Electromagnetic Field Theory

Week 1

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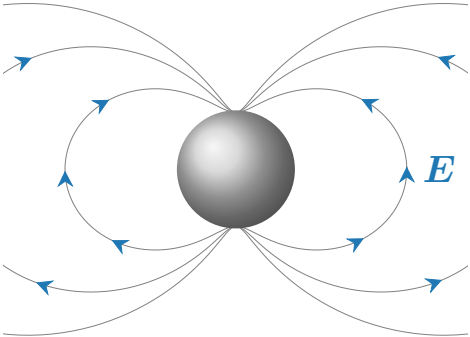
September 9, 2025
Winter semester 2025/26

Outline

1. Course BAB17EMP
2. History of Electromagnetism
3. Fundamental Interactions
4. Vector Functions



Introduction

Electromagnetic field is everywhere and touches every aspect of our everyday life.

- This course is about learning the basics of electromagnetic field theory and its mathematical description.

About the Course

- Lectures: Wednesday from 4:15 PM, T2:C3-132.
- Exercises: Thursday, T2:C2-82 & T2:C4-459.
- Web: Courseware
- Students are expected to make their own notes!

Contact

em@fel.cvut.cz

Team of Teachers

Miloslav Čapek

Course guarantor
(Lectures, Exam)

Vojtěch Neuman

Course assistant
(Exercises, Tests)

Štěpán Bosák

Course assistant
(Exercises, Tests)

Contact

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Requirements

To get the points during the semester:

- $4\times$ homework ($4 \times 8 = 32$ pts).
- $2\times$ semester test ($2 \times 9 = 18$ pts).
- Exam (written part) 40 pts.
- Exam (oral part) 20 pts.

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Notes:

- All the points are the subject of final classification.
- At least 15 pts from the semester.
- At least 10 pts from the written part of the exam.
- The oral part of the exam is optional.

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ECTS	Points	Grade
A	90-110	1
B	80-89	1.5
C	70-79	2
D	60-69	2.5
E	50-59	3
F	0-49	4

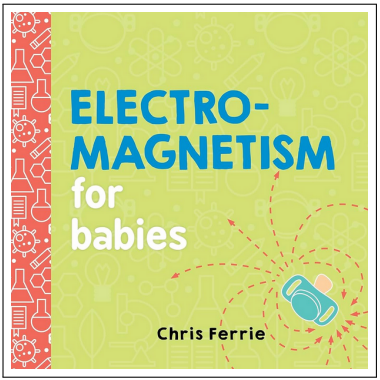
Syllabus (The best guess. . .)

1. Introduction to the topic, terminology, scope, history
2. Electrostatics, Part #1, Homework 1
3. Electrostatics, Part #2
4. Conductors, Homework 2
5. Dielectrics and capacity, Test 1
6. Forces and Energy in Electrostatics
7. Clausius-Mossotti Relation, Dielectrophoresis
8. Stationary currents
9. Stationary magnetic field, Part #1, Homework 3
10. Stationary magnetic field, Part #2
11. Magnetic materials, Part #1, Test 2
12. Magnetic materials, Part #2
13. Time-harmonic field, Homework 4
14. Maxwell's equations, wave equation

Exam: Written part + Oral part

Literature

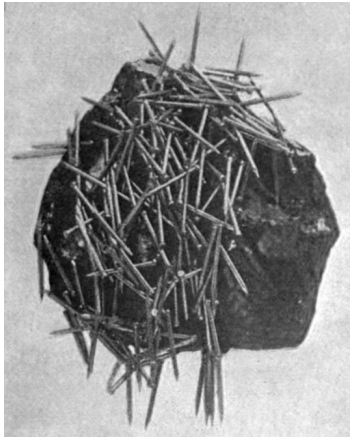
1. Novotný, K.: *Teorie elektromagnetického pole*
2. Feynman, R. P.: *Feynmanovy přednášky z fyziky*, 2. díl
3. Sedlák, B., Štoll, I.: *Elektřina a magnetismus*
4. Štoll, I.: *Dějiny fyziky*
5. Griffiths, D. J.: *Introduction to electrodynamics*
6. Hayt, W.: *Engineering Circuit Analysis*
7. Purcell, E. M., Morin, D. J.: *Electricity and Magnetism*
8. Nasar, S. A.: *2008+ Solved Problems in Electromagnetics*
9. Pierrus, J.: *Solved Problems in Classical Electromagnetism: Analytical and Numerical Solutions with Comments*
10. Franklin, J.: *Solved Problems in Classical Electromagnetism*
11. Bloise, F. S., *et al.*: *Solved Problems in Electromagnetics*
12. Zangwill, A.: *Modern Electrodynamics*



Ancient Time

$\approx$ 600 BCE: Sparking Amber in Ancient Greece (Thales of Miletus)

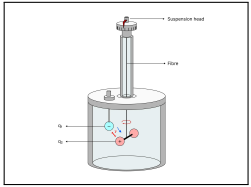
$\approx$ 221–206 BCE: Chinese Lodestone Compass (Qin dynasty)



Lodestone attracting nails.

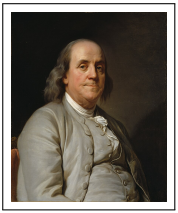
17th and 18th Centuries

William Gilbert (1600s) Earth's Magnetism and Electrical Attraction
Benjamin Franklin (1752) Lightning Rod
Charles-Augustin de Coulomb (1785) Coulomb's Law
Luigi Galvani (1789) Animal Electricity
Alessandro Volta (1790) Electric Battery



de Coulomb's experiment

William Gilbert



Benjamin Franklin

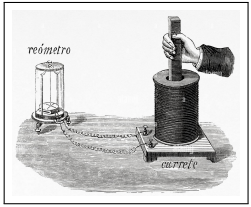
Charles-A. de Coulomb

Luigi Galvani

Alessandro Volta

19th Century, Part #1

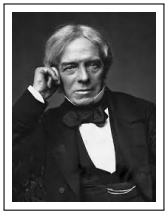
Hans Christian Ørsted (1820) Electromagnetism
Andre Marie Ampère (1821) Ampère's Law
Michael Faraday (1831) Electromagnetic Induction
James Clerk Maxwell (1873) Unification of electricity and magnetism
Heinrich Hertz (1887) Electromagnetic Waves



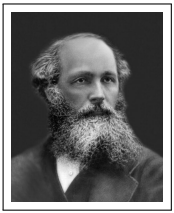
Faraday's experiment

Hans Ch. Ørsted

Andre Marie Ampère



Michael Faraday



James Clerk Maxwell

Heinrich Hertz

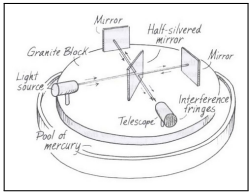
19th Century, Part #2

Nikola Tesla (1888) Inventor of AC Technology

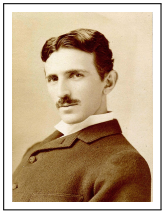
Albert A. Michelson and Edward W. Morley (1887) Absence of "Luminiferous Aether"

Guglielmo Marconi (1895) Long-distance Radio Transmission

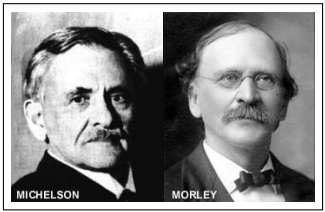
Joseph John Thomson (1897) Electron and Charge-to-Mass Ratio



Experiment of Michelson and Morley



Nikola Tesla



Albert A. Michelson and Edward W. Morley

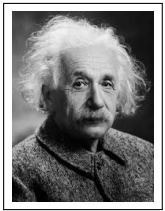
Guglielmo Marconi

Joseph J. Thomson

20th Century

Albert Einstein (1905) Quantum Nature of Electromagnetic Radiation

Richard Feynman (1965) Quantum Electrodynamics



Albert Einstein

Richard Feynman

21th Century...

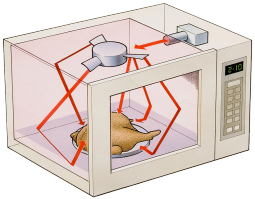
It is your turn...! :)

Fundamental Interactions

S	“color”	quarks/gluons	gluons	$\approx 10^{-15}\,\mathrm{m}$	1-10
E	el. charge	e^-, p^+	photons	∞	10^{-2}
W	“flavour”	quarks/leptons	intermed. bossons	$10^{-18}\,\mathrm{m}$	10^{-10}
G	matter	all	(gravitons?)	∞	10^{-38}

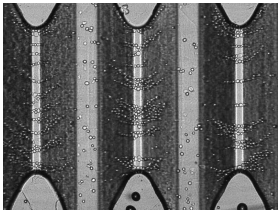
Fundamental interactions – comparison.

A Few Applications of EM



Microwave oven.

Magnetic Resonance Imaging (MRI).



Dielectrophoresis assembling cancer cells in a 3D microfluidic model.

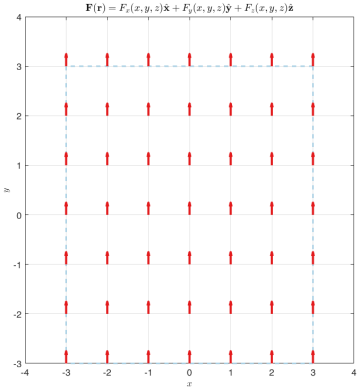
Green laser.

Vector Functions

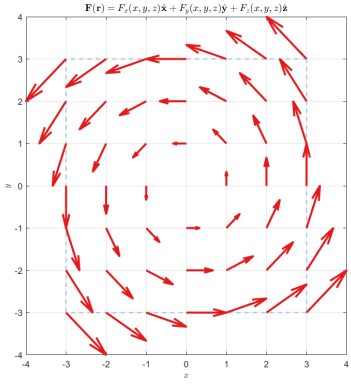
$$\boldsymbol{F}(x,y,z,t) = F_x(x,y,z,t)\hat{\boldsymbol{x}} + F_y(x,y,z,t)\hat{\boldsymbol{y}} + F_z(x,y,z,t)\hat{\boldsymbol{z}}$$

$$\boldsymbol{r} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

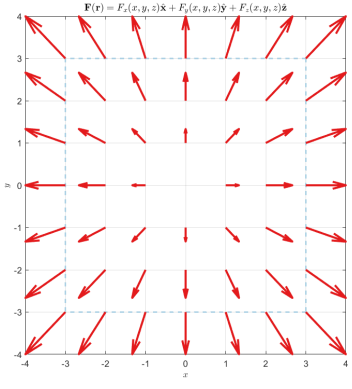
Vector Functions – Examples



$\boldsymbol{F}_1(\boldsymbol{r}) = x/4\hat{\boldsymbol{y}}$



$\boldsymbol{F}_2(\boldsymbol{r}) = -y/3\hat{\boldsymbol{x}} + x/3\hat{\boldsymbol{y}}$



$\boldsymbol{F}_3(\boldsymbol{r}) = x/3\hat{\boldsymbol{x}} + y/3\hat{\boldsymbol{y}}$

Basic EM Quantities and Their Units

Quantity	**Symbol**	**Units**	**SI Units**
Charge	q	Coulombs (C)	$\mathrm{A\,s}$
Current	I	Amperes (A)	A
Potential	φ, V	Volts (V)	$\mathrm{kg\,m^2\,A^{-1}\,s^{-3}}$
Capacitance	C	Farads (F)	$\mathrm{A^2\,s^4\,kg^{-1}\,m^{-2}}$
Resistance	R	Ohms (Ω)	$\mathrm{kg\,m^2\,A^{-2}\,s^{-3}}$
Inductance	L	Henrys (H)	$\mathrm{kg\,m^2\,A^{-2}\,s^{-2}}$
Magnetic Flux	Φ	Webers (Wb)	$\mathrm{kg\,m^2\,A^{-1}\,s^{-2}}$
Electric Field	$\boldsymbol{E}$	Volts per meter (V/m)	$\mathrm{kg\,m\,A^{-1}\,s^{-3}}$
Magnetic Field	$\boldsymbol{B}$	Teslas (T)	$\mathrm{kg\,A^{-1}\,s^{-2}}$
EM Force	$\boldsymbol{F}$	Netwon (N)	$\mathrm{kg\,m\,s^{-2}}$

Several fundamental electromagnetic quantities. More detailed table is in supplementary material “Formulas”.

Questions?

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