Some Notes on SI vs. cgs Units

by Jason Harlow

Last updated Feb. 8, 2011 by Jason Harlow.

Introduction

Within "The Metric System", there are actually two separate self-consistent systems. One is the *Systme International* or **SI system**, which uses Metres, Kilograms and Seconds for length, mass and time. For this reason it is sometimes called the MKS system. The other system uses centimetres, grams and seconds for length, mass and time. It is most often called the **cgs system**, and sometimes it is called the *Gaussian* system or the electrostatic system. Each system has its own set of derived units for force, energy, electric current, etc.

Surprisingly, there are important differences in the basic equations of electrodynamics depending on which system you are using! Important textbooks such as Classical Electrodynamics 3e by J.D. Jackson ©1998 by Wiley and Classical Electrodynamics 2e by Hans C. Ohanian ©2006 by Jones & Bartlett use the **cgs system** in all their presentation and derivations of basic electric and magnetic equations. I think many theorists prefer this system because the equations look "cleaner". Introduction to Electrodynamics 3e by David J. Griffiths ©1999 by Benjamin Cummings uses the **SI system**.

Here are some examples of units you may encounter, the relevant facts about them, and how they relate to the SI and cgs systems:

Force

The SI unit for force comes from Newton's 2^{nd} law, $F = ma$, and is the Newton or N. 1 N = 1 kg·m/s^2.

The cgs unit for force comes from the same equation and is called the dyne, or dyn. 1 dyn = 1 g·cm/s^2.

dynes are a lot smaller than Newtons: 10^5 dyn = 1 N.

Energy

The SI unit for energy is the Joule, or J. 1 J = 1 kg·m^2/s^2.

The cgs unit for energy is the erg. 1 erg = 1 g·cm^2/s^2.

ergs are a lot smaller than Joules; 10^7 ergs = 1 J.

[Other common units for energy include the electron volt: 1 eV = 1.602×10^{-19} J, the calorie and the Calorie. The calorie is a very seldom used unit, 1 calorie = 4.184 J. When referring to food energy, the Calorie (with an upper-case C) is much more common. A Calorie, or Cal, is equal to 1000 calories, and is sometimes called a kilocalorie, or kcal. 1 Cal = 1 kcal = 4184 J.]

Pressure

The SI unit for pressure is Pascal, or Pa. 1 Pa = 1 N/m^2. The Earths atmosphere at sea level has a pressure of 1.013×10^5 Pa.

The cgs unit for pressure does not have a special name. It is dyne/cm^2. The Earths atmosphere at sea level has a pressure of 1.013×10^6 dyn/cm^2.

1 dyne/cm^2 represents 10 times less pressure than a Pascal. 10 dyn/cm^2 = 1 Pa.

[Other common units for pressure are: 1 torr = 133.3 Pa, 1 bar = 10^5 Pa, and 1 atm = 1.013×10^5 Pa.]

Viscosity

The SI unit for η, viscosity, is N·s/m^2. This is often called the Poiseuille, or PI. (pronounced pwah-soy). Water has a viscosity of 10^{-3} PI.

The cgs unit for viscosity is dyn·s/cm^2. This is called the poise, or P. (pronounced pwahz). It is much more commonly used than PI. Water has a viscosity of 0.01 P, or one centi-poise, or 1 cP.

1 poise represents 10 times less viscosity than Poiseuille. 10 P = 1 PI.

Electric Current and Electric Charge

The SI unit for electric current is Ampere, or A. One Ampere is defined to be the constant current which will produce a force of 2×10^{-7} Newton per metre of length between two straight, parallel conductors of infinite length and negligible circular cross section placed one metre apart in free space (http://en.wikipedia.org/wiki/Ampere).

The SI unit for electric charge is the Coulomb, or C. It is the amount of charge delivered by 1 Ampere of current in 1 second. The magnitude of the charge of an electron is $e = 1.602 \times 10^{-19}$ C. Despite the hugeness of the Coulomb, it is a very popular unit.

The cgs unit for electric charge is the electrostatic unit, or esu. The size of the esu is set so that Coulomb's Law is $F = \frac{q_1 q_2}{r^2}$. Notice that in the cgs system, Coulomb's constant equals one. Therefore, two charges each with charge 1 esu sitting 1 cm apart will feel a force between them of 1 dyne. The magnitude of the charge of an electron is $e = 4.8 \times 10^{-10}$ esu.

Coulombs are much bigger than esu. 1 C = 3×10^9 esu. In fact the ratio of esu per Coulomb is numerically equal to the speed of light in decimetres per second.

Magnetic Field

The SI unit for magnetic field is the Tesla, or T. It comes from the cross-product equation for magnetic force on a moving particle: $\vec{F} = q\vec{v} \times \vec{B}$. The magnetic field, B, must be in units of force per charge per velocity. So 1 T = 1 N·s/(C·m).

In cgs units, the equation for magnetic force is $\vec{F} = q\frac{\vec{v}}{c} \times \vec{B}$. You have to divide velocity by the speed of light, c. The cgs unit for magnetic field, B, is called the Gauss, G, where 1 G = 1 dyne/esu. The Earth's magnetic field at the surface is about 1 G, which makes it a very popular unit.

Teslas are bigger than Gauss. 1 T = 10^4 G.

Other Electrodynamic Variables

The following table is from Appendix 2 of Classical Electrodynamics by Hans C. Ohanian. Note some surprises, such as the fact that, in the cgs system, resistivity is measured in seconds!

Table A·1 Numerical Correspondences*

Physical Quantity	Amount in SI Units		Amount in CGS Units
Charge	1 coulomb (C)	⇔	2.998×10^9 esu
Charge density	1 coulomb/m^3 (C/m^3)	⇔	2.998×10^3 esu/cm^3
Electric E field	1 volt/m (V/m)	⇔	$\frac{1}{2.998} \times 10^{-4}$ statvolt/cm
Potential	1 volt (V)	⇔	$\frac{1}{299.8}$ statvolt
Dipole moment	1 coulomb·m (C·m)	⇔	2.998×10^{11} esu·cm
Polarization	1 coulomb/m^2 (C/m^2)	⇔	2.998×10^5 esu/cm^2
Electric D field	1 coulomb/m^2 (C/m^2)	⇔	$2.998 \times 4\pi \times 10^5$ statvolts/cm
Capacitance	1 farad (F)	⇔	$(2.998)^2 \times 10^{11}$ cm
Magnetic B field	1 tesla (T)	⇔	10^4 gauss
Current	1 ampere (A)	⇔	2.998×10^9 statamperes
Current density	1 ampere/m^2 (A/m^2)	⇔	2.998×10^5 statamperes/cm^2
Conductivity	1 ohm^{-1}·m^{-1} ($\Omega^{-1}\cdot$m^{-1})	⇔	$(2.998)^2 \times 10^9$ s^{-1}
Resistivity	1 ohm·m (Ω·m)	⇔	$\frac{1}{(2.998)^2} \times 10^{-9}$ s
Resistance	1 ohm (Ω)	⇔	$\frac{1}{(2.998)^2} \times 10^{-11}$ s·cm^{-1}
Magnetic moment	1 ampere·m^2 (A·m^2)	⇔	10^3 gauss·cm^3
Magnetization	1 ampere/m (A/m)	⇔	10^{-3} gauss
Magnetic H field	1 ampere-turn/m (A/m)	⇔	$4\pi \times 10^{-3}$ gauss†
Magnetic flux	1 weber (Wb)	⇔	10^8 gauss·cm^2
Inductance	1 henry (H)	⇔	$\frac{1}{(2.998)^2} \times 10^{-11}$ s^2·cm^{-1}

*The numerical factor 2.998 appearing in this table is the same factor that appears in the speed of light; its exact value is 2.997 924 58.

†For no good reason, the CGS unit for H is often called the *oersted*; but this is the same as the gauss.