

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. No score for wrong choice or less choice.

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_2
- D. TEM

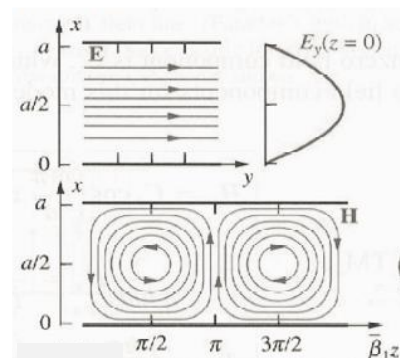


Figure 1

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

答案：C

解析：

对各选项的分析如下：

1. 选项 A：

- 错误。位移电流是时变电场的等效电流，本身不会产生焦耳热（焦耳热由传导电流的电荷运动产生）；且导体中主要是传导电流，位移电流可忽略，因此“仅在导体中产生焦耳热”的描述错误。

2. 选项 B：

- 错误。稳恒磁场中，若闭合回路**运动**（切割磁感线），会产生动生电动势，因此“无电动势”的结论不成立。

3. 选项 C：

- 正确。平行板电容器充电时，极板间无传导电流，但电场随时间变化，对应电位移通量的变化率（即位移电流），因此极板间存在位移电流。

4. 选项 D：

- 错误。导体中的电流除了自由电荷定向运动形成的传导电流，还可能存在位移电流（时变电场等效），因此“所有电流都是自由电荷定向运动”的描述不准确。

答案：A、B

解析：

法拉第电磁感应定律有**积分形式**和**微分形式**两种表达：

1. **选项 A**是法拉第定律的**积分形式**，描述闭合路径的感应电动势等于磁通量的时间变化率的负值；
2. **选项 B**是法拉第定律的**微分形式**（由斯托克斯定理从积分形式推导而来），描述电场的旋度等于磁感应强度的时间变化率的负值；
3. **选项 C**是修正后的安培环路定律，描述磁场的旋度与电流、位移电流的关系，不属于法拉第定律；
4. **选项 D**是高斯电场定律，描述电位移通量与闭合面内电荷的关系，也不属于法拉第定律。

- 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. For a uniform plane wave propagating in dielectrics, the E and H vectors always have 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 _____

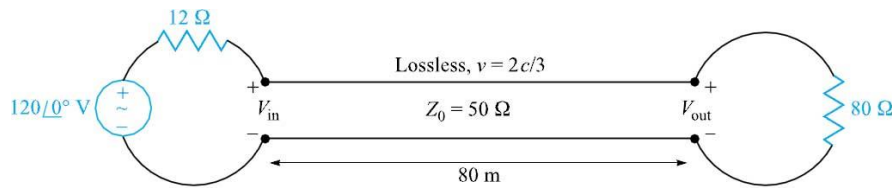


Figure 2

- 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

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

- 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.

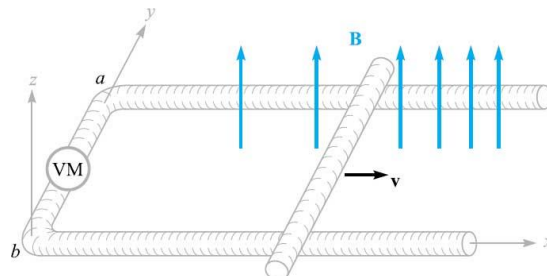


Figure 3

- 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

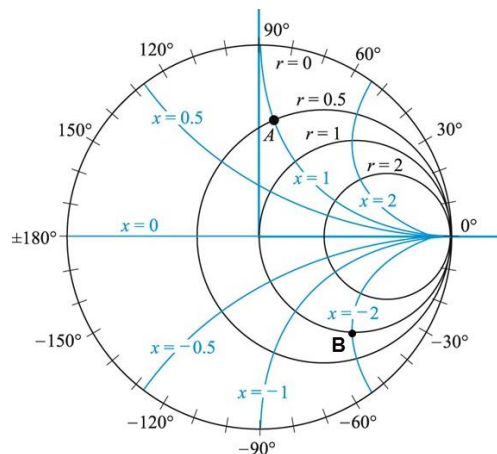


Figure 4 smith chart

- 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. Given that the intrinsic impedance of the uniform plane wave in vacuum is about $377\ \Omega$, 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} . Determine the range of the ray angle measured from the normal to the interface _____

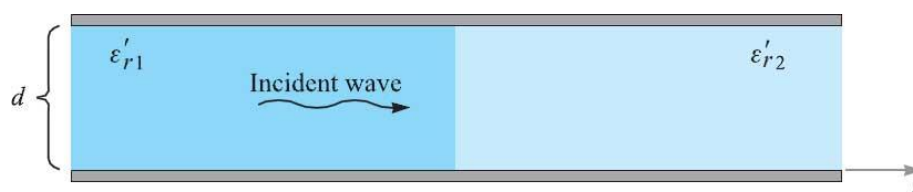


Figure 5

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 TE₁₀ and TE₀₁ modes and no others?

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

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

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 $v_p = 2.5 \times 10^8 \text{ m/s}$, with $\omega = 2 \times 10^8 \text{ s}^{-1}$. Evaluate R , G , L , C , λ , and ϕ .