NATIONAL EXAMS, DECEMBER 2011

07-ElecA7, 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 current loop consists of two semicircles of 10 cm radius. One of the semicircles lies in a vertical plane, the other in a horizontal plane. The two semicircles are joined on the line of intersection of the two planes. A 2A current circulates in the loop. Viewed from above the current circulates clockwise.

   What is the magnitude and direction of the magnetic flux density vector B at the common center of the two semicircles?

2. The strength of a DC magnetic field is 10^{-5} teslas. The field points 30° down from north and is monitored by a circular loop of 5 cm radius lying in vertical plane, having 10 turns, and rotating at 3600 RPM about its vertical diameter.

   What is the RMS value of EMF induced in the loop?

3. Plate area of a parallel plate capacitor is 4 cm^2. The gap between the plates is 1 mm wide. One of the plates is coated by 0.9 mm thick layer of dielectric of relative permittivity 100, leaving an air gap of 0.1 mm width.

   Determine the values of electrostatic energies in the dielectric layer and the air gap at 5 volts potential between the plates. Comment on the results.

4. A transmission line consists of two metallic ribbons 1 cm wide separated by a 0.5 mm wide gap filled with dielectric of relative permittivity 2.5.

   Calculate the characteristic impedance and propagation velocity of the line. Disregard the effects of fringing fields.

5. A 10 GHz (10^{10} Hz) plane wave propagates in free space 30° east of north and 60° up. The electric field of the wave is polarized in the vertical plane and the power density of the wave is 0.5 W/m^2. The magnetic field of the wave is monitored by a circular loop of 2 mm diameter lying in the vertical plane and slowly rotating about its vertical diameter.

   For what orientation of the plane of the loop will the amplitude of induced EMF be maximum, and what will be the RMS value of the maximum?

6. The EMF of a generator is a step function of 12 V amplitude. The generator internal resistance is 50 ohms and its load is an infinitely long transmission line of 50 ohm characteristic impedance and 2×10^8 m/s propagation velocity. A 50 ohm resistor is connected across the line 1 km away from the generator terminals.

   What are:

   (i) initial voltage and current at generator terminals;

   (ii) steady state voltage and current at generator terminals and,

   (iii) time at which the steady state has been established?

7. A short-circuited section 20 cm long of a 50 ohm, 3×10^8 m/s transmission line acts as a series and parallel resonant circuits at a set of frequencies.

   What are the lowest frequencies for the series and parallel resonances?

8. A short vertical current element radiates a CW signal at constant frequency. The element is located 1 km above a conducting ground plane. Both the length of the element and the wavelength of the radiated signal are much shorter than 1 km. The maximum power density of the signal if radiated into free space (i.e. no ground plane) is 2 W/m^2.

   What is the magnitude and direction of the power density vector on the ground plane 1.73 km horizontally away due east from the point directly below the radiating element?

   Aids: (i) method of images,

   (ii) $H = lI\ k\ sin\theta\ exp\ (-jkr)/(4\pi r)$.