NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHSYICS DEPARTMENT

SPH 2105 – ELECTROMAGNETISM

BSc HONOURS PART II: *JANUARY 2004* *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF QUESTION 1 IN SECTION A AND ANY **THREE** QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B 60 MARKS

SECTION A

1. (a) A satellite power station is known to be in synchronous orbit, beaming a microwave power to the earth. The bandwidth of the transmitting antenna on the satellite is 0.15°. The distance from the earth's surface to the satellite is 40 000 km. Calculate the size of the spot illuminated by the antenna on the earth's surface assuming circular spot or beam area [5]

(b) Show that the voltage standing wave ratio $(VSWR) = \frac{1+|\rho_v|}{1-|\rho_v|}$ where ρ_v is the reflection coefficient for voltage. [6]

(c) Briefly explain what you understand by the term *stub matching*. [5]

(d) (i) A travelling plane wave in free space has an average Poynting vector of $1\,Wm^{-2}$. Calculate the average energy density of the wave. [3]

(ii) A transmission line is described as a lossless line. Explain what you understand by the term '*lossless line*' [3]

(e) Given a wave propagating in the TE_{11} **mode**, write down the field components. [7]

(f) Show that the directivity of an isotropic antenna equals to unity. [3]

(g) What is the gain in decibels of an antenna whose bandwidth is 2° ? [5]

(h) What is a wave guide ? [3]

SECTION B

2. (a) For a string responding to a tension force τ exerted along it, the second derivative of displacement $u(x,t)$ for forces in the y-direction may be represented by the relation $\tau \sin\theta_2 - \tau \sin\theta_1 = \rho dx \frac{\partial^2 u(x,t)}{\partial t^2}$

where ρ is the material density of the string, τ is the tension in the string and θ_1 and θ_2 are angles of tension forces at the ends of the string to the horizontal after the string has (say) been plucked. Show that the velocity of the wave in the string depends on the properties of the string. [10]

(b) A harmonic wave is incident upon a boundary between two media. Medium number 1 has density ρ_1 while medium number 2 has density ρ_2. Show that the reflection coefficient $R_{12} = \frac{\rho_1 v_1 - \rho_2 v_2}{\rho_1 v_1 + \rho_2 v_2}$ and the transmission co-efficient $T_{12} = \frac{2\rho_1 v_1}{\rho_1 v_1 + \rho_2 v_2}$; v_1 and v_2 are the velocities in medium number 1 and medium number 2 respectively. [10]

3. (a) The electric field of a propagating wave is given by the relation

$$E(z,t) = E\exp(-k\frac{\omega x}{c})\exp(-i\omega(t - \frac{nx}{c})).$$

Explain the quantities $\frac{c}{n}$ and $\frac{k\omega}{c}$. Proceed to further explain what you understand by the term skin depth, showing from where it comes in the expression. [5]

(b) What is a complex vector? [3]

(c) With the aid of a diagram, explain what you understand by the term polarisation of (say) a vector, E, at a given point in space as a function of time. Clearly explain in your answer, the terms: linear polarisation, right-hand and left-hand elliptical polarisation and circular polarisation. [12]

4. (a) A plane travelling wave of electric field $E_x = 100\exp(-\gamma z)$ (Vm^{-1}) propagates through a material whose properties are: $\varepsilon_r' = 4$, $\sigma = 0.1Sm^{-1}$, $\mu_o = \mu$. The frequency is 2.45 GHz. Find α and β and the attenuation in the material in decibels per metre. [8]

(b) Calculate the intrinsic impedance for the material whose properties are given in Question 4 (a) above. And thus calculate both the impedance and the propagation constant using loss approximations. How do the results compare? [12]

5. (a) (i) Two half-wave dipole antennas are used to establish a communication link with free space. The transmitter delivers 1 kW of power to the transmitting antenna. A dipole receiver is placed at a distance of 500 km away from the transmitter and receives signals of 200 *MHz* frequency. Assuming the path between the dipoles is normal to each dipole (implying that $\theta = 90^\circ$) and the dipoles are aligned, calculate the power received at the receiving antenna. [A *half-wave dipole has directivity of 1.64]*. [5]

(ii) Calculate the power that is received by a properly terminated half-wave dipole from a plane wave of 20 *MHz* frequency with an r.m.s. electric field of 5 mVm^{-1}. [5]

(b) A lossless transmission line is terminated by a 35Ω load with a potential voltage of 100V across it from a sinusoidal source of frequency 1kHz. The line has capacitance of $200pFm^{-1}$ and an inductance of $0.5\mu Hm^{-1}$. Calculate the following parameters for the circuit: R_0, U, ρ_L, λ and β. [10]

- END OF EXAMINATION -