NATIONAL EXAMS, MAY 2010

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

1. Electric charge density in an infinite positive, horizontal flat charge layer of 2μ thickness is $25C/m^3$. An infinite, parallel, negative surface charge layer of surface charge density – $3x10^{-5}$ C/m^2 is located 1μ above the positive charge layer. Another negative, parallel, infinite surface charge layer is located 2μ below the positive layer. Total charge of the system is zero and relative permittivity of the medium, charged and neutral is 10.

   Sketch the pattern of electric field in the system and calculate the potential of the upper negative layer with respect to the lower negative layer.

2. Radii of inner and outer conductors of a coaxial line are 2.5mm and 5mm respectively. Inner conductor is covered by a 2mm thick layer of dielectric of relative permittivity 2.5. The remaining space is air. Breakdown field of the dielective is 10^7V/m, that of air is 10^6V/m.

   What is the upper limit on electric energy that can be stored in a 1m long section of the line?

3. A 2A current loop located in a vertical east-west plane consists of a 25cm radius semicircle and its own horizontal diameter. Looking north through the loop the current circulates clockwise.

   Calculate horizontal component of magnetic field generated by the current loop at a point 25cm horizontally north of the centre of the loop.

4. EMF of a generator of internal impedance of 377 ohms is a single pulse of constant amplitude. The generator drives an infinite transmission line of 377 ohms characteristic impedance and $3x10^8$ m/s propagation velocity. Energy contained in outgoing pulse is 0.2 joules. 10km from generator terminals a 377 ohms resistance is connected across the transmission line.

   What are

   (i) the upper limit on the pulse length if the return and outgoing pulses are not to overlap at the generator terminals and,

   (ii) energy content of the return pulse?

5. Internal impedances of two 100Mhz generators are 50ohms, amplitudes and phases of the EMFs of the two generators are identical. The generators are connected to opposite ends of a 20m long section of a transmission line of 50 ohm characteristic impedance and $2x10^8$ m/s propagation velocity. A standing wave pattern is set up by signals of the two generators.

If the phase of EMF of one of the generators is delayed by 90°, by what distance and in what direction will the new standing wave pattern shift from its original shape?

6. Direction of propagation of a 300 MHz horizontally polarized (electric field) plane wave is north-east and 30° up. Power density in the wave is 2 W/m^2. Magnetic field of the wave is monitored by a horizontal loop of 5 cm^2 area.

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

7. Electric field intensity $\overline{E}$ in an electromagnetic field of 10^{10}Hz frequency possesses only the z-component $E_z = 2E_o \cos[wt - k(x-y)/2]\sin[k(x-y/2]$, with E_o=2μV/m RMS and k=(2π/3)cm^{-1}.

   What is the RMS amplitude of the associated magnetic field at a point x=0 and y=0?

   Assistance: Curl (X,Y.Z) $= (\frac{\partial Z}{\partial y} - \frac{\partial Y}{\partial z}, \frac{\partial X}{\partial z} - \frac{\partial Z}{\partial x}, \frac{\partial Y}{\partial x} - \frac{\partial X}{\partial y})$

8. A 1m long vertical current element radiates a 10MHz signal into free space. At a point at which power density of the signal on a 1km radius sphere centered on the current element is maximum the field intensity of the signal is 20 μV/m RMS.

   What would be the vertical component of electric field intensity at a point 1km above the maximum power density point specified above if the frequency of the current element were reduced to 5MHz, with the amplitude of the current remaining constant?