 \qquad \Phi = \frac{1}{\cancel{4\pi}\varepsilon_0}\cdot\frac{q}{\cancel{r^2}}\cdot\cancel{4\pi r^2}$$

$$\Phi = \frac{q}{\varepsilon_0} \qquad \boxed{\Phi = \frac{\sum q}{\varepsilon_0}} \qquad \text{Gauss theorem}$$

Gauss's theorem in differential form

$$\Phi = \oint_S \vec{E}\cdot d\vec{S} = \frac{\sum q}{\varepsilon_0}$$

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



$$d\Phi = \vec{E}\cdot d\vec{S} = \vec{E}_x\cdot d\vec{S}_x + \vec{E}_y\cdot d\vec{S}_y + \vec{E}_z\cdot d\vec{S}_z$$

$$\vec{E}_x\cdot d\vec{S}_x = E_{x+dx}\,dS\cos 0^0 - E_x\,dS\cos 180^0$$

$$\vec{E}_x\cdot d\vec{S}_x = \underbrace{\left(E_{x+dx} - E_x\right)}\,dydz$$

$$\vec{E}_x\cdot d\vec{S}_x = dE_x\,dydz \qquad dE_x = kdx$$

$$k = \left(\frac{dE_x}{dx}\right)_{y,z} = \frac{\partial E_x}{\partial x} \qquad dE_x = \frac{\partial E_x}{\partial x}dx$$

$$\vec{E}_x\cdot d\vec{S}_x = \frac{\partial E_x}{\partial x}\,\overset{dV}{dxdydz}$$

Gauss's theorem in differential form

$$\vec{E}_x \cdot d\vec{S}_x = \frac{\partial E_x}{\partial x} dV \quad \vec{E}_y \cdot d\vec{S}_y = \frac{\partial E_y}{\partial y} dV \quad \vec{E}_z \cdot d\vec{S}_z = \frac{\partial E_z}{\partial z} dV$$

$$d\Phi = \frac{\partial E_x}{\partial x} dV + \frac{\partial E_y}{\partial y} dV + \frac{\partial E_z}{\partial z} dV \qquad d\Phi = \underbrace{\left(\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} \right)}_{\mathrm{div}\vec{E}} dV$$

$$\left.\begin{aligned} d\Phi &= \mathrm{div}\vec{E} dV \\ d\Phi &= \frac{dq}{\varepsilon_0} = \frac{\rho dV}{\varepsilon_0} \end{aligned}\right\} \quad \boxed{\mathrm{div}\vec{E} = \frac{\rho}{\varepsilon_0}}$$

Gauss's theorem in differential form