NUMERO : 377

DATA : 17/10/2012

A P P U N T I

STUDENTE : Gemello

MATERIA : Fisica II
Prof. Kaniadakis

INTRODUZIONE

ESAME: ESONERO ULTIMA SETT. LEZIONE
- TEORIA 1h MERC
- ESERCIZI 1h GIOV

APPELLI
- SCRITTO
- ORALE

PRINCIPI NEWTON → ASSIOMI

EQ. DIFFERENZIALI ← LINGUAGGIO FISICA

$\ddot{x} = \frac{1}{m} \overline{F}$ INVENTATE DAI FISICI

FORZE

ELETTROSTATICA
MAGNETICA } ① } ② TEORIA INTERAZ. ELETTRODEBOLE
DEBOLE (FERMI)
FORTE
GRAVITAZIONALE

MAXWELL → VS NEWTON

RELATIVITÀ RISTRETTA ← EINSTEIN → $\vec{V}$ LUCE COSTANTE

NEWTON DA AGGIUSTARE AD ALTE $\vec{V}$

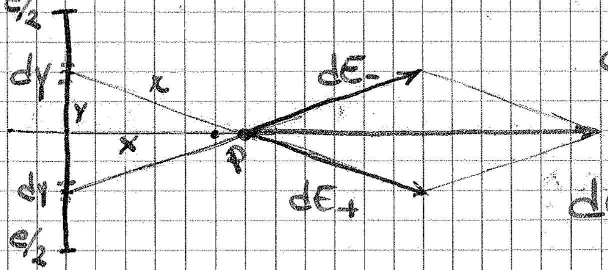
TAXYΣ → P. VELOCI

BPAΔYΣ → P. LENTE

TUTTE LE GRANDEZZE CHE SI CONSERVANO STANNO DIETRO A UNA SIMMETRIA (MATEMATICA)

↳ ES: CONS. EN. ELETTRICA ← LEGGI MAXWELL

CAMPO ELETTRICO GENERATO DA UN FILO



$$dq = \frac{Q}{\ell} dy$$

$$dE_+ = K \frac{dq}{x^2+y^2} = \frac{KQ}{\ell} \frac{dy}{x^2+y^2}$$

$$dE = 2 dE_+ \cos\theta \longleftarrow dE = dE_+ + dE_- \qquad |dE_+| = |dE_-|$$

$$= 2\, dE_+ \frac{x}{\sqrt{x^2+y^2}} = 2K \frac{Qx}{\ell} \frac{dy}{(x^2+y^2)^{3/2}}$$

$$= \frac{2KQ}{\ell} x \frac{dy}{(x^2+y^2)^{3/2}}$$

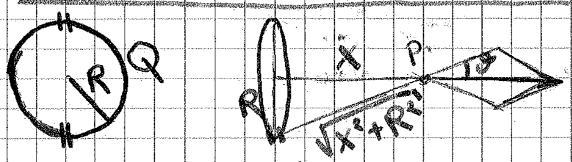
$$E = \int dE = \frac{2KQ}{\ell} x \int_0^{\ell/2} \frac{dy}{(x^2+y^2)^{3/2}} = \frac{2KQ}{x\sqrt{4x^2+\ell^2}}$$

SE ρ COST $\rightarrow E = \dfrac{2K\rho\ell}{x\sqrt{4x^2+\ell^2}}$

SE PRENDO CORPO DI ℓ ∞, MA CARICA FINITA E ρ COST.

$$E = \frac{2K\rho\ell}{x\ell\sqrt{1+\frac{4x^2}{\ell^2}}} = \frac{2K\rho}{x} \rightarrow E \text{ DECRESCE } 1/x$$

CAMPO GENERATO DA UN ANELLO SOTTILE



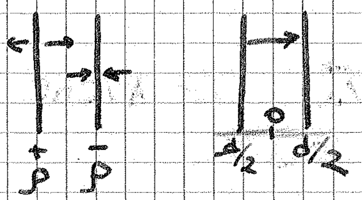
$$dq = \frac{Q}{2\pi r} d\ell$$

$$dE_+ = K \frac{Q}{2\pi r} \frac{d\ell}{x^2+R^2} \qquad |dE_+| = |dE_-|$$

$$dE = dE_+ + dE_- = 2K \frac{Q}{2\pi r} \frac{d\ell}{x^2+R^2} \underbrace{\cos\theta}_{= \frac{x}{\sqrt{x^2+R^2}}}$$

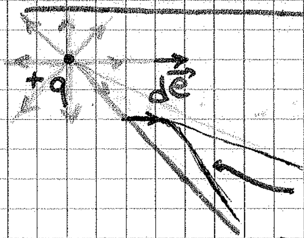
$$dE = \frac{KQx}{\pi r} \frac{d\ell}{(x^2+y^2)^{3/2}}$$

E CREATO DA UN PIANO + E UN PIANO −



$$E(x)=\begin{cases}0 & x<-d/2\\ \dfrac{\rho}{\varepsilon_0} & -d/2<x<d/2\\ 0 & x>d/2\end{cases}$$

LINEA DI FORZA → + : USCENTE ; − : ENTRANTE



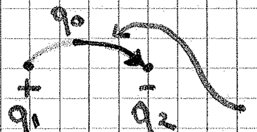
$d\vec{\ell} \propto \vec{E}$

SI AVVICINA ASINTOTIC.

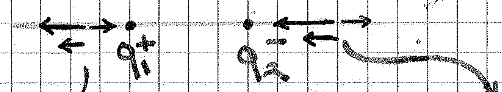
SE INIZIALM. FERMA VA LUNGO LINEE FORZA (RADIALE)

SE VELOCITÀ INIZ. → SI AVVICINA ASINTOTIC. A LINEE FORZA

LINEE CAMPO → DA CARICA POSIT A NEGATIVA



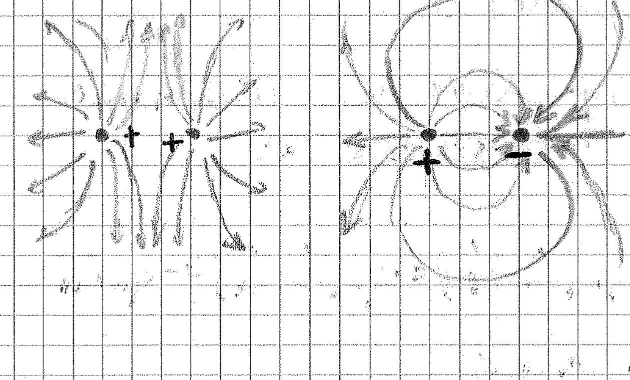
VA VS q_2^-



SENTE DI + q_1^+ → SI ALLONTANA (DA q^+ A ∞)

SENTE DI + q_2^- → SI AVVICINA (DA ∞ A q^-)

SEMIINFINITE



$U = q_0 V$ ENERGIA ELETTROSTATICA

$W_{AB} = -q_0 V_B + q_0 V_A = -U_B + U_A = -(U_B - U_A) = -\Delta U$

$\boxed{W_{AB} + \Delta U = 0}$ PRINC. DI CONSERV. DELL'ENERGIA

SOLO IN CONDIZ. STAZIONARIE (NO CONDIZ. DINAMICHE)

$\vec{E}$ E' CONSERVATIVO

$\int \vec{E}\, d\vec{r} = V_A - V_B = \Delta V \qquad \vec{E} = -\vec{\nabla} V = -\text{GRAD}\, V$

$\vec{E}\, d\vec{r} = -dV \rightarrow \vec{E} = -\frac{dV}{d\vec{r}} = \vec{\nabla} V = \left(\frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial z}\vec{k}\right) V$

$\vec{\nabla} = \frac{\partial}{\partial x}\vec{i} + \frac{\partial}{\partial y}\vec{j} + \frac{\partial}{\partial z}\vec{k} \qquad \boxed{\vec{E} = \vec{\nabla} V}$

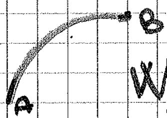
$$\text{ROT}\,\vec{E} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix} = \left(\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right)\vec{i} + \left(\frac{\partial E_x}{\partial z} - \frac{\partial E_z}{\partial x}\right)\vec{j} + \left(\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y}\right)\vec{k}$$

$E_x = -\frac{\partial V}{\partial x} \quad E_y = -\frac{\partial V}{\partial y} \quad E_z = -\frac{\partial V}{\partial z}$

$$\text{ROT}\,\vec{E} = \left(-\frac{\partial}{\partial y}\frac{\partial V}{\partial z} + \frac{\partial}{\partial z}\frac{\partial V}{\partial y}\right)\vec{i} + (\dots)\vec{j} + (\dots)\vec{z} = 0\vec{i} + 0\vec{j} + 0\vec{z} = 0$$

VETTORE CONSERVATIVO

$\boxed{\text{ROT}\,\vec{E} = 0}$



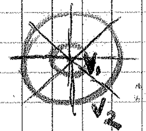
$W_{AB} = \Delta E_{CIN}$

$\Delta E_{CIN} + \Delta U = 0 \quad \Delta(E_{CIN} + U) = 0 \quad \Delta E_{TOT} = 0$

$E_{CIN\,B} + U_B = E_{CIN\,A} + U_A \rightarrow E_{TOT\,B} = E_{TOT\,A}$

$\oint_c \vec{E}\, d\vec{r} = V_A - V_A = 0 \qquad \boxed{\oint_c \vec{E}\, d\vec{r} = 0}$

<u>SUPERFICI EQUIPOTENZIALI</u>



SUP. SFERICHE CON CENTRO IN q

$\forall$ PUNTO DELLA SUP. V E' UGUALE $\qquad V_1 > V_2$

$$\oint_{d\Gamma} \vec{E}\,d\vec{e} = E_x\left(x, y-\frac{dy}{2}\right)dx + E_y\left(x+\frac{dx}{2}, y\right)dy - E_x\left(x, y+\frac{dy}{2}\right)dy + -E_y\left(x-\frac{dx}{2}, y\right)$$

$$f(\tau+d\tau) \simeq f(\tau) + \frac{\partial f(\tau)}{\partial \tau}d\tau \qquad f(x) \simeq f(x_0) + \frac{\partial f(x)}{\partial x}(x-x_0)$$

$$f\left(\tau+\frac{d\tau}{2}\right) \simeq f(\tau) + \frac{1}{2}\frac{\partial f(\tau)}{\partial \tau}d\tau \qquad \begin{cases} x = \tau + d\tau \\ x_0 = \tau \end{cases}$$

$$f\left(\tau-\frac{d\tau}{2}\right) \simeq f(\tau) - \frac{1}{2}\frac{\partial f}{\partial \tau}d\tau$$

$$E_x\left(x, y-\frac{dy}{2}\right) \simeq E_x(x,y) - \frac{1}{2}\frac{\partial E_x(x,y)}{\partial y}dy$$

$$E_y\left(x+\frac{dx}{2}, y\right) \simeq E_y(x,y) + \frac{1}{2}\frac{\partial E_y(x,y)}{\partial x}dx$$

$$E_x\left(x, y+\frac{dx}{2}\right) \simeq E_x(x,y) + \frac{1}{2}\frac{\partial E_x(x,y)}{\partial y}dy$$

$$E_y\left(x-\frac{dx}{2}, y\right) \simeq E_y(x,y) - \frac{1}{2}\frac{\partial E_y(x,y)}{\partial x}dx$$

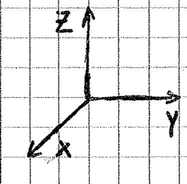
$$\oint \vec{E}\,d\vec{e} = \left(\cancel{E_x} - \frac{1}{2}\frac{\partial E_x}{\partial y}dy\right)dx + \left(\cancel{E_y} + \frac{1}{2}\frac{\partial E_y}{\partial x}dx\right)dy - \left(\cancel{E_x} + \frac{1}{2}\frac{\partial E_x}{\partial y}dy\right)dx + -\left(\cancel{E_y} - \frac{1}{2}\frac{\partial E_y}{\partial x}dx\right)dy = -\frac{\partial E_x}{\partial y}dy\,dx + \frac{\partial E_y}{\partial x}dx\,dy =$$

$$\oint_{d\Gamma_{xy}} \vec{E}\,d\vec{e} = \left(\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y}\right)dx\,dy \qquad \oint_{d\Gamma_{xy}} \vec{E}\,d\vec{e} = \left(\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right)dx\,dz$$

$$\oint_{d\Gamma_{zy}} \vec{E}\,d\vec{e} = \left(\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right)dz\,dy$$

AREE FACCE CIRCUITO

SE CIRCUITO NON E' PIANO:

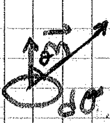


$$\oint_{d\Gamma} \vec{E}\,d\vec{e} = \oint_{d\Gamma_{xy}} \vec{E}\,d\vec{e} + \oint_{d\Gamma_{xz}} \vec{E}\,d\vec{e} + \oint_{d\Gamma_{zy}} \vec{E}\,d\vec{e}$$

TEOREMA DI GAUSS (1ª EQUAZ. DI MAXWELL)

LEGGE COULOMB   SOVRAPPOSIZ. EFFETTI

$\vec{E} = \frac{Kq}{r^3}\vec{r}$ $E = \frac{c}{r^n}$ $\begin{cases} n = 2 \\ c = Kq \end{cases}$ $V = \frac{Kq}{r}$ $V = \frac{c}{(n-1)r^{n-1}}$

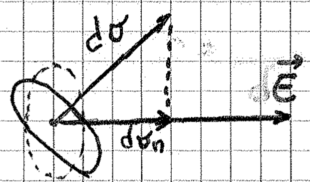


$d\vec{\sigma} = \vec{n}\, d\sigma$ $d\phi = \vec{E}\, d\vec{\sigma}$ $d\phi = E\, d\sigma \cos\theta$

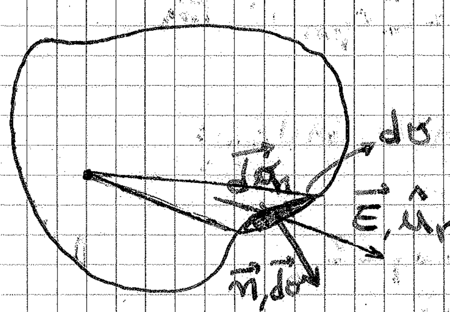
FLUSSO

$= E_n\, d\sigma$

$= E\, d\sigma_n$



2 SUPERF: $d\sigma$, $d\sigma_n$



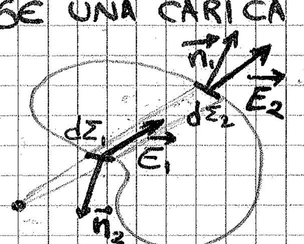
$$d\phi = \vec{E}\, d\vec{\sigma} = \frac{Kq}{r^2}\hat{u}_r \vec{n}\, d\sigma = \frac{Kq}{r^2}\cos\theta\, d\sigma = \frac{Kq}{r^2} d\sigma_n = Kq\frac{d\sigma_n}{r^2} = Kq\, d\Omega$$

$$d\phi = \frac{q}{4\pi\varepsilon_0} d\Omega$$

$$\phi = \frac{q}{4\pi\varepsilon_0} d\Omega_1 + \frac{q}{4\pi\varepsilon_0} d\Omega_2 + \ldots = \frac{q}{4\pi\varepsilon_0}(d\Omega_1 + d\Omega_2 + \ldots) = \frac{q}{4\pi\varepsilon_0}\int d\Omega = \frac{q}{4\pi\varepsilon_0}4\pi = \frac{q}{\varepsilon_0}$$

$$\phi_\Sigma(\vec{E}) = \frac{q_{int}}{\varepsilon_0}$$

SE UNA CARICA È ESTERNA:



$d\phi_1 = \vec{E}_1 d\vec{\Sigma}_1 < 0$

$d\phi_2 = E_2 d\Sigma_2 > 0$

$dS = r^2 d\Omega$

$$d\phi_x = \left[\cancel{E_x(x,y,z)} + \frac{1}{2}\frac{\partial E_x(x,y,z)}{\partial x}dx - \left(\cancel{E_x(x,y,z)} - \frac{1}{2}\frac{\partial E_x(x,y,z)}{\partial x}dx\right)\right]dy\,dz =$$

$$\frac{\partial E_x(x,y,z)}{\partial x}dx\,dy\,dz = \frac{\partial E_x(x,y,z)}{\partial x}dV$$

$$d\phi = d\phi_x + d\phi_y + d\phi_z = \frac{\partial E_x}{\partial x}dV + \frac{\partial E_y}{\partial y}dV + \frac{\partial E_z}{\partial z}dV$$

$$d\phi = \left(\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z}\right)dV = \mathrm{DIV}\,\vec{E}\,dV$$

$$\vec{\nabla}\vec{E} = \mathrm{DIV}\,\vec{E} = \left(\vec{i}\frac{\partial}{\partial x} + \vec{j}\frac{\partial}{\partial y} + \vec{k}\frac{\partial}{\partial z}\right)\left(\vec{E}_x\vec{i} + \vec{E}_y\vec{j} + \vec{E}_z\vec{k}\right)$$

$$d\phi = \mathrm{DIV}\,\vec{E}\,dV$$

$$\phi = \frac{q}{\varepsilon_0} \qquad \forall\Sigma \qquad \leftarrow \text{INTEGRALE}$$

$$d\phi = \mathrm{DIV}\,\vec{E}\,dV \qquad d\Sigma$$

$$\frac{dq}{\varepsilon_0} = \frac{\rho\,dV}{\varepsilon_0} \qquad \mathrm{DIV}\,\vec{E}\,dV = \frac{\rho}{\varepsilon_0}dV \qquad \mathrm{DIV}\,\vec{E} = \frac{\rho}{\varepsilon_0} = \frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z}$$

$$\mathrm{DIV}\,\vec{E} = \frac{\rho}{\varepsilon_0} \leftarrow \text{DIFFERENZIALE}$$

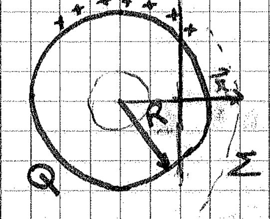
$$\vec{E} = -\vec{\nabla}V \qquad \vec{\nabla}\cdot(-\vec{\nabla}V) = \frac{\rho}{\varepsilon_0} = -\left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}\right)$$

$$(\vec{\nabla}\vec{\nabla})V = -\frac{\rho}{\varepsilon_0}$$

$$\underbrace{\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right)}V = -\frac{\rho}{\varepsilon_0}$$

OPERATORE DI 2° ORDINE
LAPLACEIANO (Δ) $\longrightarrow \Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$

3) SFERA CARICA UNIFORMEMENTE VUOTA



UNIONE DI ANELLI

$$\oint \vec{E}\, d\vec{\sigma} = 4\pi r^2 E = \frac{Q}{\varepsilon_0} \qquad E = \frac{Q}{4\pi\varepsilon_0 r^2} \text{ SE } r > R$$

PER UN PUNTO ALL'ESTERNO SFERA PIENA = SFERA CAVA

$$\text{SE } r < R \quad \oint \vec{E}\, d\vec{\sigma} = 4\pi r^2 E = \frac{0}{\varepsilon_0} \rightarrow E = 0$$

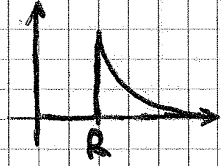
↓

CAMPO INTERNO A SFERA È NULLO

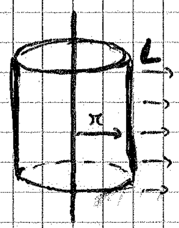
↓

GABBIA DI FARADAY

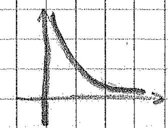
$$E = \begin{cases} 0 & r < R \\ \dfrac{Q}{4\pi\varepsilon_0 r^2} & r > R \end{cases}$$



4) FILO CARICO UNIF.



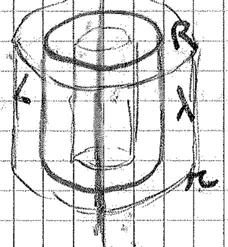
CAMPO RADIALE



$$E \cdot \underbrace{2\pi r L}_{\text{SUP LAT}} + \underbrace{0 + 0}_{\text{SUP BASI}} = \frac{\lambda L}{\varepsilon_0} \qquad E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

$\forall L \rightarrow$ ANCHE $L\ \infty$

5) CILINDRO CAVO



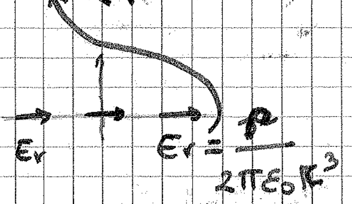
$$2\pi r L E = \frac{\lambda L}{\varepsilon_0} \qquad \lambda L = 2\pi R \sigma L$$

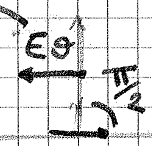
$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \text{ SE } r > R \qquad \sigma = \frac{\lambda}{2\pi R}$$

$$2\pi L E \cancel{r} = 0 \text{ SE } r < R \rightarrow E = 0$$

$$E = \begin{cases} r \le R & 0 \\ r > R & \dfrac{\lambda}{2\pi\varepsilon_0 r} \end{cases}$$

$$E_r = \frac{\cancel{2}\,p\cos\theta}{2\cancel{4}\pi\varepsilon_0 r^3} \qquad E_\theta = \frac{p\sin\theta}{4\pi\varepsilon_0 r^3} \qquad V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$

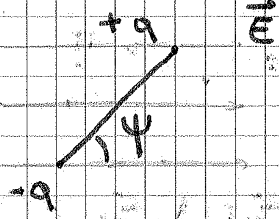




LINEE SEMINFINITE

$$V = \frac{\vec{p}\,\vec{u}_r}{4\pi\varepsilon_0 r^2}$$

$$\begin{cases} E_r = \dfrac{2p\cos\theta}{4\pi\varepsilon_0 r^3} \\ E_\theta = \dfrac{p\sin\theta}{4\pi\varepsilon_0 r^3} \end{cases}$$



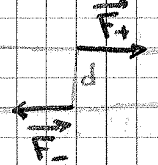
$U = qV_+ - qV_- = qV$

$-q \rightarrow (x, y, z)$

$+q \rightarrow (x+d_x, y+d_y, z+d_z)$

QUANTITÀ PICCOLE (INFINITESIMALI)

$$U = qV(x+d_x, y+d_y, z+d_z) - qV(x,y,z)$$
$$= q\left(V(x,y,z) + \frac{\partial V}{\partial x}d_x + \frac{\partial V(x,y,z)}{\partial y}d_y + \frac{\partial V}{\partial z}d_z\right) - qV(x,y,z)$$
$$= q\left(\frac{\partial V}{\partial x}d_x + \frac{\partial V}{\partial y}d_y + \frac{\partial V}{\partial z}d_z\right) = q\left(\frac{\partial V}{\partial x}\vec{i} + \frac{\partial V}{\partial y}\vec{j} + \frac{\partial V}{\partial z}\vec{k}\right)\left(d_x\vec{i} + d_y\vec{j} + d_z\vec{k}\right)$$
$$= q\vec{\nabla}V\vec{d} = -q\vec{E}\,\vec{d} = -\vec{E}\,\vec{p}$$



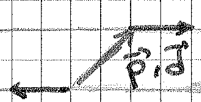
$\vec{F}_+ = F\vec{i}$

$\vec{F}_- = -F\vec{i}$

$M = Fd\sin\psi \qquad \vec{M} = -Fd\sin\psi\cdot\vec{K}$

ENTRANTE

$F = qE \qquad \vec{M} = -qE\cdot d\sin\psi\cdot\vec{K} = -pE\sin\psi\vec{K}$



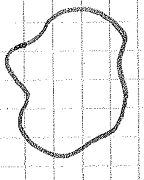
$M = |\vec{p}\wedge\vec{E}| =$

$\vec{M} = p\hat{j}\wedge E\hat{i} = -pE\sin\psi\hat{K}$

CONDUTTORI

PERMETTONO CONDUZIONE INTERNA

SE NON CI SONO CAMPI ESTERNI, LE q SONO FERME



SE ALL'INTERNO DEL CONDUTTORE $E=0$

↓

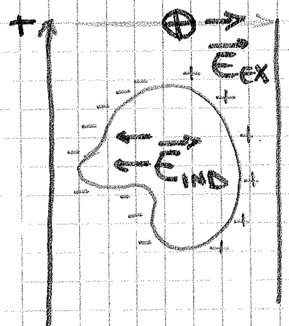
$\rho=0$ → NON CI SONO CARICHE

1) SONO SULLA SUPERFICIE

2) GRADIENTE POTENZIALE $=0$ → POTENZIALE È COSTANTE (ANCHE SULLA SUP)

SUP. EQUIPOTENZIALE

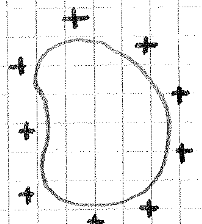
ALL'ESTERNO DEL CONDUTTORE $E\neq 0$



$\vec{E}=0$

$\vec{E}_{EX}+\vec{E}_{INDOTTO}=0$

EX ↳ ESTERNO



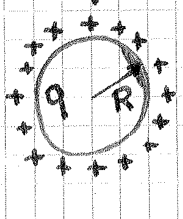
q, V

$C=\frac{q}{V}$ = CAPACITÀ DEL CONDUTTORE $=[F]$

$[C]=\frac{C}{\frac{Nm}{C}}=\frac{C^2}{Nm}=F$ → FARAD

COULOMB

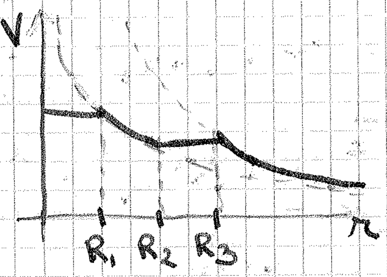
$\vec{E}=\frac{F}{q}\rightarrow NC^{-1}=\frac{[V]}{m}$ $\quad [V]=\frac{Nm}{C}$



$E=\frac{q}{4\pi\varepsilon_0 r^2}$ $\quad r>R$ $\quad V=\int -E\,dr + cost$

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

$$
\begin{cases}
0<r<R_1 & \dfrac{q}{4\pi\varepsilon_0}\left(\dfrac{1}{R_3}-\dfrac{1}{R_2}+\dfrac{1}{R_1}\right)\\
R_1<r<R_2 & \dfrac{q}{4\pi\varepsilon_0}\left(\dfrac{1}{R_3}-\dfrac{1}{R_2}\right)+\dfrac{q}{4\pi\varepsilon_0}\dfrac{1}{r}\\
R_2<r<R_3 & \dfrac{q}{4\pi\varepsilon_0}\dfrac{1}{R_3}\\
r>R_3 & \dfrac{q}{4\pi\varepsilon_0}\dfrac{1}{r}
\end{cases}
$$

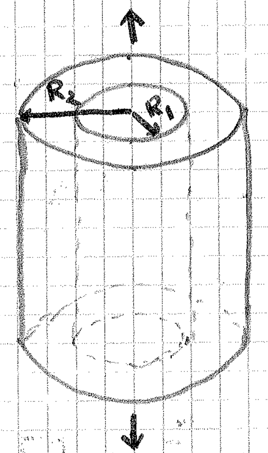


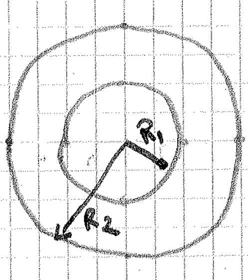
$$C=\frac{Q}{\Delta V}=\frac{q}{\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R_3}-\frac{1}{R_2}+\frac{1}{R_1}\right)-\frac{q}{4\pi\varepsilon_0}\frac{1}{R_3}}$$

CAPACITÀ DI UN SIST. DI CONDUTTORI

$$C=\frac{q}{\frac{q}{4\pi\varepsilon_0}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}=\frac{4\pi\varepsilon_0}{\frac{1}{R_1}-\frac{1}{R_2}}$$

CAPACITÀ DIPENDE DALLA FORMA

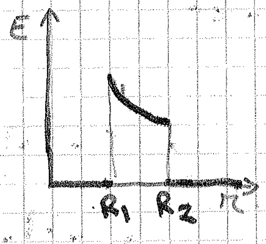




$$E\,2\pi r\,\ell=\frac{\ell\lambda}{\varepsilon_0}$$

$$E=\frac{\lambda}{2\pi\varepsilon_0 r}$$ ← ALL'INTERNO

$E=0$ ← ALL'ESTERNO $(r>R_2)$

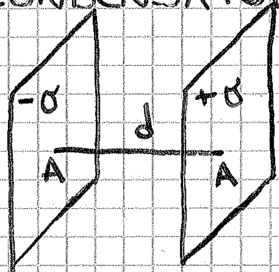


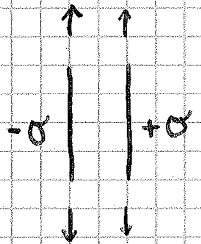
$$E=-\frac{\partial V}{\partial r}$$

$$V=-\int E\,dr+A_2=-\frac{\lambda}{2\pi\varepsilon_0}\int\frac{dr}{r}+A_2=-\frac{\lambda}{2\pi\varepsilon_0}\ln(r)+A_2$$

$$V=\begin{cases}0<r<R_1 & A_1\\ R_1<r<R_2 & -\dfrac{\lambda}{2\pi\varepsilon_0}\ln r+A_2\\ r>R_2 & A_3\end{cases}$$

CONDENSATORI





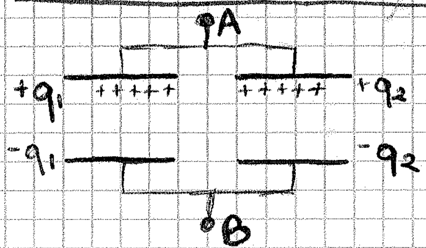
$$E = \frac{\sigma}{\varepsilon_0}$$

$$E = -\frac{dV}{dx}$$

$$V = \int E\,dx + A = -\frac{\sigma}{\varepsilon_0}\int dx + A = -\frac{\sigma}{\varepsilon_0}x + A$$

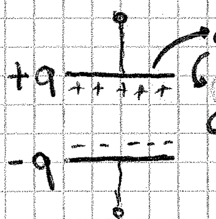
$$\left.\begin{array}{l} V_S = A \\ V_D = -\frac{\sigma}{\varepsilon_0}d + A \end{array}\right\} \rightarrow \Delta V = \frac{\sigma d}{\varepsilon_0} \qquad C = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0}d} = \frac{\varepsilon_0 A}{d}$$

CONDENSATORI IN PARALLELO



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

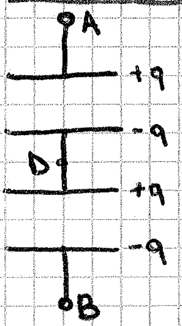
$$C_1 = \frac{q_1}{V_{AB}} \qquad C_2 = \frac{q_2}{V_{AB}}$$



$$q = q_1 + q_2$$

$$C_{eq} = \frac{q}{V_{AB}} = \frac{q_1 + q_2}{V_{AB}} = \frac{C_1 V_{AB} + C_2 V_{AB}}{V_{AB}} = C_1 + C_2$$

CONDENSATORI IN SERIE



$$C_1 = \frac{q}{V_1} \longrightarrow V_1 = \frac{q}{C_1}$$

$$C_2 = \frac{q}{V_2} \longrightarrow V_2 = \frac{q}{C_2}$$

$$V_{AB} = V_{AD} + V_{DB} = V_1 + V_2$$

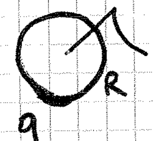
$$V_{AB} = V_1 + V_2 = \frac{q}{C_1} + \frac{q}{C_2} = q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

$$\frac{1}{C_1} + \frac{1}{C_2} = \frac{V_{AB}}{q}$$

$$\frac{q}{V_{AB}} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} = C_{eq}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

ESERCIZIO: CONDENSATORE SFERICO



$$E = \begin{cases} r<R & \dfrac{Q}{4\pi\varepsilon_0 r^3} R \\ r>R & \dfrac{Q}{4\pi\varepsilon_0 r^2} \end{cases}$$

$$U = \frac{1}{2}\varepsilon_0 \int_V E^2 dV = \frac{1}{2}\varepsilon_0 \int_{V_{INT}} E^2 dV + \int_{V_{EST}} \frac{1}{2}\varepsilon_0 E^2 dV =$$

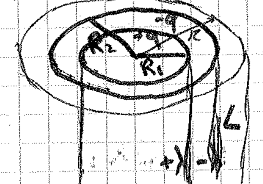
$$= \frac{1}{2}\varepsilon_0 \frac{Q^2}{(4\pi\varepsilon_0 R^3)^2} \int_0^R r^2 \pi r^2 dr + \frac{1}{2}\varepsilon_0 \frac{q^2}{(4\pi\varepsilon_0)^2} \int_R^{+\infty} \frac{1}{r^4} 4\pi r^2 dr$$

$$= \frac{1}{2}\varepsilon_0 \frac{q^2 \, 4\pi}{(4\pi\varepsilon_0 R^3)^2} \int_0^R r^4 dr + \frac{1}{2}\varepsilon_0 \frac{q^2 \, 4\pi}{(4\pi\varepsilon_0)^2} \int_R^{+\infty} r^{-2} dr =$$

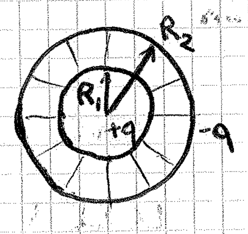
$$= \frac{1}{2}\varepsilon_0 \frac{q^2}{(4\pi\varepsilon_0 R^3)^2} 4\pi \frac{R^5}{5} + \frac{1}{2}\varepsilon_0 \frac{q^2}{(4\pi\varepsilon_0)^2} 4\pi \left(\frac{1}{R}\right)$$

$$= \frac{1 \, q^2}{40\pi\varepsilon_0 R} + \frac{q^2}{8\pi\varepsilon_0 R} \rightarrow U = \frac{1}{2}\varepsilon_0 \int E^2 dV = \frac{3}{5}\frac{q^2}{4\pi\varepsilon_0 R}$$

CONDENSATORI CILINDRICI



$$E = \begin{cases} r<R_1 & 0 \\ R_1<r<R_2 & \dfrac{\lambda}{2\pi\varepsilon_0 r} \\ r>R_2 & 0 \end{cases}$$

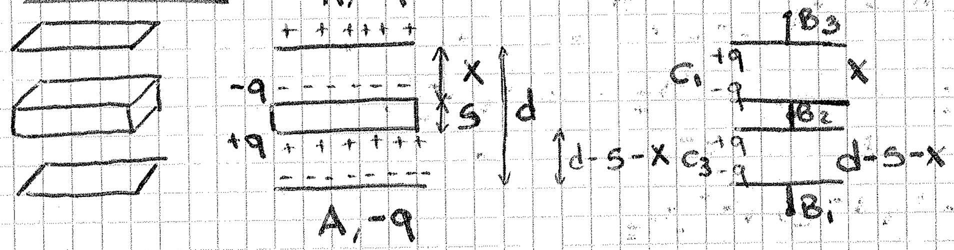


$$U = \frac{1}{2}\varepsilon_0 \int_V E^2 dV = \frac{1}{2}\varepsilon_0 \int_{V_{R_1R_2}} E^2 dV = \frac{1}{2}\varepsilon_0 \frac{\lambda^2}{(2\pi\varepsilon_0)^2} \int_{V_{R_1R_2}} \frac{dV}{r^2} =$$

$$= \frac{1}{2}\varepsilon_0 \frac{\lambda^2}{4\pi^2\varepsilon_0^2} \int \frac{L \, 2\pi r}{r^2} dr = \frac{1}{2}\varepsilon_0 \frac{\lambda^2}{4\pi^2\varepsilon_0^2} L \, 2\pi \int \frac{dr}{r} =$$

$$U = \frac{\lambda^2 L}{4\pi\varepsilon_0} \ln\frac{R_2}{R_1} = \frac{q^2}{4\pi\varepsilon_0 L} \ln\frac{R_2}{R_1}$$

ESERCIZIO



COME FOSSERO 2 CONDENSATORI IN SERIE

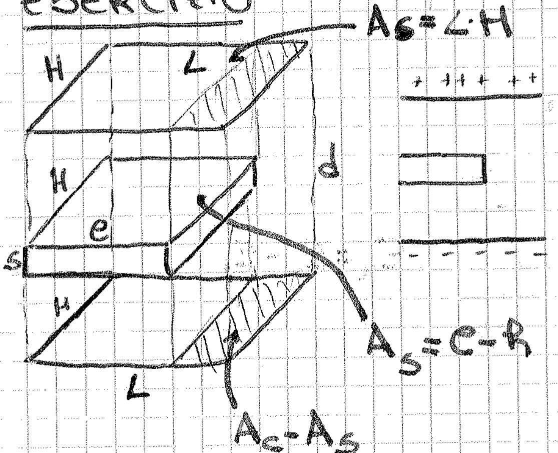
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_3} = \frac{d-s-x}{\varepsilon_0 A} + \frac{x}{\varepsilon_0 A} = \frac{d-s}{\varepsilon_0 A}$$

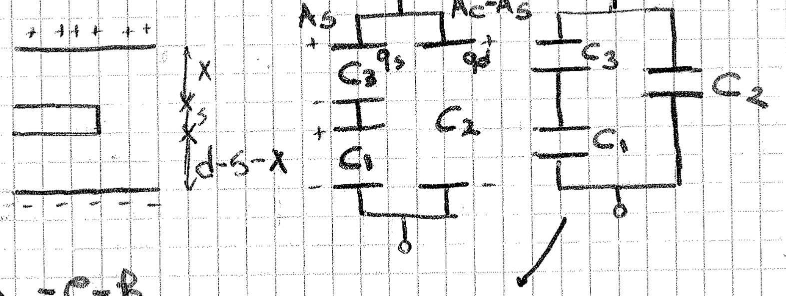
LA CAPACITÀ DEL CONDUTTORE NON DIPENDE DA POSIZIONE DELL'OGGETTO INSERITO, MA DAL SUO SPESSORE

$$C_{eq} = \frac{q}{V_{13}} \qquad V_{13} = \frac{q}{C_{eq}} = \frac{q}{\varepsilon_0 A}(d-s)$$

$$V_{23} = \frac{q}{C_3} \qquad V_{23} = \frac{q}{\varepsilon_0 A}x \qquad V_{12} = \frac{q}{\varepsilon_0 A}(d-s-x)$$

ESERCIZIO





2 CONDENS. IN SERIE MESSI IN PARALLELO CON UN ALTRO

$$C_3 = \frac{q}{V_{13}} = \frac{\varepsilon_0 A_S}{x} = \varepsilon_0 \frac{eH}{x}$$

$$C_1 = \frac{\varepsilon_0 A_S}{d-s-x} = \frac{\varepsilon_0 eH}{d-s-x}$$

$$C_2 = \frac{\varepsilon_0 (A_c - A_S)}{d} = \frac{\varepsilon_0 H (L-e)}{d}$$

$\chi = K-1$ SUSCETTIBILITÀ ELETTRICA DEL MEZZO

$\chi_{vuoto} = 0$

$$K = \frac{E_0}{E_K}$$

$$\left.\begin{aligned} E_0 &= \frac{\sigma_0}{\varepsilon_0} \\ E_p &= \frac{\sigma_p}{\varepsilon_0} \end{aligned}\right\} \frac{E_p}{E_0} = \frac{\sigma_p}{\sigma_0}$$

$$E_p = E_0 - E_K = E_0 - \frac{E_0}{K} = E_0\left(1 - \frac{1}{K}\right) =$$

$$= E_0 \frac{K-1}{K} = \frac{\chi}{K} E_0$$

$$\frac{E_p}{E_0} = \frac{\sigma_p}{\sigma_0} \Longrightarrow \frac{\chi}{K}\frac{E_0}{E_0} = \frac{\sigma_p}{\sigma_0} \qquad \sigma_p = \frac{\chi}{K}\sigma_0$$

$$K = \frac{V_0}{V_K} = \frac{E_0}{E_K} \qquad \varepsilon = K\varepsilon_0 \qquad \chi = K-1$$

$$\sigma_p = \frac{\chi}{K}\sigma_0 \qquad E_K = E_0 - E_p \qquad E_p = \frac{\chi}{K}E_0 \qquad E_K = \frac{1}{K}E_0$$

$$C_0 = \frac{Q_0}{V_0} \qquad C_0 = \frac{\varepsilon_0 A}{d} \qquad E_0 = \frac{\sigma_0}{\varepsilon_0} \qquad \varepsilon_0 = \frac{\sigma_0}{E_0}$$

$$C_0 = \frac{\sigma_0}{E_0}\frac{A}{R} \qquad V_0 = E_0 R \qquad C_0 = \frac{\sigma_0 A}{V_0} = \frac{Q_0}{V_0}$$

$$C_K = \frac{Q_0}{V_K} = \frac{Q_0}{\frac{V_0}{K}} = K\frac{Q_0}{V_0} = KC_0 \longrightarrow C_K = \frac{\varepsilon A}{R}$$

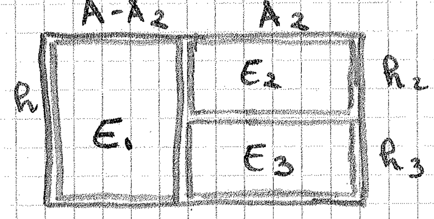
$$\vec{P} = \varepsilon_0 \chi \vec{E}_K = \varepsilon_0 (K-1)\vec{E}_K = (K\varepsilon_0 - \varepsilon_0)\vec{E}_K = (\varepsilon - \varepsilon_0)\vec{E}_K$$

$$\vec{P} = \varepsilon \vec{E}_K - \varepsilon_0 \vec{E}_K = \varepsilon(\vec{E}_0 - \vec{E}_p) - \varepsilon_0(\vec{E}_0 - \vec{E}_p) =$$

$$= \varepsilon\vec{E}_0 - \varepsilon\vec{E}_p - \varepsilon_0\vec{E}_0 + \varepsilon_0\vec{E}_p = (\varepsilon - \varepsilon_0)\vec{E}_0 - (\varepsilon - \varepsilon_0)\vec{E}_p$$

$$= \chi\varepsilon_0(\vec{E}_0 - \vec{E}_p)$$

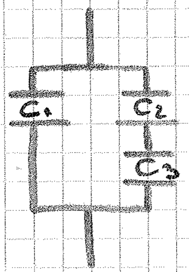
ESERCIZIO



$$C_1 = \frac{\varepsilon_1 (A - A_2)}{h}$$

$$C_2 = \frac{\varepsilon_2 A_2}{h_2}$$

$$C_3 = \frac{\varepsilon_3 A_2}{h - h_2}$$

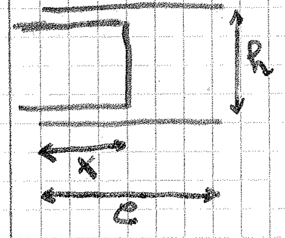


$$\frac{1}{C_{23}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{h_2}{\varepsilon_2 A_2} + \frac{h - h_2}{\varepsilon_3 A_2}$$

$$C_{23} = \frac{A_2}{\frac{h_2}{\varepsilon_2} + \frac{h - h_2}{\varepsilon_3}} = \frac{\varepsilon_2 \varepsilon_3 A_2}{\varepsilon_3 h_2 + (h - h_2)\varepsilon_2}$$

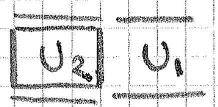
$$C_{123} = C_1 + C_{23} = \frac{\varepsilon_1 (A - A_2)}{h} + \frac{\varepsilon_2 \varepsilon_3 A_2}{\varepsilon_3 h_2 + (h - h_2)\varepsilon_2}$$

ESERCIZIO



$$C = C_{\varepsilon_0} + C_\varepsilon = \frac{\varepsilon_0 (e - x) L}{h} + \frac{\varepsilon L x}{h} =$$

$$= \frac{\varepsilon_0 e L - \varepsilon_0 L x + \varepsilon L x}{h} = \frac{\varepsilon_0 e L + (\varepsilon - \varepsilon_0) L x}{h}$$



$$U = U_1 + U_2 = u_1 V_1 + u_2 V_2 = \frac{1}{2} \varepsilon_0 E_0^2 (e - x) L h +$$

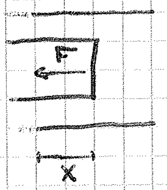
$$+ \frac{1}{2} \varepsilon E^2 x L h$$

$$V = E h \rightarrow E = \frac{V}{h} \rightarrow E_0 = \frac{V_0}{h} \qquad E_0 = \frac{\sigma_0}{\varepsilon_0} \qquad V_0 = \frac{\sigma_0 h}{\varepsilon_0} \qquad V = \frac{\sigma_0 h}{\varepsilon}$$

$$U = \frac{1}{2} \varepsilon_0 V_0^2 \frac{(e - x) L}{h} + \frac{1}{2} \varepsilon V^2 \frac{x L}{h}$$

$$= \frac{1}{2} \cancel{\varepsilon_0} \frac{\sigma_0^2 h^{\cancel{2}}}{\varepsilon_0^{\cancel{2}}} \frac{e - x}{\cancel{h}} L + \frac{1}{2} \cancel{\varepsilon} \frac{\sigma_0^2 h^{\cancel{2}}}{\varepsilon^{\cancel{2}}} \frac{x L}{\cancel{h}}$$

AGGIUNTA DIELETTRICO



$dW = F\,dx$

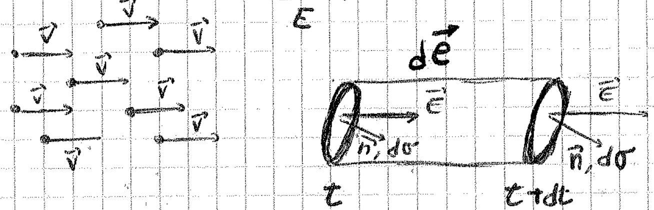
$W = \int_0^{\ell} F\,dx$

F CERCA DI ESPELLERE DIELETTRICO

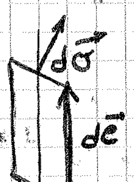
SE FORZO, FACCIO UN LAVORO, CHE FA AUMENTARE EN. ELETTRICA

AUMENTA CAPACITÀ SE METTO UN DIELETTRICO

CAMPO ELETTRICO IN CONDIZIONI DINAMICHE



$d\vec{\ell} \cdot d\vec{\sigma} = d\ell\, d\sigma \cos\theta$



$dV = \vec{v}\, d\tau \cdot d\vec{\sigma}$

$dq = N \cdot e \cdot dV$

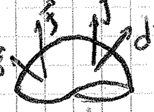
CARICA DI UNA SINGOLA PARTICELLA

$\vec{j} = N e \cdot \vec{v}$ DENSITÀ DI CARICA x VELOCITÀ → DENSITÀ DI CORRENTE

$dq = N \cdot e\, dV = N e \vec{v}\, d\tau\, d\vec{\sigma} = \vec{J}\, d\vec{\sigma}\, d\tau$

$\frac{dq}{d\tau} = \vec{J}\, d\vec{\sigma} = di$

$i = \int_S \vec{J}\, d\vec{\sigma}$



INTENSITÀ DI CORRENTE

CARICA dq CHE FLUISCE IN UN CERTO TEMPO $d\tau$ (ATTRAVERSO UNA SUPERF. FINITA)

$\frac{\partial q}{\partial t}=0$ LA DERIVATA DELLA CARICA COMPLESSIVA È = A ZERO → NON VARIA NEL TEMPO

↳ q COSTANTE

LA CARICA COMPLESSIVA NON DIPENDE DAL TEMPO

EQ.NE CONTINUITÀ → VALE INDIPENDENTEMENTE DA FORMA DI ρ E DI $\vec{J}$

ℓ = DIST. MEDIA CHE L'e^- PERCORRE TRA UN P.TO E L'ALTRO

τ = TEMPO MEDIO CHE IMPIEGA L'e^- $=\frac{\ell}{v}$

L'UNICA FORZA CHE RISENTE DELL'e^- È LA F. ELETTR. (COSTANTE)

ACC. COSTANTE → $\vec{a}=\frac{\vec{F}}{m}=-\frac{e}{m}\vec{E}$

$\vec{v}=\vec{a}\tau \rightarrow \vec{v}=-\frac{e\tau}{m}\vec{E}$

$\vec{J}=-eN\vec{v}=\frac{Ne^2\tau}{m}\vec{E}=\sigma\vec{E}$

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

DENSITÀ DI CORRENTE ∝ AL CAMPO $\vec{E}$

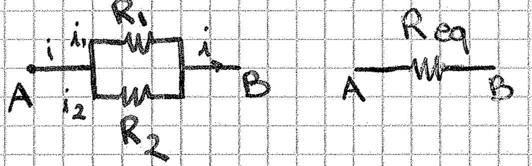
$\sigma=\frac{Ne^2\tau}{m}$ CONDUTTIVITÀ

$\frac{1}{\sigma}=\rho$ = RESISTIVITÀ (N.B. QUI $\rho \neq$ DENSITÀ CARICA)

CONDUTTORE (CHE CREA $\vec{E}$ COST)

$V=V_A-V_B$ $\quad$ $V=ER$

RESISTORI IN PARALLELO



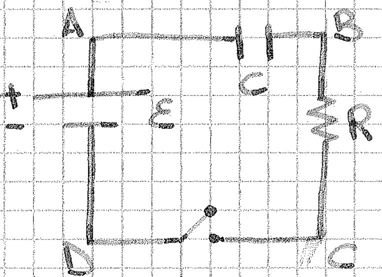
$V_1 = R_1 \cdot i_1 \Rightarrow V_{AB} = R_1 i_1 \Longrightarrow i_1 = \frac{V_{AB}}{R_1} \qquad i_2 = \frac{V_{AB}}{R_2}$

$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \qquad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

$i = \left(\frac{1}{R_1} + \frac{1}{R_2}\right) V_{AB} \qquad V_{AB} = R_{eq} \cdot i$

CIRCUITI ELETTRICI

INSIEME RESISTORI / CONDENSATORI + UN GENERATORE



NODI

$i_1 + i_2 + i_3 = 0$ ← NODO NON È CAPACE DI ACCUMULARE CARICA

$i_1 = i_2 + i_3$

$\sum q_e = \sum q_u \rightarrow \sum_K i_K = 0$

PRIMO PRINCIPIO DI KIRCHOFF

MAGLIE

$\sum_K V_K = 0$

$V_{AB} + V_{BC} + V_{CD} + V_{DA} = \cancel{V_B} - \cancel{V_A} + \cancel{V_C} - \cancel{V_B} + \cancel{V_D} - \cancel{V_C} + \cancel{V_A} - \cancel{V_D} = 0$

SECONDO PRINCIPIO DI KIRCHOFF

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$\int e^{ax}dx = \frac{1}{a}e^{ax}$

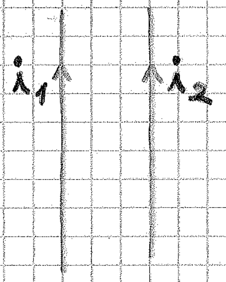
$q_1(t) = A_1 - i_0 \tau e^{-\frac{t}{\tau}}$

$q_2(t) \longrightarrow \int dq_2(t) = \int i(t)\,dt$ → COME X q_1 → $q_2(t) = A_2 - i_0 \tau e^{-\frac{t}{\tau}}$

$q_2(0) \Longrightarrow A_2 - i_0 \tau = 0$

CAMPO MAGNETICO E FORZE MAGNETICHE

CARICHE IN MOVIMENTO



i_1 IMMERSA NEL CAMPO MAGNETICO $\vec{B}_2$ SENTE UNA FORZA $\vec{F}_1$, = E CONTRARIA A $\vec{F}_2$

i_2 SENTE B_1, QUINDI $\vec{F}_2$

CI DEVE ESSERE MOVIM. CARICHE IN ENTRAMBE

$i_1 \to \vec{B}_1 \to \vec{F}_2$

$i_2 \to \vec{B}_2 \to \vec{F}_1$

$\vec{F}_1 = -\vec{F}_2$

$q_1, \vec{v}_1, \vec{B}_{ex} \to q_1$ SENTE UNA FORZA DOVUTO AL CAMPO EXT.

$\boxed{\vec{F}_1 = q_1 \vec{v}_1 \wedge \vec{B}_{ex}}$ → $\vec{F}_1 \perp \vec{B}_{ex}$; $\vec{F} \perp \vec{v}$

$q_2, \vec{v}_2 \Rightarrow \boxed{\vec{B}_2 = \frac{\mu_0}{4\pi} q_2 \frac{\vec{v}_2 \wedge \vec{r}}{r^3}}$ $\qquad \vec{E} = \frac{1}{4\pi\varepsilon_0} q_2 \frac{\vec{r}}{r^3}$

CAMPO MAGNETICO $\qquad$ CAMPO ELETTRICO

μ_0 = PERMEABILITÀ MAGNETICA DEL VUOTO

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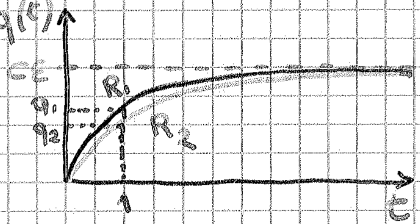
$$q = CE\left(1 \pm \exp\left(-\frac{1}{RC}t\right)\right)$$

$$q = CE\left(1 - \exp\left(-\frac{1}{RC}t\right)\right)$$

TENGO SEGNO NEGATIVO PERCHE' ALL'ISTANTE INIZIALE ($t=0$) q DEVE ESSERE $=0$



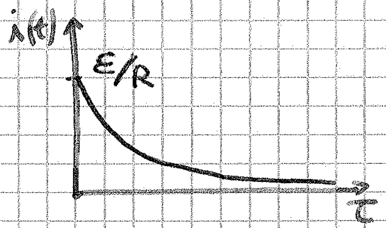
$R_2 > R_1$

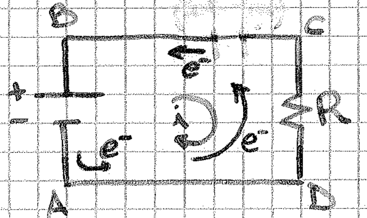
(CE ASINTOTO)

A R PICCOLE IL GRAFICO SALE SUBITO (CI METTE MENO TEMPO A CARICARSI)

$$q(t) = CE\left(1 - e^{-\frac{t}{\tau}}\right) \qquad \tau = RC$$

$$i(t) = \frac{E}{R} e^{-\frac{t}{RC}} \qquad i = \frac{dq}{dt}$$





CORRENTE DI ELETTRONI CARICANO IL CONDENSATORE

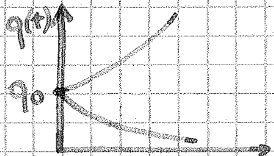
↳ e^- VIAGGIANO IN VERSO OPPOSTO AL VERSO DELLA CORRENTE i

i INDICA UN PASSAGGIO (TEORICO) DI CARICHE POSITIVE

$$q(0) = q_0$$

$$-\frac{1}{C}q(t) - R \cdot i(t) = 0 \rightarrow \frac{1}{C}q(t) + R\frac{dq(t)}{dt} = 0$$

$$\begin{cases} \frac{dq}{dt} = -\frac{1}{RC}q \\ q_0 = q(0) \end{cases} \qquad \int_{q_0}^{q} \frac{dq}{q} = \int_{t=0}^{t} -\frac{1}{RC}\,dt$$

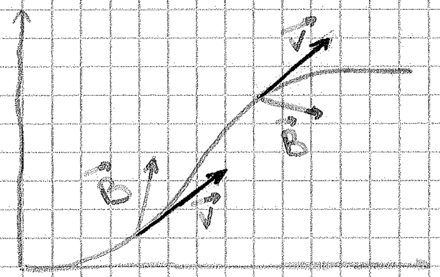


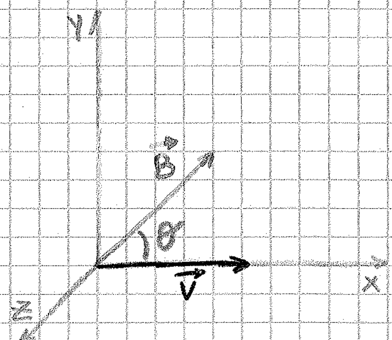
$$\ln|q| - \ln|q_0| = -\frac{1}{RC}t \rightarrow \ln\left|\frac{q}{q_0}\right| = -\frac{1}{RC}t$$

$$\left|\frac{q}{q_0}\right| = e^{-\frac{1}{RC}t} \qquad \frac{q}{q_0} = \pm e^{-\frac{1}{RC}t} \qquad q = q_0 e^{-\frac{1}{RC}t}$$

FORZE MAGNETICHE

$\vec{F} = q \cdot \vec{v} \wedge \vec{B}$ SE $\vec{v} = 0 \rightarrow \vec{F} = 0$





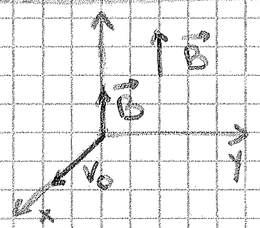
PRENDO GLI ASSI IN MODO CHE L'ASSE X COINCIDA CON $\vec{v}$

F MAGNETICA SI PUÒ CHIAMARE FORZA DI LORENTZ
↓
ALTRI LIBRI CHIAMANO F LORENTZ $F_{magn} + F_e$

$$\vec{F}_L = q\,\vec{v} \wedge \vec{B} + q\vec{E}$$

LA PARTICELLA CARICA SENTE UNA FORZA ⊥ ALLA PROPRIA $\vec{v}$

CAMPO MAGNETICO UNIF.



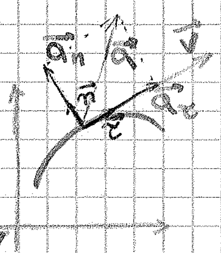
PARTICELLA IN UN CAMPO MAGNETICO UNIFORME

$\vec{B} = B \cdot \vec{K}$ $\begin{cases} \vec{v}(0) = v_0 \vec{i} \\ \vec{r}(0) = 0 \end{cases}$

SE CI METTIAMO IN UN SIST. DI RIFERIM. INERZIALE CON $\vec{v} = 0$ NON SENTE IL CAMPO $\vec{B}$

$\vec{F} = m\vec{a}$

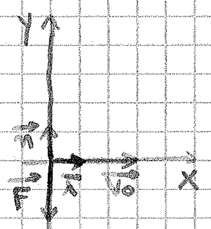
$\vec{F} = q\,\vec{v} \wedge \vec{B} = q \cdot v \cdot B(\vec{i} \wedge \vec{k}) = -qvB\,\vec{j}$



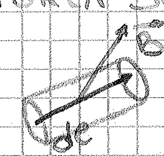
USO COORDINATE INTRINSECHE

$m\vec{a} = \vec{F} \Rightarrow \begin{cases} m\vec{a}_n = \vec{F}_n \Rightarrow ma_n = -qv_0B \\ m\vec{a}_\tau = \vec{F}_\tau \Rightarrow ma_\tau = 0 \end{cases}$

$\frac{v^2}{R} \cdot m = +qvB$ IN MODULO



FORZA SENTITA DA UN CONDUTTORE DI LUNGH. dl IN $\vec{B}$



$d\vec{F} = ?$

$\vec{j} = -Ne\vec{v}$ $\quad \vec{F}_1 = -e\vec{v} \wedge \vec{B}$ $\quad d\vec{l} = dl \frac{\vec{v}}{v}$

$dV = S\,dl$ $\quad \vec{F} = q\vec{v} \wedge \vec{B}$

$d\vec{F} = \vec{F}_1 N\,dV = e\vec{v} \wedge \vec{B}\, N S\,dl$

$= (-Ne\vec{v}) \wedge \vec{B}\, S\,dl = \vec{j} \wedge \vec{B} S\,dl = S(\vec{j}\,dl) \wedge \vec{B}$

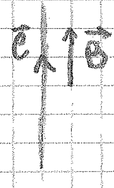
$= S \cdot j\, d\vec{l} \wedge \vec{B} = i\, d\vec{l} \wedge \vec{B}$

$$\boxed{d\vec{F} = i\, d\vec{l} \wedge \vec{B}}$$

$$\vec{F} = i \int_C d\vec{l} \wedge \vec{B} = -i \int_C \vec{B} \wedge d\vec{l} = -i\vec{B} \wedge \int_C d\vec{l}$$

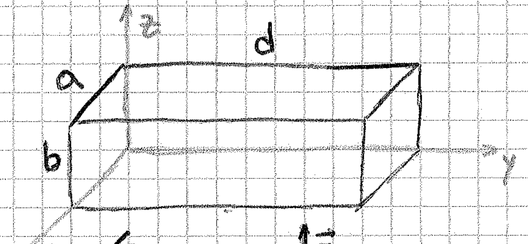
SE TRAIETTORIA È UNA RETTA $\vec{F} = -i\vec{B} \wedge \vec{l} = i\vec{l} \wedge \vec{B}$

$\vec{F} = ilB \otimes$



$\vec{F} = 0$

EFFETTO HALL



$\vec{j} = \frac{i}{ab}\hat{u}_y = Ne\vec{v}$

$$\begin{cases} v = \frac{i}{abNe} \\ \vec{v} = \frac{i}{abNe}\hat{u}_y \end{cases}$$

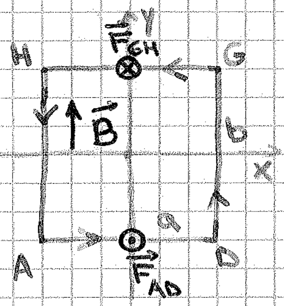
$\vec{B} = B\hat{u}_x$

$$\vec{F} = e\vec{v} \wedge \vec{B} = e\frac{i}{abNe} B\, \hat{u}_y \wedge \hat{u}_x = -\frac{iB}{abN}\hat{u}_z$$

CARICA PARTIC. ELEM.

ACCUMULO PARTIC. IN PARTE INFERIORE

2) CAMPO MAGNETICO CHE AGISCE SUL PIANO DELLA SPIRA RETTANGOLARE



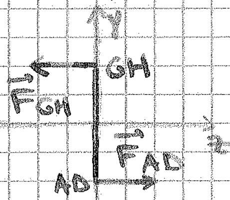
$\vec{F}_{AD} = i\vec{l}_{AD} \wedge \vec{B} = iBa\,\hat{u}_x \wedge \hat{u}_y = iBa\,\hat{u}_z$

$\vec{F}_{GH} = -iBa\,\hat{u}_z$

$\vec{F}_{DG} = iBb\,\hat{u}_y \wedge \hat{u}_y = 0$

$\vec{F}_{HA} = 0$

$\vec{B} = B\,\hat{u}_y$



$\vec{M} = (\vec{GH-O}) \wedge \vec{F}_{GH} + (\vec{AD-O}) \wedge \vec{F}_{AD}$

$= \frac{b}{2}\hat{u}_y \wedge (-iBa\,\hat{u}_z) + \left(-\frac{b}{2}\hat{u}_y\right) \wedge (iBa\,\hat{u}_z)$

$\vec{M} = -\frac{b}{2} iBa\,\hat{u}_x - \frac{b}{2} iBa\,\hat{u}_x = -iBab\,\hat{u}_x$

MOMENTO MECCANICO $\to \vec{M} = iB\underbrace{ab}_{S}(-\hat{u}_x) = iSB(-\hat{u}_x)$

$\boxed{\vec{M} = i\vec{S} \wedge \vec{B}}$ $\quad \vec{S} = S\,\hat{u}_z$ $\quad S \to$ SUP. SPIRA

AREA ORIENTATA

VALE ANCHE SE IL CAMPO VA LUNGO L'ASSE X

VALE ANCHE SE $\vec{B} \parallel \vec{S} \to \vec{M} = 0$

$\boxed{\vec{m} = i\vec{S} = iS\,\vec{n}}$ MOMENTO MAGNETICO

$\boxed{\vec{M} = \vec{m} \wedge \vec{B}}$

SE $\vec{B} \parallel y \Rightarrow \vec{M}$ LUNGO X

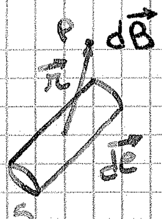
SE $\vec{B} \parallel \vec{n} \Rightarrow \vec{M} = 0$ $\qquad$ SE $\vec{B} \parallel x \Rightarrow \vec{M}$ LUNGO Y

$\vec{M} = -\frac{dU}{d\theta}$ $\quad \left(F = -\frac{dU}{dx}\right)$ $\quad \boxed{U = -\vec{m} \cdot \vec{B}}$ $\quad M = mB\sin\theta$

$U = -mB\cos\theta$

DIPOLO MAGN. $\vec{n}$ $\quad \vec{m} = iS\vec{n}$ $\quad \vec{M} = \vec{m} \wedge \vec{B}$ $\quad U = -\vec{m} \cdot \vec{B}$

DIPOLO ELETTR. $\ominus \to \oplus$ $\quad \vec{p} = q\vec{d}$ $\quad \vec{M} = \vec{p} \wedge \vec{E}$ $\quad U = -\vec{p} \cdot \vec{E}$



$i = S j \qquad \vec{j} \parallel \vec{d\ell} \qquad j\,\vec{d\ell} = \vec{j}\, d\ell$

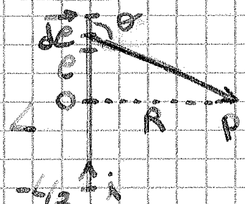
$\vec{B}_1 = \frac{\mu_0}{4\pi} q \frac{\vec{v}\wedge\vec{r}}{r^3} \qquad d\vec{B} = N\, dV\, \vec{B}_1 = N\, d\ell\, S \frac{\mu_0}{4\pi} q \frac{\vec{v}\wedge\vec{r}}{r^3}$

$$d\vec{B} = \frac{\mu_0}{4\pi} S \frac{d\ell\, \vec{j}\wedge\vec{r}}{r^3} = \frac{\mu_0}{4\pi} S j \frac{\vec{d\ell}\wedge\vec{r}}{r^3} = \frac{\mu_0}{4\pi} i \frac{\vec{d\ell}\wedge\vec{r}}{r^3}$$

$$\boxed{d\vec{B} = \frac{\mu_0}{4\pi} i \frac{\vec{d\ell}\wedge\vec{r}}{r^3}}$$

$$\boxed{\vec{B} = \frac{\mu_0}{4\pi} i \oint_c \frac{\vec{d\ell}\wedge\vec{r}}{r^3}} = -\frac{\mu_0}{4\pi} i \oint_c \frac{\vec{r}}{r^3}\wedge \vec{d\ell}$$

CAMPO B GENERATO DA UNA LINEA RETTA



$$d\vec{B} = \frac{\mu_0}{4\pi} i \frac{\vec{d\ell}\wedge\vec{r}}{r^3} = \hat{u}_\varphi \frac{\mu_0}{4\pi} i \frac{d\ell\, r \sin\theta}{r^3}$$

$=$

$$\vec{B} = \hat{u}_\varphi \frac{\mu_0 i}{4\pi}\int \frac{d\ell}{r^2}\sin\theta$$

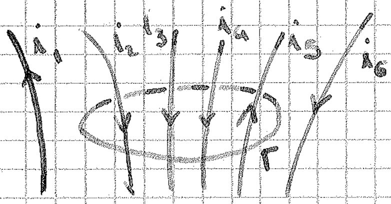
$$\sin\theta = \sin(\pi-\theta) = \frac{R}{r} \Rightarrow \frac{1}{r^2} = \frac{\sin^2\theta}{R^2}$$

$$\tan\theta = -\tan(\pi-\theta) = -\frac{R}{\ell} \Rightarrow \ell = \frac{R}{\tan\theta} \Rightarrow d\ell = \frac{R\,d\theta}{\sin^2\theta}$$

$$\vec{B} = \hat{u}_\varphi \frac{\mu_0 i}{4\pi}\int_{(L/2)^+} \frac{d\ell}{r^2}\sin\theta$$

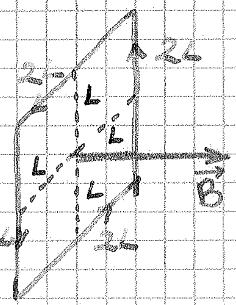
$$\vec{B} = \hat{u}_\varphi \frac{\mu_0 i}{4\pi}\frac{1}{R}\int_{\pi/2}^{\theta_*}\sin\theta\, d\theta = -\hat{u}_\varphi \frac{\mu_0 i}{4\pi}\frac{\cos\theta_*}{R}$$

$$\vec{dB} = \vec{dB}_D + \vec{dB}_S = \frac{\mu_0 i}{2\pi}(d\varphi - d\varphi) = 0$$



$$\oint_\Gamma \vec{B}\, d\vec{\ell} = \mu_0 (i_2 - i_3 - i_4 + i_5)$$

PARETE PIANA

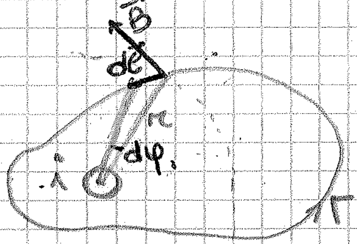


$$\vec{B} = 4\,\frac{\mu_0 i}{2\pi L}\,\frac{L}{\sqrt{L^2 + L^2}}$$

$$= 2\,\frac{\mu_0 i}{\pi L\sqrt{2}} = \frac{\mu_0 \sqrt{2}\, i}{\pi L} = \frac{\mu_0 i \sqrt{2}}{\pi \sqrt{A}}$$

$\square$ $\quad B = \frac{\sqrt{2}}{\pi L}\mu_0 i = \frac{\mu_0 i \sqrt{2}}{\pi \sqrt{A}} = \frac{\sqrt{2}}{\pi}\,\frac{\mu_0 i}{\sqrt{A}}$

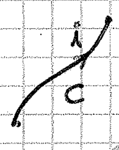
$\bigcirc$ $\quad B = \frac{\sqrt{\pi}}{2R}\mu_0 i = \frac{\mu_0 i \sqrt{\pi}}{2\sqrt{A}} = \frac{\sqrt{\pi}}{2}\,\frac{\mu_0 i}{\sqrt{A}}$



$$\oint_\Gamma \vec{B}\cdot d\vec{\ell} = \frac{\mu_0 i}{2\pi}\oint_\Gamma d\varphi = \mu_0 i$$

$$\vec{B}\cdot d\vec{\ell} = \frac{\mu_0 i}{2\pi r}\, d\ell \cos\theta = \frac{\mu_0 i}{2\pi r}\, ds = \frac{\mu_0 i}{2\pi r}\, r\, d\varphi = \frac{\mu_0 i}{2\pi}\, d\varphi$$

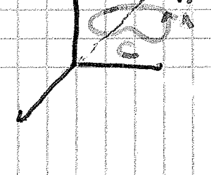
$$\vec{F} = i\int_c d\vec{\ell} \wedge \vec{B}$$



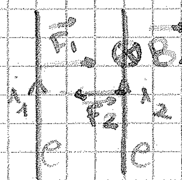
CAMPO MAGN. CREATO DA UN CONDUTTORE

$$\vec{B} = \frac{\mu_0 i}{4\pi}\oint_c \frac{d\vec{\ell} \wedge \vec{r}}{r^3}$$

AMPERE-LAPLACE



FORZA CHE SI SCAMBIANO 2 CONDUTTORI



$$\vec{B}_1 = \frac{\mu_0 i_1}{2\pi d}(-\hat{k})$$

$$d\vec{F}_2 = i_2\, d\vec{l} \wedge \vec{B}_1 = i_2\, dl\, \hat{j} \wedge \frac{\mu_0 i_1}{2\pi d}(-\hat{k}) = -\frac{\mu_0 i_1 i_2}{2\pi d}\, dl\, \hat{u}_i$$

$$\vec{F}_2 = -\frac{\mu_0 i_1 i_2}{2\pi d}\oint_C dl\, \hat{u}_i = -\frac{\mu_0 i_1 i_2}{2\pi d}\, l\, \hat{u}_i$$

$$\vec{B}_2 = \frac{\mu_0 i_2}{2\pi d}(\hat{u}_k)$$

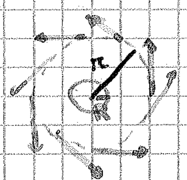
$$d\vec{F}_1 = i_1\, d\vec{l} \wedge \vec{B}_2 = i_1\, dl\, \hat{u}_j \wedge \frac{\mu_0 i_2}{2\pi d}\hat{u}_k = \frac{\mu_0 i_1 i_2}{2\pi d}\hat{u}_i$$

$$\vec{F}_1 = \frac{\mu_0 i_1 i_2}{2\pi d}\, l\, \hat{u}_i$$

$$\vec{F}_1 + \vec{F}_2 = \frac{\mu_0 i_1 i_2}{2\pi d}\, l - \frac{\mu_0 i_1 i_2}{2\pi d}\, l = 0$$ ← $\sum F$ INTERNE $= 0$

CONDUTTORE IDEALE = NO DIM. SE NON LA LUNGH.

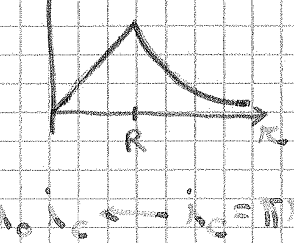
↳ CAMPO ∞ VICINO AL CONDUTTORE



$$\oint_{\Gamma_{circ}} \vec{B}\, d\vec{l} = B \oint_{\Gamma_{circ}} dl = B\, 2\pi r = \mu_0 i$$

$$B\, 2\pi r = \mu_0 i \to B = \frac{\mu_0 i}{2\pi r}$$ ← = CAMPO $\vec{B}$ CREATO DA UN FILO IDEALE

$$\begin{cases} r > R & B = \dfrac{\mu_0 i}{2\pi r} \\ r < R & B = \dfrac{\mu_0 i r}{2\pi R^2} \end{cases}$$



$i = J\pi R^2$

$$\oint_\Gamma \vec{B}\, d\vec{l} = B\, 2\pi r = \mu_0 i_c \leftarrow i_c = \pi r^2 J = \frac{\pi r^2 i}{\pi R^2} = \frac{r^2}{R^2} i$$

$$\int_\Sigma \vec{\nabla}\wedge\vec{B}\, d\vec{\sigma} = \mu_0 \int \vec{j}\, d\vec{\sigma}$$

$$\int_\Sigma (\vec{\nabla}\wedge\vec{B} - \mu_0\vec{j})\, d\vec{\sigma} = 0$$

EQUAZIONI DI MAXWELL

* $\oint_\Sigma \vec{E}\, d\vec{\sigma} = \frac{q}{\varepsilon_0}$ $\quad \vec{\nabla}\cdot\vec{E} = \frac{\rho}{\varepsilon_0}$ GAUSS

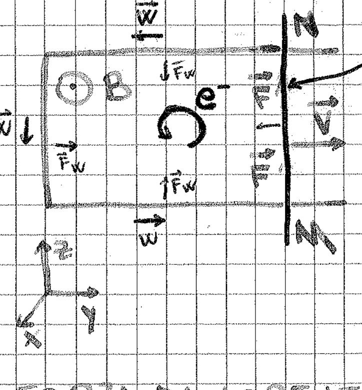
* $\oint_\Sigma \vec{B}\, d\vec{\sigma} = 0$ $\quad \vec{\nabla}\cdot\vec{B} = 0$

* $\oint_\Gamma \vec{E}\, d\vec{\ell} = 0$ $\quad \vec{\nabla}\wedge\vec{E} = 0$ FARADAY

* $\oint_\Gamma \vec{B}\, d\vec{\ell} = \mu_0 i$ $\quad \vec{\nabla}\wedge\vec{B} = \mu_0\vec{j}$ AMPERE

LE PRIME 2 VALIDE ANCHE IN CONDIZ. DINAMICHE, LE ALTRE 2 VALIDE SOLO IN CONDIZ. DI STATICITÀ

EQ. FARADAY IN CONDIZ. DINAMICHE



SBARRETTA MOBILE

$\vec{w}$ = VELOC. e^-

FORZA DI LORENTZ: $\vec{F} = -e\,\vec{v}\wedge\vec{B} = -e(v\hat{u}_y)\wedge(B\,\hat{u}_x)$
CHE SENTE e^- SU $= evB\,u_z$
BARRETTA MOBILE

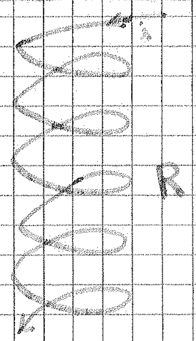
$$\vec{E} = \frac{\vec{F}}{-e} = \frac{-vBu_z e}{e} = -vBu_z = \vec{v}\wedge\vec{B}$$

LUNGO $\overline{MN}$ e^- SENTONO UNA F VS L'ALTO $\to$ FLUSSO e^-

$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \pi e r^2 \frac{\partial B}{\partial t}$ → VELOCITÀ (ED EN. CINETICA) AUMENTANO

$B = \frac{mv}{er}$ $\qquad r = \frac{mv}{eB}$ $\qquad e^-$ ACCELERANO

SOLENOIDE



$B = \mu_0 \frac{N}{e} i$

$\phi_B = NSB = \mu_0 \frac{\pi r^2 N^2}{e} i = L i$ ← INDUTTANZA

$\mathcal{E} = -\frac{\partial \phi}{\partial t} = -L \frac{\partial i}{dt}$

$i_L = \frac{\mathcal{E}}{R} = \frac{L}{R}\frac{\partial i}{\partial t}$

	INTEGRALE		DIFF.
GAUSS	$\phi(\vec{E}) = \frac{q}{\varepsilon_0}$	$\Rightarrow \oint_\Sigma \vec{E}\, d\vec{\sigma} = \frac{q}{\varepsilon_0}$	$\mathrm{DIV}\vec{E} = \frac{\rho}{\varepsilon_0}$
	$\phi(\vec{B}) = 0$	$\Rightarrow \oint_\Sigma \vec{B}\, d\vec{\sigma} = 0$	$\mathrm{DIV}\vec{B} = 0$
FARADAY	$C(\vec{E}) = -\frac{\partial}{\partial t}\phi(\vec{B})$	$\Rightarrow \oint_\Gamma \vec{E}\, d\vec{\ell} = -\frac{\partial}{\partial t}\int \vec{B}\, d\vec{\sigma}$	$\mathrm{ROT}\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
AMPERE	$C(\vec{B}) = \mu_0 i$	$\Rightarrow \oint_\Gamma \vec{B}\, \vec{\ell} = \mu_0 i$	$\mathrm{ROT}\vec{B} = \mu_0 \vec{J}$

AMPERE IN CONDIZ. DINAMICHE

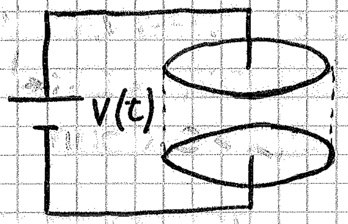
$\vec{\nabla} \wedge \vec{B} = \mu_0 \vec{J}$ $\qquad$ AMPERE

$\vec{\nabla} \cdot (\vec{\nabla} \wedge \vec{B}) = \mu_0 \vec{\nabla} \vec{J} \longleftarrow \vec{\nabla} \cdot (\vec{\nabla} \wedge \vec{V}) = 0$

$0 = \mu_0 \vec{\nabla} \vec{J} \Longrightarrow \vec{\nabla} \vec{J} = 0$ $\qquad$ EQ. CONTINUITÀ

EQUAZ. CONTINUITÀ $\vec{\nabla} \vec{j} + \frac{\partial \rho}{\partial t} = 0$

ESERCIZIO



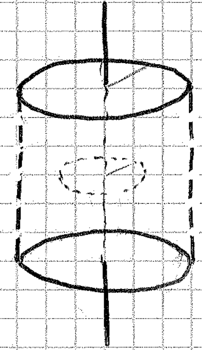
$$C=\frac{q}{V}\qquad q(t)=C\,V(t)$$

$$C=\frac{\varepsilon_0 A}{d}\qquad E=\frac{\rho}{\varepsilon_0}$$

$$\rho(t)=\frac{q(t)}{\pi R^2}$$

$$E(t)=\frac{q(t)}{\pi R^2\varepsilon_0}=\frac{C\cdot V(t)}{\varepsilon_0\pi R^2}=\frac{\cancel{\varepsilon_0}A}{d}\,\frac{V(t)}{\cancel{\varepsilon_0}\pi R^2}=\frac{\cancel{\pi R^2}\cdot V(t)}{d\,\cancel{\pi R^2}}=\frac{V(t)}{d}$$

$$E(t)=\frac{1}{d}V(t)$$

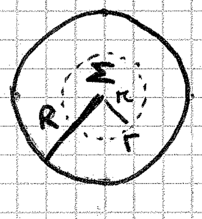


$$\oint_\Gamma \vec{B}\,d\vec{\ell}=\mu_0\varepsilon_0\underbrace{\frac{\partial}{\partial t}\int_\Sigma \vec{E}\,d\vec{\sigma}}_{i_s}+\cancel{\mu_0 i}\;(=0)$$

$$B\,2\pi\cancel{r}=\mu_0\varepsilon_0\frac{\partial}{\partial t}\underbrace{\pi r^{\cancel{2}}E}$$

AREA È POICHÉ

$E \perp$ SUPERF.

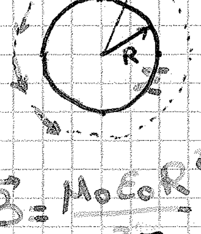


$$B=\frac{\mu_0\varepsilon_0}{2}r\frac{\partial E}{\partial t}=\frac{\mu_0\varepsilon_0}{2d}r\frac{dV(t)}{dt}$$

NEL CENTRO (ASSE) r $\vec{B}$ È NULLO, SU R È MAX

$\vec{B}$ IN MODULO È = $\forall$ CIRCONF. DI RAGGIO r CENTRATE NELL'ASSE

LINEE DI CAMPO DI $\vec{B}$ SONO DELLE CIRCONF.

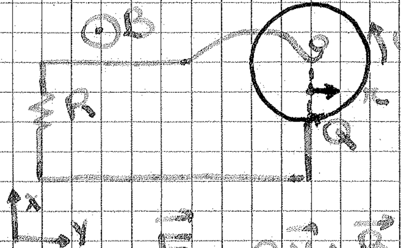


USO COME Γ UNA CIRC., COSÌ $|\vec{B}|$ COST

$$B\,2\pi r=\mu_0\varepsilon_0\frac{\partial}{\partial t}\underbrace{\pi R^2 E}\;\rightarrow\;\text{ESTERNO NON INVESTITO DA }\vec{E}$$

$$\vec{B}=\frac{\mu_0\varepsilon_0 R^2}{2r}\frac{\partial E}{\partial t}=\frac{\mu_0\varepsilon R^2}{2rd}\frac{\partial V(t)}{\partial t}$$

ESERCIZIO



QO GENERA UNA FEM

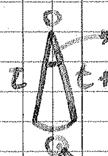
$\vec{B} = B\hat{u}_z$

$\vec{v} = \ell\omega\hat{u}_y$

$\vec{F} = -e\vec{v}\wedge\vec{B} = -e\ell\omega B\,\hat{u}_x\wedge\hat{u}_z = e\ell\omega B\,\hat{u}_y$

$E = \omega B\ell$

$\mathcal{E} = \int_0^r \omega B\ell\,d\ell = \frac{1}{2}\omega B r^2 \Rightarrow i_L = \frac{\mathcal{E}}{R} = \frac{\omega B r^2}{2R}$



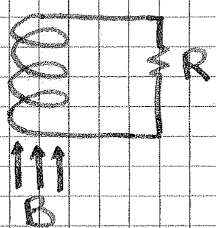
$dA = \frac{1}{2}r^2 d\theta = \frac{1}{2}r^2\omega dt$

$\frac{dA}{dt} = \frac{1}{2}\omega r^2 \qquad B\frac{dA}{dt} = \frac{1}{2}\omega r^2 B \qquad \frac{d\phi}{dt} = \frac{1}{2}\omega B r^2$

$\mathcal{E} = \mathcal{C}(\vec{E})$ LEGGE FARADAY

$\mathcal{E} = \frac{1}{2}B\omega r^2$

ESERCIZIO

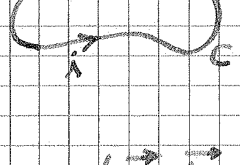


$\phi = NSB$

$\mathcal{E} = -\frac{\partial\phi}{\partial t} = -NS\frac{\partial B}{\partial t}$

$i_L = \frac{\mathcal{E}}{R} = -\frac{NS}{R}\frac{\partial B}{\partial t}$

$\boxed{\text{INDUTTANZA}}$



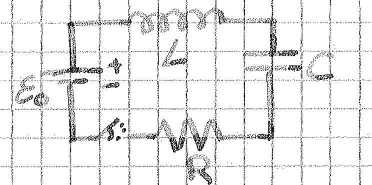
PERCORSO DA $\vec{i}$ → CREA $\vec{B}$

$\vec{B} = \frac{\mu_0 i}{4\pi}\oint_c \frac{d\vec{\ell}\wedge\vec{r}}{r^3}$

$\phi = \int_S \vec{B}\,d\vec{\sigma} \qquad \mathcal{E} = -\frac{\partial}{\partial t}\int_S\left[\frac{\mu_0 i}{4\pi}\oint_c\frac{d\vec{\ell}\wedge\vec{r}}{r^3}\right]d\vec{\sigma} =$

$= \frac{\mu_0}{4\pi}\underbrace{\left[\int_S d\vec{\sigma}\oint_c\frac{d\vec{\ell}\wedge\vec{r}}{r^3}\right]}_{L}\frac{\partial i}{\partial t} = 0$

ESERCIZIO



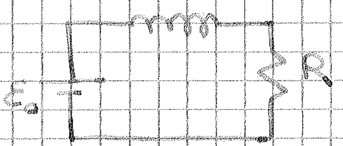
$$\mathcal{E}_0 - L\frac{di}{dt} - \frac{q}{C} - Ri = 0 \qquad i = \frac{dq}{dt}$$

$$\frac{d^2q}{dt^2} + \frac{R}{L}\frac{dq}{dt} + \frac{1}{LC}q = \frac{\mathcal{E}_0}{L}$$

$q(0) = 0$

$q'(0) = i(0) = 0$

ESERCIZIO



$$\mathcal{E}_0 - L\frac{di}{dt} - Ri = 0$$

$$\mathcal{E} = Ri + L\frac{di}{dt}$$

$$W = \int \mathcal{E}\,dq = \int \mathcal{E}\, i\,dt = \int \underbrace{Ri^2}_{P_R = \text{POTENZA } R} dt + \int L\,i\,di$$

$W_{tot} = W_R + W_L$

W_R → LAVORO RESISTORE; W_L → LAVORO INDUTTORE

$W_L = L\int_0^i i\,di = \frac{1}{2}Li^2$ LAVORO x FAR PASSARE CORRENTE DA 0 A i

L: INDUTTANZA

$$i(t) = \frac{\mathcal{E}_0}{R}\left(1 - e^{-\frac{R}{L}t}\right) \qquad i(\infty) = \frac{\mathcal{E}_0}{R}$$

$W_L = \frac{1}{2}Li^2 = \frac{1}{2}L\frac{\mathcal{E}_0^2}{R^2}$ ENERGIA MAGN. (SI CREA $\vec{B}$)

$\boxed{\text{EN. MAGNETICA}}$ $\frac{1}{2}Li^2(\infty) = U_L = \frac{1}{2}\mu_0 n^2 S\ell i^2$

PER SOLENOIDE

$$U_L = \frac{1}{2}\mu_0 n^2 S\ell \frac{B^2}{\mu_0^2 n^2} = \frac{1}{2}\underbrace{S\ell}_{\text{VOLUME}}\frac{B^2}{\mu_0} = \frac{1}{2}\frac{1}{\mu_0}B^2 V$$

③ $\text{ROT}\,\vec{E} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \partial_x & \partial_y & \partial_z \\ E_x & E_y & E_z \end{vmatrix} = -\dfrac{\partial \vec{B}}{\partial t} \Rightarrow \begin{cases} 0 = -\dfrac{\partial B_x}{\partial t} \\ \dfrac{\partial E_z}{\partial x} = \dfrac{\partial B_y}{\partial t} & (a) \\ \dfrac{\partial E_y}{\partial x} = -\dfrac{\partial B_z}{\partial t} & (b) \end{cases}$

④ $\begin{cases} 0 = \mu_0 \varepsilon_0 \dfrac{\partial E_x}{\partial t} \\ -\dfrac{\partial B_z}{\partial x} = \dfrac{1}{\mu_0 \varepsilon_0}\dfrac{\partial E_y}{\partial t} & (c) \\ +\dfrac{\partial B_y}{\partial x} = \dfrac{1}{\mu_0 \varepsilon_0}\dfrac{\partial E_z}{\partial t} & (d) \end{cases}$

$\left.\begin{array}{l} \vec{E}_x(x,t) = 0 \\ \vec{B}_x(x,t) = 0 \end{array}\right\}$ $\vec{B}, \vec{E}$ GIACCIONO SUL PIANO

$\dfrac{\partial}{\partial t}$ (a): $\dfrac{\partial^2 E_z}{\partial x \partial t} = \dfrac{\partial^2 B_y}{\partial t^2}$ $\qquad \dfrac{\partial}{\partial x}$ (a): $\dfrac{\partial^2 E_z}{\partial x^2} = \dfrac{\partial^2 B_y}{\partial x \partial t}$

$\dfrac{\partial}{\partial x}$ (c): $\dfrac{\partial^2 E_z}{\partial x \partial t} = \dfrac{\partial^2 B_z}{\partial x^2}\dfrac{1}{\mu_0 \varepsilon_0}$ $\qquad \dfrac{\partial}{\partial t}$ (c): $\dfrac{\partial^2 E_z}{\partial t^2} = \dfrac{1}{\varepsilon_0 \mu_0}\dfrac{\partial^2 B_y}{\partial t \partial x}$

$(a, c) \Rightarrow \dfrac{\partial^2 B_y}{\partial t^2} = \dfrac{1}{\varepsilon_0 \mu_0}\dfrac{\partial^2 B_y}{\partial x^2} \Rightarrow B_y = B_y(x - ct) \qquad \dfrac{1}{\varepsilon_0 \mu_0} = c^2$

$(a, c) \Rightarrow \dfrac{\partial^2 E_z}{\partial t^2} = \dfrac{1}{\varepsilon_0 \mu_0}\dfrac{\partial^2 E_z}{\partial x^2} \Rightarrow E_z = E_z(x - ct) = R = R(x,t)$

$(b, d) \Rightarrow B_z = B_z(x - ct) \qquad E_y = E_y(x - ct)$

$\dfrac{1}{c^2}\dfrac{\partial^2 R}{\partial t^2} - \dfrac{\partial^2 R}{\partial x^2} = 0$; $\quad W = x - ct \quad R(x,t) = R(W)$

ESQUAZ. LAPLACE

$\dfrac{\partial R}{\partial t} = \dfrac{\partial R}{\partial W}\dfrac{\partial W}{\partial t} = -\dfrac{\partial R}{\partial W} c$

$\dfrac{\partial^2 R}{\partial t^2} = \dfrac{d}{dt}\left(-c\dfrac{\partial R}{\partial W}\right) = \dfrac{\partial W}{\partial t}\dfrac{\partial}{\partial W}\left(-c\dfrac{\partial R}{\partial W}\right) = c\dfrac{d}{dW}\left(c\dfrac{\partial R}{\partial W}\right) =$

$= c^2\dfrac{\partial^2 R}{\partial W^2} \qquad \dfrac{\partial R}{\partial x} = \dfrac{\partial W}{\partial x}\dfrac{\partial R}{\partial W} = \dfrac{\partial R}{\partial W} \qquad \dfrac{\partial^2 R}{\partial x^2} = \dfrac{\partial^2 R}{\partial W^2}$

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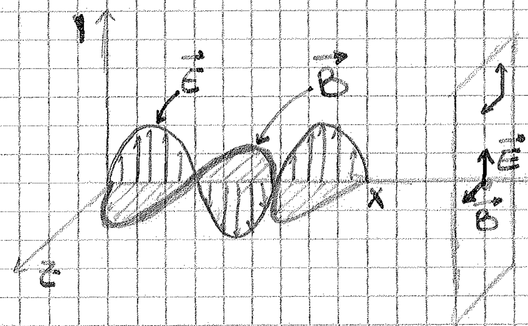


$\vec{E}=E_{0y}\sin Kx\;\hat{u}_y$

$\vec{B}=\frac{1}{c}E_{0y}\sin Kx\;\hat{u}_z$

$\vec{E}=E_{0y}\sin(Kx-\omega t)\,\hat{u}_y+E_{0z}\sin(Kx-\omega t+\delta)\,\hat{u}_z$

$Kx-\omega t=K\left(x-\frac{\omega}{K}t\right)=K(x-ct)$

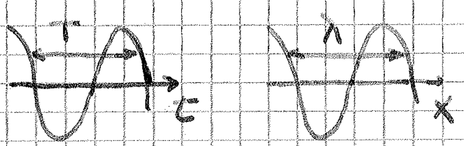
$\vec{E}=E_{0y}\sin[K(x-ct)]\,\hat{u}_y+E_{0z}\sin[K(x-ct)]\,\hat{u}_z$

K = NUMERO D'ONDA

$K=\frac{2\pi}{\lambda}$ λ = LUNGHEZZA D'ONDA

$\omega=K\cdot c$ ω = PULSAZIONE

$T=\frac{2\pi}{\omega}$ = PERIODO $\nu=\frac{1}{T}$ = FREQUENZA $\omega=2\pi\nu$

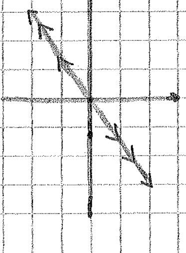


SE $\delta=0 \vee \pi$

$\vec{E}=E_{0y}\sin(Kx-\omega t)\,\hat{u}_y\pm E_{0z}\sin(Kx-\omega t)\,\hat{u}_z$

$\frac{E_z}{E_y}=\frac{\pm E_{0z}\sin(\omega t+Kx)}{E_{0y}\sin(Kx-\omega t)}=\pm\frac{E_{0z}}{E_{0y}}=\pm\tan\theta_0$

$\theta=\pm\theta_0$



POLARIZZAZIONE LINEARE