

# Notes for Lecture #1

## 1 Introduction

1. Textbook and course structure
2. Motivation
3. Chapters I and 1 and Appendix of Jackson
  - (a) Units - SI vs Gaussian
  - (b) Laplace and Poisson Equations
  - (c) Green's Theorem

## 2 Units - SI vs Gaussian

Coulomb's law has the form:

$$F = K_C \frac{q_1 q_2}{r_{12}^2}. \quad (1)$$

Ampere's law has the form:

$$F = K_A \frac{i_1 i_2}{r_{12}^2} d\mathbf{s}_1 \times d\mathbf{s}_2 \times \hat{\mathbf{r}}_{12}, \quad (2)$$

where the current and charge are related by  $i_1 = dq_1/dt$  for all unit systems. The two constants  $K_C$  and  $K_A$  are related so that their ratio  $K_C/K_A$  has the units of  $(m/s)^2$  and it is *experimentally* known that in both the SI and CGS (Gaussian) unit systems, it the value  $K_C/K_A = c^2$ , where  $c$  is the speed of light.

The choices for these constants in the SI and Gaussian units are given below:

	CGS (Gaussian)	SI
$K_C$	1	$\frac{1}{4\pi\epsilon_0}$
$K_A$	$\frac{1}{c^2}$	$\frac{\mu_0}{4\pi}$

Here,  $\frac{\mu_0}{4\pi} \equiv 10^{-7} N/A^2$  and  $\frac{1}{4\pi\epsilon_0} = c^2 \cdot 10^{-7} N/A^2 = 8.98755 \times 10^9 N \cdot m^2/C^2$ .

Below is a table comparing SI and Gaussian unit systems. The fundamental units for each system are so labeled and are used to define the derived units.

Variable	SI		Gaussian		SI/Gaussian
	Unit	Relation	Unit	Relation	
length	$m$	fundamental	$cm$	fundamental	100
mass	$kg$	fundamental	$gm$	fundamental	1000
time	$s$	fundamental	$s$	fundamental	1
force	$N$	$kg \cdot m^2/s$	$dyne$	$gm \cdot cm^2/s$	$10^5$
current	$A$	fundamental	$statampere$	$statcoulomb/s$	$\frac{1}{10c}$
charge	$C$	$A \cdot s$	$statcoulomb$	$\sqrt{dyne \cdot cm^2}$	$\frac{1}{10c}$

One advantage of the Gaussian system is that all of the field vectors:  $\mathbf{E}$ ,  $\mathbf{D}$ ,  $\mathbf{B}$ ,  $\mathbf{H}$ ,  $\mathbf{P}$ ,  $\mathbf{M}$  have the same dimensions, and in vacuum,  $\mathbf{B} = \mathbf{H}$  and  $\mathbf{E} = \mathbf{D}$  and the dielectric and permittivity constants  $\epsilon$  and  $\mu$  are unitless.

CGS (Gaussian)	SI
$\nabla \cdot \mathbf{D} = 4\pi\rho$	$\nabla \cdot \mathbf{D} = \rho$
$\nabla \cdot \mathbf{B} = 0$	$\nabla \cdot \mathbf{B} = 0$
$\nabla \times \mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{B}}{\partial t}$	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
$\nabla \times \mathbf{H} = \frac{4\pi}{c} \mathbf{J} + \frac{1}{c} \frac{\partial \mathbf{D}}{\partial t}$	$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$
$\mathbf{F} = q(\mathbf{E} + \frac{\mathbf{v}}{c} \times \mathbf{B})$	$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$
$u = \frac{1}{8\pi}(\mathbf{E} \cdot \mathbf{D} + \mathbf{B} \cdot \mathbf{H})$	$u = \frac{1}{2}(\mathbf{E} \cdot \mathbf{D} + \mathbf{B} \cdot \mathbf{H})$
$\mathbf{S} = \frac{c}{4\pi}(\mathbf{E} \times \mathbf{H})$	$\mathbf{S} = (\mathbf{E} \times \mathbf{H})$