Seat Number

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

Subject: EIE 325 Electromagnetic fields and waves

For: Electronic and Telecommunication Engineering, 3rd Yr (Inter. Program)

Exam Date: Wednesday September 24, 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
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This examination has been approved by the committees of the ENE department.

R. Silapunt

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Formula sheet

1. Cartesian coordinates are (x, y, z)
2. Cylindrical coordinates are (ρ, ϕ, Z)
3. Spherical coordinates are (r, θ, ϕ)
4. Conversion table: Cartesian coordinates vs. cylindrical coordinates

4.1 Magnitude conversion

P (x, y, z) to P (r, θ, ϕ)	P (r, θ, ϕ) to P (x, y, z)
$\rho = \sqrt{x^2 + y^2}$ $\phi = \tan^{-1}\left(\frac{y}{x}\right)$ $z = z$	$x = \rho\cos\phi$ $y = \rho\sin\phi$ $z = z$

4.2 Component conversion

	$\hat{a}_\rho$	$\hat{a}_\phi$	$\hat{a}_z$
$\hat{a}_x \bullet$	$\cos\phi$	$-\sin\phi$	0
$\hat{a}_y \bullet$	$\sin\phi$	$\cos\phi$	0
$\hat{a}_z \bullet$	0	0	1

5. A unit vector $\hat{a}_R = \frac{R}{\vec{R}}$

6. Electric field intensity is defined as $\vec{E} = \frac{\vec{F}}{Q}$ V/m

where $\vec{F}$ = force acting on the charge Q (Newton)

7. Electric field intensity produced by

7.1 a point charge $\vec{E} = \frac{Q}{4\pi\varepsilon_0 R^2}\hat{a}_r$ V/m (spherical coordinates)

7.2 an infinite line charge $\vec{E} = \frac{\rho_L}{2\pi\varepsilon_0 \rho}\hat{a}_\rho$ V/m (cylindrical coordinates)

where ρ_L = line charge density (C/m)

ρ = radial distance from the line charge (m)

$\hat{a}_\rho$ = unit vector in the radial direction

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8. Gauss's law

   8.1 Integral form $\Psi = \oint \vec{E} \cdot d\vec{S} = \frac{q_{en}}{\varepsilon_0}$ V•m,

   where Ψ = electric flux (V•m) or

   8.2 Integral form $\oint \vec{D} \cdot d\vec{S} = q_{en}$ Coulomb,

   where the electric flux density $\vec{D} = \varepsilon_0 \vec{E}$ C/m^2

   8.3 Point form $\nabla \cdot \vec{D} = \rho_v$ C/m^3

   Divergence in Spherical coordinates:

$$\nabla \cdot \vec{D} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 D_r\right) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\left(D_\theta \sin\theta\right) + \frac{1}{r\sin\theta}\frac{\partial D_\phi}{\partial\phi}$$

9. Total charge on the surface: $Q = \iint \rho_s dS$ Coulomb,

where ρ_s = surface charge density (C/m^2)

dS = surface differential element (m^3) = $r^2 \sin\theta d\theta d\phi$ for spherical coordinates

10. Absolute potential $V = \frac{Q}{4\pi\varepsilon_0 r}$ Volt,

where r = distance between the point charge and the observation point (m)

11. Potential difference between point *A* (destination) and point *B* (starting point)

$$V_{AB} = -\int_B^A \vec{E} \cdot d\vec{L} \quad \text{Volt,}$$

where $d\vec{L}$ = line differential element

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

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1. Electrostatics Concept: (20 pt)

(a) Two point charges Q_1 = 10 nC and Q_2 = 100 nC are located 100 nm apart, is the force acting on Q_2 equal to that acting on Q_1? Explain. (5 pts)

(b) Which factors can change the magnitude of electric flux moving through an area,? (5 pt)

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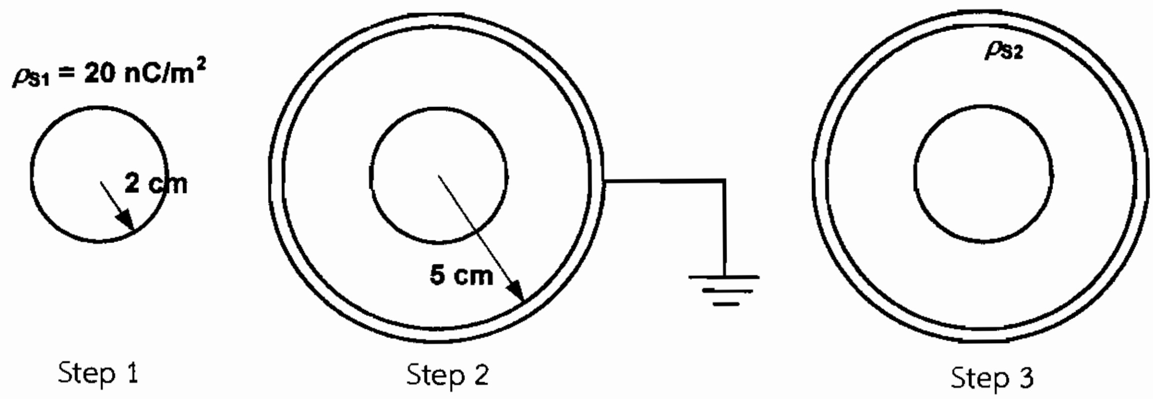
(c) The Faraday's experiment of displacement flux is illustrated below. Draw electric field lines appeared on each step. (5 pt)



(d) Explain the differences between convection current and conduction current. (5 pts)

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2. Coordinate systems: Convert $\vec{D} = \dfrac{(x\hat{a}_x - 2y\hat{a}_y)}{(x^2 + y^2)}$ to the vector in cylindrical coordinates. (20 pts)

(a) Show the answer in terms of cylindrical coordinates variables (10 pts)

(b) Find $\vec{D}$ at the point in cylindrical coordinates of $\boldsymbol{\rho} = 1$, $\boldsymbol{\varphi} = 0.3\boldsymbol{\pi}$, and $z = 5$. Also provide the answer in Cartesian coordinates. (10 pts)

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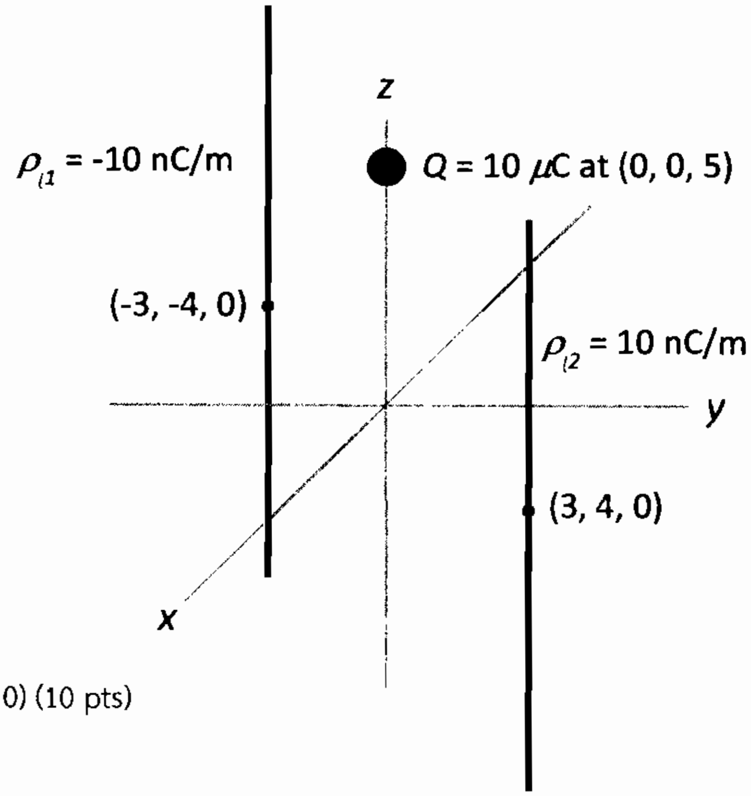
3. Gauss's law: The figure below shows 2 infinite line charges directed along the z axis and a point charge. The first line charge is located x = -3 m, y = -4 m with ρ_{l1} = 10 nC/m. The second line charge is located at x = 3 m, y = 4 m with equal density of ρ_{l2} = 10 nC/m. The point charge is 10 nC and located at point (0, 0, 5). Determine the total electric field vector at (20 pts)



(a) point (0, 0, 0) (10 pts)

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(b) point (0, 0, -5) (5 pts)

(c) point (0, 0, 10) (5 pts)

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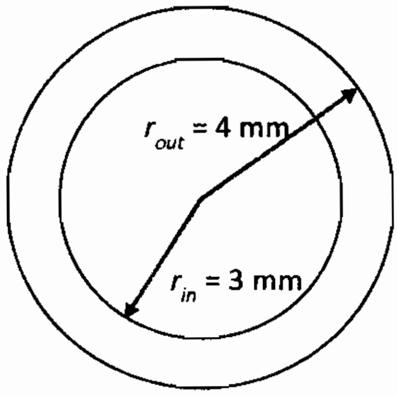
4. Gauss's law and Divergence: The **hollow** sphere has an inner radius (r_{in}) of 3 mm and outer radius (r_{out}) of 4 mm. The electric flux density is $\vec{D} = 5r^2\hat{a}_r$ C/m^2, determine (20 pts)



(a) volume charge density ρ_v at r = 4 mm (5 pts)

(b) magnitudes of electric flux density D and electric field intensity E at r = 4 mm (5 pts)

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(c) radial electric flux Ψ at r = 4 mm (5 pts)

(d) electric charge inside this sphere at r = 4 mm (5 pts)

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5. Work and electric potential: A uniform surface charge density ρ_s = 10 nC/m^2 is present on the spherical surface r = 0.5 cm in free space. (20 pts)

(a) Fine the absolute potential at P (r = 1 cm, θ = 25°, φ = 50°). (10 pts)

(b) Fine the potential difference V_{AB} given points A(r = 1 cm, θ = 45°, φ = 60°) and B(r = 3 cm, θ = 30°, φ = 90°). (10 pts)