November 2, 2004

University of Saskatchewan
Department of Electrical Engineering

EE301 Electricity, Magnetism and Fields
Midterm Examination
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Welcome to the EE301 Midterm. This is a closed book and closed notes examination. A formulae sheet is attached. You may use a calculator. The examination lasts **2** hours.

Each problem is worth 25 points; if subparts are weighted differently, the points for each are shown in parentheses. Show your work; credit will be given only if the steps leading to the answer are **clearly** shown. If a symmetry argument is used, it is sufficient to write "By symmetry we know that...". Partial credit will be given for partially correct answers. Be reasonably neat; credit will not be given for illegible answers.

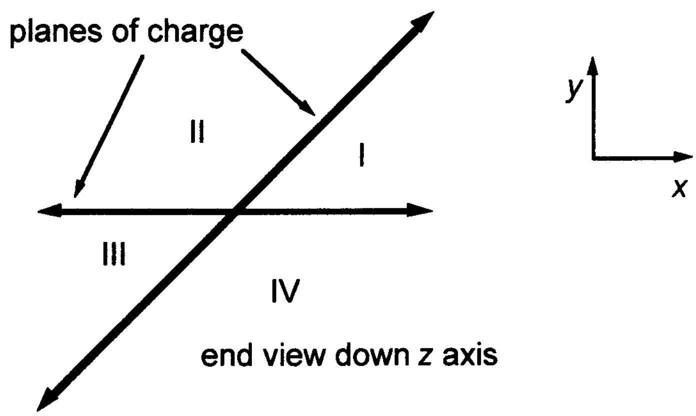
You are to answer **4** of the 6 problems as follows: answer any three of problems 1 to 4 and also either problem 5 or problem 6. Do not solve more than four problems or severe penalties will apply.

None of the problems require intricate mathematical manipulations. Cartesian coordinate triples are always (x, y, z).

Answer any three of problems 1 to 4 and answer either problem 5 or problem 6.

Problem 1

Two infinite planes of charge intersect at 45° as shown. Each plane has a uniform surface charge density of +10 nC/m2. Determine the electric field in each of the four regions I, II, III, IV. Use the coordinate system shown in the figure.



Problem 2

A charge of 10 nC is at (1, 0, 0) and charges of −10 nC are at (0, 1, 0) and (0, 0, 1). Determine the electric field vector and the electric potential at the point (1, 1, 1). (Cartesian coordinates, distances in meters)

Problem 3

a) (8 pts) A charge distribution expressed in cylindrical coordinates depends only on the variable ρ. What does symmetry imply about the electric field $\vec{E}(\rho,\varphi,z)$ produced by this charge?

b) (17 pts) Within a cylindrical region, the charge density is given by

$$\rho_V = \frac{2Q}{\pi a^2}\left(1-\frac{\rho^2}{a^2}\right) \text{ for } \rho < a.$$

$\rho_V = 0$ outside this region. Use Gauss's Law to calculate the electric field both inside and outside the charge.

Problem 4

Two concentric, spherical shells of metal form a capacitor. The inner shell has radius r_1 and the outer shell has radius r_2. A dielectric with dielectric constant ε_R fills the space between the two shells.

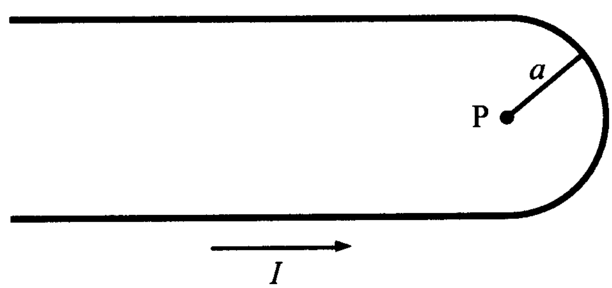
a) (9 pts) The inner shell has charge Q and the outer shell has charge $-Q$. What is the surface charge density on each shell? What is the electric field inside the inner shell, between the two shells, and outside the shells?

b) (16 pts) Determine the formula for the capacitance. How does the capacitance of the spherical capacitor relate to that of the parallel plate capacitor when the separation between the shells is small compared to the radius, $r_2 - r_1 << r_1$?

Problem 5

The middle of an infinitely long wire is bent in a half circle as shown; the radius of the bend is a. A current I flows in the wire. Calculate the magnetic field vector at the center of the bend P.

You might be interested to know that $\int_0^\infty \frac{dx}{(a^2+x^2)^{3/2}} = \frac{1}{a^2}$ although if you are clever you won't need it.



Problem 6

A triaxial cable consists of three concentric, hollow, cylindrical conductors of radii r_1, r_2, and r_3. A current of $I/2$ flows through the inner and outer conductor and a current of $-I$ (i.e. in the opposite direction) flows through the center conductor. Use Ampere's Law to calculate the magnetic field everywhere.