INDIAN INSTITUTE OF TECHNOLOGY

Date : 29.4.11 Time : 3 Hrs. Full Marks 100 No. of Students 82

End Sem. Dept. of E & ECE Sub. No. EC21006

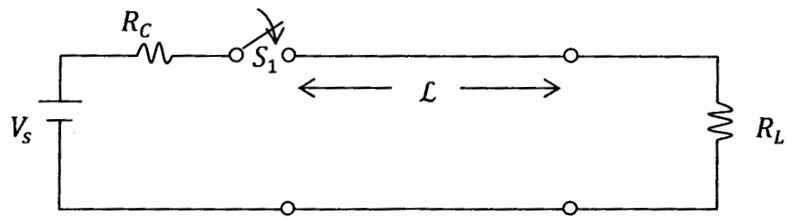
Sub.: Electromagnetic Engineering

Instructions : 1) ATTEMPT ALL THE QUESTIONS
2) MAKE NECESSARY ASSUMPTIONS WITH JUSTIFICATIONS, IF NECESSARY
3) ATTEMPT ALL THE PARTS OF A QUESTIION AT ONE PLACE
4) USE SMITH CHART IF NECESSARY
5) ALL QUESTIONS CARRY EQUAL MARKS OF 10.

1. In a region where $\mu_r = \epsilon_r = 1$ and $\sigma = 0$, the retarded potentials are given by $V = (z - ct)x\ Volt$ and $A = \left(\frac{z}{c} - t\right) x\ \hat{a}_z$ Wb/m, where $c = 1/\sqrt{\mu_0 \epsilon_0}$.
   a) Show that $\nabla \cdot \vec{A} = -\mu\epsilon \frac{\partial V}{\partial t}$
   b) Find $\vec{B}, \vec{H}, \vec{E}$ and $\vec{D}$
   c) Show that these fields satisfy Maxwell's equations in a source-free region.

2. A standing wave ratio of 2.5 exists on a lossless 60Ω line, whose location is marked by a small scratch on the line. When the load is replaced by a short circuit, the successive minima are 25 cm apart and one minima is located at a point 7 cm toward the source from the scratch. Find Z_{L_r} in two ways.
   a) Using Smith Chart
   b) Without using Smith Chart.

3.



The transmission line shown is having characteristic resistance of 50Ω. It is terminated by a load resistance of 25Ω. The source is a dc voltage source of value V_s with resistance of 25Ω. The switch S_1 is closed at t = 0 and is opened again at $t = \frac{\mathcal{L}}{4v}$, thus creating a rectangular voltage pulse in the line. v is the wave velocity through the line. Construct an appropriate lattice diagram for this case and use it to make a plot of the voltage at the load resistor as a function of time for $0 < t < 8\mathcal{L}/v$.

4. A certain non-magnetic material has the material constants $\epsilon'_r = 2$ and $\epsilon''/\epsilon' = 4 \times 10^{-4}$ at $\omega = 1.5$ G rad/s. Find the distance a uniform plane wave can propagate through the material for the three cases :
   a) before it gets attenuated by 1 Np.
   b) before the power level is reduced by 3 dB
   c) before the phase shifts by 360^0.

5. The electric field of a uniform plane wave in free space is given by

$$\tilde{E} = 100\,(\hat{a}_z + j\,\hat{a}_x)\,e^{-j50y}\ V/m$$

Determine

a) frequency
b) Magnetic field phasor
c) Time average power flow
d) polarisation of the wave.

6. The region z<0 is characterised by $\epsilon'_r = \mu_r = 1$ and $\epsilon''_r = 0$. The total $\tilde{E}$ field in this region is given as the sum of two uniform plane waves

$$\tilde{E} = 150\,e^{-j10z}\,\hat{a}_x + (50 < 20^0)e^{j10z}\,\hat{a}_x\,V/m.$$

a) What is the operating frequency?
b) Specify the intrinsic impedance of the region z>0 that would provide the appropriate reflected wave?
c) At what value of z, -10cm < z < 0, is the amplitude of total electric field intensity a maximum?

7. Consider a Hertzin dipole of length 1 cm carrying a phasor current of $\tilde{I} = 10 < 30^0 A$. If the frequency is 100 MHz, determine the electric and magnetic fields at a distance of 10 cm away from the dipole and $\theta = 45^0$. Compute the ratio $|\tilde{E}_\theta|/|\tilde{E}_r|$ and $|\tilde{E}_\theta|/|\tilde{H}_\phi|$ at this point. Repeat for distances of 1 m and 10 m and $\theta = 45^0$.
Is the result for 10 m distance expected?

8. A lossless 100Ω transmission line is connected between a 50Ω source and a load of (100 + j 70)Ω. Determine a length of this line such that maximum time-average power is delivered from the source to the load.

9. We want to determine the value of an unknown impedance Z_L attached to a length of a transmission line having a characterisation resistance of 100Ω. Removing the load yields an input impedance of –j80Ω. With the unknown impedance attached, the input impedance is (30+j40)Ω. Determine the unknown impedance using Smith Chart.

10. A rectangular coil is composed of 150 turns of a filamentary conductor. Find the mutual inductance in free space between this coil and an infinite straight filament on the z axis if the four corners of the coil are located at (1,1,0), (1,3,0) (1,3,1) and (1,1,1).

The Complete Smith Chart

Black Magic Design