Seat
Number

King Mongkut's University of Technology Thonburi
Final Examination
Semester 1 -- Academic Year 2014

Subject: EIE 325 Electromagnetic fields and waves
For: Electronic and Telecommunication Engineering, 3rd Yr (Inter. Program)
Exam Date: Friday November 28, 2014 **Time:** 9.00am-12.00 pm.

Instructions:-

1. This exam consists of 5 problems with a total of 11 pages, including the cover.
2. This exam is closed books.
3. Answer each problem on the exam itself.
4. A calculator compiling with the university rule is allowed.
5. A dictionary is **not** allowed.
6. **Do not** bring any exam papers and answer sheets outside the exam room.
7. Open Minds ... No Cheating! GOOD LUCK!!!

Remarks:-

- **Raise your hand when you finish the exam to ask for a permission to leave the exam room.**
- **Students who fail to follow the exam instruction might eventually result in a failure of the class or may receive the highest punishment with university rules.**
- **Carefully read the entire exam before you start to solve problems. Before jumping into the mathematics, think about what the question is asking. Investing a few minutes of thought may allow you to avoid twenty minutes of needless calculation!**

Exam No.	1	2	3	4	5	TOTAL
Full Score	20	20	20	20	20	100
Graded Score						

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This examination is designed by
Dr. Rardchawadee Silapunt; Tel: 9062.

This examination has been approved by the committees of the ENE department.

(Asst. Prof. Suwat Pattaramalai, Ph.D.)
Acting Head of Electronic and Telecommunication Engineering Department

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Formula sheet

All vector quantities are represented in bold such that $\boldsymbol{E} = \vec{E}$

1. Boundary conditions:

   1.1 Tangential field

$$\boldsymbol{E}_{t1} = \boldsymbol{E}_{t2}$$

   1.2 Normal field

$$\boldsymbol{D}_{n1} - \boldsymbol{D}_{n2} = \rho_s$$

where $\boldsymbol{D}$ = electric flux density = $\varepsilon\boldsymbol{E}$ (C/m^2)

ρ_S= surface charge density (C/m^2)

   1.3 Electric flux density relation $\boldsymbol{D} = \varepsilon_0\boldsymbol{E} + \boldsymbol{P}$

where $\boldsymbol{P}$ = electric polarization vector (C/m^2)

2. Ampère's law

   2.1 Integral form $\oint \boldsymbol{H} \cdot \boldsymbol{dL} = I_{en}$

   2.2 Point form $\nabla \times \boldsymbol{H} = \boldsymbol{J}$

   where $\boldsymbol{J}$ = surface current density (A/m^2)

   2.3 Curl in cylindrical coordinates

$$\nabla \times \boldsymbol{u} = \hat{\boldsymbol{r}}\left(\frac{1}{r}\frac{\partial u_z}{\partial \phi} - \frac{\partial u_\phi}{\partial z}\right) + \hat{\boldsymbol{\phi}}\left(\frac{\partial u_r}{\partial z} - \frac{\partial u_z}{\partial r}\right) + \hat{\boldsymbol{z}}\frac{1}{r}\left[\frac{\partial(r u_\phi)}{\partial r} - \frac{\partial u_r}{\partial \phi}\right].$$

3. Current and current density $\int \boldsymbol{J} \cdot \boldsymbol{dS} = I$

4. Magnetic flux density $\boldsymbol{B} = \mu\boldsymbol{H}$ Tesla

5. Magnetic field intensity of the surface current sheet $\boldsymbol{H} = \frac{1}{2}\boldsymbol{K} \times \hat{a}_n$

where $\boldsymbol{K}$ = current per cross-sectional width (A/m)

$\hat{a}_n$= a unit vector from the current sheet to the observation point

6. Magnetic force from the uniform current sheet $\boldsymbol{F} = K\boldsymbol{S} \times \boldsymbol{B}$

where $\boldsymbol{S}$ = surface area vector (m^2)

7. Motional electromotive force (EMF) $emf = -N\frac{d\phi}{dt} = \oint(\boldsymbol{v} \times \boldsymbol{B}) \cdot \boldsymbol{dl}$ Volt

8. Uniform plane wave

   8.1 The uniform plane wave propagates in *z* direction and the magnetic field has 2 components, the instantaneous magnetic field can be shown as

   $\boldsymbol{H}(x, y, z, t) = (H_{x0}\hat{a}_x + H_{y0}\hat{a}_y)\cos(\omega t - \beta z)$ A/m

   8.2 Electric field intensity $\boldsymbol{E} = -\eta\hat{a}_\rho \times \boldsymbol{H}$ A/m

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where $\hat{a}_\rho$ = the direction of wave propagation

8.3 EM wave properties in lossless media

8.3.1 Phase constant $\beta = \omega\sqrt{\mu\varepsilon}$ rad/m

8.3.2 Attenuation constant $\alpha = 0$ Np/m

8.3.3 Wavelength $\lambda = \frac{2\pi}{\beta}$ m

8.3.4 Wave impedance $\eta = \sqrt{\frac{\mu}{\varepsilon}}\ \Omega$

9. Free space permittivity ε_0 = 8.854x10^{-12} F/m

10.Free space permeability μ_0 = 4πx10^{-7} H/m

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1. Electric boundary conditions: The surface $x = 0$ separates two perfect dielectrics. For $x > 0$, let $\varepsilon_r = \varepsilon_{r1} = 2$, while $\varepsilon_{r2} = 5$ where $x < 0$. If $\boldsymbol{E_1} = 80\hat{a}_x - 50\hat{a}_y - 30\hat{a}_z$ V/m, find

(a) E_{N1} and $\boldsymbol{E_{t1}}$ **(5 pts)**

(b) the angle θ_1 between $\boldsymbol{E_1}$ and a normal to the surface **(5 pts)**

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(c) $\boldsymbol{D}_2$ **(5 pts)**

(d) $\boldsymbol{P}_2$ **(5 pts)**

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2. Magnetic field intensity: Given the field $\boldsymbol{H} = 20\rho^2\hat{\boldsymbol{a}}_\phi$ A/m (20 pts)

(a) Determine the current density vector $\boldsymbol{J}$. (7.5 pts)

(b) Integrate $\boldsymbol{J}$ over the circular surface $\rho \le 1$, $0 < \phi < 2\pi$, $z = 0$, to determine the total current passing through that surface in the $\hat{\boldsymbol{a}}_z$ direction. (5 pts)

(c) Find the total current once more, this time by a line integral around the circular path $\rho = 1$, $0 < \phi < 2\pi$, $z = 0$. (7.5 pts)

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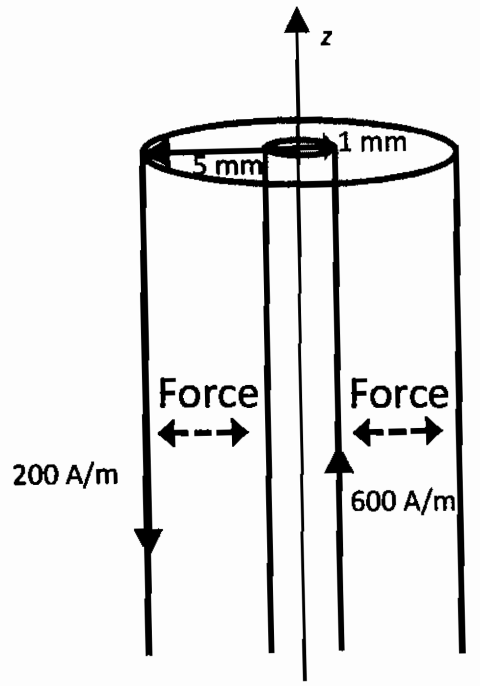
3. Magnetic force: A current of $-200\hat{a}_z$ A/m flows on the conducting cylinder ρ = 5 mm, and $+600\hat{a}_z$ A/m is present on the conducting cylinder ρ = 1 mm. Find the magnitude of the total force per meter length that is acting to split the outer cylinder apart along its length. (20 pts)



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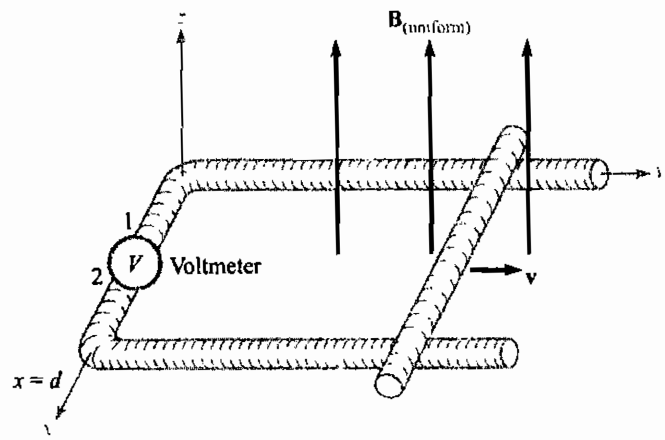
4. Electromotive force: With reference to the sliding bar shown, let d = 7 cm, $\boldsymbol{B} = 0.3\hat{\boldsymbol{a}}_z$ T, and $\boldsymbol{v} = 0.1e^{20y}\hat{\boldsymbol{a}}_y$ m/s. Let $y = 0$ at $t = 0$. Find (20 pts)



(a) v at $t = 0$ (5 pts)

(b) y at $t = 0.1$ (5 pts)

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(c) v at t = 0.1 (5 pts)

(d) the emf V_{12} at t = 0.1 (5 pts)

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5. Uniform plane wave (UPW): The phasor magnetic field intensity for a 400 MHz uniform plane wave propagating in a certain lossless material is $\boldsymbol{H}^s = \left(1\hat{a}_y - 5\hat{a}_z\right)e^{-j20x}$ A/m. Knowing that the maximum amplitude of $\boldsymbol{E}$ is 1,000 V/m, find

(a) β (4 pts)

(b) η (4 pts)

(c) ε_r (4 pts)

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(d) μ_r (4 pts)

(e) $\boldsymbol{H}(x, y, z, t)$ (4 pts)