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The evolution of the Gaussian Units

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1795 – Republic of France adopts the first basic Metric System proposed by the French Academy of Sciences.

1832 – K. F. Gauss [1] propose the possibility of making magnetic measurements in terms of mechanical units of the earth's' magnetic force (millimeter, gram and second) as "absolute measure".

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[1] K.F. Gauss,"Intensitas vis magneticae terrestris ad mensuram absolutam revocata", in K.F. Gauss, Werke, Gottingen, V, 1832, pp. 293-304.

1851 – W. Weber [2] studies magnetism with Gauss and publish his "Electrodynamic Proportional Measures" containing absolute measurements for electric currents, which is a complete set of "absolute units".

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[2] W. Weber's Werke, Berlin 1893, Banden 5 .

1861 – The British Association for Advancement of Science (that included W. Thomson, J.C. Maxwell and J.P.Joule) introduce the concept of system of units. The meter, the gram and the mean solar second are considered as "base units".

1856-1865 – J.C. Maxwell creates a unified theory based on the field concept introduced by Faraday in a series of papers. He predicts the existence of electromagnetic waves and identifies the ratio of the measure units with the *c* speed of light.

1873 – The second committee of the British Association for the Advancement of Science recommends a centimeter-gram-second system of units (CGS), because in this system the density of water is unity.
This system of units is devised in the electrostatic and the electromagnetic subsystem, depending on whether the law of force for electric charge $(F_e = q_1 q_2 / r^2)$ or for electric currents $(F_m = 2\ell I_1 I_2 / r)$ is taken as fundamental. The ratio of the electrostatic to the electromagnetic unit of charge or current represents a fundamental experimental constant *c*.

1888 – H. Hertz [3], [4], combines the electrostatic and electromagnetic CGS units into a single system, related by the speed of light *c*, which he called the "Gaussian system of units".

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[3] H. Hertz, "Ueber die Einwirkung einer geradlinigen electrischen Schwingung auf eine benachbarte Strombahn", Annalen der Physik, vol.270, no.5, pp.155-170 (1888);
[4] H. Hertz, "Ueber die Ausbreitungsgeschwindigkeit der electrodynamischen Wirkungen", Annalen der Physik, Vol.270, no.7, pp.551-569 (1888)].

1900 – The famous physicists: A.H. Lorentz, M. Planck, A. Einstein, A. Millikan, N. Bohr, A. Sommerfeld, W. Pauli, L. de Broglie, E. Schrodinger, M. Born, W. Heisemberg, P.A.M. Dirac, I. Tamm (and others), use in their theories the "Gaussian units".

1955 – R. Peierls [5] shows that in the electromagnetic wave we have |E| = |H|. (obvious Gaussian units).

[5] R.E. Peierls, The laws of nature, London: George Allen & Unwin, (1955).

1978 – D.P. Danescu [6], [7], [8], shows that Gaussian units represent the only not contradictory system.
The Gaussian units system must be improved regarding the transfer of the 1/c factor of units from ($\boldsymbol{\mu}$) magnetic moment expression to ($\boldsymbol{\tau}$) torque formula,

$$\boldsymbol{\mu} = \frac{1}{\not{c}}\, i\boldsymbol{A} \qquad\qquad \boldsymbol{\tau} = \frac{1}{c}\, \boldsymbol{\mu} \times \boldsymbol{B}$$

$$\downarrow \underline{\hspace{6cm}} \uparrow$$

By using this transfer of 1/c we evidence two groups of equally constants which are connected by the electron charge, respectively the electron mass. (Table 1)

Table 1

In Gaussian units (LTM): $\lvert e^{\pm}\rvert \approx 4.8 \times 10^{-10}$ ***esu, Fr;*** $\lvert\mu_S\rvert \approx 4.8 \times 10^{-10}$ ***esu;*** $2\lambda_C \approx 4.8 \times 10^{-10}$ ***cm;*** $(\mu_S = -\,g\,\frac{e}{2m_e}\,S \approx -\sqrt{3}\,\frac{e\hbar}{2m_e} = -\sqrt{3}\,\mu_B).$	***In Gaussian units (LTM):*** $m_e \approx 9.1 \times 10^{-28}$ ***g;*** $\lvert S\rvert \approx 9.1 \times 10^{-28}$ ***erg.s;*** $2\left[\langle r_1\rangle .(e/2)^2\right] \approx 9.1 \times 10^{-28}\,cm.Fr^2;$ $(\,\langle r_1\rangle = \frac{3}{2}a_0 \approx 0.8 \times 10^{-8}\ cm\,).$
In 1-dimensional system [L], LTM → L : $\lvert\mu_S\rvert \approx \lvert e^{\pm}\rvert \approx 2\lambda_C \approx 4.8 \times 10^{-10}\ cm\,.$	***In 1-dimensional system [L], LTM → L :*** $\lvert S\rvert \approx m_e \approx 2\left[\langle r_1\rangle .(e/2)^2\right] \approx 9.1 \times 10^{-28} cm^3\,.$

[6] D.P.Danescu**,** .Sistemele de unităţi de măsurare şi aspectul relativist al fenomenelor electromagnetice, Studii şi Cercetări de Fizică,6,**30**,1978, pp.559-571.
[7] D.P.Danescu, .Consideraţii asupra impedanţei caracteristice a vidului, Buletinul Ştiinţific şi Tehnic al Institutului Politehnic "Traian Vuia",Timişoara, 26, (**40**), fascicola 2, 1981, pp.37-40.
[8] D.P.Danescu,.Constantele fizice fundamentale ale electronului, Buletin de Fizică şi Chimie, Volumul **2**, 1978, pp.170-173.

2006 – In SI brochure, chapter 4, 8th ed., edited by the "Bureau International des Poids et Measures" (BIPM) it is mentioned that there is a scientific advantage of "the use of CGS-Gaussian units in electromagnetic theory applied to quantum electrodynamics and relativity".

General references

[9] B.W. Petley, A Brief History of the Electrical Units to 1964, Metrologia, **31** 481 (1995).
[10] R.A. Nelson, The International System of Units. Its History and Use in Science and Industry, Internet.
[11] BIPM SI brochure, 8th edition , Section 4.1 , Internet

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Appendix 1

Comparison between the current element and the magnetic moment in Gaussian units and correct Bohr magneton measure unit

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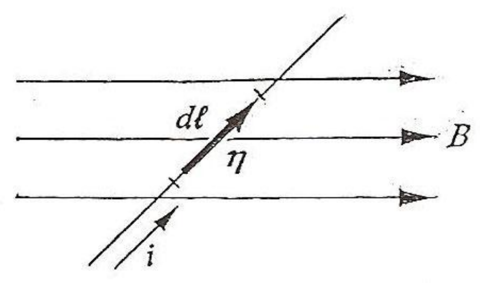

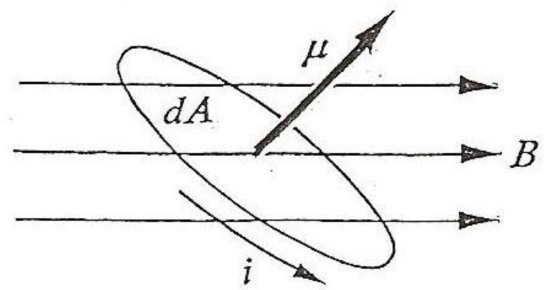

$\boldsymbol{\eta} = i d\boldsymbol{\ell}$ *(The current element)* $\boldsymbol{\mu} = i d\mathbf{A}$ *(The magnetic moment)*

$d\mathbf{F} = \frac{1}{c} \, i d\boldsymbol{\ell} \times \mathbf{B}$ *(The Laplace force)* $d\boldsymbol{\tau} = \frac{1}{c} \, i d\mathbf{A} \times \mathbf{B}$ *(The torque)*

The quantities $\boldsymbol{\eta} = i d\boldsymbol{\ell}$ *and* $\boldsymbol{\mu} = i d\mathbf{A}$*, introduced by definition do not have electrodynamic nature but geometrical and electrokinetical nature. They do not have 1/c factor of units transferred in force, respectively in torque expression *).*

Consequence:

I. The Bohr magneton is $\mu_B = \frac{e\hbar}{2m_e} = 2.780277 \times 10^{-10}$ *esu, instead of*

$$\mu_B = \frac{1}{c}\frac{e\hbar}{2m_e} = 9.274009 \times 10^{-21} \text{ emu;}$$

II. The spin magnetic moment is $|\boldsymbol{\mu}_s| = g\frac{e}{2m_e}\mathbf{S} = 4.821167 \times 10^{-10}$ *esu,*

instead of $|\boldsymbol{\mu}_s| = g\frac{1}{c}\frac{e}{2m_e}\mathbf{S} = 1.608168 \times 10^{-20}$ *emu.*

*) D.P. Dănescu, Consideraţii asupra impedanţei caracteristice a vidului (Considerations Regarding the Characteristic Impedance of the Vacuum), Buletinul Ştiinţific şi Tehnic al Institutului Politehnic "Traian Vuia",Timişoara, 26, (**40**), fascicola 2 (1981), pp.37-40.

Appendix 2

Conversion factors from the SI to the Gaussian system of units

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Quantity	SI	Gaussian	SI/Gaussian
Length, wavelength, radius (ℓ, λ, r)	m	cm	10^2
Area (A)	m^2	cm^2	10^4
Volume (V)	m^3	cm^3	10^6
Time (t)	s	s	1
Frequency, angular velocity (ν, ω)	1/s	1/s	1
Velocity, velocity of light (v, c)	m/s	cm/s	10^2
Acceleration (a)	m/s^2	cm/s^2	10^2
Mass (m, M)	kg	g	10^3
Force (F)	N, $kg.m/s^2$	dyn, $g.cm/s^2$	10^5
Impulse (J)	N.s , kg.m/s	dyn.s , g.cm/s	10^5
Energy (U, W)	J	erg	10^7
Energy density (w)	J/m^3	erg/cm^3	10
Angular momentum, action (L, $\mathcal{H}$)	J.s , $kg.m^2/s$	erg.s , $g.cm^2/s$	10^7
Power (P)	J/s	erg/s	10^7
Moment of inertia ($\mathcal{I}$)	$kg.m^2$	$g.cm^2$	10^7
Gravitation constant (G)	$N.m^2/kg^2$	$dyn.cm^2/g^2$	10^3
Gravitational field (g)	m/s^2	cm/s^2	10^2
Vacuum permittivity (electric constant), (ε_0)	F/m	1	$4\pi c^2 /10^{11}$
Vacuum permeability (magnetic constant), (μ_0)	H/m	1	$10^7/4\pi$
Electric charge (q, Q)	C	Fr., esu	c/10
Electric moment (p)	C.m	Fr.cm	10c
Current intensity (I, i)	A, C/s	Fr/s	c/10
Current element ($I.\Delta\ell$)	A.m	Fr.cm/s	10c
Magnetic moment, Bohr magneton ($I.\Delta A$, μ , μ_B)	$A.m^2$, J/T	esu *)	10^3c
Electric field (E)	V/m	dyn/Fr	$10^6/c$
Electric displacement (D)	C/m^2	dyn/Fr	$4\pi c/10^5$
Flux of electric field (ψ)	V.m	esu	$10^{10}/c$
Flux of electric displacement (Ψ)	C	esu	$4\pi c/10$
Electric potential, electric voltage (V, U)	V	erg/Fr	$10^8/c$
Magnetic field (H)	A/m	Oe, Gb/cm	$4\pi/10^3$
Magnetic induction (B)	T, Wb/m^2	Gs	10^4
Flux of magnetic field (φ)	A.m	$Oe.cm^2$	$4\pi \times 10$
Flux of magnetic induction (Φ)	Wb	$Gs.cm^2$, Mx	10^8
Magnetic potential, magnetomotive force (V_m , $\mathcal{U}$)	A	Gb	$4\pi/10$
Capacitance (C)	F	“cm”	$c^2/10^9$
Inductance (L)	H	“cm”	10^9

$c = 2.99792458 \times 10^{10}$ cm/s

*) Without 1/c factor of units transferred in torque relation

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Appendix 3

Fundamental physical constants of the electron in the SI and the Gaussian units

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The starting point of this table is CODATA: Recommended Values of the Fundamental Physical Constants -2006, by Peter J. Mohr, Barry N. Taylor, and David B. Newell. The opportunity of using the Gaussian units was shown in [1-3]. One amendment to the Bohr magneton measurement unit was developed in [3]. This amendment consisted of the transfer of 1/c factor of units from the magneton expression to the torque relation and involved the change of unit emu → esu. The importance of double Compton wavelength is derived from the description of the symmetry phenomena [4].

Quantity, symbol	**SI units**	**Gaussian units**
velocity of light in vacuum (c, c_0)	$2.997\,924\,58 \times 10^{8}$ m s^{-1}	$2.997\,924\,58 \times 10^{10}$ cm s^{-1}
vacuum permeability (μ_0)	$12.566\,370\,614 \ldots \times 10^{-7}$ N A^{-2}	1
vacuum permittivity (ε_0)	$8.854\,187\,817 \ldots \times 10^{-12}$ F m^{-1}	1
characteristic impedance of vacuum (Z_0)	$376.730\,313\,461 \ldots$ Ω	1
Compton wavelength (λ_C)	$2.426\,310\,2175\,(33) \times 10^{-12}$ m	$2.426\,310\,2175\,(33) \times 10^{-10}$ cm
electron g-factor (g)	-2.002 319 304 3622(15)	-2.002 319 304 3622(15)
Bohr magneton (μ_B)	$927.400\,915(23) \times 10^{-26}$ JT^{-1}	$2.780\,277\,998(69) \times 10^{-10}$ esu
electron magnetic moment (μ_e)	$-928.476\,377(23) \times 10^{-26}$ JT^{-1}	$-2.783\,502\,153(69) \times 10^{-10}$ esu
spin magnetic moment (theor.), (μ_S)	$1.608\,168\,258(40) \times 10^{-23}$ JT^{-1}	$4.821\,167\,12(12) \times 10^{-10}$ esu
electron charge (e)	$1.602\,176\,487(40) \times 10^{-19}$ C	$4.803\,204\,27(12) \times 10^{-10}$ esu
double Compton wavelength ($2\lambda_C$)	$4.852\,620\,4350(67) \times 10^{-12}$ m	$4.852\,620\,4350(67) \times 10^{-10}$ cm
fine-structure constant (α)	$7.297\,352\,5376\,(50) \times 10^{-3}$	$7.297\,352\,5376\,(50) \times 10^{-3}$
inverse fine-structure constant (α^{-1})	137.035 999 679(94)	137.035 999 679(94)
Bohr radius (a_0)	$0.529\,177\,208\,59(36) \times 10^{-10}$ m	$0.529\,177\,208\,59(36) \times 10^{-8}$ cm
Bohr speed (αc, v_0)	$2.187\,691\,254\,1(14) \times 10^{6}$ m s^{-1}	$2.187\,691\,254\,1(14) \times 10^{8}$ cm s^{-1}
average radius of electron cloud (1s), $\langle r_1 \rangle$	$0.793\,765\,\,812\,88(53) \times 10^{-10}$ m	$0.793\,765\,\,812\,88(53) \times 10^{-8}$ cm
Planck constant (h)	$6.626\,068\,96(33) \times 10^{-34}$ J s	$6.626\,068\,96(33) \times 10^{-27}$ erg s
Planck constant, reduced ($\hbar$)	$1.054\,571\,628(53) \times 10^{-34}$ J s	$1.054\,571\,628(53) \times 10^{-27}$ erg s
spin angular momentum (theor.), (**S**)	$9.132\,858\,19(45) \times 10^{-35}$ J s	$9.132\,858\,19(45) \times 10^{-28}$ erg s
electron mass (m_e)	$9.109\,382\,15(45) \times 10^{-31}$ kg	$9.109\,382\,15(45) \times 10^{-28}$ g
Newtonian constant of gravitation (G)	$6.674\,28(67) \times 10^{-11}$ m^{3} kg^{-1}s^{-2}	$6.674\,28(67) \times 10^{-8}$ cm^{3} g^{-1}s^{-2}
classical electron radius (r_e, r_0)	$2.817\,940\,2894\,(58) \times 10^{-15}$ m	$2.817\,940\,2894\,(58) \times 10^{-13}$ cm
Thomson cross section (σ_e)	$0.665\,245\,8558\,(27) \times 10^{-28}$ m^{2}	$0.665\,245\,8558\,(27) \times 10^{-24}$ cm^{2}
Rydberg constant (R_∞)	$10\,973\,731.568\,527(73)$ m^{-1}	$1.097\,373\,156\,852\,7(73) \times 10^{5}$ cm^{-1}

[1] D.P.Dănescu, Systems of measure units and relativist aspect of electromagnetic phenomena, Studii şi Cercetări de Fizică, 6, **30** (1978), (in Romanian).

[2] D.P.Dănescu, The fundamental physical constants of electron, Buletin de Fizică şi Chimie, Vol. **2**, 170 (1978), (in Romanian).

[3] D.P.Dănescu, Consideration of characteristic impedance of vacuum, Buletinul Ştiinţific şi Tehnic al Institutului Politehnic"Traian Vuia",Timişoara, 26, (**40**), fascicola 2, (1981), (in Romanian).

[4] D.P.Dănescu, The symmetry of Compton effect and $2\lambda_C$ constant, Revista de Fizică şi Chimie, Vol. **36**, Nr. 1-2-3 (2001).

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