NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

ELECTROMAGNETISM - SPH 2105

EXAMINATION

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

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

SECTION A

1. (a) (i) Define the terms *"relaxation time"* and *"skin effect"* [4]

(ii) A 3 GHz frequency wave (wave length of 100mm) is carried in a conductor A of μ_r and ε_r equal to unity. Determine the intrinsic impedance, Z_c for the conductor A at 100 mm. Assume that $\frac{\varepsilon\omega}{\sigma} = 2.9x10^{-9}$ for conductor A; $\mu_0 = 4\pi \times 10^{-7}$ Hm^{-1} and $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} [4]

(iii) Comment on the value of Z_c obtained in the above calculation. [2]

(b) (i) An electromagnetic wave is linearly polarised in the vertical y - direction. Explain what you understand by this statement in terms of the electric field and the magnetic field of the wave. [1]

(ii) An electromagnetic wave travels from medium 1 of impedance Z_1 into medium 2, of impedance Z_2 where $Z_1 << Z_2$. Write down the relation for the transmitted electric field, E_t. [2]

(iii) Comment on the physics implied in the relation you have written in (ii) above. [2]

(iv) The energy velocity of a wave is given by the relation $V_{en} = \frac{EH}{\varepsilon E^2}$.

Comment on this relation with reference to the phase velocity v_p and group velocity v_g in both non-dispersive and in a loss less dispersive medium. [5]

(c) (i) State the electromagnetic boundary conditions that constraint electromagnetic wave propagation at the interface between air and a perfect conductor. [4]

(ii) Explain what is meant by the term *"transverse electromagnetic wave"* and give a diagram showing the directions of propagation of electric field and magnetic field in such a wave. [4]

(iii) State how a stack of metal plates spaced at an arbitary distance apart, may be introduced into the transverse electromagnetic wave without disturbing it. [3]

(d) (i) Give a quantitative description of how the boundary conditions are satisfied for propagation in a rectangular hollow metal wave-guide of cross - sectional dimensions, A metres and B metres. Assume A > B. [3]

(ii) If A is 1 cm long, determine the lowest mode cut-off frequency of this guide if it is air filled. [3]

(iii) Comment on the probable sources of attenuation in a wave guide made up of a rectangular metal pipe filled with a substance of relative dielectric constant q. [3]

SECTION B

2. (a) A satellite power station is in synchronous orbit, beaming a microwave power to the earth. The transmitting antenna on the satellite has a band width of 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. [3]

(b) Briefly explain what you understand by the voltage standing wave ratio (VSWR) and hence show that 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 $1Wm^{-2}$. Calculate the average energy density of the wave. [3]

(ii) A transmission line is described as a loss-less line. Explain what you understand by the term *"loss less line"* [3]

3. (a) Write down the set of Maxwell's electromagnetic field equations briefly explaining the experimental law or physical origin from which they are derived [8]

(b) Derive the *"wave equation"* for the $\vec{B}$ field in free space and show that it propagates at the speed of light. [2]

(c) Given an electromagnetic wave in free space, $\vec{E} = E_m Sin(\omega t - \beta z)\hat{y}$, Deduce the following:

(i) the electric displacement, $\vec{D}$,

(ii) the magnetic field density, $\vec{B}$,

(iii) the magnetic field intensity, $\vec{H}$,

(iv) the Poynting vector, $\vec{S}$,

(v) and the magnitude of the Poynting vector? [10]

4. (a) Derive a general solution of the Laplace equation $\nabla^2 V = 0$ in a cartesian coordinate system. [10]

(b) For a parallel plate capacitor with some charge density distribution between the plates, prove that the voltage distribution follows the relation $V = V_1\left(\frac{x}{x_1}\right)^{\frac{4}{3}}$.

Determine the distance from one plate where the potential drops to half of its maximum value. [10]

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 $\theta = 90^0$) 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) Draw the polar diagram for an array of two vertical aerials, separated by a half-wave length, when the currents in the aerials are in phase. Show the calculation from which your diagram is constructed. [8]

(c) Where must a micro - wave antenna be placed in relation to a parabolic reflector, in order to take advantage of beam shaping properties of the parabola? [2]

6. (a) What is a wave guide? [3]

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

(c) (i) Assume at TM mode of propagation in a wave guide whose cut-off frequency is 3 GHz. Calculate the characteristic impedance of the wave guide for a frequency of 5 GHz. [3]

(ii) Determine the wave guide impedance for the TE mode of propagation for the conditions in (i) above. [3]

(iii) Determine the Q of a cavity resonator such that the centre frequency is 500 MHz and the response exceeds 70.7% of maximum from 495 MHz to 505 MHz. [3]

(iv) Define TEM mode. [1]

- END OF EXAM -