Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

GX 686

Semester II Examinations, 2002/2003

Front Page Template

Exam Code(s)	3BN121
Exam(s)	Third Year Electronic Engineering
Module Code(s)	EE320
Module(s)	E.M. Theory and Applications II
Paper No.	1
Repeat Paper	Special Paper
External Examiner(s)	Professor S. McLaughlin
Internal Examiner(s)	Professor D.J. Wilcox
	Dr. P. Corcoran

Instructions: Section A – Answer **all** questions
Section B – Answer three questions

Duration	2 hrs
No. of Answer books	1

Requirements:
Handout
MCQ
Statistical Tables
Graph Paper
Log Graph Paper
Other Material

No. of Pages	8
Department(s)	Department of Electronic Engineering

Section A

Attempt all questions in this section – 25 marks.

Mark each selection with a distinct "X" in the multi-choice answer sheet provided.

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

1. 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

2. 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

A3. 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

A4. The reflection coefficient, Γ, of a transmission line, terminated in a short-circuit, is?

(a) 1.0   (b) 0.0   (c) 1.0j

(d) 1.0, 1.0j   (e) -1.0   (f) none of the above

A5. At a current-free interface between two homogeneous dielectric regions one of the following relationships between the normal and tangential electric field components is true:

(a) $E_{n1} = E_{n2}$ (b) $E_{n1} = E_{t2}$ (c) $E_{n1} + E_{t1} = E_{n2} + E_{t2}$

(d) $E_{t1} = E_{t2}$ (e) $E_{n1} + E_{n2} = E_{t1} + E_{t2}$ (f) none of the above

A6. 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

A7. 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

A8. The <u>*near*</u> and <u>*far*</u> 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

A9. 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

A10. 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

A11. The reflection coefficient, Γ, of a transmission line, terminated in its *characteristic impedance*, is?

(a) 1.0
(b) 0.0
(c) 1.0j
(d) 1.0, 1.0j
(e) -1.0
(f) none of the above

A12. The time-averaged electrical power, P_i, injected into a transmission line by an *A.C.* generator is given, in terms of the input voltage, V_i and input current, I_i, as::

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

Section B

Attempt 3 questions in this section – 75 marks; 25 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) By analysing the flow of EM energy across the closed surface S shown in ***Fig. 1*** and by equating this with the decrease in stored energy less the energy dissipated within S deduce the Poynting Theorem and derive an expression for the Poynting vector at a point in space.

[10 marks]

(b) Deduce from first principles the relationship between normal and tangential components of the Electric and Magnetic fields at a current-free interface between two dielectric regions. If a current sheet, J_S, exists at the interface deduce the relationship between the magnetic field components, H_1 and H_2.

[8 marks]

(c) A current sheet J_s = 9.0j A/m is located in the plane $z = 0$, which is also the interface between two dielectric regions. In region 1, $z < 0$ and $\mu_{r1} = 4$; in region 2, $z > 0$ and $\mu_{r2} = 3$. Given that H_2 = 14.5i + 8.0k A/m find B_1, B_2, and H_1.

[7 marks]

Q 2. (a) Discuss briefly the circuit theory model of a transmission line and obtain general hyperbolic solutions for the voltage and current along such a line. Use these results to deduce an expression for the sending-end impedance of the line in terms of the characteristic and receiving-end impedances and $tanh(\gamma l)$.

[10 marks]

(b) An AC signal generator with amplitude V_G = 100Vand Z_G = 50Ω is connected to a load Z_L = 75Ω through a lossless line of length, $l = 0.15\lambda$. Compute the following:

(i) Z_{in}, the input impedance of the line at the generator end;

(ii) the input voltage and currents to the line, V_i and I_i;

(iii) the time-averaged power delivered to the line, $P_{in} = 0.5\Re e[V_i I_i^*]$;

(iv) the load voltage, V_L, current, I_L, and power delivered to the load, $P_L = 0.5\Re e[V_L I_L^*]$; and

(v) the time-averaged power delivered by the generator, P_G, and the time-averaged power dissipated in Z_G.

Is conservation of power satisfied by (iv) and (v)? Comment.

[15 marks]

Q 3. (a) State the point form of Maxwell's Equations. Given that $\vec{E} = E_m \sin(\omega t - \beta z)\hat{j}$ in free space, determine $\vec{D}, \vec{B}$ and $\vec{H}$ at $t = 0$. Show that $\vec{E}$ and $\vec{H}$ constitute a wave travelling in the z direction and verify that the wave speed and the ratio E/H depend only on the properties of free space.

[12 marks]

(b) Given that $\vec{E} = 30\pi \exp[j(\omega t + \beta z)]\hat{i}$ and $\vec{H} = H_m \exp[j(\omega t + \beta z)]\hat{j}$ with $\omega = 10^8$ constitutes a travelling wave in free space determine H_m and β.

[6 marks]

(c) In a homogeneous non-conducting region where the relative permeability, $\mu_r = 1.0$, find the relative permittivity, ε_r and the angular frequency, ω of a travelling wave given that the electric field, $\vec{E} = 30\pi \exp[j(\omega t - \beta y)]\hat{k}$, and the magnetic field, $\vec{H} = 1.0\exp[j(\omega t - \beta y)]\hat{i}$ with $\beta = 4/3$. At what fraction of the speed of light will this travelling wave propagate?

[7 marks]

Q 4. (a) Find the ***B*** field in all regions of a co-axial cable as shown in ***Fig. 2*** below. The outer conductor is of thickness $t = c - b$. Sketch the radial variation in ***B*** field in all regions and thus explain the physical advantages of a co-axial cable for carrying EM signals.

[5 marks]

(b) Define inductance in terms of flux linkages. Now calculate the inductance per unit length of the co-axial cable shown in ***Fig. 2*** below. To simplify the analysis you may assume that the thickness of the outer conductor is negligible relative to the radii of the inner and outer conductors.

[8 marks]

(c) State the required conditions for a transmission line to be distortionless and thus show that:

(i) $\alpha = R\sqrt{C/L}$; (ii) $\beta = \omega\sqrt{LC}$ (iii) $Z_0 = \sqrt{L/C}$

For a distortionless line with characteristic impedance, $Z_0 = 50\Omega$, attenuation constant, $\alpha = 40$ mNp/m and velocity of propagation, $v_p = 2.5\text{x}10^8$ m/s, find the line parameters and the wavelength, λ, at 250 MHz.

[12 marks]

Q 5. (a) Given that the static electric and magnetic potential within a closed volume are given as:

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

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

[6 marks]

(b) Derive detailed expressions for the ***E*** and ***H*** fields around a small elemental antenna which carries a current of $I_0e^{j\omega t}$.

[12 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.

[7 marks]

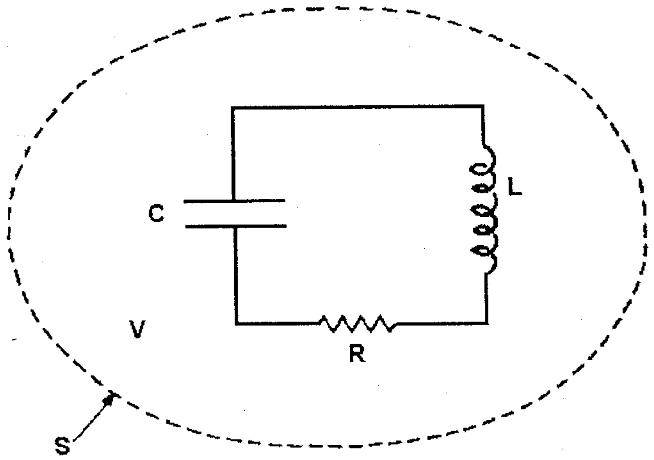

Fig 1:.An RLC circuit representing energy storage and dissipation elements working within the volume **V** *which is contained by the closed surface S.*

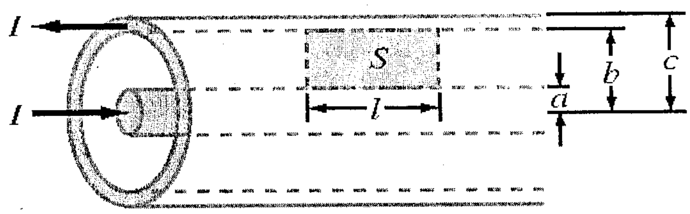

Fig 2: Co-axial cable with inner conductor of finite radius, ***a*** *and outer conductor of inner radius* ***b*** *and outer radius* ***c****. Current flows in opposite directions in the two conductors.*