Introduction to Electromagnetism
The Electromagnetic Model
(1-1, 1-2, 1-3)

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The Electromagnetic Model

Electromagnetics?

The study of the effects of electric charges at rest and in motion

Inductive or deductive approach?

The course book uses deductive or axiomatic approach:

Elegant and orderly

Three essential steps for building an electromagnetic theory:

- First: Defining the basic quantities of electromagnetics
- Second: Rules of operation (vector algebra, vector calculus, & partial differential equations)
- Third: Fundamental postulates to deal with electromagnetic fields

Two basic quantities in our electromagnetic model:

- Source quantities
- Field quantities

} The cause and effect are not always distinct!

Source Quantities

- Electric charge: q *or* Q $\quad (\mathrm{C})$ $\quad \leftarrow$ Conservation of electric charge

  e.g. the charge of an electron: $-e = -1.60 \times 10^{-19}$ (C)

- Volume charge density: $\rho = \lim_{\Delta v \to 0} \dfrac{\Delta q}{\Delta v} \quad (\mathrm{C/m^3})$

- Surface charge density: $\rho_s = \lim_{\Delta s \to 0} \dfrac{\Delta q}{\Delta s} \quad (\mathrm{C/m^2})$

- Line charge density: $\rho_l = \lim_{\Delta l \to 0} \dfrac{\Delta q}{\Delta l} \quad (\mathrm{C/m})$

- Current (Rate of change of charge w.r.t. time): $I = \dfrac{dq}{dt} \quad (\mathrm{C/s\ or\ A})$

- Volume current density: $\mathbf{J} \quad (\mathrm{A/m^2})$

- Surface current density: $\mathbf{J}_s \quad (\mathrm{A/m})$

Fundamental Field Quantities

Symbols and Units	Field Quantity	Symbol	Unit
Electric	Electric field intensity	**E**	V/m
	Electric flux density (Electric displacement)	**D**	C/m^2
Magnetic	Magnetic flux density	**B**	T
	Magnetic field intensity	**H**	A/m

Constitutive relations:

The relations between **E** and **D** and between **B** and **H**

SI Units and Universal Constants

SI (International System of Units): MKSA system

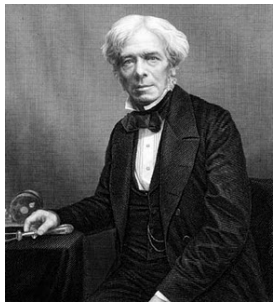
Quantity	Unit	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s
Current	ampere	A

Universal constants:

Quantity	Symbol	Value	Unit
Velocity of light in free space	c	$\sim 3\times10^{8}$	m/s
Permeability of free space	μ_0	$4\pi\times10^{-7}$	H/m
Permittivity of free space	ε_0	$\sim 1/36\pi\times10^{-9}$	F/m

$$\rightarrow c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \quad (\mathrm{m/s})$$

Maxwell's Equations



Michael Faraday
(1791–1867)

Andre Marie Ampere
(1775 - 1835)

Carl Friedrich Gauss
(1777 - 1855)

Static fields until Chap. 7

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$ Faraday's law

$$\nabla \times \mathbf{H} - \frac{\partial \mathbf{D}}{\partial t} = \mathbf{J}$$ Ampère's law

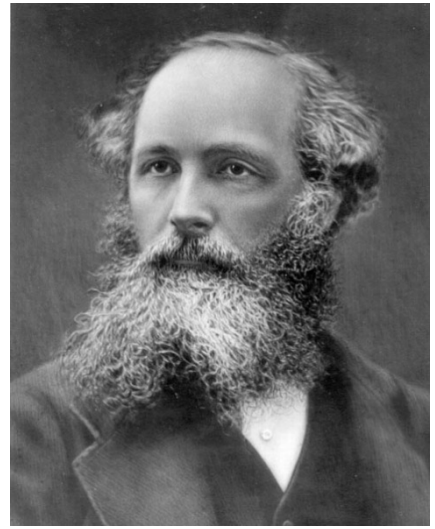
$$\nabla \cdot \mathbf{D} = \rho$$ Gauss's law

$$\nabla \cdot \mathbf{B} = 0$$ No free magnetic monopole (?)

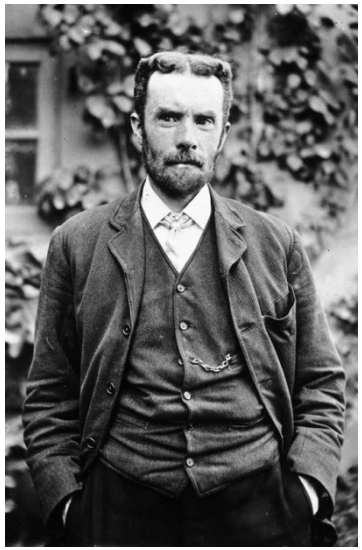
$$\mathbf{D} = \varepsilon \mathbf{E} = \varepsilon_o \mathbf{E} + \mathbf{P}$$

$$\mathbf{H} = \frac{\mathbf{B}}{\mu} = \frac{\mathbf{B}}{\mu_o} - \mathbf{M}$$

Constitutive relations



James Clerk Maxwell
(1831–1879)



Oliver Heaviside
(1850–1925)