NATIONAL EXAMS, DECEMBER 2009

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. The EMF of a generator of 50 ohm internal impedance is a train of pulses of 50 kHz pulse repetition frequency, 10 volts amplitude and 0.5μs pulse width. The generator drives a load consisting of an infinite transmission line of 3×10^8 *m/s* propagation velocity and 50 ohm characteristic impedance. A 100 ohm resistor is connected across the line 300 m away from the generator terminals.

   What is the shape as an function of time of the generator terminal voltage at steady state?

2. The internal impedance of a sinusoidal generator is 50 ohms. The generator drives a 25 cm long section of a transmission line of 50 ohm characteristic impedance and 3×10^8 *m/s* propagation velocity. The section is terminated in a parallel combination of a 50 ohm resistor and a 25 cm long open circuited section of a 50 ohm, 3×10^8 *m/s* transmission line. The generator EMF is one volt RMS.

   Calculate the generator current at

   (i.) 300 MHz and ,

   (ii.)600 Mhz.

   Aid: $Z(s)Z(s \pm \frac{\lambda}{4}) = Z_0^2$

3. Four short vertical current elements are located on a conducting ground plane each in four corners of a horizontal square of 4 km side. Frequencies, amplitudes and phases of four currents in the elements are same. Power densities of individual elements at the centre of the square are $5 \times 10^{-8}\ W/m^2$ at 10 MHz frequency.

   What is the direction and RMS amplitude of electric field intensity vector at a point 1.65 km above the centre of the square at 5 MHz frequency, all other system parameters remaining unchanged.

4. Two 10^9 Hz plane waves propagate in free space in horizontal directions, one 30^0 west of north, the other 30^0 east of north. Both waves are linearly polarized in vertical direction. Power density of each wave is $10^{-6}\ W/m^2$.

At a point in space the amplitude of total electric field (super position of electric fields of the two waves) is zero.

What is the RMS amplitude and direction of the total magnetic field intensity vector at the point considered?

5. The three components of a 10^{10} Hz magnetic field intensity vector $\vec{H} = (H_x, H_y, H_z)$ are:

$$H_x = H_0 \sin(\pi \frac{x}{a}) \cos(wt - kz),$$

$$Hy = 0$$

$$Hz = H_0 \cos(\pi \frac{x}{a}) \sin(wt - kz)$$

with $!H_0 = 5\frac{A}{m}, a = 2.5cm, k = \frac{2\pi}{d}, d = 3.75cm$

What is the RMS amplitude of electric field intensity vector at $x = 1.25cm$?

Aid: curl $(Ax, Ay, Az) = (\frac{\partial Az}{\partial y} - \frac{\partial Ay}{\partial z}, \frac{\partial Ax}{\partial z} - \frac{\partial Az}{\partial x}, \frac{\partial Ay}{\partial x} - \frac{\partial Ax}{\partial y})$.

6. An infinite transmission line consists of two vanishingly thin metallic strips 10 mm wide separated by 0.1 mm thick layer of dielectric of relative permittivity 2.25. A 10^9 Hz signal propagates along the line. The signal power is 1W.

   Disregarding fringe effects determine the RMS amplitudes and directions of electric and magnetic field intensity vectors of the electromagnetic field in the line.

7. A spatially uniform magnetic field is confined inside an infinitely long circular cylinder. The axis of the cylinder is the z-axis of an (r, φ, z) cylindrical coordinate system. The magnetic flux density vector $\vec{B}$ is $\vec{B} = (B_r, B_\varphi, B_z) = (0, 0, B_o e^{-t/\tau})$

   with

   $B_0 = -0.1$ teslas and $\tau = 10^{-2}$ seconds

   What is the induced electric field at $t = 5x10^{-3}$ seconds and r=3cm?

   Specify magnitude and direction of the field.

8. A capacitor consists of a two circular, parallel metallic plates and of 100 cm^2 area separated by a 1 mm wide gap. A 0.9 mm layer of teflon fills part of the gap while the remaining 0.1 mm is air. The relative permittivity and breakdown electric field of teflon is 2.5 and $10^7\ V/m$ respectively. What is the upper limit on electric energy that can be stored in the capacitor for breakdown field of air at 10^6 V / m?