National Exams December 2003

98-Elec-A7

Electromagnetics

3 Hours' Duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Candidates may use one of two calculators, the Casio or Sharp approved models. This is a closed book exam.

3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

5. Aids: $\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$, $\mu_0 = 4\pi \times 10^{-7}\ H/m$

1. A capacitor consists of a circular cross-section metallic rod of 1mm radius and a coaxial hollow metallic cylinder of 3mm radius of the inner surface. The length of the capacitor is 20cm. The space between the rod and the cylinder is filled by a dielectric of 2.5 relative permittivity and 10^7 V/m breakdown strength.

   What is the upper limit on electric energy that can be stored in the capacitor?

   Disregard the effects of fringing fields at the ends of the coaxial system.

2. The iron core of an electromagnet is a torus (doughnut shape body) of circular cross-section of 1cm diameter and circular centerline of 10cm diameter. The relative permeability of the core material is 100. The magnet is excited by 100 turns of DC current wound around the core. A 1mm air gap is cut in the core, perpendicular to the axis.

   What is the current required to produce a field of 0.2 tesla in the gap?

   In your calculations assume that the magnetic field is distributed uniformly in the cross-section of the core, and neglect the effects of fringing fields in the gap.

3. The EMF of a 377 ohm generator is a single pulse of 1μs duration. The generator drives an infinite, 3×10^8 m/s, 377 ohm transmission line. Connected across the line, 1km away from the generator is a 754 ohm resistor. Another 754 ohm resistor is connected across the line 150m further away. The energy of the pulse launched on the line is 1 joule.

   (i) Plot as a function of time voltages appearing across the generator terminals.

   (ii) The answer to the above question contains a simplistic illustration of some features of radar systems. Comment very briefly on these features.

4. A 50 ohm generator drives a section of a 50 ohm, 2×10^8 m/s transmission line terminated in a parallel combination of a 50 ohm resistor and two short-circuited sections of the same type of transmission line. The EMF of the generator is a superposition of 100 MHz and 400 MHz signals.

   What are the shortest lengths of the two short-circuited sections required to optimize the 400 MHz power delivered to the 50 ohm resistor, and prevent 300 MHz power from reaching the resistor?

   Aid: for short-circuited section $Z_{in} = jZ_0 \tan\beta d$.

5. Two sides of a square shaped open-circuited loop are horizontal, the other two sides are vertical. The number of turns in the loop is 10. The loop rotates slowly about its vertical axis in a 1 MHz magnetic field of 10^{-9} tesla RMS. The direction of the magnetic field is NE-SW.

   (i) What are the largest and the smallest RMS values of EMF induced in the loop and,

   (ii) At what orientations of the loop do they occur?

6. A signal propagates in a rectangular, 3m ×2.5m tunnel with metallic walls.

   (i) What is the range of signal frequencies for which only one wave will propagate in the tunnel and,

   (ii) What is the phase velocity of the signal at the centre of the above frequency range?

7. Two vertical current elements located at the same point on a horizontal conducting ground plane radiate 5 MHz and 10 MHz signals. 5 km away on the ground plane the electric field of the 10 MHz signal is 10 μ V/m RMS. The vertical component of the 5 MHz signal, 2.89 km above the 5 km point is 2.3 μV/m. The length of the 5 MHz current element is one half of that of the 10 MHz one.

   What is the ratio of the 5 MHz and 10 MHz currents?

8. The time averaged power density of a 30 MHz plane wave propagating 60° east of north in a horizontal direction is 0.265 p W/m^2. The wave is linearly polarized (electric field) in the vertical direction. At a point A in space and instant of time t_o the instantaneous value of electric field is 10 μ V/m RMS, pointing up.

   What is the RMS value and direction of magnetic flux density vector at a point 5m north of point A and 25ns after time t_o?