EE2-10B

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2017

EEE PART II: MEng, BEng and ACGI

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FIELDS

Monday, 19 June 10:00 am

Time allowed: 1:30 hours

There are THREE questions on this paper.

Question One carries 40 marks. Question Two and Question Three carry 30 marks each.

Answer ALL questions.

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible First Marker(s) : R.R.A. Syms

Second Marker(s) : S. Lucyszyn

2. a) Assuming polarization and propagation in the x- and z-directions, respectively, sketch the electric and magnetic fields in a travelling electromagnetic wave. Sketch the electric and magnetic fields in a coaxial cable. How do the two fields vary outside the cable?

[6]

b) Explain the operation of a Van de Graaf generator in terms of Gauss' Law.

[6]

c) Assuming the reflection coefficient for a mismatched transmission line, derive the expression for the input impedance of a length d of line with parameters Z_0 and k terminated by a load Z_L.

[8]

d) Consider a coaxial cable made with a plastic fill of relative dielectric constant $\varepsilon_r = 2.25$ and characteristic impedance $Z_0 = 50\ \Omega$, operated at 10 MHz frequency.

i) Calculate its propagation constant.

ii) Calculate the input impedance of a 5 m length of cable terminated with a 100 Ω resistor.

iii) Show how an impedance equivalent to an inductance may be achieved using only a short-circuited length of transmission line.

iv) Calculate the length of cable that will give an inductance of 1 μH.

[10]

3. a) A metal walled waveguide is constructed using two parallel metal sheets as shown in Figure 3.1. Assuming polarization in the y-direction, write down an expression for the electric field inside the guide in the form of travelling waves. By applying suitable boundary conditions, express this field in modal form and find an expression for the propagation constant. Sketch the transverse field of the lowest order mode.

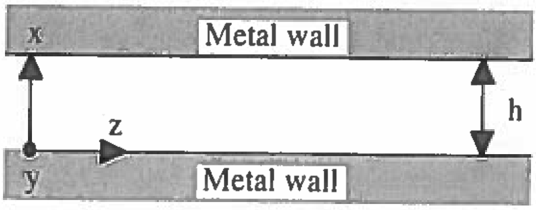

Figure 3.1

[10]

b) In free space, the scalar wave equation is $\nabla^2 E + \omega^2 \mu_0 \varepsilon_0 E = 0$, where E is the electric field, ω is the angular frequency and μ_0 and ε_0 are the permeability and permittivity. Assuming that the electric field is a function of radius r only, show that the wave equation can be reduced to the differential equation $d^2E/dr^2 + (2/r)\, dE/dr + \omega^2 \mu_0 \varepsilon_0 E = 0$.

[10]

c) Show that the spherical wave $E(r) = (E_0/r) \exp(-jk_0 r)$, where E_0 is a constant and k_0 is the propagation constant, is a valid solution to the wave equation above, and hence show that the power carried by the wave is independent of radial distance.

[10]