ELEC 353
Basic Electromagnetics and Transmission Line Theory

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Office Hours: Tuesday 2:45 to 4:00, EV15.189.

Web Site For the Course

www.ece.concordia.ca/~trueman/web_page_353.htm

- **Course outline**
- Lecture notes
- Assignments
- Practice Problems
- Class tests from previous years
- Software: BOUNCE, TRLINE, WAVES

Text Book:

U.S. Inan, A.S. Inan and R.K. Said, “Engineering Electromagnetics and Waves”, 2nd edition, Pearson, 2014. ISBN 978-0-13-266274-0

Chapter 1 Introduction: Lumped and distributed circuits.
Chapter 2 Transient Response of Transmission Lines
Chapter 3 Steady-State Waves on Transmission Lines
Chapter 7 Time-Varying Fields and Maxwell’s Equations
Chapter 8 Electromagnetic Waves
Chapter 9 Reflection, Transmission and Refraction of Waves at Planar Interfaces
Introduction to Antennas (not covered in the textbook).

References

Undergraduate Electromagnetics Textbooks:

- M.N.O. Sadiku, “Elements of Electromagnetics”, 3rd edition, Oxford University Press, New York, 2001.
- W.H. Hayt and J.A. Buck, “Engineering Electromagnetics”, 6th edition, McGraw-Hill, New York, 2001.
- K.R. Demarest, "Engineering Electromagnetics", Prentice-Hall, 1998.
- J.D. Kraus, "Electromagnetics", 4th edition, McGraw-Hill, 1992.

Why consult another textbook?

- You don’t understand the explanation in the Inan book.
- You want a different point of view than given by Inan.
- You want to find some additional problems.
- You want a textbook dealing with Antennas, which is not covered in Inan.

Background Material for ELEC 353

- E. Bogatin, “Signal Integrity – Simplified”, Prentice-Hall, 2004.
- B. Young, “Digital Signal Integrity”, Prentice-Hall, 2001.
- H. Johnson and M. Graham, “High-Speed Digital Design – A Handbook of Black Magic”, Prentice-Hall, 1993.
- H. Johnson and M. Graham, “High-Speed Signal Propagation, Advanced Black Magic”, Prentice-Hall, 2003.
- W.J. Dally and J.W. Poulton, “Digital Systems Engineering”, Cambridge University Press, 1998.

Grading Scheme

Tutorial Workshops	10	Must be handed in at the end of each tutorial.
Class Test	30	**Thursday February 14, 2019**
Final Examination	60	
Total	100	

Tutorials start this week, on Friday January 11, 2019.

Tutorial Workshop Problems

- In each tutorial you will be given a problem to solve.
- You will solve the problem during the tutorial and hand in your answer at the end of the tutorial.
- The tutorial problems will count for 10 marks.
- There will be 12 tutorial workshops and 12 tutorial problem sets. Your mark will be found by taking the best 10 of the grades that you earn for the tutorial problems.

First tutorial: Friday January 11, 3:15-4:05,
WA in H621
WB in H633

ELEC 353 Formula Sheet

Constants

$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

$\mu_0 = 4\pi \times 10^{-7}$ H/m

Maxwell's Equations

$$\nabla \cdot \overline{D} = \rho_v \qquad \nabla \times \overline{H} = \overline{J} + \frac{\partial \overline{D}}{\partial t}$$

$$\nabla \cdot \overline{B} = 0 \qquad \nabla \times \overline{E} = -\frac{\partial \overline{B}}{\partial t}$$

Time-Domain Transmission Lines

$$\frac{\partial v}{\partial z} = -\ell \frac{\partial i}{\partial t}$$

$$\frac{\partial i}{\partial z} = -c \frac{\partial v}{\partial t}$$

$$R_c = \sqrt{\frac{\ell}{c}}$$

$$u = \frac{1}{\sqrt{\ell c}}$$

Reflection at a load:

$$\Gamma = \frac{R_L - R_c}{R_L + R_c}$$

Transmission from line #1 onto line #2:

$$T_{12} = \frac{2R_{c2}}{R_{c1} + R_{c2}}$$

Sinusoidal Steady State

$$\frac{dV}{dz} = -(r + j\omega\ell)I$$

$$\frac{dI}{dz} = -(g + j\omega c)V$$

$$\gamma = \alpha + j\beta = \sqrt{(r + j\omega\ell)(g + j\omega c)}$$

$$Z_0 = \sqrt{\frac{(r + j\omega\ell)}{(g + j\omega c)}}$$

With the generator at $z = 0$ and the load at $z = L$:

$$V(z) = V^+ e^{-j\beta z} + V^- e^{j\beta z}$$

$$V^- = V^+ \Gamma_L e^{-2j\beta L}$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = |\Gamma_L| e^{j\phi}$$

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta L}{Z_0 + jZ_L \tan \beta L}$$

Time-Harmonic Maxwell's Equations

$$\nabla \cdot \overline{E} = \frac{\rho_v}{\varepsilon} \qquad \nabla \times \overline{H} = (\sigma + j\omega\varepsilon)\overline{E}$$

$$\nabla \cdot \overline{H} = 0 \qquad \nabla \times \overline{E} = -j\omega\mu\overline{H}$$

$$E_x(z) = E_x^+ e^{-\gamma z} + E_x^- e^{\gamma z}$$

$$\gamma = \alpha + j\beta = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$$

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$$

Reflection

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\tau = \frac{2\eta_2}{\eta_2 + \eta_1}$$

Transmission through a Wall

$$T = \frac{4\eta_0 \eta_w e^{-j\beta_w d}}{(\eta_0 + \eta_w)^2 - (\eta_0 - \eta_w)^2 e^{-2j\beta_w d}}$$

Antennas

Hertzian Dipole: $E_\theta = \frac{j\eta_0 \beta I_0 \ell}{4\pi} \sin\theta \frac{e^{-j\beta r}}{r}$

Ideal Dipole of arm length h:

$$E_\theta(\theta) = \frac{jI_0\eta_0}{2\pi} F(\theta) \frac{e^{-j\beta r}}{r}$$

$$F(\theta) = \frac{\cos(\beta h \cos\theta) - \cos(\beta h)}{\sin\theta}$$

Half-wave Dipole Antenna

$$P_{rad} = 36.5 I_0^2$$

Friis Transmission Equation

$$P_R = \left(\frac{\lambda}{4\pi R}\right)^2 G_R G_T P_{in}$$

How to Get an A in ELEC353

- Read the textbook. Stay ahead of the lectures.
- Attend the lectures:
  - The lectures cover the course material comprehensively and include sample problems that are solved in class.
  - Writing notes in class will help you to remember the lecture material.
- Attend the tutorial workshops:
  - The workshops help you to keep up with the course week by week.
  - The workshops let you earn some marks for the workshop problems.
  - The workshop problems help you to get started with the homework problems.
- Do the homework problems:
  - Engineering is **learn by doing** so you can develop you skills by doing the homework problems.
  - Check you work against the solutions posted on the course web site.

Broad Learning Objectives

Learn about “distributed circuit analysis” and “travelling waves”:

- Waves on circuit boards
  - wave equation, speed of travel, time delay, reflection and transmission
  - waves in the time domain
  - waves in the frequency domain
- Waves in space:
  - wave equation, plane waves travelling through space
  - frequency domain

Specific Learning Objectives

Distributed circuit analysis for waves on circuit boards:

- Time domain: Understand how reflections on circuit interconnections give rise to timing hazards and other errors in logic circuits.
- Frequency domain: Learn how to use A.C. circuit analysis to understand problems on circuit interconnections.

Waves in Space

- Electromagnetic wave travelling through space.
- Antennas and wireless links.

The Big Picture

- Accreditation:
  - Engineers Canada: affiliation of the provincial licencing boards such as the Ordre des Ingenieurs du Quebec and the Professional Engineers of Ontario.
  - Canadian Engineering Accreditation Board
  - Accreditation of B.Eng programs every six years

- Graduate Attributes:
  - What at are we trying to teach you?
  - Each course teaches one or more of the Graduate Attributes.
  - Individual students are not assessed and there is no individual “grade”.
  - Instead the class as a whole is assessed.

Engineering Graduate Attributes

KB - A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

PA: Problem Analysis: An ability to use appropriate knowledge and skills to identify, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

INV - Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

DE - Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

UET - Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

ITW-Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

Engineering Graduate Attributes, continued

CO - Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

PR - Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

IES - Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

EE - Ethics and equity: An ability to apply professional ethics, accountability and equity.

EPM - Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering and to understand their limitations.

LLL - Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

Graduate Attributes for ELEC 353

- The "graduate attributes" for ELEC353 are:
  KB-2 Knowledge base of natural sciences (physics)
  KB-3 Knowledge base in a specific domain
  LLL-1 Life Long Learning: Identifying missing knowledge and learning opportunities
  LLL-2 Continuous improvement and self-learning

- Knowledge base: the technical content of the course.
  - Natural science: the wave equation, travelling waves
  - Specific domain: maintaining signal integrity
- Life-long learning includes reading textbooks, doing problems, and in a broader professional sense reading professional magazines and research journals, attending short courses and workshops, and attending conferences.
- To practice life-long learning in ELEC353, you are responsible for:
  Vector calculus (identifying missing knowledge)
  A.C. circuit analysis (continuous improvement and self-learning)
- These topics will not be covered in the lectures. You must study them on your own to practice "self-learning".
- There will be exam questions that use vector calculus and AC Circuit Analysis to assess the "self-learning" attribute for accreditation purposes.

Ethics and Professionalism

The Four Core Values of the Ordre des Ingenieurs du Quebec

- Competence
- Responsibility
- Ethical conduct
- Social commitment

Ethics:

- Disciplined dealing with moral duty.
- Moral Principles or Practice.
- System of right behavior.

Professionalism

- You are training to become a professional engineer.
- We expect you to behave like a professional throughout your university career.

- **Professionalism:**
  - The conduct, aims or qualities that characterize a professional person.

- **What characterizes a "professional"?**
  - a professional accepts responsibility fully – does not blame others for failure.
  - a professional is competent - gets the correct answer.
  - a professional is reliable - gets the job done on time.
  - a professional does not offer excuses in lieu of completed work.
  - a professional follows up on all the details.
  - a professional works independently – finds out what he/she does not know.
  - a professional is resourceful.
  - a professional has initiative.
  - a professional is respectful to others.
  - a professional has high standards of ethical behavior – does not lie or cheat.
  - a professional does not steal the work of others and present it as his own.
  - a professional succeeds in spite of obstacles and road blocks.
  - a professional has *justifiable* self-confidence.