NATIONAL EXAMS, MAY 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. A beam of electrons propagating in horizontal north direction in a vacuum carries a current of 10 microampers. The velocity of the electrons in the beam is $6x10^5 \frac{m}{s}$, the cross-section of the beam is circular with 1 mm diameter and the density of the electrons is uniform both radially and longitudinally.
What is the direction and magnitude of force exerted on an electron $(e = -1.6x10^{-19}C)$ *at a point 0.25 mm above the axis of the beam?*

2. An infinitely long transmission line consists of two thin parallel, horizontal metallic ribbons 10 mm wide separated by a 0.20 mm wide gap. The line is oriented in an east-west horizontal direction and carries a 2 ampere current. The current in the top ribbon flows east, the return current floes in the bottom ribbon.
Calculate, disregarding the effects of fringe fields:
   (i) magnitude and direction of magnetic flux density vector and,
   (ii) magnitude of magnetic flux of a 1 cm long section of the line.

3. Characteristic impedance and propagation velocity of a transmission line are 50 ohms and $3x10^8 \frac{m}{s}$ respectively. A section of the line driven by a sinusoidal generator is terminated in an impedance consisting of a series connection of a resistance and reactance. In a standing wave produced the distance between adjacent voltage minima is 1.0 m. When a 25 cm long short-circuited section of the line is connected across the line 50 cm away from the load, the standing wave ratio reduces to one (i.e. no standing wave).
What was the original load impedance?
Aid: $Z(s)Z(s \pm \frac{\lambda}{4}) = Z_0^2$

4. Two infinite, parallel plates of charge are 1 micron thick each and are separated by a neutral gap 1 micron wide. The charge density of one of the plates is $0.50\frac{C}{m^3}$ and $-0.50\frac{C}{m^3}$ in the other. The relative permittivity of the medium both neutral and charged is 11.3.

What is the value of electric energy stored in a 0.1 mm x 0.1 mm section of the system?

5. A two milliampere current circulates in a horizontal square loop of $10^{-10}m$ side. Viewed from above the current circulates clockwise.

What is the magnitude and direction of magnetic flux density vector at a point $0.50x10^{-10}m$ above the center of the square?

Aid: $\int \frac{du}{(1+u^2)^{\frac{3}{2}}} = \frac{u}{(1+u^2)^{\frac{1}{2}}}$

6. The propagation direction of a $1GHz(=10^9 Hz)$ circularly polarized plane wave is north-east and $45°$ up. The power density of the wave is $1\frac{mW}{m^2}$. The magnetic field of the wave is monitored by a flat, 10 turns circular loop of $10cm^2$ area located in a vertical plane which rotates slowly about the vertical diameter of the loop.

Determine:

(i) at what orientation of the loop plane will the induced EMF be maximum and,

(ii) the RMS value of the maximum.

7. Internal dimensions of an X-band rectangular waveguide are 1 cm x 2 cm. In an (x, y, z) right-handed coordinate system the x-axis is aligned along the 2 cm side, the y-axis along the 1 cm side, with coordinate origin in one of the waveguide corners. Electric field $\bar{E}$ in the waveguide of a $10GHz(=10^{10}Hz)$ is $(0, E, 0)$ with

$$E(x,z,t) = E_0 \sin\left(\pi \frac{x}{a}\right)\cos(wt - kz),\ \ a = 2cm\ .$$

Determine:

(i) the proprogation constant k and,

(ii) components of magnetic field of the wave.

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

8. Two 50 cm long vertical current elements located on horizontal perfectly conducting ground plane radiate 30 MHz signals into empty space. The position of one element is 100 m south of a point A, that of the other is 175 m north of the point A. Power radiated by the south element is 0.5W.

(i) what should be the power radiated by the north element if the amplitudes of electric and magnetic fields of the two elements are to be the same at a point B, 100 m above point A?

(ii) Is it possible to effect cancellation of magnetic field at point B by suitable adjustment of phases of the current in the two elements? Answer only "yes" or "no".

(iii) Is it possible to effect cancellation of electric field at point B by suitable adjustment of phases of the currents in the elements? Answer only "yes" or "no".

Aid: $H = \frac{\ell Ik \sin\theta \exp j(\omega t - kr)}{(4\pi r)}$