



Beijing-Dublin International College



SEMESTER 1 FINAL EXAMINATION - 2020/2021

BDIC3018J Electromagnetics 2

MODULE COORDINATOR: Xiaoli Li

Time Allowed: 120 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)**

Instructions for Invigilators

All electronic devices, notebooks, books, work papers are strictly prohibited.

Final Exam

Note: In this paper, let $\pi = 3.14$, 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. Multiple-Choice Problems. There are 7 problems in total, each is worth 4 points. For each question, at least one answer is correct.

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

- A. Displacement current could be induced in conductors as well as dielectrics, but only in conductors it results in the generation of Joule Heat;
- B. No electromotive force (emf) can be produced in a steady magnetic field;
- C. During charging process of a parallel-plate capacitor, there can be some displacement current produced between the two plates;
- D. All the currents in a conductor are formed by the directional movement of free charges.

1.2 Figure 1 shows the field configurations of a guided wave named as _____ mode in a parallel-plate waveguide.

- A. TE_1
- B. TE_2
- C. TM_1
- D. TEM

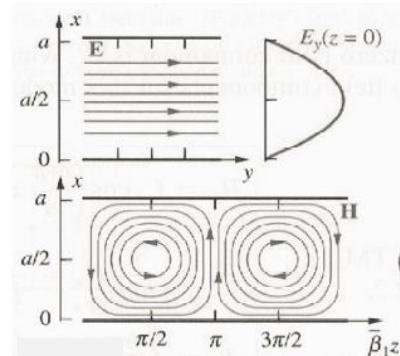


Figure 1

1.3 Which equation is describing the Faraday's Law of Induction _____

- A. $\oint_C \mathbf{E} \cdot d\mathbf{L} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{S}$
- B. $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
- C. $\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$
- D. $\oint_S \mathbf{D} \cdot d\mathbf{S} = Q_{encl}$

1.4 Find correct descriptions of a uniform plane wave from the options bellow _____

- A. The uniform plane wave has a plane equal phase surface, where the magnitude and direction of E (or H) at any point are constant;

- B. The energy density of electric field is larger than that of magnetic field for a uniform plane wave propagating in dielectrics;
- C. The E and H vectors of a uniform plane wave propagating in dielectrics are in the same phase while the amplitude of both are attenuated along with the propagating direction;
- D. The E and H components of the uniform plane wave in the propagating direction are always zero.

1.5 For the transmission line represented in Figure 2, find correct analysis about the circuit parameters at different working frequency f _____

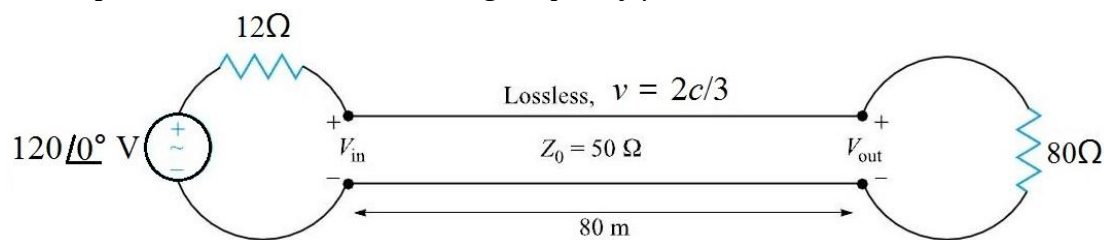


Figure 2

- A. If $f = 20$ Hz, the equivalent circuit is the voltage source driving the series combination of $(12+50+80)$ ohm resistor;
- B. If $f = 60$ Hz, the line is a lumped circuit, where $V_{s,out} = 104V$;
- C. If $f = 500$ kHz, the equivalent circuit is the voltage source driving the series combination of Z_{in} and the 12 ohm resistor;
- D. If $f = 800$ kHz, $V_{s,out}$ is a complex quantity given by $V_{s,out} = V_0^+ (1 + \Gamma_L)$.

1.6 Assume the electric field vector of a uniform plane wave in free space is given by

$$\mathbf{E}_s = 5e^{-j\beta x} \mathbf{a}_z + 7e^{-j\pi/4} e^{-j\beta x} \mathbf{a}_y \text{ V/m. Then the wave has } ______ \text{ polarization.}$$

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

1.7 Here are some descriptions about guided waves in a rectangular waveguide, Find out the wrong statements _____

- A. The TM Wave in Rectangular waveguide is standing wave along X and Y direction and traveling wave along z direction;
- B. In a hollow metal-pipe waveguide, the TEM wave is propagating in the conductor cavity;
- C. TE_{30} mode and TM_{30} mode have the same propagation constant;
- D. TE_{12} mode and TM_{12} mode have the same cutoff frequency.

Part 2. Fill-Up Problems. There are 8 problems in total, each is worth 4 points.

Please fill the blank in each question with a short answer.

- 2.1 As show in Figure 3, the location of a sliding bar is given by $x = 3t^2 + 4t$. The separation of the two rails is 50 cm. If $\mathbf{B} = 0.6x^3\mathbf{a}_z$ T, then what is the voltmeter reading at $t = 0.2$ s ? Please give the answer _____ V.

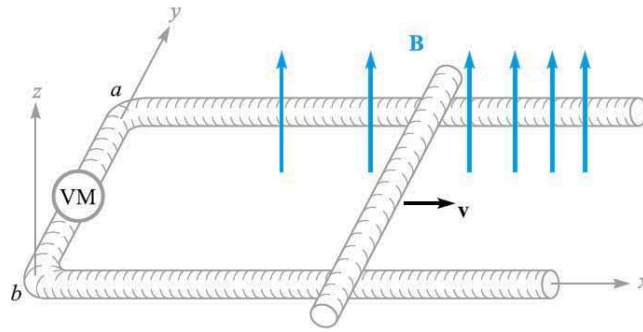
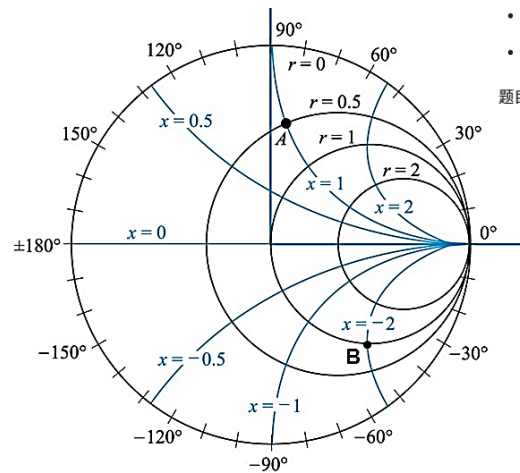


Figure 3

- 2.2 Consider a transmission line with a characteristic impedance of 20Ω , it has a smith chart as shown below. The normalized input and load impedances are marked as point A and point B, respectively. Then the load impedance can be written as _____ Ω



- 点 B 标记的是归一化负载阻抗 ($\bar{z}_L$)。
- 点 A 标记的是归一化输入阻抗 ($\bar{z}_{in}$)。

题目明确要求填写的是负载阻抗 (Z_L)。因此，您只需要根据点 B 来计算 Z_L 即可。

Figure 4 smith chart

- 2.3 Assume the elevator in a Teaching Building is made of the stainless steel which has some material parameters known as $\sigma = 1.2 \times 10^6$ S/m and $\mu_r = 500$ (If $\mu_0 = 4\pi \times 10^{-7}$ H/m for vacuum). When taking this elevator, People often found that the mobile phone working at 2 GHz frequency band had very weak signal. Please give some brief explanation about the physics underpinning this phenomenon and do the quantitative calculation for the related parameters. _____

- 2.4 A parallel-plate waveguide is known to have a cutoff wavelength of $\lambda_{c1} = 0.6$ cm for the $m=1$ TE and TM modes. Assume the waveguide is operated at wavelength $\lambda = 2$ mm. How many modes propagate? _____

2.5 A uniform plane wave is normally incident from air onto a material whose intrinsic impedance is unknown. Measurements yield a standing wave ratio of 3 and the appearance of an electric field minimum at 0.375 wavelengths in front of the interface. When the reflection coefficient is a complex number with a phase of ϕ , the field minimum is located at $z_{\min} = -(\phi + \pi)/2\beta$. Given that the intrinsic impedance of the uniform plane wave in vacuum is about 377Ω , Determine the impedance of the unknown material _____ Ω

2.6 A uniform plane wave in free space has electric field given by the expression $\mathbf{E}_s = 10e^{-j\beta x}\mathbf{a}_z + 15e^{-j\beta x}\mathbf{a}_y$ V/m. Then determine the average power density vector for the wave according to the definition $\mathbf{P}_{avg} = \frac{1}{2} \text{Re}\{\mathbf{E}_s \times \mathbf{H}_s^*\}$ W/m² _____

2.7 An air-filled rectangular waveguide is to be constructed for single-mode operation at 15 GHz. Specify the guide dimensions $a =$ _____ cm and $b =$ _____ cm, such that the design frequency is 10 percent higher than the cutoff frequency for the TE₁₀ mode, while being 10 percent lower than the cutoff frequency for the next-higher-order mode.

2.8 In the guide of Figure 5, it is found that $m = 1$ modes propagating from left to right totally reflect at the interface, so that no power is transmitted into the region of dielectric constant ϵ'_{r2} . where $\epsilon'_{r1} = 4.0$, $\epsilon'_{r2} = 2.1$, and $d = 1$ cm. Determine the range of frequencies over which this will occur _____

(Hint: Remember the critical angle? And the ray angle θ is given by $\cos\theta = f_{cm} / f$)

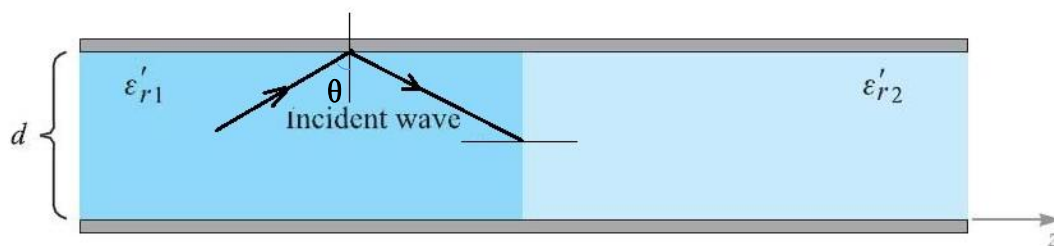


Figure 5

Part 3. Quantitative Calculation and Analysis. There are 3 problems with the total points of 40. Problem3.1 and Problem3.2 are worth 10 points respectively, Problem 3.3 is worth 20 points.

3.1 If the vector of magnetic field intensity for a uniform plane wave is given by $\mathbf{H} = \cos(10^{10}t - 2\beta x)\mathbf{a}_z$ A/m, Let $\mu = 3 \times 10^{-5}$ H/m, $\epsilon = 1.2 \times 10^{-10}$ F/m, and $\sigma = 0$ everywhere. Please use Maxwell's equations to obtain expressions for $\mathbf{B}$, $\mathbf{D}$, $\mathbf{E}$, and β .

3.2 A rectangular waveguide has dimensions $a = 8$ cm and $b = 5$ cm. (a) Over what range of frequencies will the guide operate single mode? (b) Over what frequency range will the guide support *both* TE_{10} and TE_{01} modes and no others?

3.3 A sinusoidal wave on a transmission line is specified by voltage and current in phasor form:

$$V_s(z) = V_0 e^{\alpha z} e^{j\beta z} \quad \text{and} \quad I_s(z) = I_0 e^{\alpha z} e^{j\beta z} e^{j\phi}$$

where V_0 and I_0 are both real. (a) In which direction does this wave propagate and why? (b) It is found that $\alpha = 0$, $Z_0 = 100 \, \Omega$, and the wave velocity is $v_p = 2.5 \times 10^8$ m/s, with $\omega = 2 \times 10^8 \, \text{s}^{-1}$. Evaluate R , G , L , C , λ , and ϕ .