GX557

OLLSCOIL NA hÉIREANN, GAILLIMH
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SEMESTER II EXAMINATION, 2000/2001

THIRD YEAR ELECTRONIC ENGINEERING

E.M. THEORY AND APPLICATIONS II

Professor L.E. Davis
Professor D.J. Wilcox
Dr. P. Corcoran

Duration of Examination: *Two* hours

Instructions: Section A - Answer **all** questions
Section B - Answer **two** questions

Section A

Attempt all questions in this section – <u>40 marks</u>.

(NB: where applicable you must include rough-work calculations to obtain full marks for these questions.)

A1. What forms of EM waves occur naturally in free space?

(a) TM waves only
(b) TE and TM waves only
(c) TE waves only
(d) TE, TM and TEM waves
(e) TEM waves only
(f) none of the above

A2. To analyse a TM wave, propagating in the z-direction in a rectangular waveguide we separate the field components into?

(a) H_{xy}, E_{xy}, and H_z
(b) H_{xy}, and E_z only
(c) E_{xy}, and E_z only
(d) H_{xy}, E_{xy}, and E_z
(e) H_{xy}, and E_{xy} only
(f) none of the above

A3. The requirements for a transmission line to be lossless are:

(a) L = R = 0
(b) L = C = 0
(c) L = C = 0
(d) R = G = 0
(e) C = R = 0
(f) none of the above

A4. For a TE guided wave propagating in the z-direction the perpendicular field components are given as:

(a) $h_z = 0; e_z \neq 0$
(b) $h_z \neq 0; e_z = 0$
(c) $h_z = 0; e_z = 0$
(d) $h_z \neq 0; e_z \neq 0$
(e) *all of the above*
(f) none of the above

A5. The requirements for a transmission line to be distortionless are:

(a) LG = RC
(b) LC = RG
(c) LR = CG
(d) LR = GC
(e) CL = GR
(f) none of the above

A6. For a conventional rectangular waveguide which of the following conditions will cause only the TE_{10} mode to propagate, given that $a = 2b$:

(a) $a < \lambda_0 < b$
(b) $a < \lambda_0 < 2b$
(c) $a < \lambda_0 < 2a$
(d) $a/2 < \lambda_0 < a$
(e) $b < \lambda_0 < 2b$
(f) none of the above

A7. The typical operating frequency of a conventional rectangular waveguides lies in the range:

(a) 1 – 25 GHz
(b) 25 – 100 GHz
(c) 100 – 1000 GHz
(d) 1 – 10 THz
(e) 100 – 1000 MHz
(f) none of the above

A8. The Poynting vector, ***P***, is given by the expression:

(a) $\vec{P} = \nabla.\vec{E} \times \nabla.\vec{H}$
(b) $\vec{P} = \nabla.(\vec{E} \times \vec{H})$
(c) $\vec{P} = \nabla \times (\vec{E} \times \vec{H})$
(d) $\vec{P} = (\nabla \times \vec{E}).(\nabla \times \vec{H})$
(e) $\vec{P} = \vec{E} \times \vec{H}$
(f) none of the above

A9. By measuring the short-circuit and open-circuit impedances of a transmission line we can determine the following constants for that line:

(a) Z_0, the characteristic impedance
(b) γ, the propagation coefficient
(c) Both Z_0 and γ
(d) VSWR (voltage standing wave ratio)
(e) all of the above
(f) none of the above

A10. The *near* and *far* radiation fields are generally discussed in the context of:

(a) waveguides
(b) transmission lines
(c) optic fibres
(d) cavity resonators
(e) antennas
(f) none of the above

A11. For a TEM guided wave propagating in the z-direction the perpendicular field components are given as:

(a) $h_z = 0;\ e_z \neq 0$
(b) $h_z \neq 0;\ e_z = 0$
(c) $h_z = 0;\ e_z = 0$
(d) $h_z \neq 0;\ e_z \neq 0$
(e) *all of the above*
(f) none of the above

A12. The velocity of propagation in a transmission line can be written in terms of the phase change coefficient, β, as:

(a) $\upsilon_p = 2\pi\beta/\omega$
(b) $\upsilon_p = \beta/\omega$
(c) $\upsilon_p = \omega/\beta$
(d) $\upsilon_p = \omega/2\pi\beta$
(e) $\upsilon_p = 2\pi\beta\omega$
(f) none of the above

A13. In a rectangular waveguide which propagates a standard TE or TM mode, which of the following has a value greater than c, the velocity of light:

(a) v_g, the group velocity
(b) v_g, the guide velocity
(c) v_0, the free-space velocity
(d) v_p, the phase velocity
(e) v_π, the rotational velocity
(f) none of the above

A14. The time-averaged electric energy, W_e, stored in an E field with sinusoidal time variation is given as:

(a) $W_e = \frac{1}{\sqrt{2}} E.E^*$
(b) $W_e = \frac{1}{2} E.E^*$
(c) $W_e = \frac{1}{2\sqrt{2}} E.E^*$
(d) $W_e = \sqrt{2} E.E^*$
(e) $W_e = \frac{1}{4} E.E^*$
(f) none of the above

A15. At the interface to a current-carrying conductor the relationship between magnetic field and surface current density is given as:

(a) $\hat{n} \times \vec{H} = \vec{J}_s$
(b) $\hat{n} \times \vec{H} = \nabla.\vec{J}_s$
(c) $\vec{H} = \hat{n} \times \nabla.\vec{J}_s$
(d) $\hat{n} \times \vec{H} = \vec{E}.\vec{J}_s$
(e) $\hat{n} \times \vec{H} = \nabla \times \vec{J}_s$
(f) none of the above

Section B

Attempt 2 questions in this section – <u>60 marks</u>; 30 marks per question.

(NB: Candidates should note that marks may be lost if answers are not presented in a neat and orderly manner)

Q 1. **(a)** Discuss briefly the circuit theory model of a transmission line. Derive general equations for voltage and current at an arbitrary point along the line and obtain general hyperbolic solutions to these equations.

[12 marks]

(b) State the conditions for a transmission line to be loss-free. Describe and derive the relevant expressions for attenuation and phase change coefficients for low-loss, high-frequency and distortionless transmission lines. In each case explain how these lines approximate to a loss-free line. State clearly your assumptions.

[12 marks]

(c) Explain the concepts of *phase* and *group* delay. Why is it desirable for a transmission line to have a phase coefficient that varies linearly with frequency?

[6 marks]

Q 2. **(a)** Explain how a TE wave can propagate in a waveguide. Derive modified forms of Maxwell's equations, in terms of field components parallel and perpendicular to the main axis of the waveguide.

[12 marks]

(b) Outline the main steps in the analysis of the propagation of a TE wave in a guide. In the TE_{10} mode of propagation, given that $H_z = A_0 \cos(\pi x/a)$ derive expressions for (i) the time-averaged electric energy, (ii) average power flow and (iii) group velocity in the guide.

[18 marks]

Q 3. **(a)** Describe briefly how a rectangular waveguide carrying a TE_{10} mode can be made to operate as a cavity resonator.

[10 marks]

(b) Given that, for the TE_{101} mode,

$$E_y = A \sin(\pi x/a)\sin(\pi z/d)$$
$$H_x = [-j\pi/(\omega\mu_0 d)]A \sin(\pi x/a)\cos(\pi z/d)$$
$$H_z = [j\pi/(\omega\mu_0 d)]A \cos(\pi x/a)\sin(\pi z/d)$$

Calculate (i) the total time-averaged energy stored in the cavity, (ii) the power loss in the cavity walls and (iii) the quality factor (Q-factor) of the cavity.

(Note: You may assume that the energy stored by the electric field is equal to the energy stored by the magnetic field.)

[20 marks]

Q 4. (a) Given that the static electric and magnetic potential within a closed volume are given as:

$$V = \frac{1}{4\pi\varepsilon}\int\frac{\rho.dV}{r} \text{ (electric potential)} \qquad \vec{a} = \frac{\mu}{4\pi}\int\frac{\vec{J}.dV}{r} \text{ (magnetic potential)}$$

Demonstrate that equivalent, but *retarded*, potentials exist for time-varying electric and magnetic fields.

[8 marks]

(b) Derive detailed expressions for the ***E*** and ***H*** fields around a small elemental antenna which carries a current of $I_0 e^{j\omega t}$.

[14 marks]

(c) What are the *induction* and *radiation* fields around the elemental antenna of (b)? At what distance from the antenna are they equal in magnitude? Show that at a distance $r >> \lambda$ from the antenna that the ***E*** and ***H*** fields form a spherical TEM wave.

[8 marks]
