CAN209

Exam Preparation and Revision_AY2425

Zhenzhen Jiang

School of Advanced Technology

Xi'an Jiaotong-Liverpool University
西交利物浦大學

Registry-Important rules and tips for the upcoming final exams

1.Bring **two documents** for admission 携带**双证**参加考试:

a. XJTLU Student ID Card **学生证**

b. Official Identity Verification Document **官方身份证件**

i. Mainland China: Resident Identity Card（居民身份证）;

ii. Hong Kong, Macau, Taiwan: Mainland Travel Permit （通行证）

iii. International: Passport (护照)

2.Use the washroom **before** admission check. **No washroom breaks are allowed within the first two hours and last 15 minutes of each exam**. 入场**前**如厕。考试开始后两小时内及考试结束前15分钟不得离场如厕。

3. (Students) Arrive at least **30 minutes early** for admission and **metal scanner** check.

至少提前30分钟到达考场门口进行入场检查。

4.Any unauthorized materials or misbehaviors are strictly prohibited. Violation of exam rules will result in **disciplinary actions** and **the imposition of demerit points on transcripts**.

严禁携带任何考试违禁品及任何违纪行为。违反考试规则者将受到纪律处分，并在成绩单上记录违规积分。

ABOUT THE EXAM

1. This is a closed-book examination.
   - Date: Dec 31st, 2024;
   - Reading Time: 10 minutes for reading the exam paper (14:00-14:10)
   - Writing Time: 180 minutes for answering ALL questions (14:10-17:10)

No annotating is allowed in reading time or after the end of writing time

2. **FOUR** questions in total (100%)
   - 50% for **Electromagnetics** + 50% for **Electrical Circuits**
   - Each question has several sub-questions

ABOUT THE EXAM

3. **ONLY** the university approved calculator - **Casio FS82ES/83ES** can be used. Calculators are permitted in accordance with the rules of the university. They may be used for the processing of numerical solutions ONLY. They must not have been programmed nor should they store additional information.

4. ALL materials must be returned to the exam invigilators upon completion of the exam period. **Failure to do so will be deemed academic misconduct and will be dealt with accordingly**.

INSTRUCTIONS

1. This is a closed book examination. **NO notes or books are permitted**.
2. Total marks available are 100. The number on the right indicates the mark for each question.
3. Attempt **ALL** questions. Write all the answers in the answer booklet provided.
4. Only solutions **in English** are acceptable.
5. Correct answers do not guarantee a full score: **mark penalties** may be imposed for **missing intermediate solution steps** or **illogical solution processes**.

INSTRUCTIONS

6. **ALL** communications enabled & network accessible devices **MUST** be switched OFF & placed in the storage area.

7. Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, and one scientific calculator.

8. You are **NOT** permitted to have on your desk or on your person any unauthorised materials. This includes but is not limited to laptops, tablets, mobile phones, smart watches and bands, smart glasses, cheat sheet , draft paper, and electronic dictionaries **Unauthorised material will be confiscated**.

Xi'an Jiaotong-Liverpool University 西交利物浦大学

PAPER CODE	EXAMINERS	DEPARTMENT	TEL
CAN209	ZHENZHEN JIANG MARK LEACH	CAN	1327 7735

2024/25 SEMESTER 1 - FINAL

BACHELOR DEGREE – Year 3

Advanced Electrical Circuits and Electromagnetics

Reading Time: 10 mins

Writing Time: 180 mins

INSTRUCTIONS TO CANDIDATES

a) This is a closed-book examination. NO notes or books are permitted.
b) Total marks available are 100. The number on the right indicates the mark for each question.
c) Attempt ALL questions. Write all the answers in the answer booklet provided.
d) Only solutions written in English will be accepted.

5. To ensure clarity of drawn solutions use different coloured pens/pencils to indicate different question answers.

h) A list of equations and constant values is provided at the end of this examination paper.

AUTHORISED MATERIALS

1. Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, and one scientific calculator.
2. Only the university approved calculator - Casio FS82ES/83ES can be used. Calculators are permitted in accordance with the rules of the university. They may be used for the processing of numerical solutions ONLY. They must not have been programmed nor should they store additional information.
3. You are NOT permitted to have on your desk or on your person any unauthorised materials. This includes but is not limited to laptops, tablets, mobile phones, smart watches and bands, smart glasses, cheat sheet, draft paper, and electronic dictionaries. Unauthorised material will be confiscated.
4. ALL communications-enabled & network accessible devices must be switched OFF & placed in the storage area.
5. To ensure clarity of drawn solutions use different coloured pens/pencils to indicate different question answers.

PAPER CODE: CAN209/24-25/S1/FINAL Page 1 of 9

携带彩色(铅)笔，按照题目要求使用不同颜色笔作图

All kinds of academic misconduct WILL BE PUNISHED!

ELECTROMAGNETICS PART (W1–W6)

- L02-L03 Static Fields
- L04 Dipoles & Nature of Materials
- L05 Electromagnetic Boundary Conditions & Electric Currents
- L06 Passive Components (*Resistors* & *Capacitors*)
- L07 Time-Varying Fields & Inductors
- L08-1 Time Harmonic Fields & Complex Power
- L08-2 EM Wave Propagation
- L09 TEM Transmission Lines

L02-L03 STATIC FIELDS

Law	Integral	Differential	Physical meaning
Gauss's law for **E-field**	$\oint\!\!\oint_S \vec{D} \cdot \mathrm{d}\vec{s} = Q$	$\nabla \cdot \vec{D} = \rho$	Electric flux through a closed surface is proportional to the charges enclosed
E-field Loop Theorem	$\oint_C \vec{E} \cdot \mathrm{d}\vec{l} = 0$	$\nabla \times \vec{E} = 0$	Work done by moving a charge in the E-field along a closed loop is zero
Gauss's law for **H-field**	$\oint\!\!\oint_S \vec{B} \cdot \mathrm{d}\vec{s} = 0$	$\nabla \cdot \vec{B} = 0$	The total magnetic flux through a closed surface is zero
H-field Loop Theorem	$\oint_C \vec{H} \cdot \mathrm{d}\vec{l} = \mathrm{I}$	$\nabla \times \vec{H} = \vec{J}$	The H-field produced by an electric current is proportional to the current

L02-L03 STATIC FIELDS

1. Be able to find the field

Coulomb's Law $\vec{D} = \int d\vec{D} = \frac{1}{4\pi}\int \frac{dQ}{r^2}\hat{r}$

Gauss's Law $\oiint_S \vec{D} \cdot d\vec{s} = Q$

From the electric scalar potential $\vec{E} = -\nabla V$

Biot-Savart Law $\vec{H} = \int_L \frac{1}{4\pi}\frac{Id\vec{l} \times \vec{r}}{r^3}$

Ampere's Law $\oint_C \vec{H} \cdot d\vec{l} = I_{encl}$

2. Be able to find electric potential/magnetic force

Coulomb's Law $V = \int dV = \frac{1}{4\pi\varepsilon_0}\int \frac{dQ}{r}$

Gauss's Law $V_{AB} = \int_A^B \vec{E} \cdot d\vec{l} = V_A - V_B$

On a moving charge

$$\vec{F}_L = \vec{F}_E + \vec{F}_B = q(\vec{E} + \vec{v} \times \vec{B})$$

On a current-carrying wire $\vec{F}_{21} = I_2\vec{l}_2 \times \vec{B}_1$

3. Be able to draw electric/magnetic field lines

Point charges, surface charges, and shell *etc.*

Current loop, bar magnet, solenoid, toroid *etc.*,

L04 DIPOLES & NATURE OF MATERIALS

1. Understand electric dipole and dipole moment

2. Be able to calculate the voltage & electric field intensity of an electric dipole

3. Understand the concept of magnetic dipoles

4. Be able to apply unique properties of conductors

1) The **static** electric field intensity inside a conductor is **zero**.

2) The **static** electric field intensity at the surface of a conductor is everywhere directed **normal** to that surface.

3) Conductor's surface is an **equipotential** surface. The tangential component of the static electric field intensity on the surface is zero.

4) Net charge can **only** reside on the surface when reaches electrostatic equilibrium.

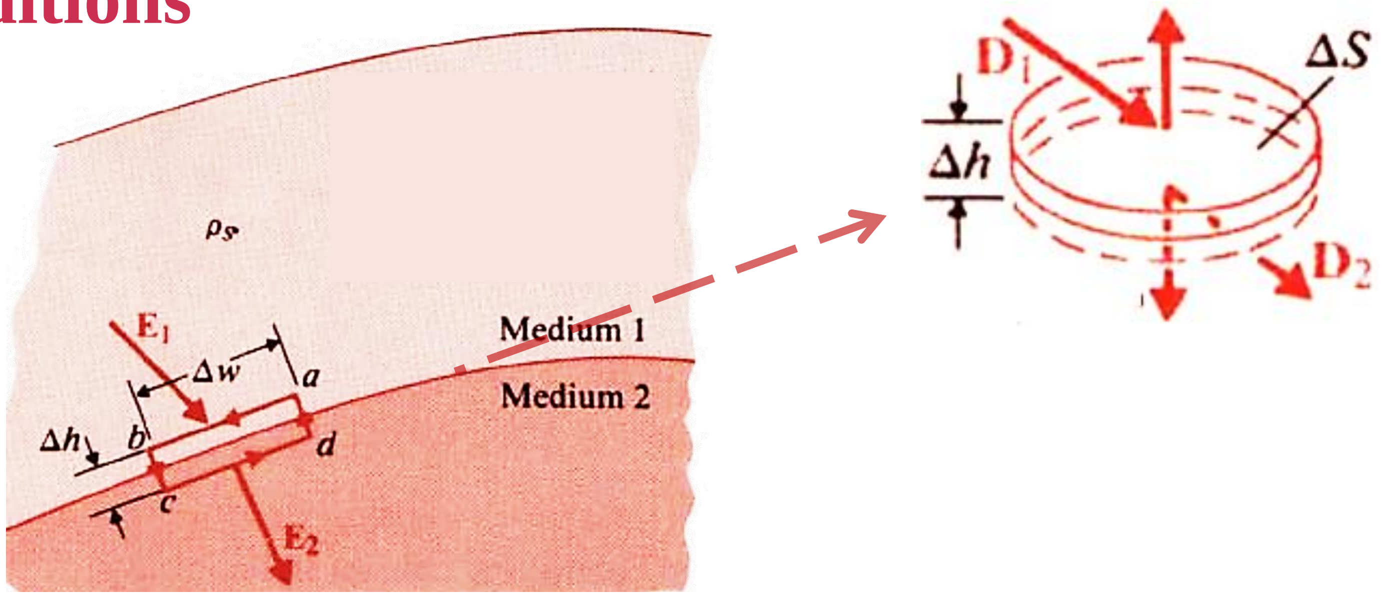
L05-1 BOUNDARY CONDITIONS

Be able to apply **Boundary Conditions**

- In Electrostatics

$$(\vec{E}_2 - \vec{E}_1) \times \hat{n}_{12} = 0$$

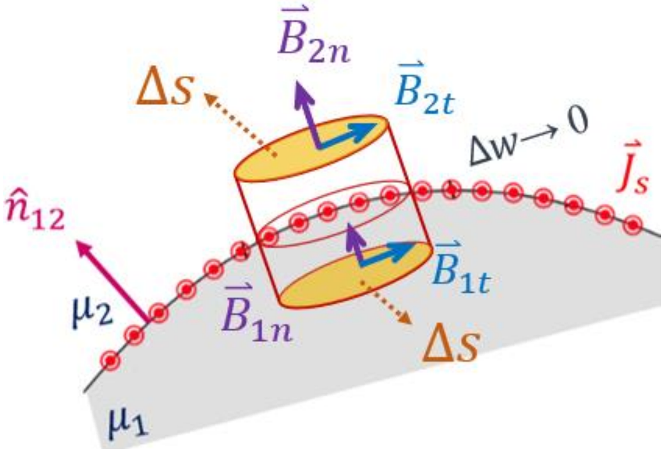
$$(\vec{D}_2 - \vec{D}_1) \cdot \hat{n}_{12} = \rho_s$$

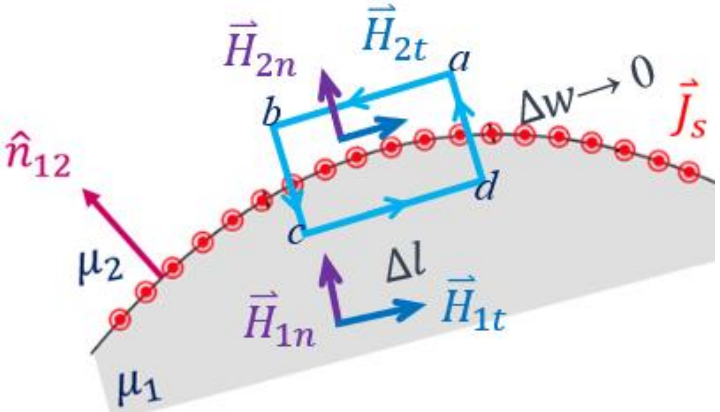


- In Magnetostatics

$$(\vec{B}_2 - \vec{B}_1) \cdot \hat{n}_{12} = 0$$

$$(\vec{H}_1 - \vec{H}_2) \times \hat{n}_{12} = \vec{J}_s$$





L05-2 ELECTRIC CURRENTS

1. Be able to calculate drift velocity & volume current density & current

   Drift Velocity

   Volume Current Density

   Current

$$\vec{v}_d = \frac{q\tau}{m_e}\vec{E} \qquad \vec{J} = Nq\vec{v}_d \qquad I = \frac{q^2 N\tau}{m_e}\vec{A}\cdot\vec{E}$$

2. Be able to calculate conductivity & resistivity

   Conductivity

   Resistivity

$$\sigma = \frac{q^2 N\tau}{m_e} \qquad \rho = \frac{1}{\sigma}$$

3. Understand Ohm's Law in microscopic and macroscopic views

4. Understand Continuity and KCL

$$\nabla\cdot\vec{J} = -\frac{\partial\rho}{\partial t} = 0 \Rightarrow \oiint_S \vec{J}\cdot d\vec{s} = 0 \Rightarrow \sum_j I_j = 0 \longrightarrow \textbf{KCL}$$

Microscopic Ohm's law

$$\vec{J} = \sigma\vec{E}$$

$$\Downarrow$$

Macroscopic Ohm's law

$$V = IR$$

L06 RESISTORS & CAPACITORS

1. Be able to calculate resistance

$$R = \int dR = \int \frac{\rho}{A} dl$$

Series connection: $R_t = R_1 + R_2 + \cdots + R_n$

Parallel connection: $R_t = R_1 \| R_2 \| R_3 \| \ldots$

2. Be able to calculate capacitance & storage energy

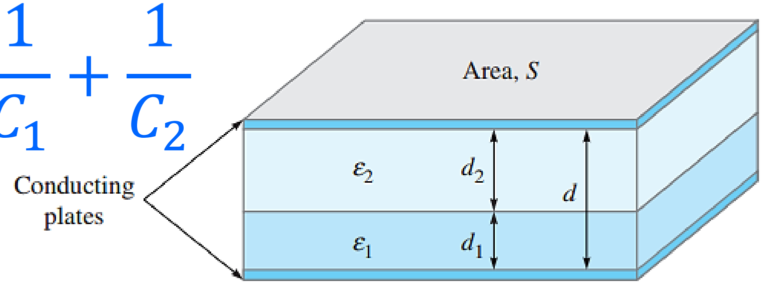
$$C = \frac{Q}{V}$$

Parallel plates, spherical & cylindrical capacitors *etc.*

Series connection, parallel connection

Stored energy

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$



$$W = \frac{1}{C}\frac{Q^2}{2} = \frac{1}{2} C V^2$$

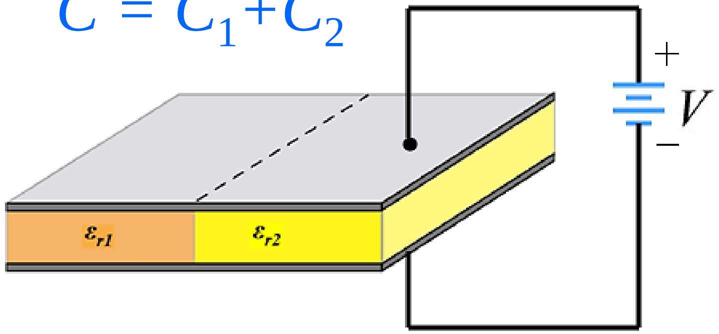
3. Be able to calculate inductance

Self-inductance for coaxial cable, solenoid, toroid *etc.*

Mutual inductance

$$L = N \frac{\Phi}{I}$$

$$C = C_1 + C_2$$



L07 TIME-VARYING FIELDS

Law	Integral	Differential	Physical meaning
Gauss's law for E-field	$\oiint_S \vec{D} \cdot d\vec{s} = Q$	$\nabla \cdot \vec{D} = \rho$	Electric flux through a closed surface is proportional to the charges enclosed
Faraday's law	$\oint_C \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	Changing magnetic flux produces an E-field
Gauss's law for H-field	$\oiint_S \vec{B} \cdot d\vec{s} = 0$	$\nabla \cdot \vec{B} = 0$	The total magnetic flux through a closed surface is zero
Maxwell-Ampere's law	$\oint_C \vec{H} \cdot d\vec{l} = I_c + \varepsilon_0 \frac{d\Phi_E}{dt}$	$\nabla \times \vec{H} = \vec{J}_c + \frac{\partial \vec{D}}{\partial t}$	Electric current and changing electric flux produces a magnetic field

L07 TIME-VARYING FIELDS

1. Be able to calculate *emf* using Faraday's Law $emf = -\frac{d\Phi}{dt}$ (V)

2. Be able to determine directions of induced *emf* & current by Lenz's Law

3. Be able to solve motional *emf* problems

   Typical: a conducting bar

   Induced current, induced *emf*

   External force, power delivered by the external force

4. Be able to solve problems of **displacement & conduction** currents

$$\oint_C \vec{H} \cdot d\vec{l} = I_c + \varepsilon_0 \frac{d\Phi_E}{dt} \qquad \nabla \times \vec{H} = \vec{J}_c + \frac{\partial \vec{D}}{\partial t}$$

L08 EM WAVES

1. Understand the time-harmonic fields

Given $\vec{E}(x,y,z,t) = E_x(x,y,z,t)\hat{x} + E_y(x,y,z,t)\hat{y} + E_z(x,y,z,t)\hat{z}$

$$\because \vec{E}(r,t) = Re\{[\tilde{E}_x(r)\hat{x} + \tilde{E}_y(r)\hat{y} + \tilde{E}_z(r)\hat{z}]e^{j\omega t}\} = Re[\tilde{E}(r)e^{j\omega t}]$$

$$\therefore \tilde{E}(r) = \tilde{E}_x(r)\hat{x} + \tilde{E}_y(r)\hat{y} + \tilde{E}_z(r)\hat{z}$$

Phasor form of $\vec{E}$

2. Be able to determine the travelling direction of a plane wave

$$E_x(z,t) = E_{xf}\cos(\omega t - \beta z + \theta_{xf}) + E_{xb}\cos(\omega t + \beta z + \theta_{xb})$$

Travel in the + z direction → **forward** travelling

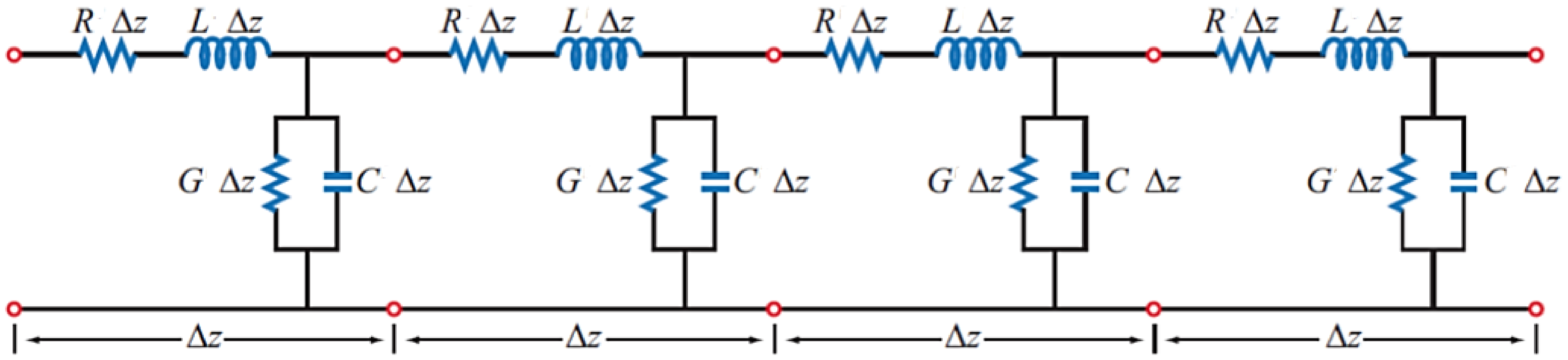
Travel in the - z direction → **backward** travelling

3. Be able to determine key parameters of a uniform plane wave

Phase constant, wavelength, relative permittivity, wave frequency, propagation velocity, intrinsic impedance, magnetic/electric field intensity, poynting vector, *etc*.

L09 TEM TRANSMISSION LINES

1. Understand the Lumped-element model of a TX line



2. Understand the general wave equations for TX lines

3. Be able to determine key parameters of a plane wave

   Characteristic impedance, phase velocity (speed), propagation constant, attenuation constant, phase constant, *etc*.

ELECTROMAGNETICS PART

SI PREFIXES

$$m = 10^{-3}$$

$$K = 10^{3}$$

$$\mu = 10^{-6}$$

$$M = 10^{6}$$

$$n = 10^{-9}$$

$$G = 10^{9}$$

$$p = 10^{-12}$$

$$T = 10^{12}$$

THANK YOU

Good Luck