CURS 1 18.02.2022

Electrotehnics ET
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I Electromagnetic field theory
II Electronic circuits theory

I Course 1 : 1. Introduction in Electromagnetic Field theory
2. 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
Resistor 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

II 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 electrical two port networks (quadripols)

Course 13 : Study of electrical circuits in transitory regime

Course 14 : Linear circuits in non-sinusoidal regime

Part I. Electromagnetic field theory

Electrification state:
- by friction
- by heating
- by chemical effects
- by crystal deformation
- by X-ray or ultraviolet rays interaction

Electric charge : $[q]_{is} = C$

Electric charge distribution

a) Point electric charges distribution

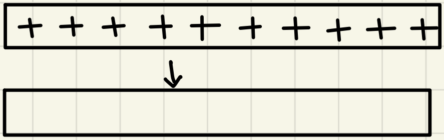
$$q = \sum_{k=1}^{n} q_n$$

$\cdot q_1 \quad \cdot q_2$

$\cdot q_3 \quad \cdot q_4 \quad \cdot q_5 \ldots \cdot q_n$

b) Line or linear electric charges distribution (density)

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

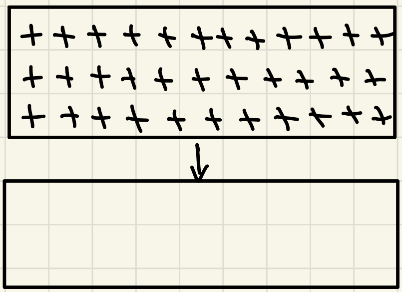


The point el. charge is distributed uniform on a line

linear charge distribution

c) Surface charge distribution (density)

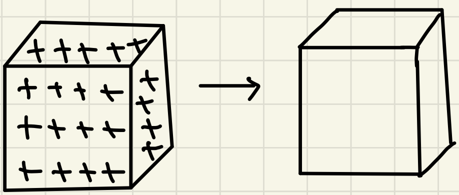
$$\rho_s = \lim_{\Delta A \to 0} \frac{\Delta q}{\Delta A} = \frac{dq}{dA} \quad \left[\frac{C}{m}\right] \qquad q = \int_A \rho_s \, dA$$



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

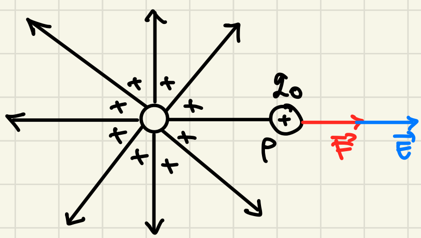
d) Volume charge density (distribution)

$$\rho_v = \lim_{\Delta V \to 0} \frac{\Delta q}{\Delta V} = \frac{dq}{dV} \quad \left[\frac{C}{m^3}\right] \qquad dq = \rho_v \, dV \Rightarrow q = \int_V \rho_v \, dV$$



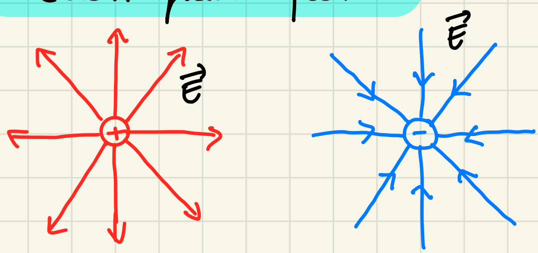
Electric field intensity

$\vec{E}$ - el. field intensity

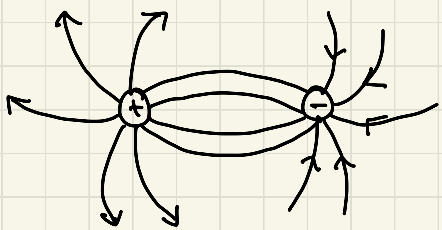


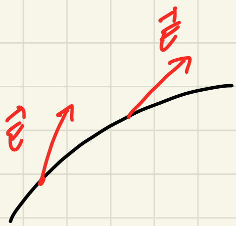
$$\vec{E} \overset{def}{:=} \frac{\vec{F}}{q} \qquad [E] = \left[\frac{N}{C}\right]$$

Electric field spectrum



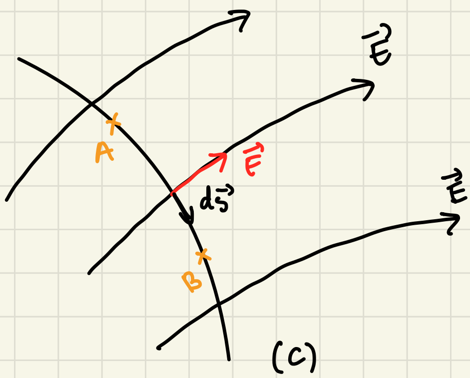
el. field spectrum





Field line :
- 2 lines never intersect
- $\vec{E}$ is tangent in any point
- $dL = \vec{F}_B \cdot d\vec{s}$

Voltage. Electric potential



$$\vec{E} \overset{def}{:=} \frac{\vec{F}}{q_0} \quad (1)$$

$$dL = \vec{F} \cdot ds$$

$\Rightarrow$ The total mechanical work $= L_{AB} = \int_A^B \vec{F} \cdot d\vec{s} \overset{(1)}{\Longrightarrow} L_{AB} = \int_A^B q_0 \cdot \vec{E} \cdot d\vec{s}$

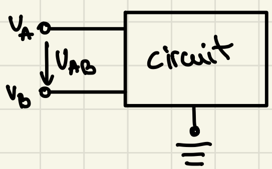
$q_0 = ct \Longrightarrow L_{AB} = q_0 \int_A^B \vec{E} \cdot d\vec{s}$; $\frac{L_{AB}}{q_0}$ - voltage $U_{AB} = \frac{L_{AB}}{q_0} = \int_A^B \vec{E} \cdot d\vec{s}$

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

Electric potential

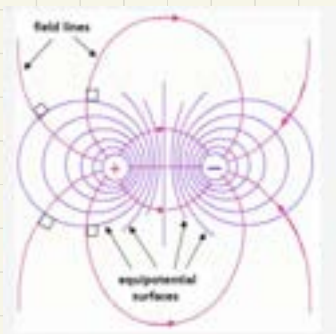
P_0 - reference frame
the potential of point A, V_A

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



$$U_{AB} = \int_A^{P_0} \vec{E} \cdot d\vec{s} + \int_{P_0}^{B} \vec{E} \cdot d\vec{s} = V_A - V_B \quad , \quad \int_{P_0}^{P_0} \vec{E} \cdot d\vec{s} = 0$$

Electric field spectrum. Equipotential surfaces



The geometric place of the points having the same potential is called equipotential surface. The electric field lines are implicity the electric field intensities are perpendicular on the equipotential surface

Specific laws of the electrostatic field

1) Temporary polarization law (LPT)

Polarization : - permanent component, $\vec{P}_p$, independent from the value $\vec{E}$
- temporary component, $\vec{P}_t$, dependent from the value $\vec{E}$

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

! At any moment and in any dielectric point, the temporary polarization, $\vec{P}_t$, depends on the el. field intensity $\vec{E}$

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

- in isotropic, linear and without permanent polarization dielectrics

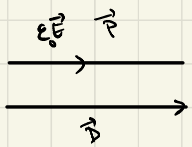
$$\vec{P}_t = \varepsilon_0 \chi_e \vec{E}$$

2) The law of dependence between $\vec{D}$, $\vec{E}$ and $\vec{P}$ in el. field

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

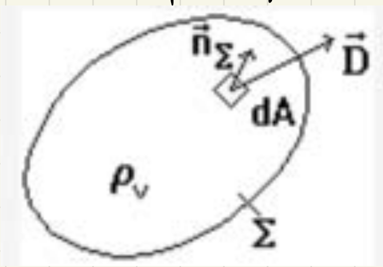
! The vectorial sum between the polarization, $\vec{P}$, and electric field intensity, $\vec{E}$, multiplied with the value of vaccum permitivity ε_0, is equal at any moment and in any point with the induction, $\vec{D}$

Obs



3) Electrical flux law

- General (global) form for the electrical flux law



$$\Psi_\Sigma = \oint\!\!\oint \vec{D} \cdot d\vec{A} = q_\Sigma$$

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

- the law can be applied in any medium

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

$$q = \iiint_{V_\Sigma} \rho_v \, dv \quad (2)$$

• we introduced (2) in (1) $\Rightarrow$ $$\oiint_\Sigma \vec{D}\,d\vec{A} = \iiint_{V_\Sigma} \rho_v \, dV \quad (3)$$

• The Gauss - Ostrodaski transformation is appliend, and the result is:

$$\oiint \vec{D}\,d\vec{A} = \iiint_{V_\Sigma} \operatorname{div}\vec{D}\,dV \quad (4)$$

$\Rightarrow$ the local form of the law $\operatorname{div}\vec{D} = \rho_v$

- superficially distributed : $\operatorname{div}_s \vec{D} = \rho_s$
- linear distributed : $\operatorname{div}_e \vec{D} = \rho_e$

$$\vec{D} = D_x\vec{i} + D_y\vec{j} + D_z\vec{k}$$

$$\operatorname{div}\vec{D} = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z}$$

Consequence

$$\vec{n}_{12}\,(\vec{D}_2 - \vec{D}_1) = 0 \Rightarrow D_{1n} = D_{2n}$$

Conclusion

in stationary electric field

Fundamental theorem of electrostatics

$$\oint_\Gamma \vec{E}\cdot d\vec{s} = 0 \rightarrow \text{not } \vec{E} = 0$$

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

Bazele Electrotehnicii

MARIMI FIZICE

1. Sarcina electrice $\rightarrow q \rightarrow C$ (Coulumb)
2. Forță $\rightarrow \vec{F} \rightarrow N$ (Newton)
3. Intensitatea câmpului electric $\rightarrow \vec{E} \rightarrow \frac{N}{C} \Leftrightarrow \frac{V}{m}$
4. Permitivitatea electrică $\rightarrow \varepsilon \rightarrow F/m$
5. Fluxul câmpului electric $\rightarrow \phi \rightarrow Vm \Leftrightarrow Nm^2C^{-1}$
6. Tensiunea electrică $\rightarrow U \rightarrow V$ (Volt)
7. Potențial electric $\rightarrow V \rightarrow V$
8. Moment electric dipolar $\rightarrow \vec{p} \rightarrow Cm$
9. Polarizare electrică $\rightarrow \vec{P} \rightarrow C/m^2$
10. Densitate de suprafață a sarcinii electrice (sarcină superficială) $\rightarrow \rho_s \rightarrow C/m^2$
11. Densitate de volum a sarcinii electrice (sarcină volumetrică) $\rightarrow \rho_v \rightarrow C/m^3$
12. Intensitatea curentului electric de conducție $\rightarrow I, i \rightarrow A$ (Amper)
13. Densitatea curentului de conducție $\rightarrow J, j \rightarrow \frac{A}{m^2}$

14. Inducția magnetică $\rightarrow \vec{B} \rightarrow T$ (Tesla)

15. Permeabilitatea magnetică $\rightarrow \mu \rightarrow H/m \Leftrightarrow N/A^2 \Leftrightarrow W/Am$

16. Intensitatea câmpului magnetic $\rightarrow \vec{H} \rightarrow A/m$

17. Momentul magnetic $\vec{m} \rightarrow A \cdot m^2 \Leftrightarrow J/T$

18. Polarizația magnetică $\vec{M} \rightarrow T$

19. Fluxul magnetic $\Phi \rightarrow Wb$ (Weber)

20. Inducția electrică (Deplasarea electrică) $D \rightarrow C/m^2$

21. Inductivitate $\rightarrow L \rightarrow H$ (Henry)

22. Densitatea fluxului de energie electromagnetică (vectorul lui Poynting) $\rightarrow W/m^2$

23. Puterea instantanee $\rightarrow P \rightarrow W = V \times A$

24. Puterea activă $\rightarrow P = U \cdot I \cdot \cos\varphi \rightarrow W$

25. Puterea reactivă $\rightarrow Q = U \cdot I \cdot \sin\varphi \rightarrow VAR$

26. Puterea aparentă $\rightarrow S = U \cdot I \rightarrow VA$

27. Puterea deformantă $\rightarrow D \rightarrow VAD$

28. Rezistență electrică $\rightarrow R \rightarrow \Omega$

29. Impedanța $\rightarrow Z \rightarrow \Omega$

30. Reactanța $\rightarrow X \rightarrow \Omega$

31. Rezistivitate $\rightarrow \rho \rightarrow \Omega \cdot m$

32. Conductanța $\rightarrow G \rightarrow S \Leftrightarrow \Omega^{-1}$ (Siemmens)

33. Admitanță $\rightarrow Y \rightarrow S$

34. Susceptanța $\rightarrow B \rightarrow S$

35. Capacitate electrică $\rightarrow C \rightarrow F$ (Farad)

36. Frecvența $\rightarrow f, \nu \rightarrow Hz$ (Hertz)

37. Pulsație $\rightarrow \omega \rightarrow rad/s$

38. Tensiunea $\rightarrow V_m \rightarrow A$

39. Tensiunea magnetică $\rightarrow F_{mm} \rightarrow A$

De la Raresh

Mărimi magnetice

1. intensitatea câmpului magnetic $H \longrightarrow [A/m]$
2. tensiunea magnetică $U_m \longrightarrow [A]$
3. tensiune magnetomotoare $F(F_m) \longrightarrow [A]$
4. inducție magnetică $B \longrightarrow [T]$ tesla
5. flux magnetic $\Phi \longrightarrow [Wb]$ Weber
6. Moment magnetic $m \longrightarrow [A \times m^2]$
7. magnetizație $M\ (H_i) \longrightarrow [A/m]$
8. polarizație magnetică $J\ (B_i) \longrightarrow [T]$
9. permeabilitate $\mu \longrightarrow [H/m]$ (henry/m)
10. permeanță $\Lambda \longrightarrow [H]$ (henry)
11. inductanță proprie $L \longrightarrow [H]$
12. inductanță mutuală $M(L_{12}) \longrightarrow [H]$
13. reluctanță $R_m \longrightarrow [H^{-1}]$

Mărimi fotometrice

1. intensitatea luminoasă $I \longrightarrow [cd]$ (candelă)
2. flux luminos $\Phi \longrightarrow [lm]$ (lumeni)

3. randament luminos $\eta_v \longrightarrow$ [lm / W]

4. cantitate lumină $Q_v \longrightarrow$ [lm × s]

5. luminanța $L_v \longrightarrow$ [cd / m²]

6. emitanță luminoasă $M_v \longrightarrow$ [lm / m²]

7. iluminare $E_v \longrightarrow$ [lx] (lux)

8. expunere luminoasă $H_v \longrightarrow$ [lx × s]

Mărimi electrice

- 0. capacitatea $C \longrightarrow$ [F] (Farad)
- 1. sarcină electrică $Q \longrightarrow$ [C] (coulomb)
- 2. densitatea sarcinii electrice $\rho \longrightarrow$ [C/m³]
- 3. intensitatea curentului electric $I \longrightarrow$ [A]
- 4 intensitatea câmpului electric $E \longrightarrow$ [V/m]
- 5. tensiunea electrică $U \longrightarrow$ [V] Volt
- 6. potențial electric $V \longrightarrow$ [V]
- 7. tensiunea electromotoare $E \longrightarrow$ [V]
- 8. moment electric $p \longrightarrow$ [C × m]
- 9. polarizație electrică $P \longrightarrow$ [C/m²]
- 10. flux electric $\Phi \longrightarrow$ [C]

11. inducție electrică $D \rightarrow [C/m^2]$

12. permitivitate $\varepsilon \rightarrow [F/m]$

13. densitatea curentului electric $J \rightarrow [A/m^2]$

14. rezistența electrică $R \rightarrow [\Omega]$

15. rezistivitate electrică $\rho \rightarrow [\Omega \times m]$

16. ~~conductanța electrică~~ $\cancel{G \rightarrow [Siemens]}$

17. reactanță $X \rightarrow [\Omega]$

18. conductanță $G \rightarrow [Siemens]$

19. impedanță $Z \rightarrow [\Omega]$

20. admitanta $Y \rightarrow [Siemens]$

21. susceptanță $B \rightarrow [Siemens]$

22. putere electrică activa $P \rightarrow [W]$ (watt)

23. putere electrică aparentă $S \rightarrow [VA]$ (volt Amper)

24. putere electrică reactivă $Q \rightarrow [Var]$

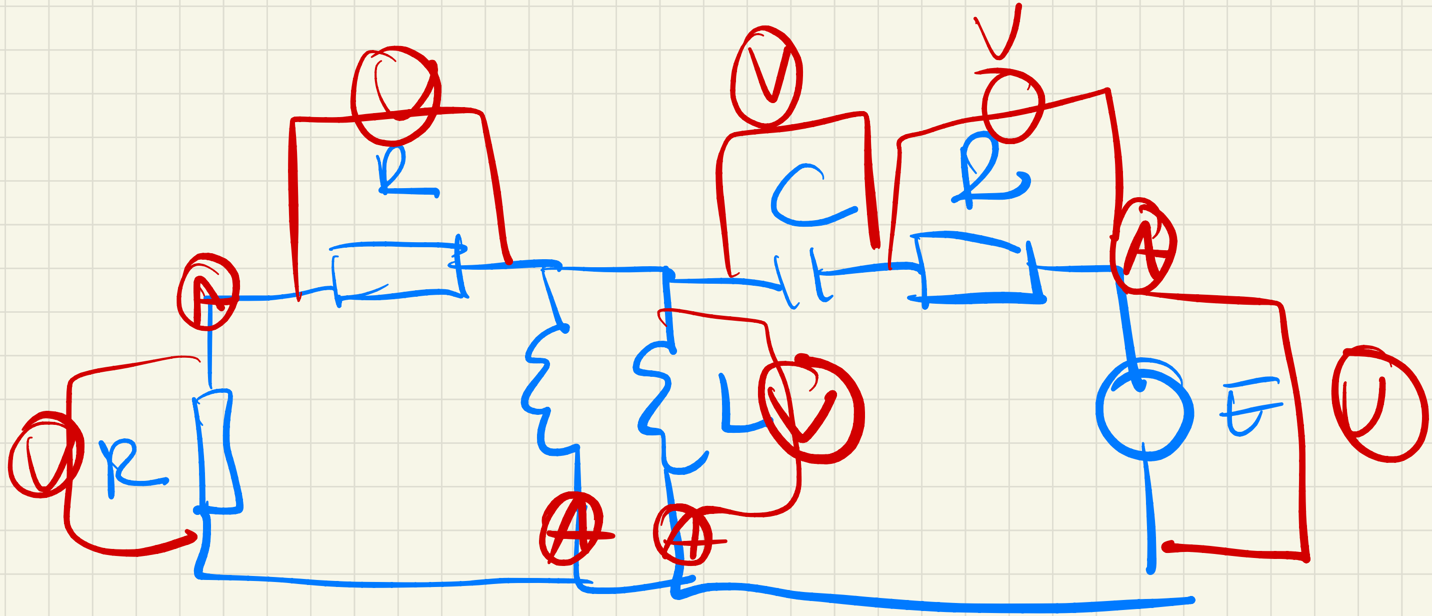
25. energie electrică $W (E) \rightarrow [Wh]$ (wattoră)

26. energie electrică reactiva $W_r \rightarrow [Varh]$ (volt-amper reactiv)

27. frecvență $f \rightarrow [Hz]$ (hertz)

28. factor de putere $\cos\varphi \rightarrow$ adimensional

29. randament $\eta \rightarrow$ —"—



$\bar{D} =$

$U =$

$R =$

$W =$

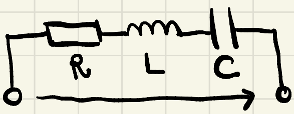
$Q =$ Var Volt-Amp reactiv

Examen ET

- 20-30 intrebari ; 1 rasp. corect doar GRILĂ
  - → which is the capacitance of... ?
  - → capacitance of cilinder
  - → unitate de măsură capacitance F

Curs 7

→ slide 26 calcul la sinusoidală
→ impedanța (slide 32) $z = \frac{U}{I}$

→ 

$z_e = ?$
echivalent impedance

→ paralel (serie impedanță) (curs 8) (s-a notat la CURS)

CURS 9

(slide 16 cum calculezi impedanta between circuitelems)

→ voltage devider / curent devider (ss exemple)

CURS 10

→ slide 12; dă curent in circuit și cere trough a circuit element

→ slide 18 să știi ce se petrece și formula cu explicație la fiecare simbol

→ Homework de la final ar fi bine să știi

CURS 11

→ pe câte loops we apply Kirchoff Theorem 2 (slide 11)

→ slide 11 Kirchoff pe un anumit ochi și scrii ecuația.

→ slide 46 impedance of loop 1 (ori dă valori ifi dă relația de aflat)

→ slide 31 ($U = E = 10 + 10j$ ... ne dă ??? (active | reactive power = ? $P = ?$ $Q = ?$)

→ ce variază la rezonanțe

CURS 13

→ (slide 9) A, B, C, D ca la lab relațiile alea

→ T compus $\underline{Z}_1, \underline{Z}_2, \underline{Y}_0$ $\underline{A} = \underline{D}$; $\underline{Z}_1 = \underline{Z}_2$

→ $Z_{1,2} = -Z_{2,1}$ impedance reciproca

→ (1,2 theorem of comutation curs 13)

TEORIE

CURS 2

Calculation Steps

1. Capacitor plates are charged with the electric charges

$+q \; ; \; -q$

2. $\vec{E}$ (electric field intensity) between the 2 plates = ?

- First, we determine $\vec{D}$ (electric induction) using electric flux Law

$$\oiint_{\Sigma} \vec{D} \cdot d\vec{A} = q_{\Sigma}$$

- second, out of $\vec{D} = \varepsilon \vec{E}$, we calculate $\vec{E}$

3. Voltage $U_{12} = ?$ $\quad U_{12} = \int_1^2 \vec{E} \cdot d\vec{s}$

4. Capacitance $C = ?$ $\quad C = \dfrac{q}{U_{12}}$

Capacitor Connections

1. Capacitors connected in series

$$\rightarrow \frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

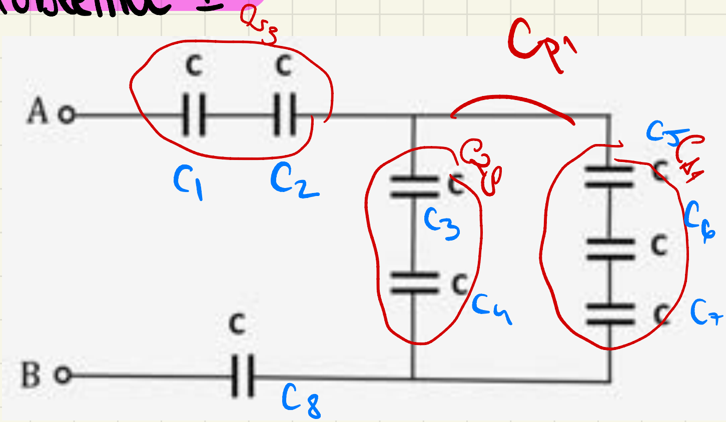
$$\Rightarrow \frac{1}{C_e} = \sum_{k=1}^{n} \frac{1}{C_k}$$

2. Capacitors connected in parallel

$$\rightarrow C_e = C_1 + C_2 + C_3 + \dots$$

$$\Rightarrow C_e = \sum_{k=1}^{n} C_k$$

Problema 1



$$\frac{1}{C_{s1}} = {}^{C_2/}\frac{1}{C_1} + {}^{C_1/}\frac{1}{C_2} = \frac{C_2 + C_1}{C_1 \cdot C_2} \Rightarrow \boxed{C_{s1} = \frac{C_1 \cdot C_2}{C_2 + C_1}} = \frac{C}{2}$$

$$\frac{1}{C_{s2}} = \frac{1}{C_3} + \frac{1}{C_4} \Rightarrow \boxed{C_{s2} = \frac{C_3 \cdot C_4}{C_3 + C_4}} = \frac{C}{2}$$

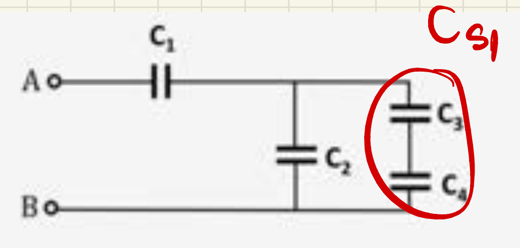
$$\frac{1}{C_{s3}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C} \Rightarrow C_{s3} = \frac{C}{3}$$

$$C_{p1} = C_{s2} + C_{s3} = {}^{3/}\frac{C}{2} + {}^{2/}\frac{C}{3} = \frac{5C}{6}$$

$$\frac{1}{C_{s4}} = {}^{5/}\frac{2}{C} + \frac{6}{5C} + {}^{5/}\frac{1}{C} = \frac{10+6+5}{5C} = \frac{21}{5C}$$

$$C_{S4} = \frac{5C}{21}\ [F]$$

Problema 2 Homework



$C_1 = 1\mu F$; $C_3 = 6\mu F$

$C_2 = 3\mu F$; $C_4 = 2\mu F$

$$\frac{1}{C_{S1}} = \frac{1}{C_3} + \frac{1}{C_4} = \frac{1}{6\mu F} + \frac{\overset{3/}{1}}{2\mu F} = \frac{4}{6\mu F}$$

$$C_{p1} = 3\mu F + \frac{6}{4}\mu F = \frac{18}{4}\mu F = \frac{9}{2}\mu F$$

$$\frac{1}{C_{S2}} = 1\mu F + \frac{2}{9}\mu F = \frac{11}{9}\mu F$$

$$\Rightarrow C_{S2} = \frac{9}{11}\mu F$$

PLANE CAPACITOR CAPACITANCE

$$C = \frac{\varepsilon \cdot A}{d}$$

CYLINDRICAL CAPACITOR CAPACITANCE

$$C = \frac{2\pi \varepsilon \cdot l}{\ln \frac{r_e}{r_i}}$$

r_e - exterior radius

r_i - interior radius

FORMULE CURS 1

a) $q = \sum_{k=1}^{n} q_k$ - point electric charges distribution

b) liniar electric charges distribution

$$\rho_l = \frac{dq}{dl} \left[\frac{C}{m}\right] \quad q = \int_l \rho_l \, dl$$

c) surface charge distribution

$$\rho_s = \frac{dq}{dA} \left[\frac{C}{m^2}\right] \quad q = \int_A \rho_s \, dA$$

d) $$\rho_v = \frac{dq}{dV} \left[\frac{C}{m^3}\right] \quad q = \int_V \rho_v \, dV$$

e) electric field intensity

$$\vec{E} = \frac{\vec{F} \text{ (force)}}{q_0 \text{ (charge of the body)}} \quad E - \left[\frac{V}{m}\right]$$

f) voltage

$$V_{AB} = \frac{L_{AB}}{q_0} [V] \quad L_{AB} \rightarrow \text{lucrul mecanic}$$

$$V_{AB} = V_A - V_B$$

g) electric potential

$$V_A = \int_A^{P_0} \vec{E} \cdot d\vec{s} \; ; \; V_{AB} = V_A - V_B$$

V - potential electric $[V]$

TEMPORARY POLARIZATION LAW

- $\vec{P} = \vec{P}_p + \vec{P}_t$

$\vec{P}_p$ - permanent component

$\vec{P}_t$ - temporary component

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

χ_e - electric susceptibility

$\vec{E}$ - electric field intensity

ε_0 - vacuum absolute permitivity

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

THE LAW OF DEPENDENCE BETWEEN $\vec{D}$, $\vec{E}$ and $\vec{P}$

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

FORMULE CURS 3

→ Electrostatic Field Energy $W_e = \frac{1}{2}\sum_{i=1}^{n} V_i \cdot q_i$

→ The energy stored in the electric field of a capacitor

$$W_e = \frac{1}{2} \cdot \varepsilon \cdot V \cdot E^2$$, V - volum

→ Location of Energy in the electric field

$$W_e = \frac{1}{2} \cdot D \cdot E$$

→ Local form of the law: 1) ELECTRICAL CONDUCTION LAW (ECL)

$$\rho \vec{J} = \vec{E} + \vec{E}_i$$

ρ - resistivity J - density of electric field

E - local intensity of electric field

E_i - instantaneous local intensity of electric field

$$\vec{J} = \sigma(\vec{E} + \vec{E}_i)$$

→ Integral form of the Law

$$R \cdot i = \underbrace{u + e}_{U} = \text{Ohm's Law}$$

or $i = G \cdot (u + e)$ G - conductanță

2.2 JOULE - LENZ LAW

(The law of Energy Transformation in Conductors)

▫ LOCAL FORM OF THE LAW

$p = \vec{E}\vec{J}$ p- volume density

$p = \rho J^2 - \vec{E}_i \vec{J} = p_R - p_g$

- p_R - volume density of the power dissipated through the joule effect
- p_g - —"— generated under the influence of the imprinted fields

▫ INTEGRAL (GLOBAL) FORM OF THE LAW

$P = u \cdot i$ P- power

$P = P_R - P_G$, $P_R = R \cdot i^2$
$P_G = e \cdot i$

▫ THE LAW OF ELECTROLYSIS

FARADAY'S LAW $m = k \cdot i \cdot t$ i- intensitate   t- time

where $K = \frac{1}{F_0} \frac{A}{\nu}$

FARADAY'S CONSTANT
$F_0 = 96\,490$ C/echivgram
$\frac{A}{\nu}$ - chemical equivalent

A - ATOMIC MASS
ν - VALENCE

THE LAW OF ELECTRICAL CHARGE CONSERVATION

GLOBAL FORM OF THE LAW

$$i_\Sigma = -\frac{dq_\Sigma}{dt}$$

LOCAL FORM OF THE LAW

$$\operatorname{div}\vec{J} = -\frac{\partial \rho_v}{\partial t}$$

ELECTRO-STATIC REGIME ⟶ ELECTRO-KINETIC REGIME

$$U_{AB} \Leftrightarrow u_{AB}$$

$$\vec{E} \Leftrightarrow \vec{E}$$

$$\vec{D} \Leftrightarrow \vec{J}$$

$$q \Leftrightarrow i$$

$$\varepsilon \Leftrightarrow \sigma$$

$$\vec{P_p} \Leftrightarrow \sigma \cdot \vec{E_i}$$

$$C \Leftrightarrow G$$

FORMULE CURS 4

ELECTRIC RESISTOR

- DIRECT METHOD: $R_{12} = \frac{\rho \cdot \ell}{A}$ $= d$ (distance)

  ℓ - the lenght of the conductor
  ρ - resistivity
  A - area of conductor

- USING OHM'S LAW: $R_{12} = \frac{u_{12}}{i} = \frac{V_1 - V_2}{i}$

- $\sigma = \frac{1}{\rho}$ $[(\Omega \times m)^{-1}]$ - electric conductivity

- USING THE ANALOGY BETWEEN ELECTROSTATIC FIELD AND ELECTROKINETIC FIELD:

$$G_{12} = \frac{1}{R_{12}} \qquad [G]_{SI} = [\Omega^{-1}]$$

$$R_{12} = \frac{1}{G_{12}}$$

- THE RESISTANCE OF THE PLANE CAPACITOR WITH LOSSES:

$$R = \frac{\rho \cdot d}{A} \qquad [\Omega]$$

- THE RESISTANCE OF THE SPHERICAL CAPACITOR WITH LOSSES:

$$R = \frac{\rho}{4 \cdot \pi} \cdot \frac{r_e - r_i}{r_i \cdot r_e} \qquad [\Omega]$$

- LOSSES IN COAXIBLE CABLE : (HOMEWORK) !!!

- SERIES RESISTORS CONNECTION:

$$R_s = \sum_{k=1}^{n} R_k$$

- PARALLEL RESISTORS CONNECTION

$$\frac{1}{R_p} = \sum_{k=1}^{n} \frac{1}{R_k}$$

SPECIFIC LAWS OF THE MAGNETIC FIELD

3.1 TEMPORARY MAGNETIZATION LAW (TML)

Magnetization → permanent component, $\vec{M}_p$
→ temporary component, $\vec{M}_t$

$$\vec{M} = \vec{M}_p + \vec{M}_t$$

H – magnetic field intensity [A/m]

$$\vec{M}_t = f(\vec{H})$$

$$\vec{M}_t = \chi_m \vec{H}$$

3.2 THE LAW OF THE DEPENDENCE BETWEEN $\vec{B}$, $\vec{H}$ and $\vec{M}$ IN MAGNETIC FIELD

$$\phi_\Sigma = \oiint_\Sigma \vec{B}\, d\vec{A} = 0$$

$[B]_{SI} - [T]$ Tesla

$[\phi]_{SI} - [Wb]$

- ELECTRIC FIELD $\longrightarrow$ MAGNETIC FIELD

Electric Field - $\vec{E}$ $\longrightarrow$ Magnetic Field $\vec{H}$
Permittivity - ε $\longrightarrow$ Permeability - μ
Capacitance - C $\longrightarrow$ Inductance - L
Scalar Potential - V $\longrightarrow$ Vector Potential - $\vec{A}$

FORMULE CURS 5

INDUCTANCE OF AN ELECTRIC INDUCTOR (COIL)

$$L = \frac{\Psi}{i}$$ Ψ - magnetic flux total

$[L]_{SI} - [H]$ Henry

1.2 METHODS USED TO INDUCTANCE CALCULATION

I DIRECT METHOD

2) $$\oint \vec{H} \cdot d\vec{s} = \Theta$$

$$\vec{B} = \mu \vec{H}$$

3) $$\Phi = \int_A \vec{B} \cdot d\vec{A} \Rightarrow \Psi = N \cdot \Phi$$

flux total

4) $$L = \frac{\Psi}{i}$$

II INDUCTANCE CALCULATION WITH THE HELP OF THE RELUCTANCE

$$R_m = \frac{U_m}{\Phi_f}$$

U_m → magnetic voltage

Φ_f → magnetic flux

R_m → magnetic resistance (reluctance)

OR

$$R_m = \frac{\ell}{\mu A}$$

ℓ → lenght of the conductor

THE SELF INDUCTANCE

$$\underset{\text{inductance}}{L} = \frac{N^2}{R_m}$$

III INDUCTANCE CALCULATION WITH THE HELP OF THE MAGNETIC ENERGY:

THE SELF INDUCTANCE:

$$L = \frac{2 W_m}{i^2} \rightarrow \text{magnetic energy}$$

NEUMANN'S FORMULA

$$L_{12} = \frac{\Phi_{12}}{i_1} = \frac{\mu}{4\pi} \oint_{\Gamma_1} \oint_{\Gamma_2} \frac{d\vec{s}_1\, d\vec{s}}{R_{12}}$$

contour

suprafete

MAGNETIC CIRCUIT LAW

$$u_{mm_\Gamma} = \Theta_{S_\Gamma} + \frac{d\Psi_{S_\Gamma}}{dt} \quad (1)$$

magnetomotive voltage

conduction currents

displacement current

$$u_{mm_\Gamma} = \oint_\Gamma \vec{H}\, d\vec{s} \; (2); \quad \Theta_{S_\Gamma} = \int_{S_\Gamma} \vec{J}\, d\vec{A} \; (3); \quad \Psi_{S_\Gamma} = \int_{S_\Gamma} \vec{B}\, d\vec{A} \; (4)$$

- THE MOST GENERAL FORM OF THE LAW:

$$\oint_{\Gamma} \vec{H} d\vec{s} = \Theta + i_D + i_v + i_a$$

- THE FIRST MAXWELL EQUATION

$$\mathrm{rot}\,\vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

FORMULE CURS 6

ELECTROMAGNETIC INDUCTION LAW (FARADAY'S LAW)

$$e_\Gamma = - \frac{d\Phi_{S_\Gamma}}{dt} \quad (1)$$

electromotive voltage

$$e_\Gamma = \oint_\Gamma \vec{E}\, d\vec{s} \quad (2)$$

$$\Phi_{S_\Gamma} = \int_{S_\Gamma} \vec{B}\, d\vec{A} \quad (3)$$

(2),(3) ⇒ INTEGRAL FORM

$$\oint_\Gamma \vec{E}\, d\vec{s} = - \frac{d}{dt} \int_{S_\Gamma} \vec{B}\, d\vec{A} \quad (4)$$

STOKES THEOREM:

$$\int_{S_\Gamma} \mathrm{rot}\,(\vec{B} \times \vec{v})\, d\vec{A} = \oint_\Gamma (\vec{B} \times \vec{v})\, d\vec{s}$$

LOCAL FORM OF THE LAW (ELECTROMAGNETIC INDUCTION):

$$\mathrm{rot}\,\vec{E} = - \frac{\partial \vec{B}}{\partial t} + \mathrm{rot}\,(\vec{v} \times \vec{B}) \quad (5)$$

ENERGIES AND FORCES IN MAGNETIC FIELD:

2.1 MAGNETIC FIELD ENERGY

THE ENERGY BALANCE

$$\sum_{k=1}^{n} e_k i_k dt = \sum_{k=i}^{n} r_k i_k^2 dt + \delta L + dW_m$$

MAGNETIC ENERGY

$$W_m = \sum_{k=1}^{n} \frac{\psi_k \cdot i_k}{2}$$

2.2 MAGNETIC FORCES

THE GENERALIZED FORCE

$$X = + \left(\frac{\partial W_m}{\partial x} \right)_{i_k = \text{constant}}$$

FORMULE CURS 7

ELECTRICAL CIRCUITS IN HARMONIC REGIME

$$u(t) = \underbrace{U\sqrt{2}}_{\text{max val (amplitude)}} \sin(\underbrace{\omega t + \gamma_u}_{\text{phase}})$$

$$i(t) = i\sqrt{2} \sin(\omega t + \gamma_i)$$

PERIODIC QUANTITIES

$$i(t) = i(t + kT) \qquad k \in \mathbb{Z}$$
$$u(t) = u(t + kT)$$

T - period $[s]$

f - frequency $\left(\frac{1}{T}\right)$ $[Hz]$

ω - pulsation $(2\pi f)$ $[rad/s]$

PROBLEME !!!

FORMULE CURS 8

- INSTANTANEOUS POWER

$$p(t) = u(t) \cdot i(t)$$

$$p(t) = Ui\left[\cos(\gamma_u - \gamma_i) - \cos(2\omega t + \gamma_u + \gamma_i)\right]$$

- THE ACTIVE POWER

$$P = R \cdot i^2$$

$$P = GU^2$$

- THE APPARENT POWER

$$S = Ui \quad , [VA]$$

- IMPEDANCE

$$Z = \frac{S}{i^2}$$

- ADMITANCE

$$Y = \frac{S}{U^2}$$

- REACTIVE POWER

$$Q = UI \sin\varphi$$

- REACTANCE

$$X = \frac{Q}{I^2}$$

- SUSCEPTANCE

$$B = \frac{Q}{U^2}$$

- TRIANGLE OF POWERS

$$S^2 = P^2 + Q^2$$

- COMPLEX CHARACTERIZATION OF LINEAR CIRCUITS

- SPECIFIC LAWS AND THEOREMS UNDER COMPLEX FORM

FORMULE CURS 9

- SUNT PROBLEME (FACEM MARȚI)

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