Electrotechnics
ET

Course 1

Year I-ISA English

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Electrotechnics (ET)

Course

Friday, 8-10

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On-line Microsoft Teams:

Team: **Electrotechnics**

Acces code: **hgqjzy5**

Attendance **is not required** !!!

Exam:

- test – theory and problems

Laboratory

Assistant Eng Sergiu Andreica, PhD Student
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Assistant Eng Marian Gliga, PhD Student
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Basic of Electrotechnics Laboratory-Room 51
26-28 George Barițiu Street

Attendance **is required**!!!

The laboratory classes can be recovered according with the ECTS rules!!!

All the presences are required to be allowed at the laboratory test and then at the exam!!!

Electrotechnics (ET)

- analyzes electric, magnetic and electromagnetic phenomena using their quantitative characterizations, and implicitly mathematical modeling of these phenomena, for their technical applications.
- covers two main parts:
  - Electromagnetic Field Theory;
  - Electric Circuits Theory.

The main objectives of the ET Couse

Development of skills, abilities and competencies in the domains of the electromagnetic field and electrical circuit analysis by acquiring fundamental knowledge, for the correct approach and solution of the electromagnetic field problems and electrical circuits problems, in permanent regime (steady state - direct current (dc) and/or single-phase (sinusoidal) and three-phase alternating current (ac)), in transient regime, respectively in permanently periodically non-sinusoidal regime, for the purpose of designing and measuring them for use in concrete applications

Electrotechnics (ET)

Part I - Electromagnetic Field Theory (6 courses):

- analyzes of the electromagnetic phenomenon, in stationary or variable regimes, paying particular attention to the spatial distribution of these phenomena.
- the main concept of this theory is the electromagnetic field, characterized by vectors variable in space and possibly in time, therefore by vectorial functions of several scalar variables.
- the electromagnetic phenomena are described in this theory using integral, differential or integral-differential equations systems, referring to the vectorial field components.

Part II - Electrical Circuits Theory (8 courses):

- in some simplifying situations, the electromagnetic physical systems can be characterized by a finite number of scalar values variable or constant in time.
- the theory associated to this systems, named electrical circuits, is based on ordinary or even algebraic differential equations, so it is much simpler. For this reason, it is very often used in practice.

ET Course Outline

Part I - ELECTROMAGNETIC FIELD THEORY

Course 1

Introduction in Electromagnetic Field Theory

Specific Laws of the Electrostatic Field

Course 2

Electric Capacitance - Calculation Methods

Energies and Forces in Electrostatic Field

Course 3

Specific Laws of the Electrokinetic Field

Resistance - Calculation Methods

Resistors Connections

Course 4

Specific Laws of the Magnetic Field

Course 5

Inductivities - Calculation Methods.

Magnetic Circuit Law

Course 6

Electromagnetic Induction Law

Energies and Forces in Magnetic Field

ET Course Outline

Part II – ELECTRIC CIRCUITS THEORY

Course 7

Electric Circuits in Harmonic Regime

Course 8

Equivalent Impedance with and without Coupling

Power in Harmonic Regime

Course 9

Theorems for solving Electrical Circuits

Course 10

Methods for solving Electrical Circuits

Course 11

Resonance in Electrical Circuits (Series, Parallel, Mixt)

Course 12

The Theory of Electric Two Port Networks (Quadripoles)

Course 13

Study of Electrical Circuits in Transitory Regime

Course 14

Linear Circuits in Non-sinusoidal Regime.

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= Course 1 =

1. Introduction in electromagnetic field theory

2. Specific laws of the electrostatic field

1. Introduction in Electromagnetic Field Theory

Introduction in Electromagnetic Field Theory

The phenomena encountered in the *Electromagnetic Field Theory* can be classified in:

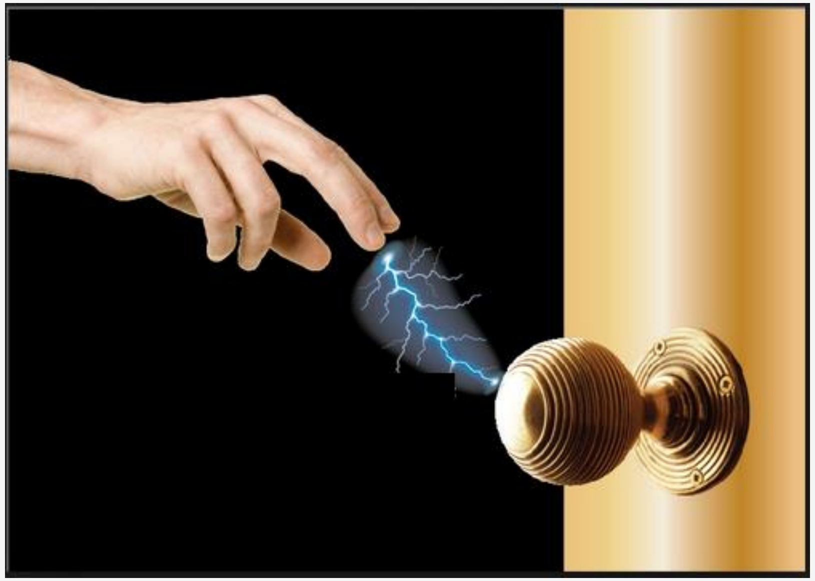
- electric phenomenon;
- magnetic phenomenon;
- galvanic phenomenon,

Corresponding to the electrification, magnetization, or electro-kinetic states of the bodies;

- electromagnetic phenomenon.

The Electrification State. Electric Charge. Electric Field Intensity

The electrification state, charging a body with electricity can be obtained:

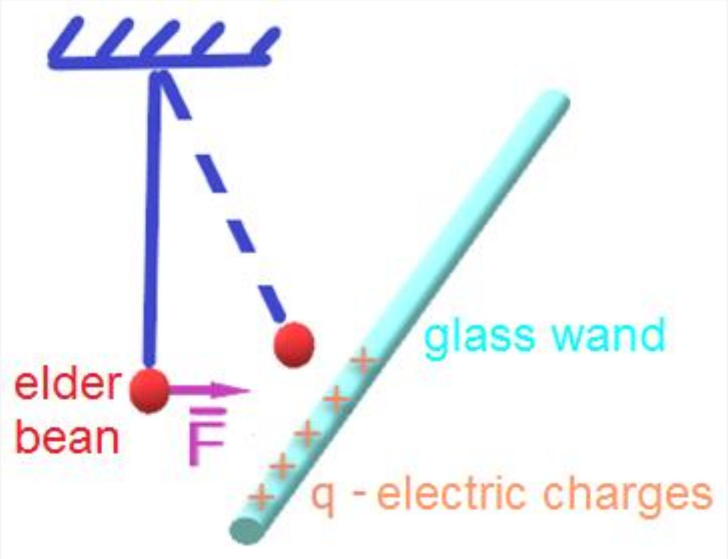


- by friction;
- by heating;
- by chemical effects;
- by crystal deformation ;
- by x-ray or ultraviolet rays' irradiation.

The Electrification State. Electrical Charge.

Experiment

- suppose we have a common elder bean and a glass wand,
- we rub the wand on a material (silk) and thus it is charged with electrical charges.
- We approach the wand to the elder bean, and it can be observed that the bean is attracted to the wand, thus creating a motion of the bean ⇨ electrification state.



Electrification state= the state in which, in the vicinity of the electrically charged bodies, forces and moments appear on the neighboring bodies.

The physical parameter which characterizes the electrification state is called electric charge. This is a scalar, primitive value, with properties irreducible to other units.

Electric charge

- there exists only two types of charges, namely positive or negative;
- like charges repel and unlike charges attract each other;
- notation: **q;**
- unit of measurement: ***Coulomb, [C]*** **;**

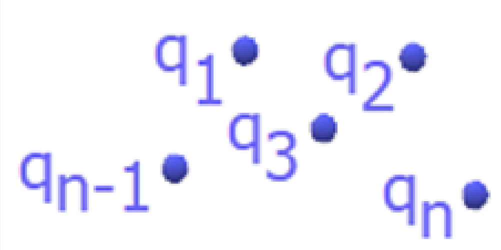
There exist different types of materials that can be:

- conductor – allows the passing of electric charges;
- insulator – doesn't allow the passing of electric charges, they are also called dielectrics;
- semiconductor.

The electric charge can be in a point or distributed in surface, body or volume

Electric charge distribution

a) Point electric charges distribution:



$$\boxed{q = \sum_{k=1}^{n} q_n}$$

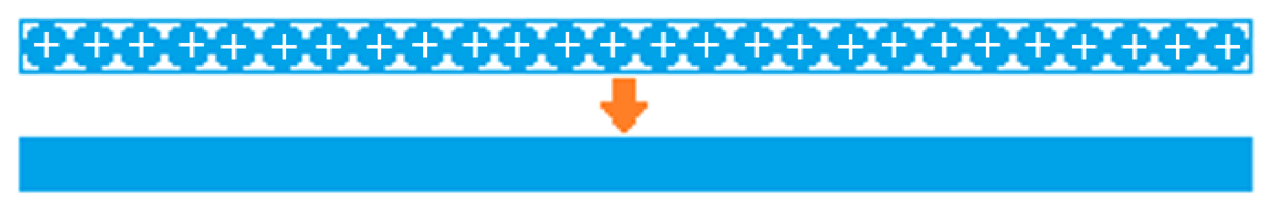
- charge is a scalar quantity;
- charge is additive in nature;
- charge is quantized;
- charge is conserved.

b) Line or Linear electric charges distribution (density):

if the charge is distributed on filiform conductors, the linear charge density is defined:

$$\boxed{\rho_l = \lim_{\Delta l \to 0} \frac{\Delta q}{\Delta l} = \frac{dq}{dl}, \left[\frac{C}{m}\right]}$$

$$\boxed{q = \int_l \rho_l \, dl}$$



The point electric charge distributed uniform on a line

Linear charge distribution

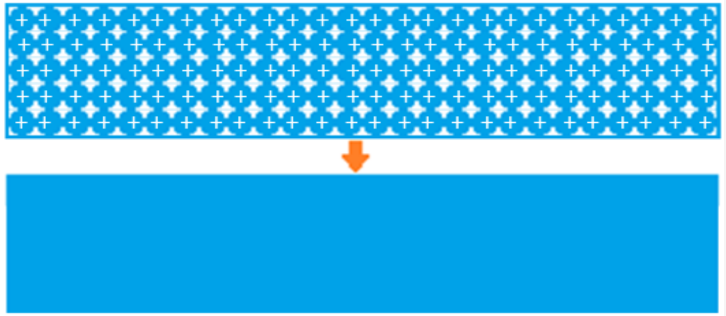
Electric charge distribution

c) Surface charge distribution (density)

if the charge is distributed over a surface area (of a conductor or an insulator), then is defined as surface charge density:

$$\rho_S = \lim_{\Delta A \to 0} \frac{\Delta q}{\Delta A} = \frac{dq}{dA}, \left[\frac{C}{m^2} \right]$$

$$q = \int_A \rho_S \, dA$$



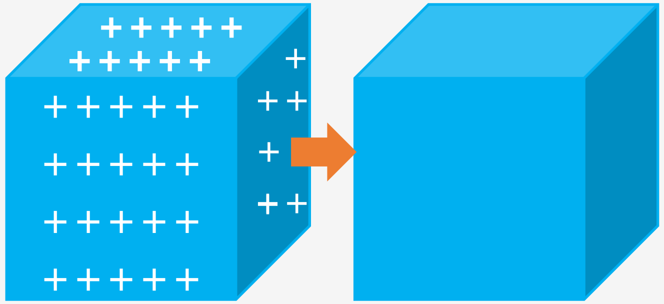
Obs: **surface charge density (surface charge distribution) is of particular importance for conductors.**

d) Volume charge distribution (density)

if the charge is distributed over a body or volumes, then is defined as volume charge density:

$$\rho_V = \lim_{\Delta V \to 0} \frac{\Delta q}{\Delta V} = \frac{dq}{dV}, \left[\frac{C}{m^3} \right]$$

$$dq = \rho_V \, dV \Rightarrow q = \int_V \rho_V \, dV$$

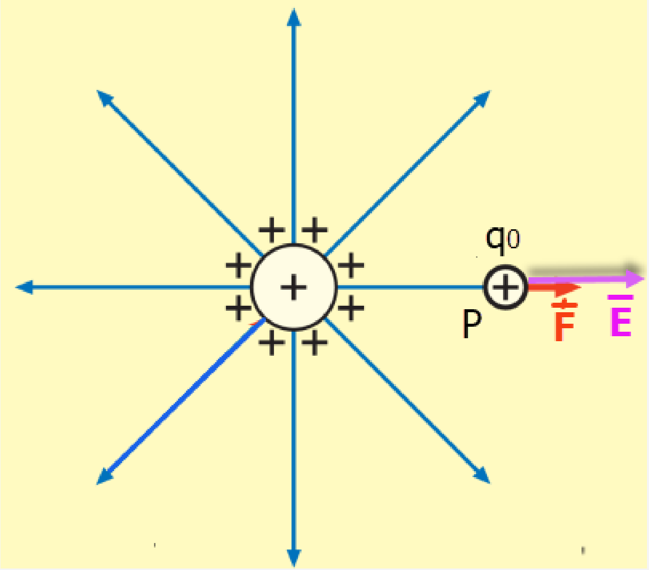


Obs: **volume charge density is found in insulating materials (dielectrics).**

Electric field intensity

The area in space where forces and couples are manifested due to the electrification state of a body (forces/couples of electrical nature) is called area in which electrical field exists. Electric field is characterized by the vector electric field intensity, $\vec{E}$.

Electric field is tested with a *probe body* of very small dimensions (point-like), a charge with the value q_0, constant in time.



If in a point P in space we have a *probe body* q_0 and a force is exerted on him, by definition $\vec{F}$:

$$\vec{E} \overset{\text{def}}{=} \frac{\vec{F}}{q_0}$$

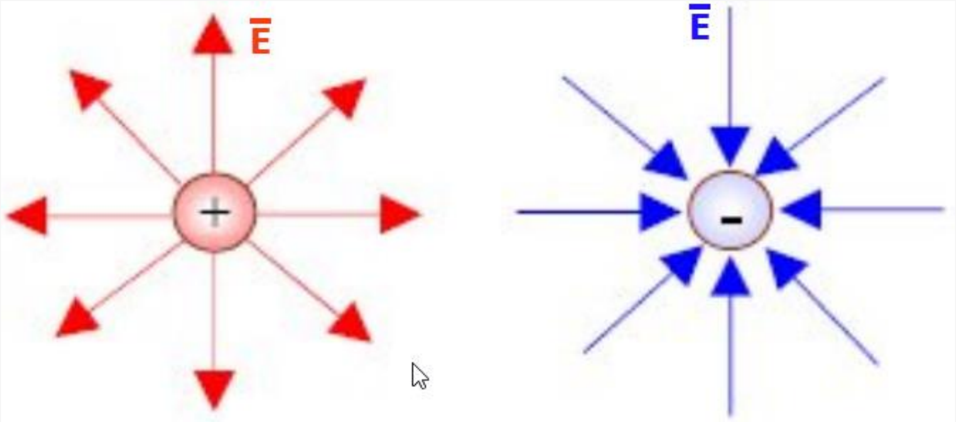
Obs: is not a calculation method for $\vec{F}$, but a **definition**.

$$[E] \overset{\text{def}}{=} \left[\frac{N}{C}\right] \qquad [E]_{SI} - \left[\frac{V}{m}\right]$$

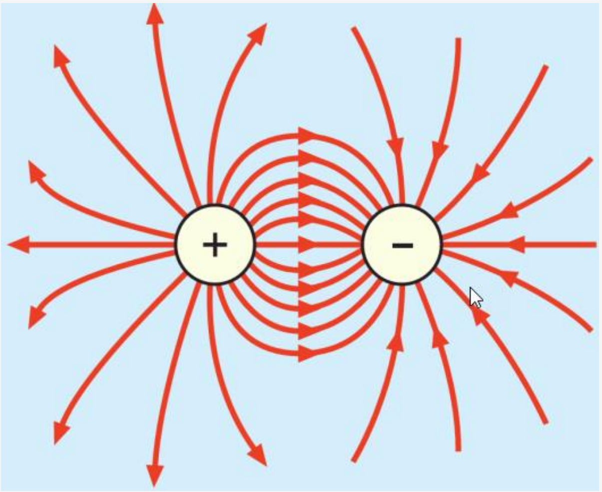
By definition we call electric field intensity, in a point P from the vicinity of a body charged with an electrical charge, the ratio between the force exerted on the probe (test) body placed in point P and the value q_0 of the charge on the probe (test) body.

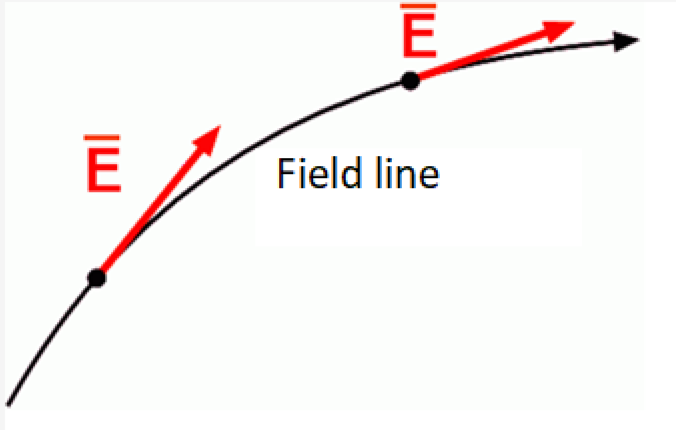
Electric field spectrum

The electric charge produces an electric field



The electric field spectrum represents all the electric field lines.



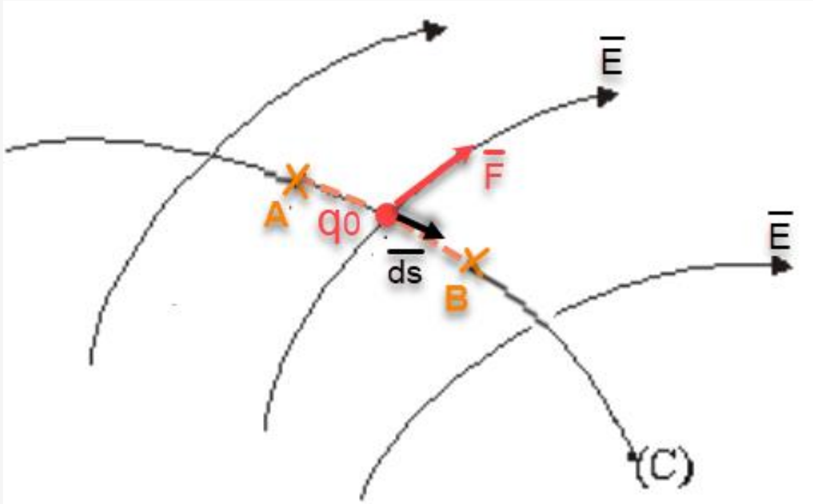


The Field line is the trajectory followed by a probe body left free in the field.

Obs.
- 2 field lines never intersect;
- vector $\vec{E}$ is tangent, in any point, to the field line;
- the electric field intensity value decreases from the source towards the end.

Voltage. Electric potential

Voltage is a derived value defined with the help of $\vec{E}$ vector. Suppose we have a test body q_0 in an area in which there is electric field.



✓ On the test body q_0 a force is exerted: $\vec{E} \overset{\text{def}}{=} \frac{\vec{F}}{q_0}$ (1)

?!?!?! What would happened if we intended to move the test body q_0 between points A and B ?! ?!

✓ To move the charge means to do a mechanical work;

✓ For a small portion: $dL = \bar{F} \cdot d\bar{s}$

$\Rightarrow$ That the total mechanical work: $L_{AB} = \int_A^B \bar{F} \cdot d\bar{s} \xRightarrow{(1)} L_{AB} = \int_A^B q_0 \cdot \bar{E} \cdot d\bar{s}$

$\xRightarrow{q_0 = ct} L_{AB} = q_0 \int_A^B \bar{E} \cdot d\bar{s}$

The ratio $\frac{L_{AB}}{q_0}$ is called voltage: $\boxed{U_{AB} = \frac{L_{AB}}{q_0} = \int_A^B \bar{E} \cdot d\bar{s}}$

Voltage. Electric potential

By definition, we call voltage between two points from the field the ratio between the mechanical work required to move the test body on a trajectory, between the 2 points (A and B) and the charge of the test body.

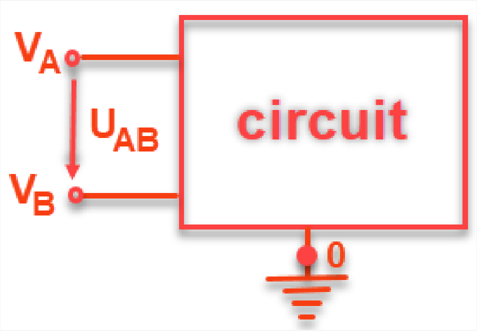
$$U_{AB} = \int_A^B \bar{E} \cdot d\bar{s}$$

Electric potential

✓ We consider P_0 as a reference point

By definition, we call the potential of point A, V_A, the voltage of the current point relative to the chosen reference point.

$$V_A = \int_A^{P_0} \bar{E} \cdot d\bar{s}$$



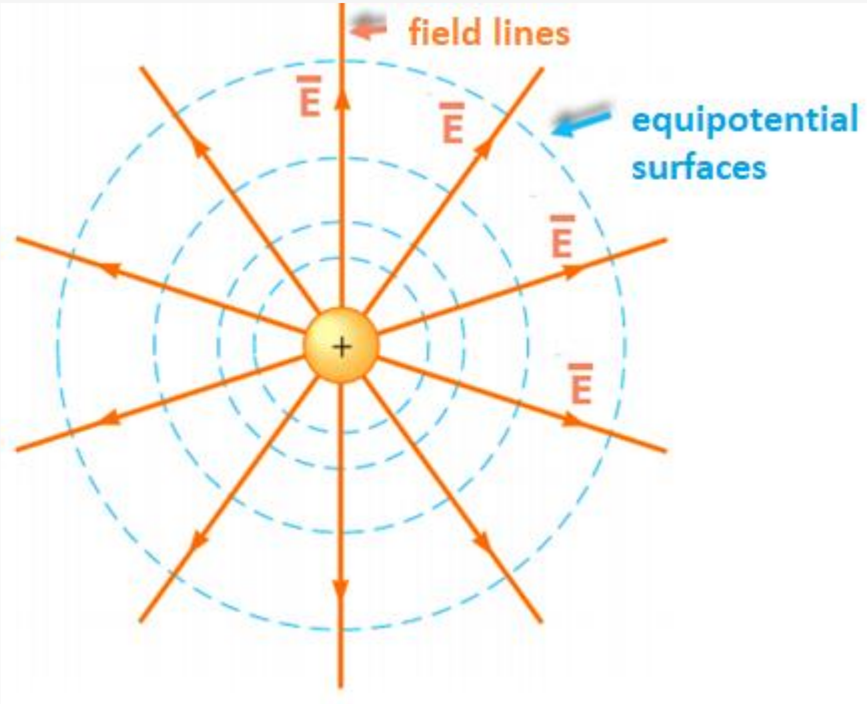
$$U_{AB} = \int_A^{P_0} \bar{E} \cdot d\bar{s} + \int_{P_0}^{B} \bar{E} \cdot d\bar{s} = V_A - V_B$$

✓ The potential of point $\mathbf{P_0}$ is zero, because:

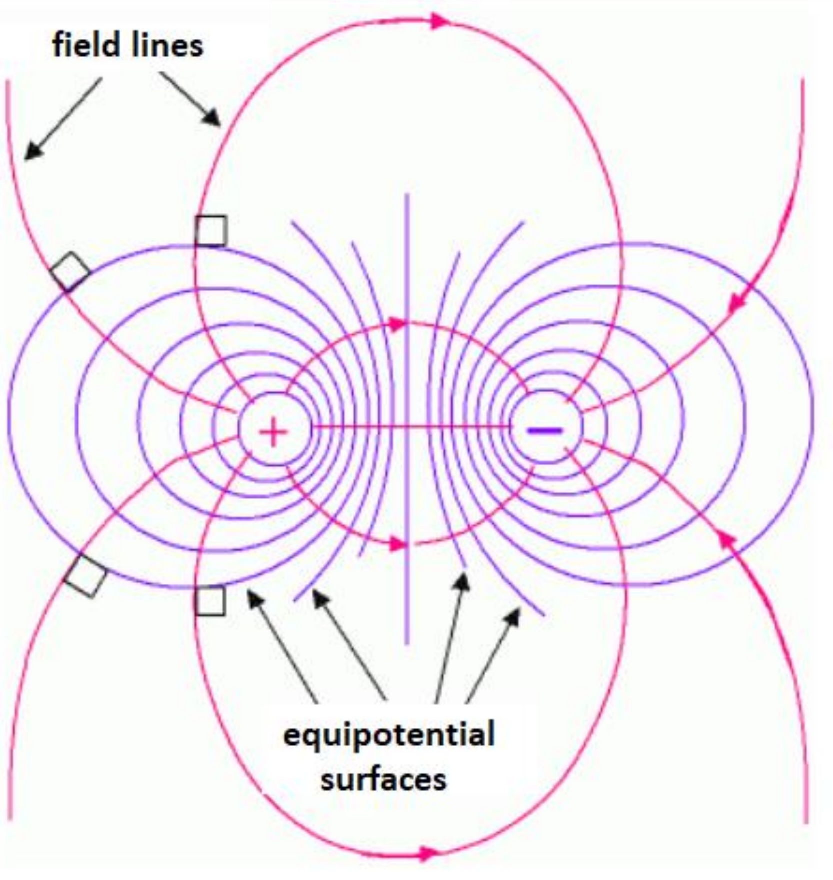
$$\int_{P_0}^{P_0} \bar{E} \cdot d\bar{s} = 0$$

Electric field spectrum. Equipotential surfaces

The geometric place of the points having the same potential is called equipotential surface. The electrical field lines and implicitly the electric field intensities are perpendicular on the equipotential surface. In electrostatics the metallic surfaces are equipotential surfaces.



For a point charge the equipotential surfaces are concentric spheres with their center on the electric charge.



2. Specific laws of the electrostatic field

1) Temporary polarization law (LPT)

Polarization
- permanent component , $\bar{P}_p$, independent from the value $\bar{E}$;
- temporary component, $\bar{P}_t$, dependent on the value $\bar{E}$.

$$\bar{P} = \bar{P}_p + \bar{P}_t$$

At any moment and in any dielectric point, the temporary polarization, $\bar{P}_t$, depends on the electric field intensity, $\bar{E}$:

$$\bar{P}_t = f(\bar{E})$$

– in isotropic, linear and without permanent polarization dielectrics:

$$\bar{P}_t = \varepsilon_0 \chi_e \bar{E}$$

where:
- χ_e - electric susceptibility;
- $\bar{E}$ - electric field intensity [V/m];
- ε_0 – vacuum absolute permittivity:

$$\varepsilon_0 = \frac{1}{4\pi \cdot 9 \cdot 10^9} \quad [F/m]$$

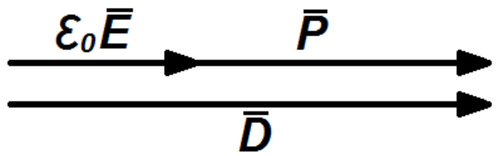
2) The law of dependence between $\bar{D}$, $\bar{E}$ and $\bar{P}$ in electric field

$$\bar{D} = \varepsilon_0 \bar{E} + \bar{P}$$

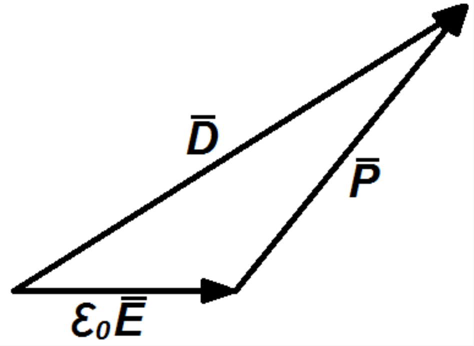
The vectorial sum between the polarization, $\bar{P}$, and electric field intensity, $\bar{E}$, multiplied with the value of vacuum permittivity ε_0 is equal at any moment and in any point with the electrical induction, $\bar{D}$.

Obs.

- in isotropic dielectric environments the vectors $\bar{D}$, $\bar{E}$ and $\bar{P}$ are collinear



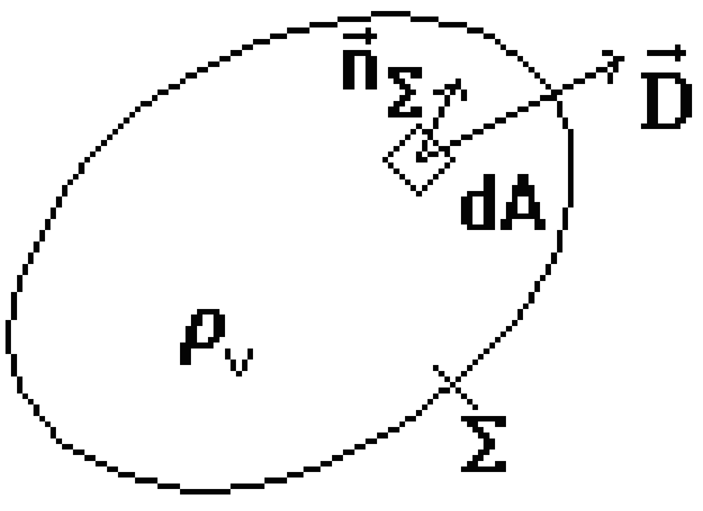
- in anisotropic dielectric environments the vectors $\bar{D}$, $\bar{E}$ and $\bar{P}$ are not collinear



- $\bar{D}$ - electrical induction [C/m^2];
- $\bar{P}$ - electrical polarization [C/m^2].

3) Electrical flux law

- General (global) form for the electrical flux law:



$$\boxed{\Psi_\Sigma = \oiint_\Sigma \bar{D} \cdot d\bar{A} = q_\Sigma} \quad (1)$$

The electrical induction flux, $\bar{D}$ on any closed surface Σ, is equal with the charge amount q contained within the surface Σ.

Obs.
- *this law can be applied* in any medium*;*
- *the electrical flux law is useful, especially in* determining the electrical induction D*; the integration surface, Σ, is conveniently chosen to be able to easily perform the scalar product $\bar{D} \cdot d\bar{A}$. It is thus possible to determine the electric induction module D; vector $\bar{D}$ is determined based on the field symmetry.*

❑ The local form of the electrical flux law:

- it is deduced from the global form;
- if the charge q is volumetrically distributed with the density ρ_V:

$$q = \iiint_{V_\Sigma} \rho_v \, dV \qquad (2)$$

- we introduce (2) in (1): ⇨ $\displaystyle\oiint_\Sigma \bar{D}\, d\bar{A} = \iiint_{V_\Sigma} \rho_v \, dV \qquad (3)$

- the Gauss-Ostrogradski transformation is applied, and the result is:

$$\oiint_\Sigma \bar{D}\, d\bar{A} = \iiint_{V_\Sigma} div\, \bar{D}\, dV \qquad (4)$$

- we introduce (4) in (3): ⇨ $\displaystyle\iiint_{V_\Sigma} div\, \bar{D}\, dV = \iiint_{V_\Sigma} \rho_v \, dV$

the local form of the law: $\boxed{div\,\bar{D} = \rho_V}$

in every field point the divergence of the instantaneous electrical induction is equal with the volume density of the instantaneous charge.

- if the charge q is superficially distributed (not volumetric) with the density $\rho_{S,}$ then the local form of the law becomes:

$$div_S\bar{D}=\rho_S$$

respectively,

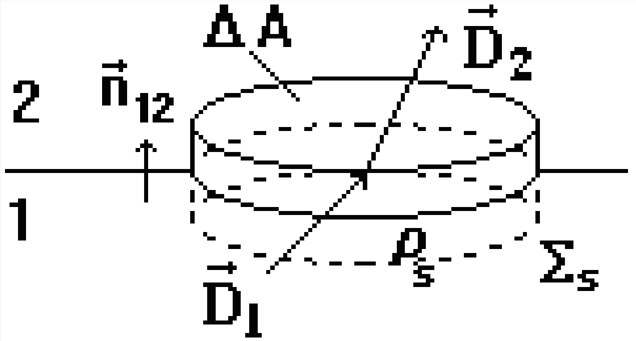
- if the charge q is linearly distributed, with the density $\rho_{l,}$ then the local form of the law becomes:

$$div_l\bar{D}=\rho_l$$

Mathematical recapitulation: $\bar{D}=D_x\,\bar{i}+D_y\,\bar{j}+D_z\,\bar{k}$

- where D_x, D_y, D_z – the components after the three directions of $\bar{D}$: $div\,\bar{D}=\dfrac{\partial D_x}{\partial x}+\dfrac{\partial D_y}{\partial y}+\dfrac{\partial D_z}{\partial z}$

Consequence **Conservation of the electrical induction's normal component on the separation surface between two environments:**



If S is a sufficiently smooth surface separating domains 1 and 2 in which the dielectrics are isotropic and $\bar{D}_1$ *and* $\bar{D}_2$ *are continuous point functions, and the density* $\rho_S = 0$ **on the surface S, from the cancellation of the superficial divergence,** $div_S \bar{D} = 0$ **, it results:**

$$\bar{n}_{12}\left(\bar{D}_2 - \bar{D}_1\right) = 0$$

$$D_{1n} = D_{2n}$$

On surfaces without electric charge the normal component of the electrical induction is preserved.

❖ **if $\rho_S \neq 0$**

$$D_{2n} - D_{1n} = \rho_S$$

Conclusions

in stationary electric field

Fundamental theorem of electrostatics

$$\oint_{\Gamma} \bar{E}\, d\bar{s} = 0 \rightarrow rot\, \bar{E} = 0$$

$$\bar{E} = -\nabla V$$

Thank you for your attention!!!

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Questions???