ECE 329 Final Exam review

Head TAs: Pratik Joshi & Shuo Liu

Smith Chart: Find Z(l), V(l) and I(l) given Z_L and Z_o

STEPS

1. Calculate $z_L = Z_L/Zo$
2. Mark z_L on the SC
3. The distance from center of SC to z_L is $|\Gamma_L|$ and angle of $\angle \Gamma_L$ is measured counterclockwise from the real axis.
4. To find z(l) rotate clockwise (towards generator) by $\theta = l*(360/0.5\lambda)$
5. Calculate $Z(l) = z(l)Zo$ and $\Gamma(l) = |\Gamma_L| \angle \Gamma_L + \theta$
6. Using voltage divider rule find $V(l) = Vg[Z(l)/Zg + Z(l)]$
7. Calculate V^+ from $V(l) = V^+(e^{-j\beta l} + \Gamma_L e^{j\beta l})$
8. Calculate V(l) for any given l by substituting V^+ back in step 4
9. $I(l) = V(l)/Z(l)$ at any given l

Smith Chart: Quarter wave transformer

STEPS

1. Calculate $z_L = Z_L/Zo$
2. Mark z_L on the SC
3. The distance from center of SC to z_L is $|\Gamma_L|$ and angle of $\angle\ \Gamma_L$ is measured counterclockwise from the real axis.
4. Draw a circle from center of SC with radius $|\Gamma_L|$
5. The point z_L' where the circle intersects the real axis (i.e. where the impedance is purely real)
6. Starting at z_L, measure the angle you rotate towards the generator (i.e. clockwise) until you reach z_L'. This angle will give you the distance (d_1) of the quarter-wave transformer from the load in λ-units
7. The impedance at this point will be $Z(d_1) = Zo \cdot z_L$'
8. Characteristic impedance of quarter wave transformer is then $Zqo = \sqrt{(Zo.Z(d_1))}$

Smith Chart: Calculate Z_L given VSWR

STEPS

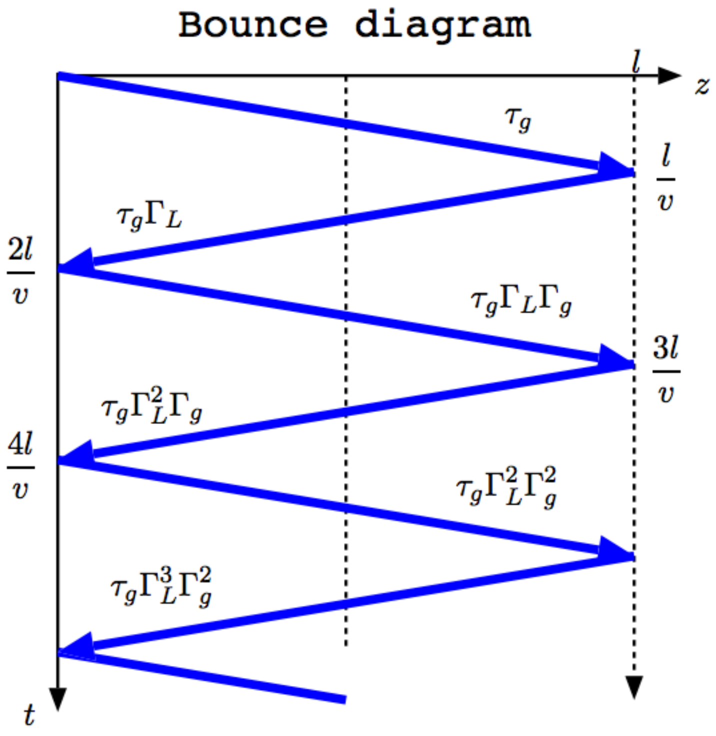
1. Calculate $d_{min\ or}$ d_{max} using the fact that on TL, 2 minima or two maxima are separated using 0.5λ.
2. On SC, mark $z(d_{max})$ = VSWR+j0 and $z(d_{min})$ = (1/VSWR)+ j0 as A and B, respectively.
3. Draw a circle from center of SC with radius = VSWR
4. Starting from point B, rotate counter-clockwise (towards load) on the circle by a distance of $d_{min.}$(in λ-units). Call this point C. Read z_L corresponding to point C
5. The distance from center of SC to point C is $|\Gamma_L|$ and angle of $\angle\ \Gamma_L = -180^o + d_{min}(360^o/0.5\lambda)$
6. Solve for $|V^+|$ and $|V^-|$ using $|V_{max}| = |V^+| + |V^-|$, $|V_{min}| = |V^+| - |V^-|$
7. VSWR = $|V_{max}| / |V_{min}|$

Smith Chart: Impedance matching using stubs

STEPS

1. Calculate $z_L = Z_L/Zo$
2. Calculate $y_L = 1/z_L$
3. Mark y_L on the SC
4. The distance from center of SC to y_L is $|\Gamma_L|$
5. Draw a circle from center of SC with radius $|\Gamma_L|$
6. Rotate along the circle from point y_L towards the generator (clockwise) until we reach the circle $g = 1$, and the intersection point reads $y(d_1) = 1 + jx$.
7. The rotated distance (d_1) is the distance from the load where the stub should be placed on the TL
8. The admittance of the stub should be $ys = -jx$.
9. **For short circuit stub**: To determine the length of the stub, we locate the short point $y = \infty$ and rotate on the outermost circle (r=0) on SC towards the generator (clockwise) until we reach the point $y = -jx$.
10. **For open circuit stub**: To determine the length of the stub, we locate the open point $y = 0$ and rotate on the outermost circle (r=0) on SC towards the generator (clockwise) until we reach the point $y = -jx$.
11. The rotation distance in λ-units is the length of the stub (ds)

Bounce diagrams



STEPS

1. $\tau = Z_o/Z_g+Z_o$
2. $|\Gamma_L| = (Z_L - Zo)/(Z_L+Z_o)$
3. $|\Gamma_g| = (Z_g - Z_o)/(Z_g+Z_o)$
4. Calculate V and I as follows:

$$\begin{aligned} V(z,t) &= \tau_g \sum_{n=0}^{\infty} (\Gamma_L\Gamma_g)^n \delta(t - \frac{z}{v} - n\frac{2\ell}{v}) \\ &+\tau_g\Gamma_L \sum_{n=0}^{\infty} (\Gamma_L\Gamma_g)^n \delta(t + \frac{z}{v} - (n+1)\frac{2\ell}{v}) \end{aligned}$$

and

$$\begin{aligned} I(z,t) &= \tfrac{\tau_g}{Z_o} \sum_{n=0}^{\infty} (\Gamma_L\Gamma_g)^n \delta(t - \frac{z}{v} - n\frac{2\ell}{v}) \\ &-\frac{\tau_g}{Z_o}\Gamma_L \sum_{n=0}^{\infty} (\Gamma_L\Gamma_g)^n \delta(t + \frac{z}{v} - (n+1)\frac{2\ell}{v}). \end{aligned}$$

. If we have electrostatics in a region where $\mathbf{J_f} = 0$, $\rho_f = 0$, $\mu = \mu_0$ but $\epsilon = \epsilon(x)$ depends on position: A

A. $\nabla \cdot \mathbf{D} = 0$

B. $\nabla \cdot \mathbf{P} = 0$

C. $\nabla \cdot \mathbf{E} = 0$

D. $\mathbf{E} = \nabla V$

$$\nabla \cdot \boldsymbol{D} = 0$$
$$\boldsymbol{D} = \epsilon_0 \boldsymbol{E} + \boldsymbol{P}$$
$$\boldsymbol{E} = -\nabla V$$

. For two conducting parallel plates with stored charge Q, potential difference V, plate area A, and distance between the plates d, that are filled with a dielectric with permittivity ε: A B

A. If ε is doubled, but Q is kept the same, V is reduced by 2x.

B. If both the permittivity, ε, and the distance between the plates, d, are doubled, Q and V can remain unchanged.

C. Capacitance decreases as A increases.

D. If ε is doubled, but V is kept the same, Q is reduced by 2x.

$$C = \frac{\epsilon A}{d}$$

ii. For a bounded material with conductivity $\sigma > 0$, permeability $\epsilon > 0$, and an initial charge distribution $\rho(x, y, z)$: **B**

A. If $\sigma \neq \infty$ then a steady-state electric field can exist inside the material.

B. In steady-state charge will be present on the surface of the material.

C. ρ will evolve in time to a spatially uniform value ρ_0.

D. The total free charge will go to zero as $t \to \infty$.

v. If $\rho(t, r, \theta, \phi) = e^{-t}$ C/m^3 for the region $r < 5$: **B D**

A. The displacement field flux through the sphere bounding $r < 5$ is increasing with time.

B. $\nabla \cdot \mathbf{J} > 0$ for $r < 5$.

$$\nabla \cdot \mathbf{J} = -\frac{dp}{dt}$$

C. The charge at the origin is always increasing.

D. The outflux of current for the sphere bounding $r < 5$ is positive.

v. Consider **two different** media (medium 1 and 2) bounded by a flat surface. The displacement flux vector **D** and electric field **E** perpendicular to and tangential with the boundary are denoted with subscript n and t, respectively. Which statement(s) are **always** true: C

A. $\mathbf{D}_{1n} = \mathbf{D}_{2n}$

B. If there is a surface current at the interface, then the **normal B** field is discontinuous.

C. $\mathbf{E}_{1t} = \mathbf{E}_{2t}$

D. If the media are perfect dielectrics, then the electric field inside each is reduced from it's free space value due to the polarization of free charges.

$$\hat{z} \cdot (\mathbf{D}^+ - \mathbf{D}^-) = \rho_s \quad \text{and} \quad \hat{z} \times (\mathbf{E}^+ - \mathbf{E}^-) = 0$$

b) (2 points) A uniform plane wave traveling in a perfect dielectric with η_1 is normal incident on a semi-infinite perfect dielectric region with η_2. It is known that the magnitude of the time-average power density of the incident wave is $| < \mathbf{S}_i > | = \frac{|E_0|^2}{2\eta_1}$. Write the letter in the box of the answer that expresses the magnitude of the time-average power density of the *transmitted* wave, $| < \mathbf{S}_t > |$, in terms of the $| < \mathbf{S}_i > |$.

(A) $| < \mathbf{S}_t > | = \Gamma | < \mathbf{S}_i > |$

(B) $| < \mathbf{S}_t > | = |\tau|^2 | < \mathbf{S}_i > |$

(C) $| < \mathbf{S}_t > | = (1 - |\Gamma|)^2 \, | < \mathbf{S}_i > |$

$\boxed{D}$

(D) $| < \mathbf{S}_t > | = \frac{\eta_1}{\eta_2} |\tau|^2 | < \mathbf{S}_i > |$

(E) $| < \mathbf{S}_t > | = |\Gamma|^2 | < \mathbf{S}_i > |$

i. (1 pt) If the transmission line is $\frac{\lambda}{2}$ long, the ratio of the voltage at the input to the voltage at the load is:

(A) 0, (B) 1, (C) -1, (D) ∞, (E) $-\infty$

$\boxed{C}$

ii. (2 pts) If $Y_{in} = \infty$ and $l = \frac{3}{4}\lambda$, then $Z_L =$

(A) 0, (B) Z_0, (C) ∞, (D) can't be determined

$\boxed{C}$

iii. (2 pts) If $\Gamma_L = j$ and $l = \frac{1}{8}\lambda$, then $\Gamma_{in} =$

(A) $-j$, (B) -1, (C) 0, (D) $+1$, (E) $+j$, (F) can't be determined

$\boxed{D}$

iv. (2 pts) If $Z_{in} = \infty$ and $l = \frac{1}{8}\lambda$, then $\Gamma_L =$

(A) $-j$, (B) -1, (C) 0, (D) $+1$, (E) $+j$, (F) can't be determined

E

v. (2 pts) If $Z_L = 2Z_0$, the voltage standing wave ratio VSWR along the line is:

(A) 0, (B) $\frac{1}{2}$, (C) 1, (D) 2, (E) ∞, (F) can't be determined

D

vi. (2 pts) If $Z_L = 2Z_0$, the fraction of power absorbed by the load is:

(A) 0, (B) $\frac{1}{9}$, (C) $\frac{1}{3}$, (D) $\frac{2}{3}$, (E) $\frac{8}{9}$, (F) 1

E

2. (17 points) True/false and multiple choice questions. No explanation necessary. No partial credit on an individual sub-question. For reference, there is a Smith chart near the back of the exam.

Knowing that the Smith Chart (SC) is the diagram of the generalized line reflection coefficient $\Gamma(d)$ satisfying a bilinear relationship with the normalized impedance $z(d)$, answer the following. Here d is the distance between the load and a location along the transmission line (TL) measured from the load.

a) (2 pts) True or False: The SC occupies the unit circle $|\Gamma(d)| \leq 1$ in the complex Γ-plane with the center at the origin of the Γ-plane. T

b) (2 pts) True or False: The load reflection coefficient Γ_L lies on the real axis of SC. F

(**Multiple choice: Indicate ALL that apply: some parts may have more than one correct answer**)

c) (2 pts) The SC corresponding to a pure capacitive load consists of this part of the unit circle:

(A) upper half (B) lower half (C) right half (D) left half (E) entire circle B

d) (2 pts) As one moves along the TL from the load side towards the generator, a travel distance of λ corresponds to a rotation of $\Gamma(d)$ on the SC by:

(A) a quarter circle (B) a half circle (C) a full circle (D) two full circles (E) the amount of rotation depends on the characteristic impedence of the TL D

e) (2 pts) The $z(d)$ values along the circumference of the unit circle ($|\Gamma(d)| = 1$) include the following:

(A) all purely resistive impedances (B) all purely reactive impedances (C) the maximum magnitude of all impedances (D) any possible impededance (E) none of the above B

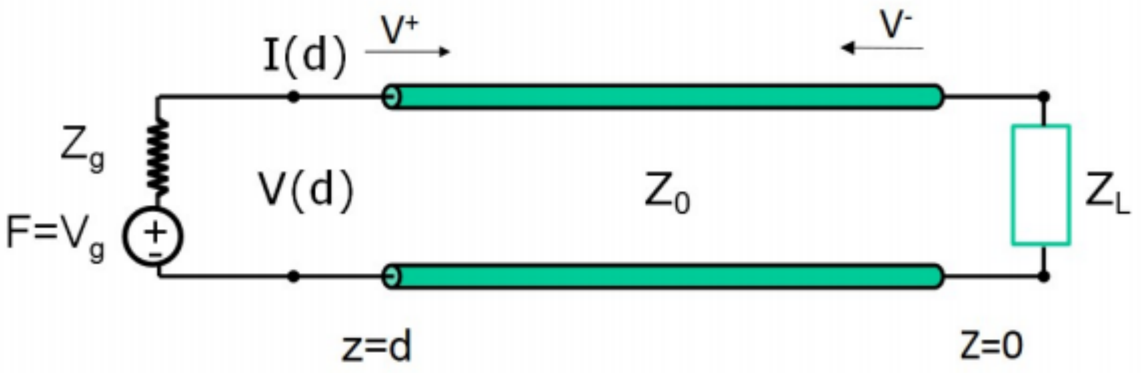
f) (3 pts) Once $z(d) = r + jx$ is found on the SC, then the normalized admittance $y(d)$ can be found by:

(A) $y(d) = -r - jx$ (B) $y(d) = -r + jx$ (C) rotating the $\Gamma(d)$ corresponding to $z(d)$ by a half circle and reading the griddings r and x of the resulting $\Gamma(d)$ (D) reading the griddings r and x of $-\Gamma(d)$ (E) none of the above C D

g) (4 pts) The voltage standing wave ratio (VSWR) along a TL can be determined as:

(A) $\frac{|V|_{max}}{|V|_{min}}$ (B) $\frac{|1+\Gamma(d)|_{max}}{|1+\Gamma(d)|_{min}}$ (C) $\frac{1+|\Gamma(d)|}{1-|\Gamma(d)|}$ at any location d (D) $z(d_{max})$ (E) $y(d_{min})$ (F) none of the above A-E

4. (24 points, 3 pts each) In the sytem shown in the figure below, the tramssion line is in steady state. **Choose ALL correct answers** to each of the following questions:



ii

a) β is the wave number for the waves propagating on the transmission line. $V^+$and V^-represent the magnitude of forward and backward traveling wave on the transmission line respectively. What is the phasor form expression of the voltage and current waveform traveling towards the load impedance?

i. Voltage: $V^+e^{j\beta d}$ Current:$V^+e^{-j\beta d}/Z_0$

ii. Voltage: $V^+e^{j\beta d}$ Current:$V^+e^{j\beta d}/Z_0$

iii. Voltage: $V^+e^{j\beta d}$ Current:$-V^+e^{j\beta d}/Z_0$

iv. Voltage: $V^+e^{-j\beta d}$ Current:$V^+e^{-j\beta d}/Z_0$

v. Voltage: $V^+e^{-j\beta d}$ Current:$-V^+e^{j\beta d}/Z_0$

vi. Voltage: $V^+e^{-j\beta d}$ Current:$V^+e^{j\beta d}/Z_0$

V

b) What is the phasor form expression of the voltage and current waveform traveling towards the source?

i. Voltage: $V^-e^{j\beta d}$ Current:$V^-e^{-j\beta d}/Z_0$

ii. Voltage: $V^-e^{j\beta d}$ Current:$V^-e^{j\beta d}/Z_0$

iii. Voltage: $V^-e^{j\beta d}$ Current:$-V^-e^{-j\beta d}/Z_0$

iv. Voltage: $V^-e^{-j\beta d}$ Current:$V^-e^{-j\beta d}/Z_0$

v. Voltage: $V^-e^{-j\beta d}$ Current:$-V^-e^{j\beta d}/Z_0$

vi. Voltage: $V^-e^{-j\beta d}$ Current:$V^-e^{j\beta d}/Z_0$

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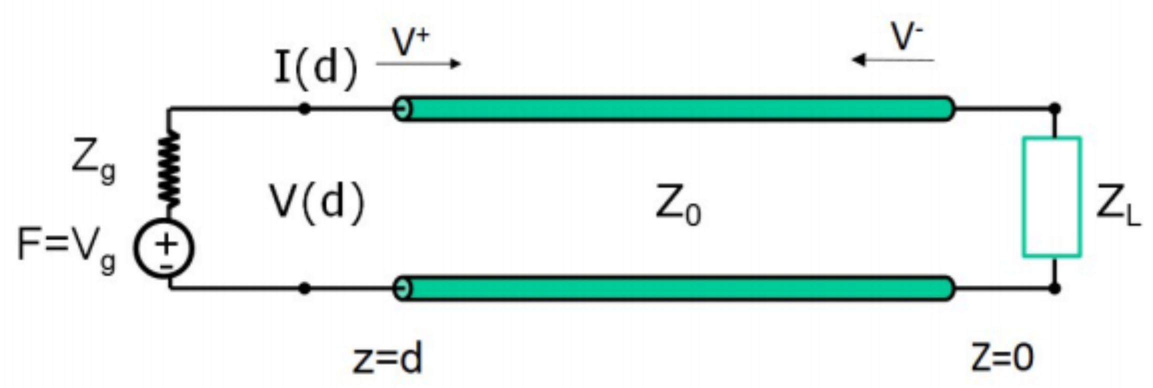


c) If the reflection coefficient at the load is given as: $\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$, which of the following expressions represent the votlage ($V(d)$) and current ($I(d)$) phasor at the input of the transmission line ($z = d$) ?

i. $V(d) = V^+ e^{j\beta d}(1 - \Gamma_L e^{-2j\beta d})$ and $I(d) = \frac{V^+ e^{j\beta d}(1+\Gamma_L e^{-2j\beta d})}{Z_0}$

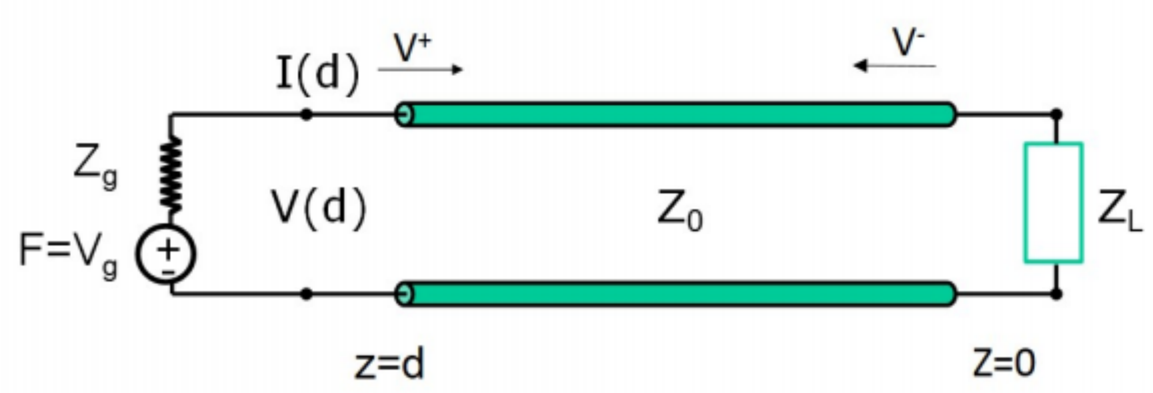
ii. $V(d) = V^- e^{-j\beta d}(\Gamma_L e^{2j\beta d} + 1)$ and $I(d) = \frac{V^- e^{-j\beta d}(\Gamma_L e^{2j\beta d}+1)}{Z_0}$

iii. $V(d) = V^- e^{-j\beta d}(\frac{1}{\Gamma_L} e^{2j\beta d} + 1)$ and $I(d) = \frac{V^- e^{-j\beta d}(\frac{1}{\Gamma_L} e^{2j\beta d}-1)}{Z_0}$

iv. $V(d) = V^+ e^{j\beta d}(1 + \Gamma_L e^{-2j\beta d})$ and $I(d) = \frac{V^+ e^{j\beta d}(1+\Gamma_L e^{-2j\beta d})}{Z_0}$

v. $V(d) = V^+ e^{j\beta d}(1 - \Gamma_L e^{-2j\beta d})$ and $I(d) = \frac{V^+ e^{j\beta d}(1-\Gamma_L e^{-2j\beta d})}{Z_0}$

4. (24 points, 3 pts each) In the sytem shown in the figure below, the tramssion line is in steady state. **Choose ALL correct answers** to each of the following questions:



ii

d) What is the smallest distance d from the load, **IN GENERAL,** for which the input voltage = the load voltage?

i. $d_{min} = 0.75\lambda$

ii. $d_{min} = \lambda$

iii. $d_{min} = 2\lambda$

iv. $d_{min} = 0.125\lambda$

v. $d_{min} = 0.25\lambda$

vi. $d_{min} = 0.5\lambda$

vi

e) What is the smallest distance d from the load for which the input impedance (Z_{in}) = the load impedance (Z_L)?

i. $d_{min} = 0.75\lambda$

ii. $d_{min} = \lambda$

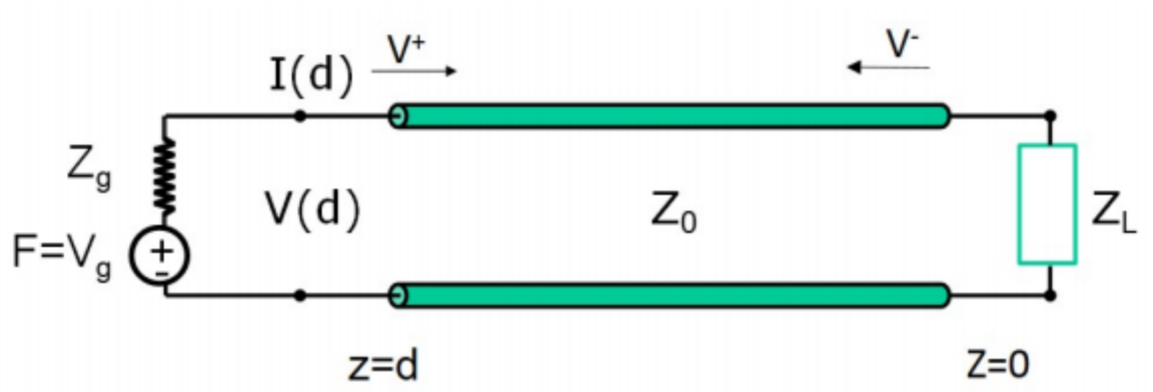
iii. $d_{min} = 2\lambda$

iv. $d_{min} = 0.125\lambda$

v. $d_{min} = 0.25\lambda$

vi. $d_{min} = 0.5\lambda$

4. (24 points, 3 pts each) In the sytem shown in the figure below, the tramssion line is in steady state. **Choose ALL correct answers** to each of the following questions:



iv v vii

f) Which of the following is/are true?

i. If the load is a pure resistor, the input impedance is also resistive.

ii. If the load is an inductor, the input impedance is always capacitive.

iii. VSWR can be smaller than 1 for the above system.

iv. if $Z_L = Z_0$, the input impedance is Z_0 for any d values.

v. If the load is an inductor and a capacitor connected in paralell, it is possible that the input impedance is inductive.

vi. The VSWR is infinity only if the load is short or open.

vii. The larger the VSWR is, the larger the magtitude of $\Gamma_L$is.

ii iii

g) If the transmission line is 2.4 λ long and reflection coefficient at the load is neither zero nor ± 1, how many voltage max points are on the transmission line for the partial standing wave ?

i. 3

ii. 4

iii. 5

iv. 2

v. 1

vi. 6