Beijing-Dublin International College

SEMESTER 1 FINAL EXAMINATION - 2023/2024

BDIC3018J Electromagnetics 2

MODULE COORDINATOR: Xiaoli Li

Time Allowed: 95 minutes

Instructions for Candidates

BJUT Student ID: _____UCD Student ID: _____

I have read and clearly understand the Examination Rules of both Beijing University of Technology and University College Dublin. I am aware of the Punishment for Violating the Rules of Beijing University of Technology and/or University College Dublin. I hereby promise to abide by the relevant rules and regulations by not giving or receiving any help during the exam. If caught violating the rules, I accept the punishment thereof.

Honesty Pledge：_____ (Signature)

Final Exam

Note: In this paper, let π = 3.14, and keep two digits after decimal point,
for example, take 1.26 for 1.257.
Please write all the answers on the answer sheet.

Part 1. Single-Choice. There are 9 problems with total points of 18.

1.1 Choose the statement that is absolutely correct from the options below _____

A. A uniform plane wave can propagate in a hollow metal rectangular waveguide;
B. No induced current can be generated in a steady magnetic field;
C. In a parallel-plate capacitor, displacement current can be generated in the air between the two plates during the charging process;
D. The displacement current can result in the loss of Joule Heat.

1.2 Assume the electric field vector of a plane wave in free space is given by $\mathbf{E}_s = 3e^{-j\beta x}\mathbf{a}_z + 7e^{j\pi}e^{-j\beta x}\mathbf{a}_y$ V/m. Then the wave has _____ polarization.

A. Linear
B. Elliptical
C. Right-handed circular
D. Left-handed circular

1.3 For a uniform plane wave normally incident from air onto a perfect conductor planar- interface, the reflection coefficient is _____

A. -1
B. 0
C. 1
D. depends on the frequency of the wave

1.4 A rectangular waveguide filled with air has cross section dimensions of a = 6 cm and b = 4 cm. How many modes will the guide support for the plane wave with frequency of 4.8 GHz? _____

A. 1 B. 2 C.3 D.4

1.5 A plane wave travels in the (+z) direction in a lossy transmission line whose medium has attenuation constant α >0. The power carried by the wave attenuates as _____

A.~ $e^{-\alpha z}$ B.~ $e^{+\alpha z}$ C.~ $e^{-2\alpha z}$ D.~ $e^{+2\alpha z}$

1.6 Figure 1 shows the field configurations of a guided wave propagating in a rectangular waveguide, it can be ____ mode.

A. TM_{10}
B. TM_{11}
C. TE_{10}
D. TEM

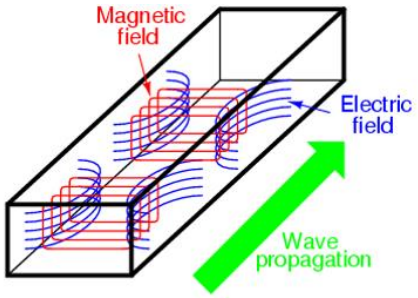


Figure 1. *Magnetic flux lines appear as continuous loops*
Electric flux lines appear with beginning and end points

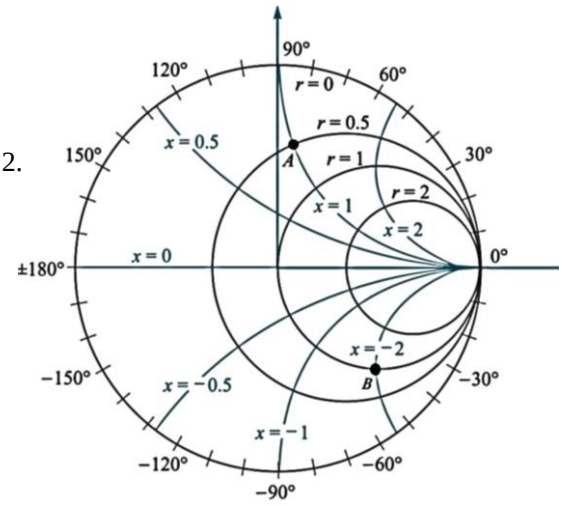
1.7 A dipole antenna with the total length of _____is the best one to be used to receive 5GHz WiFi signals.

A. 1.5cm B. 3cm C. 6cm D.12cm

1.8 Consider a transmission line with a characteristic impedance of 50 Ω. It has a load impedances represented by point *B* on the Smith Chart shown in Figure 2. Then determine the reflection coefficient at the load as _____

A. -2+j
B. 1-2j
C. 50-100j
D. 0.5-0.5j

Figure 2.



1.9 Assume an elevator in a No.4 Teaching Building is made of stainless steel which has material parameters known as $\sigma = 1.2 \times 10^6$ S/m and $\mu_r = 500$ (take $\mu_0 = 4\pi \times 10^{-7}$H/m for vacuum). Determine the skin depth of the China Mobile signal at 3.5 GHz inside the elevator_____

A. 0.26μm B. 0.35μm C. 0.39nm D. 28.8mm

Part 2. Analysis and Calculation.

2.1 In time-varying electromagnetic field, write Maxwell's equations in point form in terms of **E** and **H** as they apply to a sourceless medium. (4points)

2.2 A uniform plane wave is propagating in air, of which the electric field intensity vector is given by $\mathbf{E}=30\pi\times \boldsymbol{e}^{\,\mathrm{j}4\pi z}\,\mathbf{a}_y$, (*a*) Determine the wave frequency and the propagating direction; (*b*) Find expressions for magnetic field intensity **H** in phasor form and ***H****(z,t)* in real instantaneous form; (*c*) If the uniform plane wave in air is normally incident on a perfect dielectric ($\varepsilon=4\varepsilon_0, \mu=\mu_0$) surface at **z** = 0. What percentage of the incident power density is transmitted into the dielectric? and What is the transmission coefficient? (10points)

2.3 The rails in Figure 3 each have a resistance of 2 Ω/m. The bar moves to the right at a constant speed of 9 m/s in a uniform magnetic field of 0.8 T. Assume the bar is at x = 2 m at t = 0, (*a*) When a 0.3 Ω resistor is present across the left end with the right end open-circuited, Find I (t), 0 < t < 1 s; (*b*) a 0.3 Ω resistor is present across each end, Find I (t) at t= 1.2 s. (8 points)

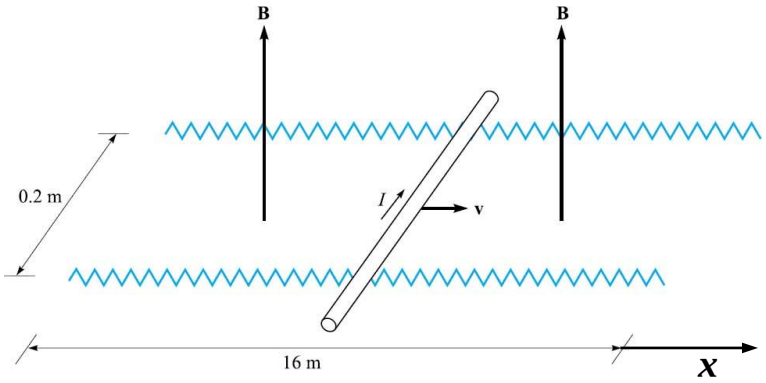


Figure 3. The rail with a moving bar in a uniform magnetic field

2.4 A parallel-plate guide is partially filled with two lossless dielectrics (Figure 4) where ε'_{r1}=9, ε'_{r2} = 1.5, μ_{r1}=μ_{r2}=1, and d = 1 cm. At a certain frequency, it is found that the TM_1 mode propagates through the guide without suffering any reflective loss at the dielectric interface. (*a*) Find this frequency. *Hint*: the wave angle θ is given by $\cos\theta = f_{\mathrm{cm}} / f$; (*b*) Is the guide operating at a single TM mode at the frequency found in (*a*)? If not, give all the modes which can propagate in this guide? (10points).

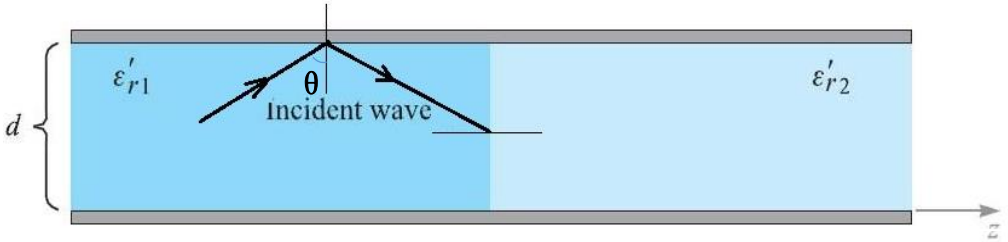


Figure 4. A parallel-plate guide is partially filled with two lossless dielectrics

2.5 Two lossless transmission lines having different characteristic impedances are to be joined end to end. The impedances of line-1 connected to the source is Z_{01} = 64 Ω and that of the other line is Z_{03} = 25 Ω. The signal frequency is 1 GHz.

(a) Considering the impedance-matching condition, please design another transmission line using conductor with capacitance per unit length of 100 pF/m, in order to allow total power transmission through all the lines, determine the position, the characteristic impedance, and the shortest length of this required line;

(b) Keep the transmission line setup same as found in (a), only double the signal frequency to be 2 GHz, evaluate the standing wave ratio that will be measured at the junction point between line-1 and other lines, and the fraction of the incident power that is reflected and propagates back to line-1. (10points).

Equations for use

$$Z_{in} = Z_0 \frac{Z_L \cos \beta l + jZ_0 \sin \beta l}{Z_0 \cos \beta l + jZ_L \sin \beta l}$$

Cutoff frequency of rectangular waveguide $f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \sqrt{(\frac{m\pi}{a})^2 + (\frac{n\pi}{b})^2}$

Cutoff frequency of parallel-plate waveguide $f_{cm} = \frac{m}{2d\sqrt{\mu\varepsilon}} = \frac{mc}{2nd}$

(n is refractive index)