CAN209 Advanced Electrical Circuits and Electromagnetics

Lecture 1 Course Introduction

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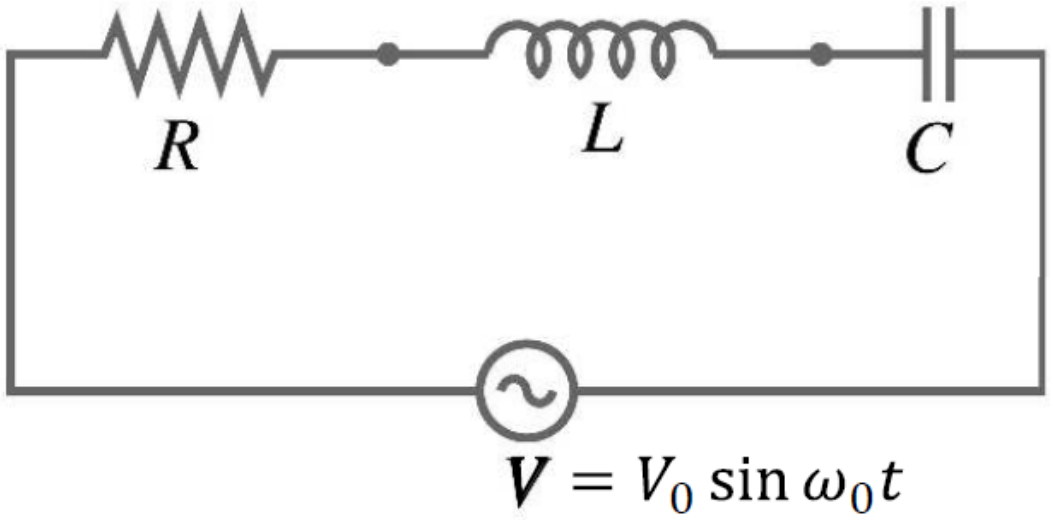
MOTIVATION

From fundamental Electrical Circuits class (EEE103), you are familiar with the *RLC* circuit, such as:



The electric voltage $v_C(t)$ in the circuit changes with time t (from ordinary differential equation):

ODE 微分方程
(Y1 Calculus 微积分)

$$\frac{d^2v_C}{dt^2} + \frac{R}{L}\frac{dv_C}{dt} + \frac{1}{LC}v_c = \frac{1}{LC}V_0 sin\omega t$$

With given initial conditions, this is an initial-value problem.

MOTIVATION

The solution of this ODE can be similar to that of a simple harmonic oscillator.

With $V=0$ and $R\neq0$, we can model energy loss like in a damped (D) harmonic oscillator:

Under- D **Critical-D** **Over-D**

And if $V\neq0$, we can model energy loss like in a forced harmonic oscillator.

Notice that in previous analysis, we never consider the electric and magnetic fields associated with the electrical circuit. It is time to do so and this involves **Electromagnetics**!

SIGNIFICANCE

Why Electromagnetism (EM)?

- ✓ Most electrical engineering, telecom, and electronic science courses build on EM knowledge
- ✓ Defines the depth of your understanding of other topics
- ✓ Typically a support discipline (‘you must have done this at the EM course’)

Why Electrical Circuits (EC)?

- ✓ Circuit Theory is the electrical engineer’s fundamental tool
- ✓ Circuit theory is simpler to work through and provides simple solutions of sufficient accuracy under predefined assumptions
- ✓ As an engineering student, learn how to solve problems.

LEARNING OUTCOMES

- A. Understand principles related to Electrostatics and Magnetostatics and analyse the operation of basic magnetically coupled circuits
- B. Apply Maxwell's equations in differential and integral form for engineering applications and the energy aspects of electromagnetic fields, and understand and analyse the properties of plane waves in free space
- C. Describe and analyse the transient and frequency responses of first order and second order networks
- D. Explain the structure and operation of three phase networks and analyse network properties
- E. Perform network analysis using appropriate parameters on two port networks

PRE-REQUISITES

Requires **physics** background on:

- ✓ Basic mechanics
- ✓ Electrostatic fields
- ✓ Magnetostatic fields
- ✓ EM induction
- ✓ Basic circuit analysis (KVL, KCL)
- ✓ DC and AC circuits
- ✓ Power and energy
- ✓ Passive sign conventions

Requires **mathematical** background knowledge on:

- ✓ Vector & scalar
- ✓ Transformation in different *C.S.*
- ✓ Complex analysis
- ✓ Gradient, divergence & curl
- ✓ Differentiation & Partial derivatives
- ✓ Linear, surface, & volume integrations
- ✓ Complex integration techniques
- ✓ (In)Homogeneous ODEs & general solutions
- ✓ Phasors

非/齐次线性微分方程解的结构

MODULE INFORMATION

- Module Code: CAN209
- Module Title: **Advanced** Electrical Circuits & Electromagnetics
- Module Credit: 5 credits
- Module Leaders: Zhenzhen Jiang and Mark Leach

Total Study Hour ≥ 150 hours
(Private Study Time ≥ **6.6h** per week for 13 weeks)

MODULE COORDINATOR

Zhenzhen Jiang

– School Assessment Coordinator

– Office: SIP Engineering Building EE204

– Consultation hour (W1–W7, W9–W13):

Wednesday 11:00-11:30

Friday 13:00–16:30

– Email address:

zhenzhen.jiang02@xjtlu.edu.cn

MODULE COORDINATOR

Mark Leach

– Deputy Dean of SAT

– Office: Engineering Building EE514

– Practical-work Support (W10 Friday Lab)

– Email address: mark.leach@xjtlu.edu.cn

Please send only email messages that are necessary for the learning process and please use only XJTLU emails for your correspondence.

GENERAL SYLLABUS

Electromagnetics (W1 - W6)

- Maxwell's Eqs: Static Fields
- Materials in Static Fields
- Passive Components (*R*, *L*, *C*)
- Steady Electric Currents
- Maxwell's Eqs: *t*-varying Fields
- Uniform Plane Waves & TX Lines

Electrical Circuits (W6-W7, W9 - W12)

- Transient Response (1^{st} & 2^{nd} order)
- Frequency Response (1^{st} & 2^{nd} order)
- Magnetically Coupled Circuits
- Three Phase Circuits
- Two-port Networks

Revision (W13)

TEACHING PLAN

MON	TUES	WED	THUR	FRI	SAT	SUN	WEEK	TOPICS
9	10	11	12	13	14	15	W1	Intro+Electromagnetics
16	17	18	19	20	21	22	W2	Electromagnetics
23	24	25	26	27	28	29	W3	Electromagnetics
30	1	2	3	4	5	6		
7	8	9	10	11	12	13	W4	Electromagnetics
14	15	16	17	18	19	20	W5	Electromagnetics
21	22	23	24	25	26	27	W6	Electrical Circuits
28	29	30	31	1	2	3	W7	Electrical Circuits
4	5	6	7	8	9	10	W8	
11	12	13	14	15	16	17	W9	Electrical Circuits
18	19	20	21	22	23	24	W10	Electrical Circuits+Lab
25	26	27	28	29	30	1	W11	Electrical Circuits
2	3	4	5	6	7	8	W12	Electrical Circuits
9	10	11	12	13	14	15	W13	Revision Week

RESOURCES

- **Core**:
  - Lecture Materials and Recorded Videos
  - Self-practice Problem Sheets (& will be discussed in tutorial class)
  - External Links (useful Animations/Demonstrations/ MIT Courses)
- **Library**:
  - Past Year Exam Papers
- **Recommended Books**:

Title	Author(s)	ISBN
Electric Circuits, 9th *Ed*.	James W. Nilsson *et.al.*	9787121157349
Engineering Circuit Analysis, 8th *Ed*.	W. Hayt, *et.al.*	9787121171376
Engineering Electromagnetics	W. Hayt, J. Buck	9787302204077
Field and Wave Electromagnetics	D. K. Cheng	9787302152125

ASSESSMENTS

- Continuous Assessment:

Group Information will be collected in Week 3

➢ Assignment for EM (CW003 15%)

Release Date: **Week 5** Monday (14/10/2024)

MATLAB coding based; Group work (5 students per group)

ONE submission per group. ALL group members will receive the same mark.

Deadline: **W7** Monday (28/10/2024)

➢ Laboratory for EC (CW002 15%)

Release Date: **Week 9** Friday (15/11/2024)

Lab Date: **Week 10** Friday 13:00-18:50 (22/11/2024)

Group work (same group allocation)

ONE submission per group. ALL group members will receive the same mark.

Deadline: **W11** Tuesday (26/11/2024)

ASSESSMENTS

- Final Exam (70%):

  3 hours, 4 Questions (50% EM + 50% EC)

- Resit Exam (100%):

  3 hours, 4 Questions (50% EM + 50% EC)

If YOU do the work, then YOU can pass the exam

EXAMINATIONS OFFICERS

- SAT School Assessment Coordinator: Zhenzhen Jiang
  - CAN EO: Dapeng Dong (dapeng.dong@xjtlu.edu.cn)
  - CPT EO: Haiyang Zhang (haiyang.zhang@xjtlu.edu.cn)
  - EEE EO: Bing Han (bing.han@xjtlu.edu.cn)
  - INT EO: Xi Yang (xi.yang01@xjtlu.edu.cn)
  - MEC EO: Yan Yan (yan.yan@xjtlu.edu.cn)

If you encounter mitigating circumstances that prevent you from submitting your coursework by the deadline, you can request an extension from the corresponding EOs. Details can be found in the file ‘Guide for MC Application’.

How to apply for coursework deadline extension
如何申请延期提交作业

To complete and submit the *Request for Extension of Coursework Submission Deadline* form with evidence to the corresponding School/Academy Assessment Coordinator or designated Departmental Examinations Officer*.
填写*Request for Extension of Coursework Submission Deadline*表格，并将该表格和证明材料交给学院的Assessment Coordinator或指定的系级Examinations Officer*进行审批。

Application Timeline
申请时间

Normally, the request should be made before the original coursework submission deadline.
原则上，延期申请应在原定的作业提交截止时间之前提出。

If there is a credible and compelling reason why you were unable to report the mitigating circumstance before the original coursework submission deadline, you can submit the form within 5 working days after the submission deadline or before the coursework feedback is provided, whichever comes earlier. The academic unit may consider such a late application on a case-by-case basis.
如果有可信且有说服力的客观理由，导致无法在原定的作业提交截止时间前提出延期申请，可以在作业提交截止时间后5个工作日内或者在获得作业反馈之前（以较早者为准）提交该表格。院系将酌情逐案考虑是否接受此类延迟申请。

However, no claims will be considered after the coursework feedback has been provided, or after 5 working days beyond the submission deadline, whichever is earlier.
但在任课老师已给出作业反馈意见，或者超过作业截止时间5个工作日后（以较早的时间为准），将不再考虑任何申请。

Possible Outcomes
申请结果

- To extend the submission deadline within the current semester or the current assessment period (August resit)
  在当前学期内（如是补考期间的申请，则在当前补考周期内）延长作业提交截止时间
- To exempt the late submission penalties
  免除迟交作业处罚
- Application declined due to unacceptable grounds and/or unacceptable evidence
  因理由不充分或证据不充足等原因申请被拒绝

Once you have made such a request for extension, you cannot apply for consideration of the same circumstances for the same assessment by the Mitigating Circumstances Committee.
申请延期提交作业以后，学生不得再向减轻情节委员会以同样的理由针对同一项作业提出情节减轻申请。

For stage 1 students, to submit the form to the Examinations Officer of the academic unit that runs the module, for stage 2 and above students, to the Assessment Coordinator or Examinations Officer of your home School/Academy.

大一学生递交给课程所属学院的Examinations Officer，其他年级学生递交给学生所属学院的Assessment Coordinator或系级Examinations Officer。

EXPECTATIONS

What do we expect from you:

- ✓ Attend classes – **onsite** & **on time**
- ✓ Review the contents on a **weekly** basis
- ✓ Ask questions during the lecture
- ✓ Complete **all** the delivered questions

If you are struggling, ask for help

ATTENDANCE

Your attendance will be recorded on
AMS

Remind that poor attendance could result in students losing their opportunity to resit the module if they fail.

ELECTROMAGNETICS (EM)

- What is “Electromagnetics” about?
- Why do we learn “Electromagnetics”?

WHAT IS EM?

- ***Electromagnetics*** (EM) – the subject that deals with the theory and applications of electric & magnetic fields and waves.
  - *Electromagnetism = Electromagnetics, n.* 电磁学

- EM is the study of the effects of electric charges ***at rest*** and ***in motion***.
  - There are two kinds of charges: positive and negative, both are sources of electric fields.
  - Moving charges produce a current, which gives rise to a magnetic field.

Electrostatics [hide]

Electric charge • Static electricity
Electric field • Conductor
Insulator • Triboelectricity
Electrostatic discharge • Induction
Coulomb's law • Gauss's law
Electric flux / potential energy
Electric dipole moment
Polarization density

Magnetostatics [hide]

Ampère's law • Magnetic field
Magnetization • Magnetic flux
Biot–Savart law
Magnetic dipole moment
Gauss's law for magnetism

Electrodynamics [hide]

Lorentz force law
Electromagnetic induction
Faraday's law
Lenz's law • Displacement current
Maxwell's equations
Electromagnetic field
Electromagnetic radiation
Maxwell tensor • Poynting vector
Liénard–Wiechert potential
Jefimenko's equations
Eddy current

MAXWELL'S EQUATIONS

- "A Dynamical Theory of the Electromagnetic Field"
  - ➢ By J. C. Maxwell, in 1864.
- Maxwell's equations are a set of **four** partial differential equations that describe the properties of the electric and magnetic fields and relate them to their sources, charge density and current density.

① Gauss' law for E-fields $\nabla \cdot \vec{D} = \rho$

② Gauss' law for H-fields $\nabla \cdot \vec{B} = 0$

③ Faraday's law of induction $\nabla \times \vec{E} = 0 - \frac{\partial \vec{B}}{\partial t}$

④ Ampere's law $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

CONTENTS

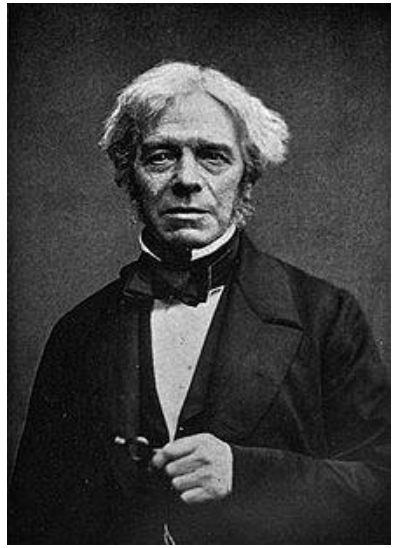
IMPORTANT SCIENTISTS

Hendrik Lorentz

Hermann von Helmholtz

James C. Maxwell

André-Marie Ampère



Michael Faraday

WHY DO WE STUDY EM?

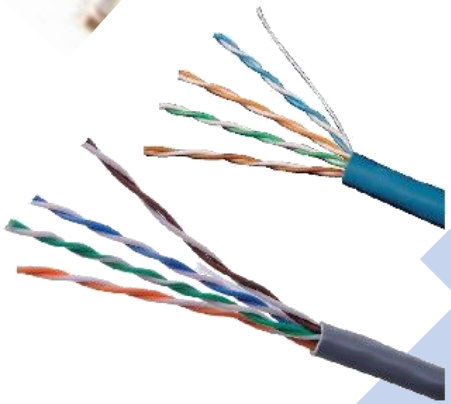
Do we know the answers to these questions?

- What is a field? What is the nature of a field?
- How is the magnetic field produced by a current-carrying coil?
- What is an induction?
- Where is the energy in a circuit? In the voltage, the current, or neither?
- How does a piece of wire (antenna) radiate or receive signals?
- How do electromagnetic fields propagate in space?
- What happens when EM energy travels from one end of a hollow pipe (waveguide) to the other?
- Where do fields travel in transmission lines?

Electromagnetic principles and laws **govern all electrical and computer engineering systems**.

Electromagnetics is everywhere

APPLICATIONS



ELECTRIC CIRCUITS (EC)

- What is “Electrical Circuits” about?
- Why do we learn “Electrical Circuits”?

WHAT IS EC?

- ***Electrical Circuits*** – also called “Electrical Networks” or “Electric Circuit Analysis”, is the subject deals with the fundamentals of electric circuits, their components and the mathematical tools used to represent and analyse electrical circuits.
- An electrical circuit is an interconnection of electrical *components* or a model of such an interconnection, consisting of *electrical elements*.
- An electrical circuit is a network consisting of a closed loop, giving a return path for the current.
  - Linear electrical networks, a special type consisting only of sources (voltage or current), linear lumped elements (resistors, capacitors, inductors), and linear distributed elements (transmission lines), have the property that signals are linearly superimposable.
  - A network that contains active electronic components is known as an electronic circuit. Such networks are generally nonlinear and require more complex design and analysis tools.

CONTENTS

IMPORTANT SCIENTISTS

A. A. Volta (1745–1827)

G. S. Ohm (1787–1854)

A. M. Ampere (1775–1836)

G. R. Kirchhoff (1824-1887)

WHY DO WE LEARN EC?

- To pass the fundamentals of engineering examination as a 1st step in becoming a registered professional engineer.
- To have a broad enough knowledge base so that you can lead design projects in your own field.
- To be able to operate and maintain electrical systems.
- To be able to communicate with electrical-engineering consultants.
- As an engineering student, learn how to solve problems.

NEXT…

- Review Static Fields