Subject Name Solutions

4351103 – Winter 2023

Semester 1 Study Material

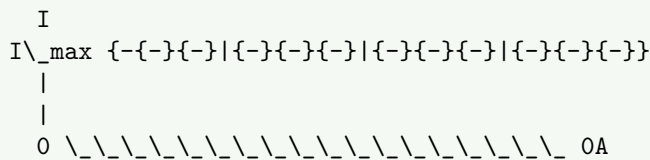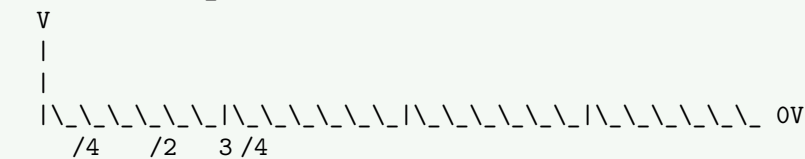*Detailed Solutions and Explanations*

Question 1(a) [3 marks]

Sketch the standing wave pattern for voltage and current along the transmission line when it is terminated with (i) Short Circuit, (ii) Open circuit, and (iii) Matched Load.
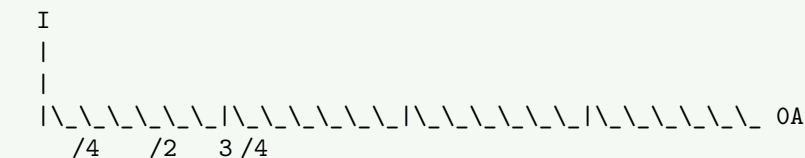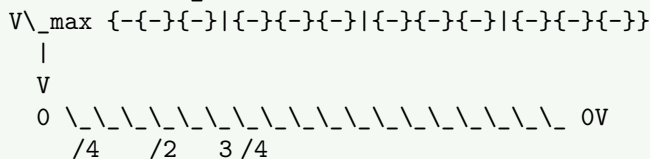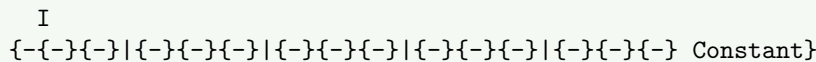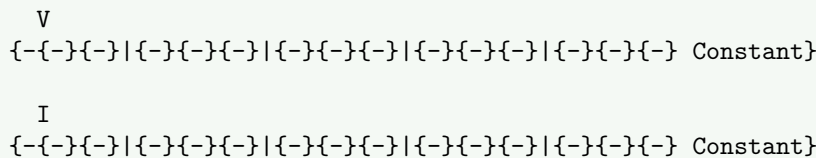
> **Solution**
>
> **Diagram:**
>
> ```
> Short Circuit (Z\_L = 0):
>     V
>     |
>     |
>     |_____|_____|_____|_____ 0V
>       /4    /2   3 /4
>
>     I
>   I\_max {-{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-}}
>     |
>     |
>     0 _____ 0A
>
> Open Circuit (Z\_L = ):
>    V\_max {-{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-}}
>     |
>     V
>     0 _____ 0V
>       /4    /2   3 /4
>
>     I
>     |
>     |
>     |_____|_____|_____|_____ 0A
>       /4    /2   3 /4
>
> Matched Load (Z\_L = Z\_0):
>     V
>    {-{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-} Constant}
>
>     I
>    {-{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-}|{-}{-}{-} Constant}
> ```
>
> - **Short Circuit**: Voltage minimum at load, current maximum at load
> - **Open Circuit**: Voltage maximum at load, current minimum at load
>
> - **Matched Load**: Constant voltage and current, no reflections
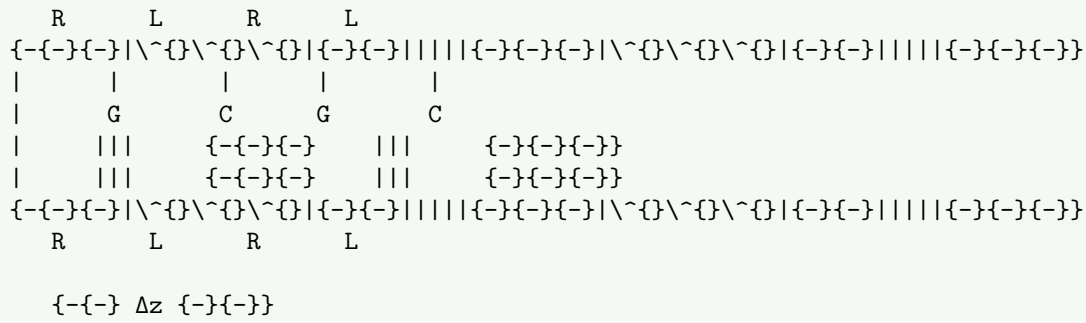
> **Mnemonic**
>
> "SOC - Short Opens Current, Open Shorts Current"

Question 1(b) [4 marks]

Draw and Explain equivalent circuit of two parallel wire transmission line at microwave frequency.

Solution

Diagram:

```
     R     L     R     L
  {-{-}{-}|\^{}\^{}\^{}|{-}{-}|||||{-}{-}{-}|\^{}\^{}\^{}|{-}{-}|||||{-}{-}{-}}
     |       |       |       |       |
     |       G       C       G       C
     |      |||    {-{-}{-}    |||     {-}{-}{-}}
     |      |||    {-{-}{-}    |||     {-}{-}{-}}
  {-{-}{-}|\^{}\^{}\^{}|{-}{-}|||||{-}{-}{-}|\^{}\^{}\^{}|{-}{-}|||||{-}{-}{-}}
     R     L     R     L


     {-{-} Δz {-}{-}}
```

- **R**: Series resistance per unit length (conductor losses)
- **L**: Series inductance per unit length (magnetic field storage)
- **G**: Shunt conductance per unit length (dielectric losses)
- **C**: Shunt capacitance per unit length (electric field storage)

Primary Constants Table:

Parameter	Symbol	Unit	Effect
Resistance	R	Ω/m	Power loss
Inductance	L	H/m	Magnetic energy
Conductance	G	S/m	Leakage current
Capacitance	C	F/m	Electric energy

Mnemonic

"RLGC - Really Large   Cables"

Question 1(c) [7 marks]

Explain Principle, construction and working of Isolator with necessary sketch.

Solution

Principle: Isolator allows microwave signal to pass in forward direction only using **ferrite material** and **Faraday rotation effect**.

Construction Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Port] {-{-}{} B[Ferrite Rod]}
    B {-{-}{} C[Permanent Magnet]}
    C {-{-}{} D[Output Port]}
    E[Resistive Load] {-{-}{} B}
    F[Waveguide] {-{-}{} B}
{Highlighting}
{Shaded}
```

Working:
- **Forward direction**: Signal passes through ferrite with minimal loss
- **Reverse direction**: Signal is rotated $45°$ and absorbed by resistive load
- **Magnetic field** biases ferrite material
- **Isolation**: 20-30 dB typical

Applications:
- **Protects** transmitter from reflected power
- **Prevents** oscillations in amplifier circuits

- **Maintains** source impedance matching

Specifications Table:

Parameter	Value	Unit
Isolation	20-30	dB
Insertion Loss	0.5-1	dB
VSWR	<1.5	-

Question 1(c OR) [7 marks]

Compare Transmission Line and Waveguide.

Solution

Comparison Table:

Parameter	Transmission Line	Waveguide
Frequency Range	DC to microwave	Above cutoff frequency
Power Handling	Limited	High power capability
Losses	Higher ($I^2 R losses$)	Lower (no center conductor)
Size	Compact	Bulky at low frequencies
Modes	TEM mode	TE and TM modes
Installation	Easy	Complex mounting
Cost	Lower	Higher
Bandwidth	Wide	Limited by modes

Key Differences:
- **Transmission line**: Uses two conductors, supports TEM mode
- **Waveguide**: Single hollow conductor, supports TE/TM modes
- **Cutoff frequency**: Waveguide has minimum operating frequency
- **Field pattern**: Different electromagnetic field distributions

Applications:
- **Transmission lines**: Low power, broadband applications
- **Waveguides**: High power radar, satellite communication

Question 2(a) [3 marks]

Define: (i) VSWR, (ii) Reflection Coefficient, and (iii) Skin effect

Solution

Definitions:
- **VSWR (Voltage Standing Wave Ratio)**: Ratio of maximum to minimum voltage amplitudes on transmission line
  - Formula: VSWR = $V\_max/V\_min = (1+|\Gamma|)/(1-|\Gamma|)$
- **Reflection Coefficient (Γ)**: Ratio of reflected to incident voltage amplitude
  - Formula: $\Gamma = (Z\_L - Z\_0)/(Z\_L + Z\_0)$
- **Skin Effect**: Current flows mainly on conductor surface at high frequencies
  - Skin depth: = $\sqrt{(2/)}$

Parameters Table: