

EE 2FH3 Winter 2012

ELECTROMAGNETICS: PART I

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Main Topics

Electrostatics

Magnetostatics

Related Math

Texts

Recommended text

1. Hayt/Buck, *Engineering Electromagnetics*, 7th or 8th ed., McGraw-Hill.
2. Lecture notes available for download from
http://www.ece.mcmaster.ca/faculty/nikolova/EM_2FH3.htm.
3. N.K. Nikolova (©M.H. Bakr), *Matlab Experiments Manual for EE2FH3*, McMaster University Courseware, available for download.

Optional text

1. Joseph A. Edminister, *Shaum's Outlines on Electromagnetics*, any edition, McGraw-Hill (problem solving).
2. Syed A. Nasar, *2008+ Solved Problems in Electromagnetics*, Scitech, 2008 (problem solving).

Material on Reserve in Thode

1. *Solutions to Drill Problems* in Hayt/Buck Textbook (1 copy)
2. Hayt/Buck, *Engineering Electromagnetics*, 7th media ed., McGraw-Hill, 2006 (1 copy)
3. Joseph A. Edminister, *Shaum's Outlines on Electromagnetics*, any edition, McGraw-Hill (problem solving) (1 copy)
4. Syed A. Nasar, 2008+ *Solved Problems in Electromagnetics*, Scitech, 2008 (problem solving) (1 copy)

Grading

Final exam:	55 %
Midterm exam:	25 %
Assignments:	15 %
Quizzes:	5 %

failure on the final exam means failure of the course

deferred exams may be oral

all grades final unless error in marking proven

marking scheme flexible only if final-exam grade ≥ 90 %

The Subject of Electromagnetics

fundamental branch of physics and engineering dealing with the generation, propagation and transformation of EM energy and its interaction with matter

EM subjects range from electrostatics and magnetostatics, through classical electrodynamics, to relativistic and quantum electrodynamics

our focus **electrostatics** and **magnetostatics**

our objectives

- give working-level understanding of the EM forces and energy
- make you comfortable with the related math
- prepare you for future courses: microwave engineering, antennas and propagation, photonics and microelectronics, biomedical diagnostic and treatment technologies

Course Outline

1. Mathematical basics: vector algebra, vector calculus, coordinate systems and transformations
2. Electrostatics in vacuum
3. Current, conductors and resistance
4. Dielectrics and capacitance
5. The steady magnetic field
6. Inductance

Studying EM: Survival Guide

- This is a **mathematically intensive course**.
- Attend ALL lectures and tutorials. Most of the examples solved in lectures are NOT included in the posted lecture notes
- **WORK AT HOME AFTER EVERY CLASS**
 1. Read the slides from the Lecture.
 2. Read the respective chapters/sections and their examples in the textbook.
 3. Solve all required problems (do not miss homework!).
 4. Write down all questions you have regarding a lecture/tutorial/solved or unsolved problems, and visit the professor **DURING THE OFFICE HOURS** (posted on the website).

Studying EM: Survival Guide

- Work out all examples/problems recommended before midterms and final exams.
- **DO NOT TRY TO REMEMBER ALL FORMULAS!** Remember only definitions and fundamental physical laws. Try to grasp the physics behind a formula or a solution.

Exam Formats

Exams are closed-book. **HOWEVER:**

Midterm allows 2 pages (1 sheet, Letter size) of your own writing

Final exam allows 4 pages (2 sheets, Letter size) of your own writing

Cheating results in 0 grade and academic dishonesty charges

Duration

midterm: 2 hours

final: 3 hours

Quizzes: 10-minutes, randomly given during lecture time slots

Assignments

instructions posted on course webpage under ‘Assignments’:

[ListAssignments_EE2FH3_2012.pdf](#)

Week #	Assignment Title	Guide	Due
#1	Vector Analysis	MatLab Manual, Set 1	Friday Jan. 13, 4 pm
#2	Surface and Volume Integrals	MatLab Manual, Set 2	Friday Jan. 20, 4 pm
#3	E Field of Line Charge	MatLab Manual, Set 3	Friday Jan. 27, 4 pm
#4	E Field of Surface Charge	MatLab Manual, Set 4	Friday Feb. 3, 4 pm
#5	Electric Flux Density D	MatLab Manual, Set 5	Friday Feb. 10, 4 pm
#6	Electric Flux	MatLab Manual, Set 6	Friday Feb. 17, 4 pm
#7	Electric Potential	MatLab Manual, Set 7	Friday Mar. 2, 4 pm
#8	Electric Energy	MatLab Manual, Set 8	Friday Mar. 9, 4 pm
#9	Electric Current	MatLab Manual, Set 9	Friday Mar. 16, 4 pm
#10	Capacitance	MatLab Manual, Set 12	Friday Mar. 23, 4 pm

Assignments, cont.

- assignment reports are individual
- copying results in 0 grade (academic dishonesty charges may follow)
- MatLab codes are required on a printout (no need to email codes)
- TAs are available for tutoring and help every day from 2:30 pm to 5:30 pm (rm ITB/AB101)

This course DOES NOT HAVE LABS

Brief History of Electromagnetics

The early stages:

the ancient Greeks aware of some electric and magnetic phenomena
(*Plato* and *Socrates*)

Hans Christian Oersted (1777-1851) discovers the relation between
current carrying wire and magnetic field

André Ampère (1775-1836) discovers the force between two current-
carrying wires

Jean-Baptiste Biot (1774-1862) and *Félix Savart* (1791-1841)
formulate the law of the force between current elements

Benjamin Franklin (1706-1790) and *Joseph Priestly* (1733-1804)
postulate the inverse square law of electrostatics

Brief History of Electromagnetics, cont.

Coulomb (in 1785) proves experimentally the inverse square law for stationary electric charges

Alessandro Volta (1745-1827) investigates reactions between dissimilar metals and develops the first electric battery (1800)

Karl Friedrich Gauss (1777-1855) formulates the divergence theorem of electricity

Brief History of Electromagnetics, cont.

Milestones of classical electromagnetism



Michael Faraday (1791-1867) discovers in 1831 that time-changing magnetic field produces electric field. Similar observations are made by Joseph Henry (1797-1878).



James Clerk Maxwell (1831-1879) formulates the mathematical model of electromagnetism (classical electrodynamics), “*A Treatise on Electricity and Magnetism*” (1873).

Brief History of Electromagnetics, cont.



Heinrich Rudolph Hertz (1857-1894) demonstrates in 1886 the first wireless EM wave link. In his memoirs on electrodynamics, he replaces all potentials by field strengths, and deduces Ohm's, Kirchhoff's and Coulomb's laws from Maxwell's equations.



Guglielmo Marconi (the father of radio) sends signals over large distances. In 1901, he performs the first transatlantic transmission from Poldhu in Cornwall, England, to Newfoundland, Canada.

SI: The International System of Units, *Système Internationale d'Unités* (the metric system)

Fundamental units (or base units)

meter	Length
kilogram	Mass
second	Time
ampere	Current
kelvin	Temperature

Units

Some secondary units (SI) relevant to electromagnetism:

Charge	Q	coulomb	C
Frequency	f	hertz	Hz
Force	F	newton	N
Work,energy	W	joule	J
Power	P	watt	W
Voltage	V	volt	V
Capacitance	C	farad	F
Inductance	L	henry	H
Resistance	R	ohm	Ω

Applications of Electromagnetism: Wireless

Personal services

- cordless telephony
- cellular telephony and data transfer
- wireless LANs (local area network) and bluetooth devices
- personal satellite communications
- global navigation/positioning systems (GPS)

Special services

- radars
- microwave relay links
- satellite systems (TV, telephony, data, military)
- radio astronomy
- biomedical engineering (imaging and treatment)
- military communications, guidance, surveillance, RCVs, etc.

Applications of Electromagnetism: “Wired”

“wired” and semiconductor technology

Cable communications (TV, data , telephony)

Digital and analog Microelectronics

Power generation, power grids, power supply, power electronics

Electro-mechanical devices and machinery

photonics and optics

optical fibers

laser technology

photonic and infrared imaging and surveillance

Recommended reading: “Why Study Electromagnetics?” by A. Taflove, posted on course webpage under ‘Lectures’

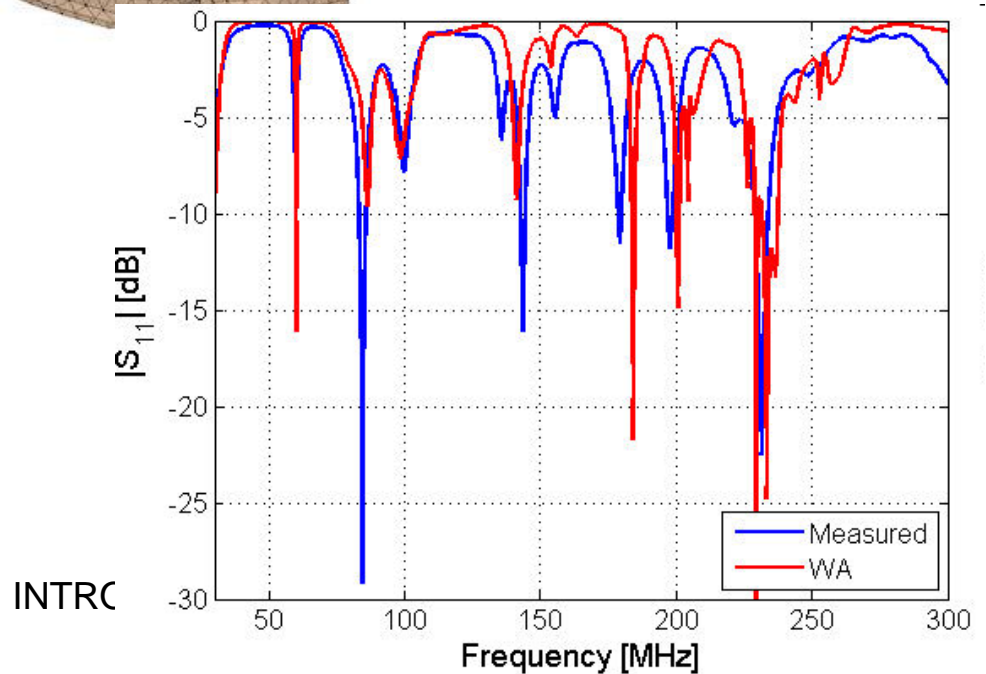
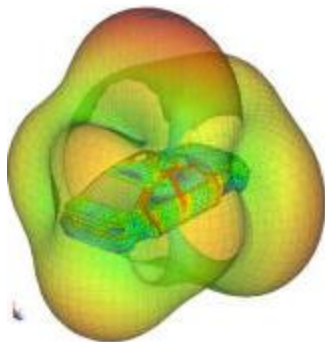
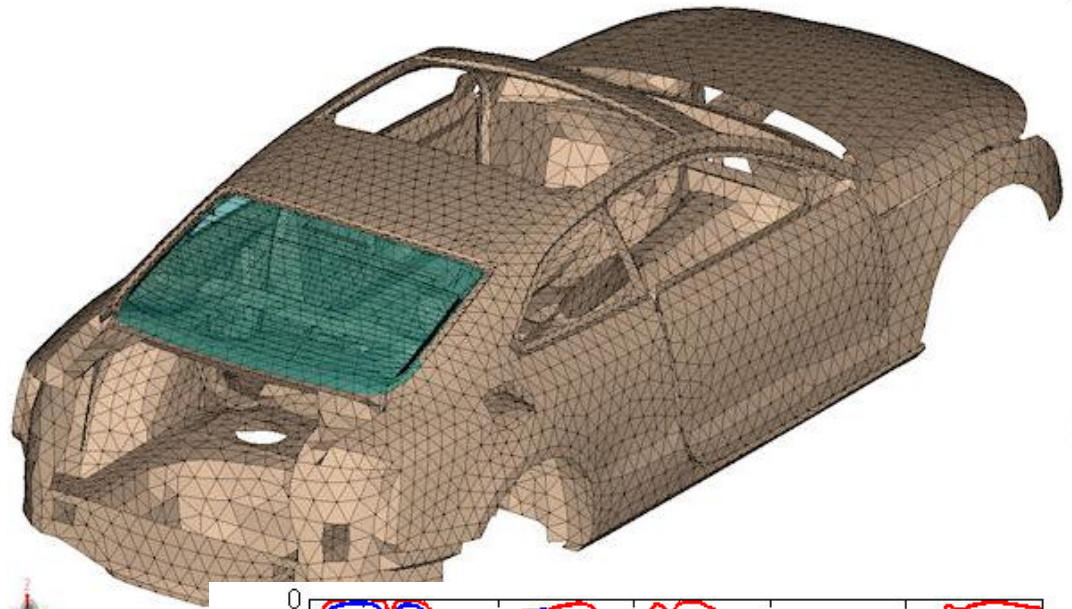
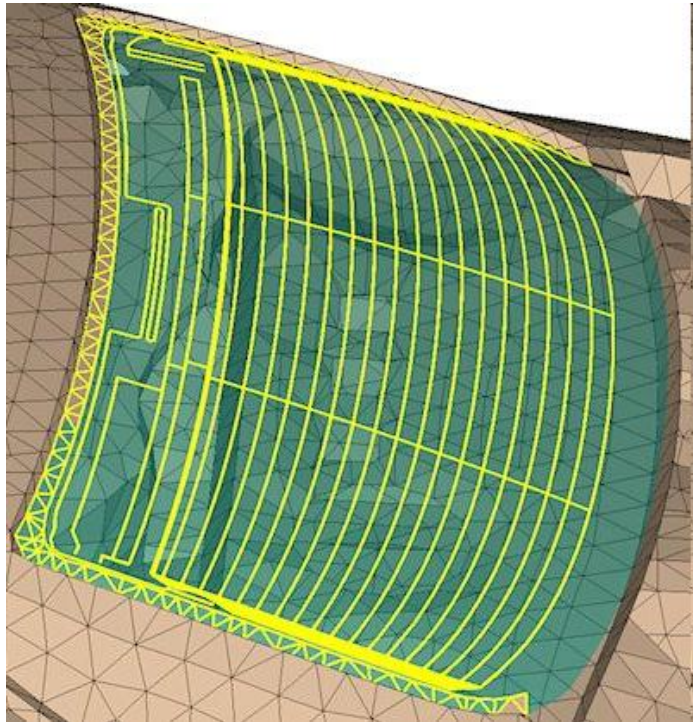
Applications of Electromagnetism: CAA and CAD

electromagnetic simulators are now required tools in research and development

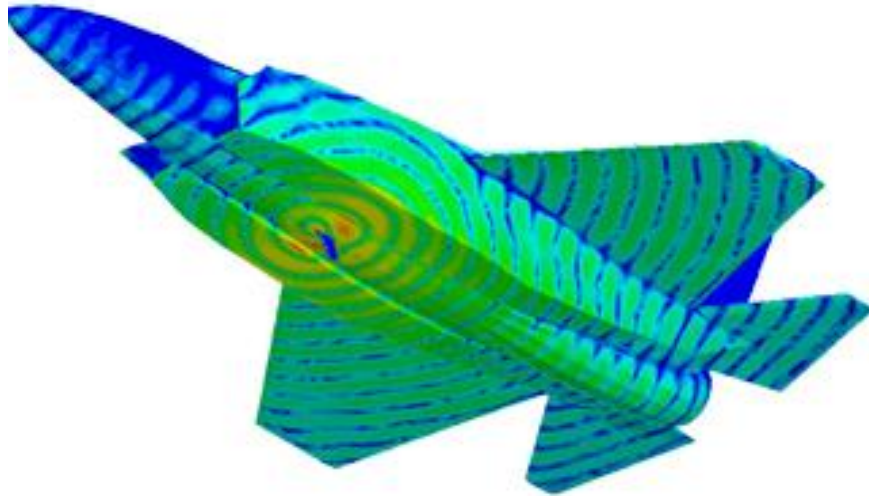
- high-frequency simulators
- static simulators
- electro-mechanical simulators

Applications of Electromagnetism: CAA and CAD

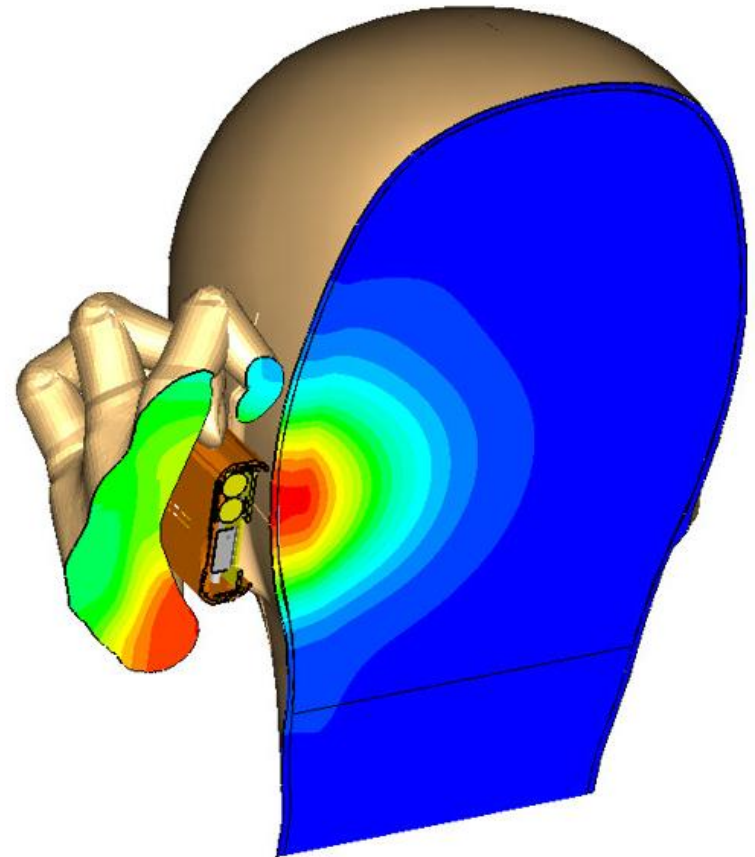
windscreen antenna design [EMSS, FEKO]



Applications of Electromagnetism: CAA and CAD



air-borne antenna
[Ansoft HFSS]



SAR distribution in human head
[CST Microwave Studio]

Frequency Spectrum

Frequency band	Wavelength	Designation	Services
3-30 kHz	100-10 km	Very Low Frequency (VLF)	Navigation, sonar*, submarine
30-300 kHz	10-1 km	Low Frequency (LF)	Radio beacons, navigation
300-3000 kHz	1000-100 m	Medium Frequency (MF)	AM broadcast, maritime/coast-guard radio
3-30 MHz	100-10 m	High Frequency (HF)	Telephone, telegraph, fax; amateur radio, ship-to-coast and ship-to-aircraft communication
30-300 MHz	10-1 m	Very High Frequency (VHF)	TV, FM broadcast, air traffic control, police, taxicab mobile radio
300-3000 MHz	100-10 cm	Ultrahigh Frequency (UHF)	TV, satellite, radiosonde, radar, bluetooth, PCS, wireless LAN
3-30 GHz	10-1 cm	Super high Frequency (SHF)	Airborne radar, microwave links, satellite, land mobile communication, local wireless ntw
30-300 GHz	10-1 mm	Extremely High Frequency (EHF)	Radar, experimental

* Sonar (an acronym for Sound, Navigation and Ranging) is a system for underwater detection and location of objects by acoustical echo. The first sonars, invented during World War I by British, American and French scientists, were used to locate submarines and icebergs. Sonar is an American term dating from World War II.

Microwave Band Designation (IEEE)

Frequency	Old	New
500-1000 MHz	VHF	C
1-2 GHz	L	D
2-3 GHz	S	E
3-4 GHz	S	F
4-6 GHz	C	G
6-8 GHz	C	H
8-10 GHz	X	I
10-12.4 GHz	X	J
12.4-18 GHz	Ku	J
18-20 GHz	K	J
20-26.5 GHz	K	K
26.5-40 GHz	Ka	K