INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date: April 2010 FN / AN Time: 3 Hrs. Full Marks 50 No. of Students 88

End Sem Spring Semester, Deptt. Electronics & Electrical Communication Eng. Sub. No. EC21006

2^{nd} Yr. B.Tech. (H) Sub. Name Electromagnetic Engineering

Instruction Answer ALL Questions. All symbols and variables have their usual meaning.

Note 1: The numbers in square brackets at the right-hand side of the text indicate the provisional allocation of maximum marks per question or sub-section of a question.

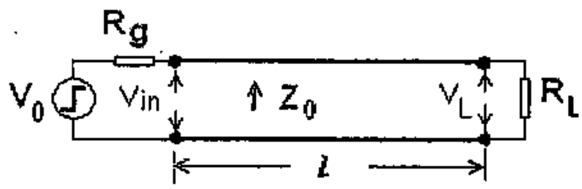
Evaluation of the answers will be entirely based on the **details of the steps** shown. Wherever relevant, solution steps should also be shown in the Smith Chart

Note 2: You may need: $\varepsilon_0 = 8.854\times10^{-12}\,F/m, \mu_0 = 4\pi\times10^{-7}\,H/m$.

Q.I **(a)** A transmission line has the following parameters at 1KHz: R= **5.12** Ω/Km, G=**1.35** μmho/Km or μS/Km, L=**2.27** mH/Km, C= **5.88** pF/Km. Determine the characteristic impedance, phase constant, guide wavelength, attenuation constant and attenuation in dB/Km. [5]

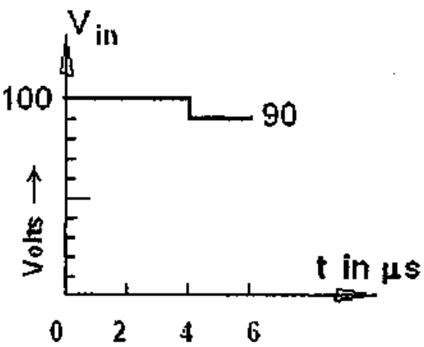
(b) A distortion less transmission line has Z_0=50Ω and resistance of 0.1 S/m. Determine: the attenuation constant in Np/m and in dB/m. [2]

Q.II In the system shown in Fig(a), a step voltage V_0 is applied at t=0. The line voltage variations with time at the input end and at the load end for the first 5μs are observed to be as shown below in Fig.(b) and (c), respectively. Find the values of V_0, R_g, R_L, and t_d. [5]

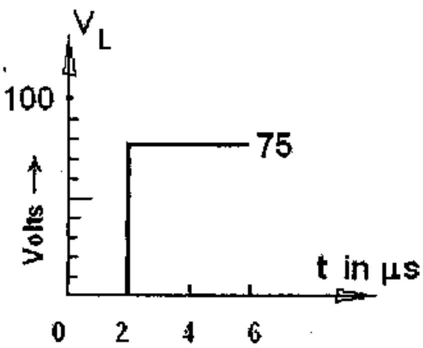


Given $Z_0 = 100\Omega$, $t_d = \frac{l}{v_p}$

(a)



(b)



(c)

Q.III With an unknown load connected to an air transmission line, S=**4.48** is recorded and minima are found at **16** cm, **91** cm, **166** cm and **241** cm. The minima nearest to the load being the one at **241** cm. When the load is replaced by a short circuit, the minima are measured at **22**cm, **97** cm and **172** cm. If Z_0 = **300Ω**, calculate **λ**, **f**, and **Z_L**. [8]

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Q.IV The load $\mathbf{Z_L = 75\text{-}j99\ \Omega}$ is to be matched to a Z_0 = $\mathbf{300\Omega}$ transmission line by means of lossless short-circuited stub. Find the (closest to the load) stub position and the stub length so that a match is obtained when

(i) the characteristic impedance of the stub is **300 Ω**. [5]

(ii) the characteristic impedance of the stub is **150 Ω**. [5]

Q.V (a) Determine the instantaneous quantities corresponding to:

(i) $I = 10 + j5$, (ii) $\vec{E} = \hat{u}_x(5 + j3) + \hat{u}_y(2 + j3)$,

(iii) $\vec{H} = (\hat{u}_x + \hat{u}_y)\, e^{j(x+y)}$, [3]

(b) A magnetic field in air is given by $\overline{B} = 25\left(\frac{x}{x^2+y^2}\hat{y} - \frac{y}{x^2+y^2}\hat{x}\right)$

Determine the source current for this field. [2]

(c) For a fixed volume ***V*** surrounded by a surface ***S***, Poynting's theorem states that

$$\iint_S \left(\vec{\mathcal{E}} \times \vec{\mathcal{H}}\right)\cdot d\vec{a} = -\frac{d}{dt}\iiint_V \left(\frac{1}{2}\varepsilon \mathcal{E}^2 + \frac{1}{2}\mu \mathcal{H}^2\right) dv - \iiint_V \sigma \mathcal{E}^2 dv$$

Explain the **physical significance** of each of the terms on the right hand side of this equation and hence, **from** energy conservation **determine** the physical significance of the Poynting vector. Give the physical significance of the divergence of the Poynting vector and of the integral [5]

$$\frac{1}{2}\mathrm{Re}[\oiint_S \vec{\mathrm{E}} \times \vec{\mathrm{H}}^* \cdot \vec{\mathrm{ds}}\,]$$

Q.VI Two dipoles are so fed and oriented in free space that they produce the following electromagnetic waves

$$E_x = 10.0\, e^{j(\omega t - \pi z/3)} \quad \text{volts/metre}$$

$$E_y = j10.0\, e^{j(\omega t - \pi z/3)} \quad \text{volts/metre}$$

(a) Obtain the magnitude, phase, direction and hence write down the expression for the corresponding magnetic field strength vector. [3]

(b) Calculate the frequency of the wave. [2]

(c) Examine the electric field vector at a point in space, say, z=0, as a function of time and give the complete description of the polarization of the wave. [5]

Note 3: You may need
$$\overline{\nabla}\cdot\overline{A} = \frac{1}{\rho}\frac{\partial(\rho A_\rho)}{\partial\rho} + \frac{1}{\rho}\frac{\partial A_\phi}{\partial\phi} + \frac{\partial A_z}{\partial z}$$

$$\overline{\nabla}\times\overline{A} = \hat{\rho}\left(\frac{1}{\rho}\frac{\partial A_z}{\partial\phi} - \frac{\partial A_\phi}{\partial z}\right) + \hat{\phi}\left(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial\rho}\right) + \hat{z}\left(\frac{1}{\rho}\frac{\partial(\rho A_\phi)}{\partial\rho} - \frac{1}{\rho}\frac{\partial A_\rho}{\partial\phi}\right)$$

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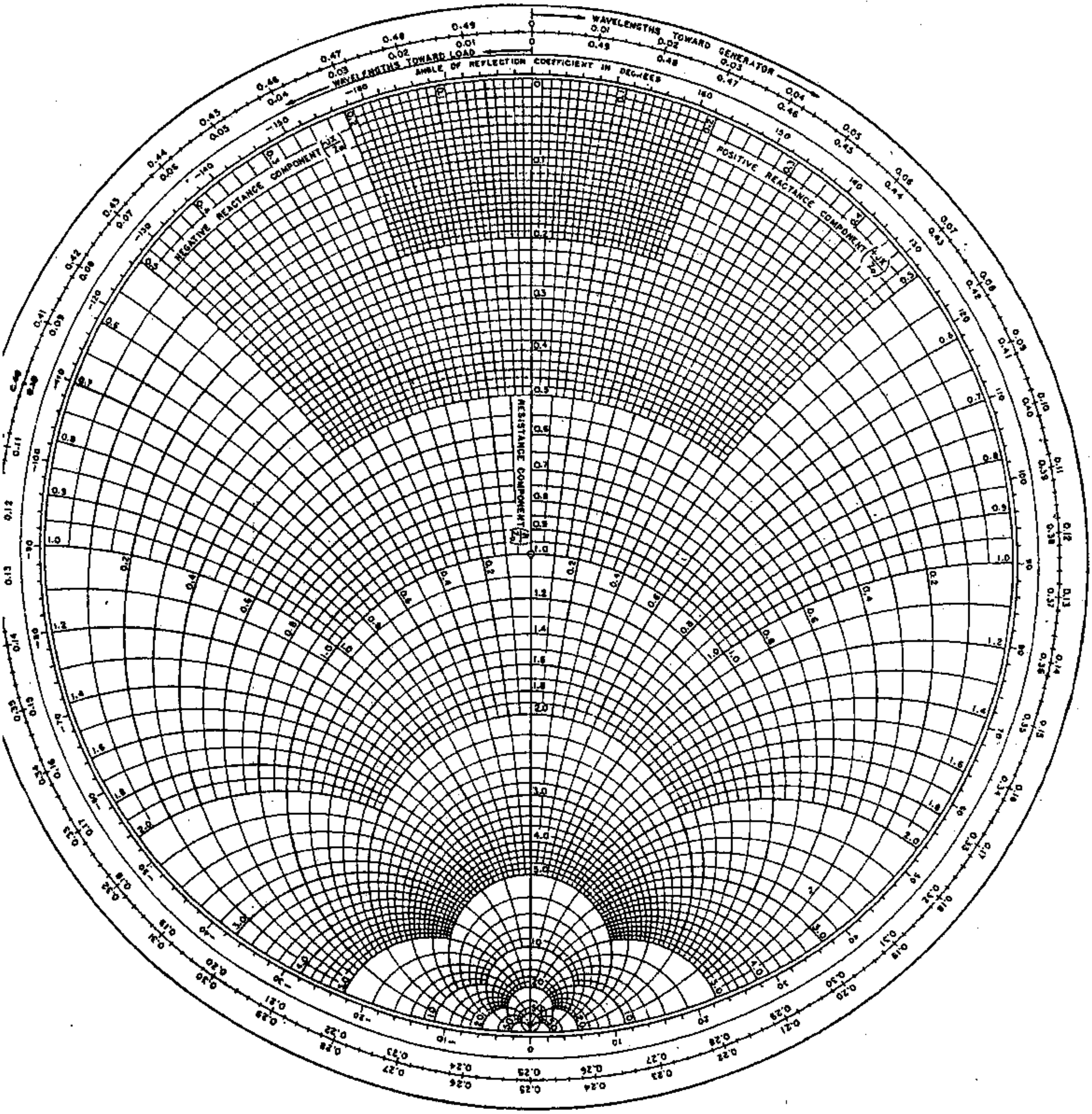
WAVELENGTHS TOWARD GENERATOR
WAVELENGTHS TOWARD LOAD
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
NEGATIVE REACTANCE COMPONENT
POSITIVE REACTANCE COMPONENT
RESISTANCE COMPONENT