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UNIVERSITI KUALA LUMPUR
KAMPUS CAWANGAN MALAYSIAN SPANISH INSTITUTE

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE	:	SAB35503
COURSE NAME	:	ENGINEERING ELECTROMAGNETICS
PROGRAMME LEVEL	:	BACHELOR
DATE	:	28 JANUARY 2026
TIME	:	9.00 AM – 11.30 AM
DURATION	:	2 HOURS AND 30 MINUTES

INSTRUCTIONS TO CANDIDATES

1. Please CAREFULLY read the instructions given in the question paper.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of TWO (2) sections; Section A and Section B.
4. Answer ALL questions in Section A. For Section B, answer THREE (3) questions from FOUR (4) questions.
5. Please write your answers in the answer booklet provided.
6. Answer all questions in English language ONLY.
7. Relevant equations have been appended for your reference.

THERE ARE 8 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

SECTION A (Total: 40 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

A technologist is conducting verification tests on a sensitive printed circuit board (PCB) that features high-impedance measurement points, plastic housings, and grounded metal supports in close proximity. During the test session, the technologist records the following observations:

- Some high-impedance voltage or sensor readings drift when a plastic cover is placed near the board.
- Dust particles tend to accumulate on certain PCB regions.
- Bringing a grounded metal tool near the board stabilizes some of the fluctuating readings.
- Two identical boards placed side-by-side show slightly different measured voltages.
- Increasing room humidity improves measurement consistency.

Using your understanding of Electrostatics, answer the following questions:

(a) Explain why placing a plastic cover near the PCB can cause the measurement readings to drift.

(4 marks)

(b) Describe why dust tends to accumulate in specific areas of the PCB during testing.

(4 marks)

(c) Explain how bringing a grounded metal tool near the PCB can stabilize certain voltage readings.

(4 marks)

(d) Explain why two identical boards placed close together may show slightly different measured voltages.

(4 marks)

(e) Explain why increasing room humidity improves measurement consistency during verification, validation and testing (VVT).

(4 marks)

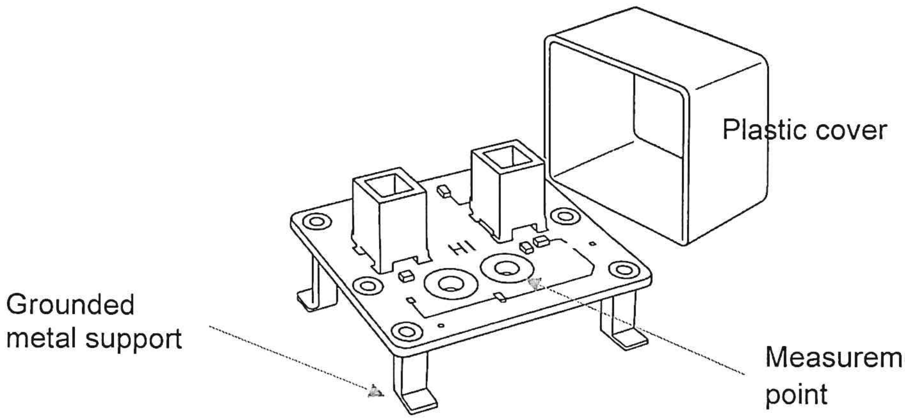

Figure 1: PCB board used in the verification test.

Question 2

A technologist is performing tests on a power control PCB that includes current-carrying traces, inductors, and magnetic sensors. During the testing process, the technologist observes several behaviors:

- A magnetic sensor shows small output fluctuations when a high-current trace is energized.
- A looped wire near the PCB causes noticeable magnetic interference during measurement.
- Bringing a small steel tool close to an inductor changes the sensor reading slightly.
- A ferrite bead added to a wire reduces noise during current switching tests.
- Two inductors placed close together affect each other's magnetic fields.

Using your understanding of Magnetostatics, answer the following questions:

(a) Explain why energizing a high-current trace can cause fluctuations in a nearby magnetic sensor reading.

(4 marks)

(b) Explain why a looped wire produces stronger magnetic interference compared to a straight wire carrying the same current.

(4 marks)

(c) Explain why bringing a steel tool close to an inductor affects the sensor reading.

(4 marks)

(d) Explain why adding a ferrite bead to a wire helps reduce noise during switching tests.

(4 marks)

(e) Explain why two inductors placed close to each other influence each other's magnetic fields.

(4 marks)

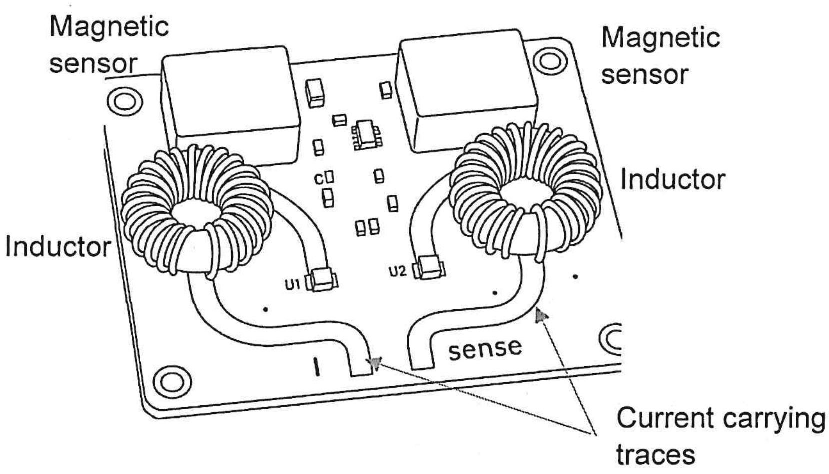

Figure 2: PCB board with inductor and magnetic sensor.

SECTION B (Total: 60 marks)

INSTRUCTION: Answer THREE questions ONLY.
Please use the answer booklet provided.

Question 3

A technologist is conducting tests on a small DC-powered switching circuit that drives a load via a MOSFET. The circuit is placed within a test enclosure that is partially covered with metal. During the course of routine testing, the technologist notes the following observations:

- Small electric-field spikes appear near the MOSFET drain during switching transitions.
- A magnetic probe detects stronger magnetic activity when the current return trace is routed far away from the supply trace.
- Leaving a small opening in the metal enclosure increases measured emissions.
- A sensor cable nearby picks up noise exactly at the MOSFET's rise and fall times.
- Placing a ferrite block near the switching area reduces some noise but causes slight additional ringing in the measured waveform.

Using your understanding from Maxwell's Equations, analyze the following in simple, engineering-technology terms

(a) Using Maxwell's ideas, explain why switching transitions at the MOSFET drain create noticeable electric-field spikes, even though the circuit uses low voltage.

(4 marks)

(b) Explain why routing the return trace far from the supply trace increases magnetic field strength during switching.

(4 marks)

(c) Using electromagnetic boundary concepts, explain why a small opening in the metal enclosure allows more EMI to escape.

(4 marks)

(d) Explain why the nearby sensor cable only picks up noise during MOSFET switching edges, not when the MOSFET is fully ON or OFF.

(4 marks)

(e) The ferrite block reduces some switching noise but slightly increases ringing. Using Maxwell-based reasoning, explain why adding ferrite can help one part of the electromagnetic behavior but worsen another

(4 marks)

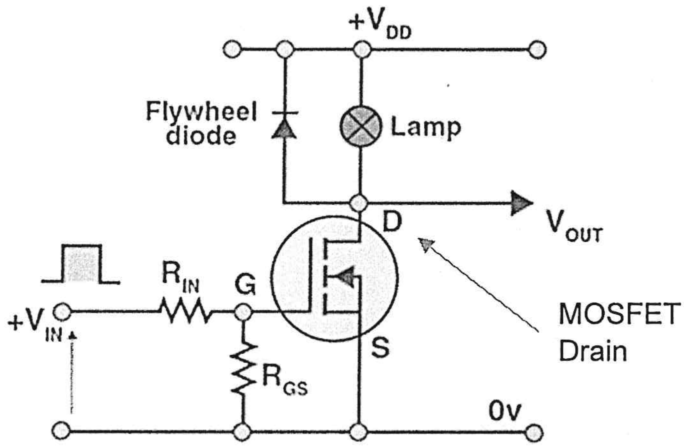

Figure 3: DC powered switching circuit driving a MOSFET.

Question 4

A technologist is evaluating a microcontroller board powered by a DC–DC converter. The board incorporates a MOSFET switch, a small inductor, a grounded metal sheet beneath it, and multiple I/O cables. During the testing process, the technologist observes the following behaviors:

- Electric-field pulses appear around the MOSFET only at the rising and falling edges of the switching waveform.
- Magnetic field readings are higher around a long power loop compared to a short, compact power loop.
- When the grounded metal sheet is slightly lifted on one side, radiated noise increases.
- An I/O cable running beside the board shows momentary noise exactly when switching occurs.
- Placing a ferrite pad under the board reduces electric noise but increases the strength of the magnetic field measured above the board.

Using simple analysis based on Maxwell's Equations, answer the following:

(a) Explain why electric-field pulses only occur during the MOSFET's switching edges and not during steady ON or OFF states.

(4 marks)

(b) Explain why a long power loop produces stronger magnetic fields than a compact loop, even if the same current flows in both.

(4 marks)

(c) Using electromagnetic boundary concepts, explain why lifting one side of the grounded metal sheet increases radiated emissions.

(4 marks)

(d) Explain why the nearby I/O cable picks up noise only during switching, not during constant voltage periods.

(4 marks)

(e) Analyze why adding a ferrite pad reduces electric noise but increases the magnetic field measured above the board

(4 marks)

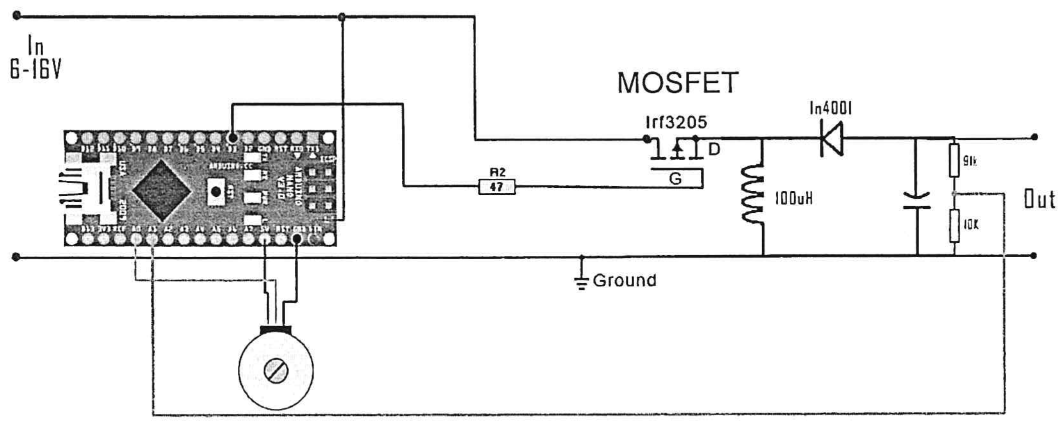

Figure 4: DC-DC converter circuit with microcontroller.

Question 5

A technologist is performing tests on a DC motor driver board that incorporates a switching MOSFET, a freewheeling diode, a small current-sense resistor, and a metal plate serving as a partial shield. A sensor cable and a power cable are routed close to the board. During the testing procedure, the technologist records the following observations:

- Electric-field bursts appear near the MOSFET only when the MOSFET turns ON and OFF.
- The magnetic-field probe shows higher readings when the motor current path forms a large loop instead of a tightly-routed loop.
- When the metal plate is not fully touching the ground point, radiated emissions become noticeably worse.
- The sensor cable picks up short spikes exactly when the MOSFET switches but remains stable when the MOSFET is fully ON.
- Adding a ferrite ring to the power cable reduces the radiated emissions but slightly increases the switching-edge distortion.

~~Using simple Maxwell-based reasoning, answer the following:~~

(a) Explain why electric-field bursts only occur during the MOSFET switching transitions, not during steady ON or OFF conditions.

(4 marks)

(b) Explain why a larger motor current loop produces stronger magnetic fields than a tightly-routed loop

(4 marks)

(c) Using electromagnetic boundary concepts, explain why poor contact between the metal plate and ground increases radiated emissions.

(4 marks)

(d) Explain why the sensor cable receives spikes only during switching events and not during steady-state current flow.

(4 marks)

(e) Analyze why adding a ferrite ring to the power cable reduces radiated emissions but increases switching-edge distortion.

(4 marks)

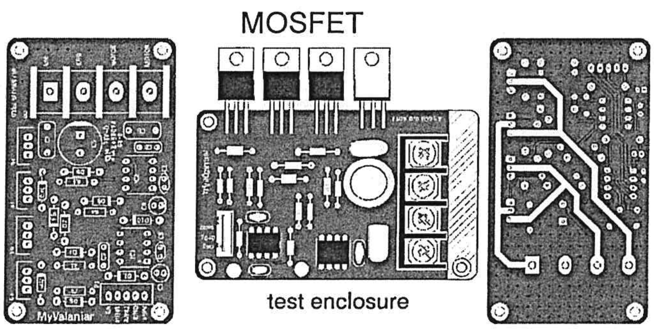

Figure 5: DC motor driver board with MOSFET.

Question 6

(a) Figure 6 shows a conductor in rod form moving with velocity U in magnetic field B. The velocity of the conducting rod can be represented as

$$\mathbf{U} = 2.5\sin 10^3 t\mathbf{a}_z \text{ (m/s)}$$

and the magnetic field can be represented as

$$\mathbf{B} = 0.04\mathbf{a}_y \text{(T)}$$

Find the induced voltage, $\mathbf{E}_\mathrm{m}$, in the moving rod conductor from $x = 0$ until $x = 0.2$.

(10 marks)

(b) Rework question 6(a) where the magnetic field is changed to

$$\mathbf{B} = 0.04\boldsymbol{a}_x \text{ (T)}$$

(10 marks)

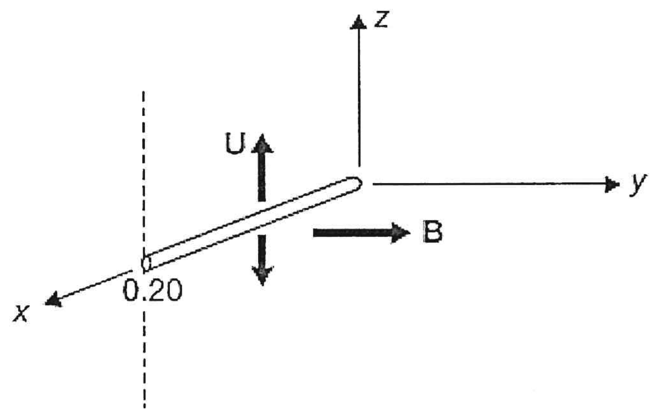

Figure 6: Conducting rod moving in magnetic field.

END OF EXAMINATION PAPER

APPENDIX

Vector analysis

$$\mathbf{A} \times \mathbf{B} = AB \sin \theta_{AB} \mathbf{a}_n$$

$$\mathbf{A} \times \mathbf{B} = \begin{vmatrix} \mathbf{a}_x & \mathbf{a}_y & \mathbf{a}_z \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \mathbf{B} \cdot (\mathbf{C} \times \mathbf{A}) = \mathbf{C} \cdot (\mathbf{A} \times \mathbf{B})$$

$$\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}$$

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B}(\mathbf{A} \cdot \mathbf{C}) - \mathbf{C}(\mathbf{A} \cdot \mathbf{B})$$

Rectangular to Cylindrical

Variable change
$$\begin{cases} x = \rho \cos \phi \\ y = \rho \sin \phi \\ z = z \end{cases}$$

Component change
$$\begin{cases} A_\rho = A_x \cos \phi + A_y \sin \phi \\ A_\phi = -A_x \sin \phi + A_y \cos \phi \\ A_z = A_z \end{cases}$$

Cylindrical to Rectangular

Variable change
$$\begin{cases} \rho = \sqrt{x^2 + y^2} \\ \phi = \tan^{-1}\left(\dfrac{y}{x}\right) \begin{cases} \sin \phi = \dfrac{y}{\sqrt{x^2 + y^2}} \\ \cos \phi = \dfrac{x}{\sqrt{x^2 + y^2}} \end{cases} \\ z = z \end{cases}$$

Component change
$$\begin{cases} A_x = A_\rho \dfrac{x}{\sqrt{x^2 + y^2}} - A_\phi \dfrac{y}{\sqrt{x^2 + y^2}} \\ A_y = A_\rho \dfrac{y}{\sqrt{x^2 + y^2}} + A_\phi \dfrac{x}{\sqrt{x^2 + y^2}} \\ A_z = A_z \end{cases}$$

Rectangular to Spherical

Variable change
$$\begin{cases} x = r \sin \theta \cos \phi \\ y = r \sin \theta \sin \phi \\ z = r \cos \theta \end{cases}$$

Component change
$$\begin{cases} A_r = A_x \sin \theta \cos \phi + A_y \sin \theta \sin \phi + A_z \cos \theta \\ A_\theta = A_x \cos \theta \cos \phi + A_y \cos \theta \sin \phi - A_z \sin \theta \\ A_\phi = -A_x \sin \phi + A_y \cos \phi \end{cases}$$

Spherical to Rectangular

Variable change
$$\begin{cases} r = \sqrt{x^2 + y^2 + z^2} \\ \theta = \cos^{-1} \dfrac{z}{\sqrt{x^2 + y^2 + z^2}} \begin{cases} \cos \theta = \dfrac{z}{\sqrt{x^2 + y^2 + z^2}} \\ \sin \theta = \dfrac{\sqrt{x^2 + y^2}}{\sqrt{x^2 + y^2 + z^2}} \end{cases} \\ \phi = \tan^{-1}\left(\dfrac{y}{x}\right) \begin{cases} \cos \phi = \dfrac{x}{\sqrt{x^2 + y^2}} \\ \sin \phi = \dfrac{y}{\sqrt{x^2 + y^2}} \end{cases} \end{cases}$$

Component change
$$\begin{cases} A_x = \dfrac{A_r x}{\sqrt{x^2 + y^2 + z^2}} + \dfrac{A_\theta xz}{\sqrt{(x^2 + y^2)(x^2 + y^2 + z^2)}} - \dfrac{A_\phi y}{\sqrt{x^2 + y^2}} \\ A_y = \dfrac{A_r y}{\sqrt{x^2 + y^2 + z^2}} + \dfrac{A_\theta yz}{\sqrt{(x^2 + y^2)(x^2 + y^2 + z^2)}} + \dfrac{A_\phi x}{\sqrt{x^2 + y^2}} \\ A_z = \dfrac{A_r z}{\sqrt{x^2 + y^2 + z^2}} - \dfrac{A_\theta \sqrt{x^2 + y^2}}{\sqrt{x^2 + y^2 + z^2}} \end{cases}$$

Coordinate system

	Displacement	Normal areas	Volume
Cartesian	$d\mathbf{l} = dx\,\mathbf{a}_x + dy\,\mathbf{a}_y + dz\,\mathbf{a}_z$	$d\mathbf{S} = dy\,dz\,\mathbf{a}_x$ $dx\,dz\,\mathbf{a}_y$ $dx\,dy\,\mathbf{a}_z$	$dv = dx\,dy\,dz$
Cylindrical	$d\mathbf{l} = d\rho\,\mathbf{a}_\rho + \rho\,d\phi\,\mathbf{a}_\phi + dz\,\mathbf{a}_z$	$d\mathbf{S} = \rho\,d\phi\,dz\,\mathbf{a}_\rho$ $d\rho\,dz\,\mathbf{a}_\phi$ $\rho\,d\rho\,d\phi\,\mathbf{a}_z$	$dv = \rho\,d\rho\,d\phi\,dz$
Spherical	$d\mathbf{l} = dr\,\mathbf{a}_r + r\,d\theta\,\mathbf{a}_\theta + r\sin\theta\,d\phi\,\mathbf{a}_\phi$	$d\mathbf{S} = r^2\sin\theta\,d\theta\,d\phi\,\mathbf{a}_r$ $r\sin\theta\,dr\,d\phi\,\mathbf{a}_\theta$ $r\,dr\,d\theta\,\mathbf{a}_\phi$	$dv = r^2\sin\theta\,dr\,d\theta\,d\phi$

Constants parameters

Symbol	Name	Value (SI Units)	Notes
ϵ_0	Vacuum permittivity (electric constant)	8.854×10^{-12}~F/m	Used in Coulomb's law, Gauss's law
k_e	Coulomb's constant	8.988×10^{9}~N·m²/C²	$k_e = \frac{1}{4\pi\epsilon_0}$
q	Elementary charge	1.602×10^{-19}~C	Charge of a proton or electron (−)
μ_0	Vacuum permeability (magnetic constant)	$4\pi \times 10^{-7}$~H/m	Appears in Ampère's Law, Biot–Savart Law
μ_r	Relative permeability	Dimensionless	$\mu = \mu_r\mu_0$
c	Speed of light in vacuum	3.00×10^{8}~m/s	$c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$
ω	Angular frequency	$\omega = 2\pi f$	rad/s
f	Frequency	Variable (Hz)	$f = \frac{\omega}{2\pi}$
λ	Wavelength	Variable (m)	$\lambda = \frac{c}{f}$

Electrostatics

- Coulomb's Law: $F = \frac{kQ_1Q_2}{r^2}$
- Electric Field from Point Charge: $E = \frac{F}{q} = \frac{kQ}{r^2}$
- Electric Flux Density: $D = \epsilon E$
- Gauss's Law (Integral Form): $\oint_S D \cdot dS = Q_{enc}$
- Gauss's Law (Differential Form): $\nabla \cdot D = \rho_v$
- Electric Field from Line Charge: $E = \frac{\rho_L}{2\pi\epsilon_0 r}$
- Electric Field from Surface Charge: $E = \frac{\rho_s}{2\epsilon_0}$
- Electric Potential: $V = -\int \mathrm{b}E \cdot dl$
- Electric Field as Gradient of Potential: $E = -\nabla V$
- Poisson's Equation: $\nabla^2 V = -\frac{\rho_v}{\epsilon}$
- Laplace's Equation: $\nabla^2 V = 0$
- Conduction Current Density: $J = \sigma E$
- Normal Component of Electric Flux Density: $D_{n1} - D_{n2} = \rho_s$
- Tangential Component of Electric Field: $E_{t1} = E_{t2}$
- Capacitance (Parallel Plate): $C = \frac{\epsilon A}{d}$
- Energy Stored in Capacitor: $W = \frac{1}{2}CV^2$
- Resistance: $R = \frac{V}{I}$
- Resistivity Relation: $R = \frac{\rho l}{A}$
- Electric Field in Conductor: $E = \frac{J}{\sigma}$

Magnetostatics

- Biot–Savart Law: $dH = \frac{Idl \times \hat{a}}{4\pi R^2}$
- Magnetic Field (Straight Conductor): $H = \frac{I}{2\pi R}$
- Magnetic Flux Density: $B = \mu H$
- Ampère's Law (Integral): $\oint \mathrm{b}H \cdot dl = I_{enc}$
- Ampère's Law (Differential): $\nabla \times H = J$
- Field Inside Conductor: $H = \frac{Ir}{2\pi a^2}$
- Field Outside Conductor: $H = \frac{I}{2\pi r}$
- Field in Solenoid: $B = \mu_0 nI$
- Lorentz Force: $F = Q(E + v \times B)$
- Force on Conductor: $F = I \int dl \times B$
- Torque on Loop: $T = IBA \sin\theta$
- Magnetic Dipole Moment: $m = IA$
- Torque on Dipole: $T = m \times B$
- Normal Boundary Condition: $B_{1n} = B_{2n}$
- Tangential Condition: $H_{1t} = H_{2t}$
- Magnetic Snell's Law: $\frac{\tan\theta_1}{\tan\theta_2} = \frac{\mu_1}{\mu_2}$
- Self-Inductance: $L = \frac{N^2\mu A}{l}$
- Mutual Inductance: $M = k\sqrt{L_1L_2}$
- Inductor Energy: $W = \frac{1}{2}LI^2$
- Induced EMF: $V = L\frac{dI}{dt}$

Electromagnetics (Time-Varying Fields)

- Faraday's Law (Integral): $\nu = -\frac{d\Phi}{dt}$
- Faraday's Law (Differential): $\nabla \times E = -\frac{\partial B}{\partial t}$
- Magnetic Flux: $\Phi = \int_S B \cdot dS$
- Transformer EMF: $V_{emf} = \oint_L \vec{E} \cdot d\vec{l} = -\int_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S}$
- Motional EMF: $V_{emf} = \oint_L E_m \cdot d\vec{l} = \oint_L (\vec{u} \times \vec{B}) \cdot d\vec{l}$
- Combination of both transformer and motional emf:

$$V_{emf} = \oint_L \vec{E} \cdot d\vec{l} = -\int_S \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S} + \oint_L (\vec{u} \times \vec{B}) \cdot d\vec{l}$$

- Displacement Current: $I_d = \epsilon_0 \frac{dE}{dt}$
- Ampère-Maxwell Law: $\nabla \times H = J + \frac{\partial D}{\partial t}$
- Gauss's Law (Electric): $\nabla \cdot D = \rho_v$
- Gauss's Law (Magnetic): $\nabla \cdot B = 0$

Maxwell Equations

Differential form	Integral form
$\nabla \cdot \boldsymbol{D} = \rho_v$	$\oint_S \boldsymbol{D} \cdot d\boldsymbol{S} = \int_V \rho_v \, dV$
$\nabla \cdot \boldsymbol{B} = 0$	$\oint_S \boldsymbol{B} \cdot d\boldsymbol{S} = 0$
$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$	$\oint_L \boldsymbol{E} \cdot d\boldsymbol{l} = -\frac{\partial}{\partial t} \int_S \boldsymbol{B} \cdot d\boldsymbol{S}$
$\nabla \times \boldsymbol{H} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t}$	$\oint_L \boldsymbol{H} \cdot d\boldsymbol{l} = \int_S \left(\boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t}\right) \cdot d\boldsymbol{S}$

Transmission Line Theory

- Telegrapher's Equations: $-\frac{\partial v}{\partial z} = R'i + L'\frac{\partial i}{\partial t}$, $-\frac{\partial i}{\partial z} = G'v + C'\frac{\partial v}{\partial t}$
- Propagation Constant: $\gamma = \alpha + j\beta = \sqrt{(R' + j\omega L')(G' + j\omega C')}$
- Voltage Wave Equation: $\frac{\partial^2 V}{\partial z^2} = \gamma^2 V$
- Characteristic Impedance (General): $Z_0 = \sqrt{\frac{R' + j\omega L'}{G' + j\omega C'}}$
- Characteristic Impedance (Lossless): $Z_0 = \sqrt{\frac{L'}{C'}}$
- Voltage Reflection Coefficient: $\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$
- Standing Wave Ratio: $SWR = \frac{1+|\Gamma|}{1-|\Gamma|}$
- Input Impedance: $Z_{in}(l) = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$
- Quarter-Wave Matching: $Z_0 = \sqrt{Z_S Z_L}$

Symbols and Units

E: Electric field intensity (V/m) D: Electric flux density (C/m²) B: Magnetic flux density (T) H: Magnetic field intensity (A/m) v, U: Velocity of conductor (m/s) v: Induced voltage/emf (V) Φ: Magnetic flux (Wb) R: Resistance (Ω) σ: Electrical conductivity (S/m) ϵ: Permittivity (F/m), $\epsilon = \epsilon_0 \epsilon_r$ ω: Angular frequency (rad/s), $\omega = 2\pi f$ A: Area (m²) i: Current (A) f: Frequency (Hz)	μ: Permeability (H/m) t: Time (s) Z_0: Characteristic impedance (Ω) Γ: Reflection coefficient SWR: Standing wave ratio α: Attenuation constant (Np/m) β: Phase constant (rad/m) γ: Propagation constant L', C': Inductance and capacitance per unit length (H/m, F/m) R', G': Resistance and conductance per unit length (Ω/m, S/m) λ: Wavelength (m)