NATIONAL EXAMS, DECEMBER 2008

98-Phys-A3 , 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: $\varepsilon_0 = 8.85\times10^{-12}\,F/m,\quad \mu_0 = 4\pi\times10^{-7}\,H/m$

$$curl\,\vec{A} = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}, \frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}, \frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right)$$

1. A parallel plate capacitor consists of two parallel circular metallic plates of 50 mm radius separated by a 2 mm wide gap. The gap is filled with dielectric the relative permittivity of which varies with distance x from one of the plates. The values of the relative permittivity ε_r are given by the relation $\varepsilon_r = 2(1 + x/a)$ with $a = 2$ mm.

   Determine the value of total electric energy stored in the capacitor if the electric potential between the plates is 5 volts. Disregard the effect of fringing fields.

2. A charged particle is moving north in a horizontal direction at 3×10^7 m/s velocity in a uniform electric field of 10^6 volts/meter pointing down and in an unknown magnetic field. Determine the direction and magnitudes of two possible magnetic density vectors $\vec{B}$ such that the particle can maintain constant motion.

3. The spatial distribution of a vertical magnetic filed B in horizontal *(x, y)* plane is $B = B_o(\cos xk_x)(\cos yk_y)\cos \omega t$ with $k_x = 2\pi/20cm$, $k_y = 2\pi/15cm$, $\omega = 2\pi$ x 2.5 x 10^9 Hz and $B_o = 10^{-8}$ teslas RMS. Calculate the RMS value of the loop integral of associated electric field intensity vector $\vec{E}$ evaluated along the sides of a rectangle the four vertices of which in *(x, y)* plane are (0, 0) cm, (5, 0) cm (5, 3.75) cm and (0, 3.75) cm.

4. A 1 GHz (10^9 Hz) plane wave propagates 30° east of north at an unknown elevation angle. The wave is linearly polarized (electric field) in a horizontal direction and its average power density is 10 W/m^2. What are the RMS value and direction of the magnetic flux density vector $\vec{B}$?

5. A generator of internal impedance of 400 ohms drives an infinite transmission line of 400 ohm characteristic impedance and 3 x 10^8 m/s propagation velocity. The EMF of the generator is a series of $2\mu s$ pulses of 200 volt amplitude and 10 kHz pulse repetition rate. A 400 ohm resistor is connected across the line 20 km away from the generator.
   (i) Plot the steady state pattern of generator terminal voltage.
   (ii) What are the energies in individual outgoing and returning pulses?

6. A 5 cm long section of rectangular waveguide of inside dimensions 10 mm x 4 mm is filled with dielectric of relative permittivity 3. One end of the section is blocked by metallic plate completely

covering it. The section is driven by a 10 GHz (10^{10} Hz) source. What are the locations of waveguide cross-sections in which the electric filed is zero?

7. A 10 MHz and a 25 MHz vertical current elements are located at the same point on a conducting ground plane. The length of the 10 MHz element is 1 m, that of 25 MHz is 40 cm. The current amplitude of the 25 MHz element is four times that of its companion. The RMS amplitude of 10 MHz electric field on the ground plane 5 km away from the radiators is 4 millivolts/meter. A 25 MHz receiver is carried in an aircraft flying at 2 km above the ground plane. What is the horizontal distance of the aircraft from the radiators at which the RMS amplitude of the 25 MHz electric field will also be 4 millivolts/meter?

8. Spatial distribution of a 1000 MHz magnetic field intensity vector independent of z-coordinate and possessing zero z-component is $H_x = H_0 \cos kx \sin ky$, $H_y = -H_0 \sin kx \cos ky$ with $k = (\pi\sqrt{2}/30) cm^{-1}$ and $H_0 =$ 50 milliamperes/meter RMS. Determine the direction and RMS amplitude of the associated electric field at origin $(x = 0, y = 0)$.