

**SRM VALLIAMMAI ENGINEERING COLLEGE**  
**(An Autonomous Institution)**

SRM Nagar, Kattankulathur – 603 203

**DEPARTMENT OF**  
**ELECTRONICS AND COMMUNICATION ENGINEERING**

**QUESTION BANK**



**VII SEMESTER**  
**EC3761 – MICROWAVE AND OPTICAL COMMUNICATION**  
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## EC3761 – MICROWAVE AND OPTICAL COMMUNICATION

| UNIT I - MICROWAVE NETWORK AND CIRCUIT REPRESENTATION                                                                                                                                                             |                                                                                                                                                                                                                                                                                                        |             |          |               |           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------|---------------|-----------|
| Microwave frequency bands, S parameter representation of N ports, Properties, Advantages, Directional coupler, Waveguide Tees, Isolator, Circulator, Slotted section, Waveguide Bends, Matched loads, Attenuator. |                                                                                                                                                                                                                                                                                                        |             |          |               |           |
| PART A                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        |             |          |               |           |
| Q.No                                                                                                                                                                                                              | Questions                                                                                                                                                                                                                                                                                              | CO          | BT Level | Competence    |           |
| 1.                                                                                                                                                                                                                | What are microwave frequencies?                                                                                                                                                                                                                                                                        | CO1         | BTL 1    | Remembering   |           |
| 2.                                                                                                                                                                                                                | Identify the S band, C band, X band microwave frequency range.                                                                                                                                                                                                                                         | CO1         | BTL 1    | Remembering   |           |
| 3.                                                                                                                                                                                                                | What is the need for S-parameters?                                                                                                                                                                                                                                                                     | CO1         | BTL 1    | Remembering   |           |
| 4.                                                                                                                                                                                                                | A waveguide termination having VSWR of 1.1 is used to dissipate 100 watts of power. Find the reflected power.                                                                                                                                                                                          | CO2         | BTL 2    | Understanding |           |
| 5.                                                                                                                                                                                                                | Mention the advantages of microwave over the low frequencies.                                                                                                                                                                                                                                          | CO1         | BTL 2    | Understanding |           |
| 6.                                                                                                                                                                                                                | Why low frequency parameters are not used in microwaves?                                                                                                                                                                                                                                               | CO1         | BTL 2    | Understanding |           |
| 7.                                                                                                                                                                                                                | List the properties of S-parameters.                                                                                                                                                                                                                                                                   | CO1         | BTL 1    | Remembering   |           |
| 8.                                                                                                                                                                                                                | Give an expression for an insertion loss and return loss.                                                                                                                                                                                                                                              | CO1         | BTL 1    | Remembering   |           |
| 9.                                                                                                                                                                                                                | Write the unitary property of S-matrix.                                                                                                                                                                                                                                                                | CO1         | BTL 2    | Understanding |           |
| 10.                                                                                                                                                                                                               | Define Lossless network.                                                                                                                                                                                                                                                                               | CO1         | BTL 1    | Remembering   |           |
| 11.                                                                                                                                                                                                               | What is directional coupler?                                                                                                                                                                                                                                                                           | CO1         | BTL 2    | Understanding |           |
| 12.                                                                                                                                                                                                               | Mention the different types of directional couplers.                                                                                                                                                                                                                                                   | CO1         | BTL 2    | Understanding |           |
| 13.                                                                                                                                                                                                               | How do you define coupling factor of a directional coupler?                                                                                                                                                                                                                                            | CO1         | BTL 1    | Remembering   |           |
| 14.                                                                                                                                                                                                               | List the basic parameters to measure the performance of a directional coupler and write the relationship between it.                                                                                                                                                                                   | CO1         | BTL 1    | Remembering   |           |
| 15.                                                                                                                                                                                                               | What are waveguide Tees? Mention the different types.                                                                                                                                                                                                                                                  | CO1         | BTL 2    | Understanding |           |
| 16.                                                                                                                                                                                                               | What is magic tee?                                                                                                                                                                                                                                                                                     | CO1         | BTL 2    | Understanding |           |
| 17.                                                                                                                                                                                                               | Represent the S-matrix of E-plane and H-plane tees.                                                                                                                                                                                                                                                    | CO1         | BTL 2    | Understanding |           |
| 18.                                                                                                                                                                                                               | Mention the applications of magic tee.                                                                                                                                                                                                                                                                 | CO1         | BTL 1    | Remembering   |           |
| 19.                                                                                                                                                                                                               | Summarize the applications of circulator.                                                                                                                                                                                                                                                              | CO1         | BTL 1    | Remembering   |           |
| 20.                                                                                                                                                                                                               | What is an isolator? Write the S-matrix for an isolator.                                                                                                                                                                                                                                               | CO1         | BTL 2    | Understanding |           |
| 21.                                                                                                                                                                                                               | Outline the uses of isolators.                                                                                                                                                                                                                                                                         | CO1         | BTL 1    | Remembering   |           |
| 22.                                                                                                                                                                                                               | State the purpose of a matched load.                                                                                                                                                                                                                                                                   | CO1         | BTL 1    | Remembering   |           |
| 23.                                                                                                                                                                                                               | What is an attenuator?                                                                                                                                                                                                                                                                                 | CO1         | BTL 1    | Remembering   |           |
| 24.                                                                                                                                                                                                               | Mention the function of variable attenuator.                                                                                                                                                                                                                                                           | CO1         | BTL 2    | Understanding |           |
| PART B                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                        |             |          |               |           |
| 1.                                                                                                                                                                                                                | (i) How microwave junction can be described by scattering matrix? Derive the scattering matrix relation between the input and output of n*n port junction.<br>(ii) Write the expression of losses in terms of S parameters.                                                                            | (10)<br>(6) | CO1      | BTL 4         | Analyzing |
| 2.                                                                                                                                                                                                                | (i) Examine the S-parameter representation of two port microwave networks.<br>(ii) Discuss and explain the properties of [S] matrix.                                                                                                                                                                   | (8)<br>(8)  | CO1      | BTL 3         | Applying  |
| 3.                                                                                                                                                                                                                | A 50 Ω microwave integrated circuit amplifier has the following s-parameters: S11=0.12 ∠-10 <sup>0</sup> , S22= 0.01 ∠-15 <sup>0</sup> , S12=0.002∠78 <sup>0</sup> & S21=9.8 ∠160 <sup>0</sup> . Calculate the input VSWR, return loss, forward insertion power gain and reverse insertion power loss. | (16)        | CO1      | BTL 3         | Applying  |
| 4.                                                                                                                                                                                                                | Show the operation of E-plane Tee. Derive its S parameters.                                                                                                                                                                                                                                            | (16)        | CO1      | BTL 4         | Analyzing |

|     |                                                                                                                                                                                                                                                                                                                                                            |            |     |       |           |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-----|-------|-----------|
| 5.  | Explain the working principle of H-plane Tee and also derive the scattering matrix for it.                                                                                                                                                                                                                                                                 | (16)       | CO1 | BTL 4 | Analyzing |
| 6.  | (i) With the help of a neat diagram describe the working principle of magic Tee.<br>(ii) Find scattering matrix and applications of magic Tee.                                                                                                                                                                                                             | (8)<br>(8) | CO1 | BTL 3 | Applying  |
| 7.  | Infer the characteristics of directional coupler in terms of S parameters and explain in detail two-hole directional coupler.                                                                                                                                                                                                                              | (16)       | CO1 | BTL 4 | Analyzing |
| 8.  | What is Circulator? With neat diagram, explain the working principle, construction, operation of four port circulator. Verify the circulator theory with necessary S-parameter equations.                                                                                                                                                                  | (16)       | CO1 | BTL 3 | Applying  |
| 9.  | With neat diagram, discuss the characteristics of series Tee and shunt Tee and derive the S matrix.                                                                                                                                                                                                                                                        | (16)       | CO1 | BTL 3 | Applying  |
| 10. | Interpret the principle of operation of non-reciprocal device and derive the S parameters.                                                                                                                                                                                                                                                                 | (16)       | CO1 | BTL 3 | Applying  |
| 11. | (i) A 20 mW signal is fed into one of collinear port 1 of a lossless H-plane T-junction. Analyze the power delivered through each port when other ports are terminated in matched load.<br>(ii) In a H-plane T-junction, examine power delivered to the loads 40 ohm and 60 ohm connected to arms 1 and 2 when 10 mW power is delivered to matched port 3. | (8)<br>(8) | CO1 | BTL 4 | Analyzing |
| 12. | (i) Show with neat diagram explain the operation of waveguide bends.<br>(ii) Discuss in detail about various matched load used for a waveguide.                                                                                                                                                                                                            | (8)<br>(8) | CO1 | BTL 3 | Applying  |
| 13. | Demonstrate the principle of microwave transmission through ferrite and explain how an isolator is designed based on this effect.                                                                                                                                                                                                                          | (16)       | CO1 | BTL 4 | Analyzing |
| 14. | Explain the construction and working of an isolator based on Faraday rotation.                                                                                                                                                                                                                                                                             | (16)       | CO1 | BTL 3 | Applying  |
| 15. | A three-port circulator has an insertion loss of 1 dB, isolation 30 dB and VSWR is 1.5. Find the S-matrix.                                                                                                                                                                                                                                                 | (16)       | CO1 | BTL 3 | Applying  |
| 16. | With neat diagram explain the operation of attenuator in detail.                                                                                                                                                                                                                                                                                           | (16)       | CO1 | BTL 4 | Analyzing |
| 17. | Derive the S matrix for a directional coupler and also verifying the properties of it.                                                                                                                                                                                                                                                                     | (16)       | CO1 | BTL 4 | Analyzing |

## UNIT II MICROWAVE DEVICES

RWH theory, Gunn effect, Gunn diode, Avalanche transit time devices, PIN diode, TRAPATT diode, IMPATT diode, Principle, characteristics of TWT, Klystron, Reflex klystron, Magnetron, Applications of microwave devices.

### PART A

| Q.No | Questions                                    | CO  | BT Level | Competence  |
|------|----------------------------------------------|-----|----------|-------------|
| 1.   | Draw the equivalent circuit of a Gunn diode. | CO2 | BTL1     | Remembering |
| 2.   | List the modes of Gunn diode.                | CO2 | BTL 1    | Remembering |

|     |                                                             |     |       |               |
|-----|-------------------------------------------------------------|-----|-------|---------------|
| 3.  | Exhibit the negative resistance property in Gunn diode.     | CO2 | BTL 2 | Understanding |
| 4.  | Draw the equivalent circuit of PIN diode.                   | CO2 | BTL 1 | Remembering   |
| 5.  | Mention the applications of TRAPATT diode.                  | CO2 | BTL 2 | Understanding |
| 6.  | Compare Gunn and IMPATT diodes.                             | CO2 | BTL 2 | Understanding |
| 7.  | State the transferred electron effect.                      | CO2 | BTL1  | Remembering   |
| 8.  | Interpret the effect of transit time.                       | CO2 | BTL 1 | Remembering   |
| 9.  | What are avalanche transit time devices?                    | CO2 | BTL1  | Remembering   |
| 10. | Compare voltage and current controlled modes.               | CO2 | BTL 2 | Understanding |
| 11. | Give the classification of microwave tubes.                 | CO3 | BTL 1 | Remembering   |
| 12. | Mention the applications of reflex klystron.                | CO3 | BTL 1 | Remembering   |
| 13. | Differences between TWTA and klystron amplifier.            | CO3 | BTL 1 | Remembering   |
| 14. | What is velocity modulation?                                | CO3 | BTL 1 | Remembering   |
| 15. | What is the use of attenuator in TWTA?                      | CO3 | BTL 1 | Remembering   |
| 16. | What is magnetron?                                          | CO3 | BTL 1 | Remembering   |
| 17. | Express the equation for cyclotron angular frequency?       | CO3 | BTL 2 | Understanding |
| 18. | Summarize the applications of TWTA.                         | CO3 | BTL 2 | Understanding |
| 19. | What is the purpose of slow wave structures in TWT.         | CO3 | BTL 1 | Remembering   |
| 20. | Distinguish between O-type and M-type tubes.                | CO3 | BTL 2 | Understanding |
| 21. | Express Hull cutoff voltage equation.                       | CO3 | BTL 1 | Remembering   |
| 22. | What do you mean by an O-type tube? Name some O-type tubes. | CO3 | BTL 1 | Remembering   |
| 23. | Mention the characteristics of magnetron.                   | CO3 | BTL 2 | Understanding |
| 24. | Why magnetron is called as Cross field Devices?             | CO3 | BTL 2 | Understanding |

#### PART B

|    |                                                                                                                                                                                                                                                                     |      |     |       |           |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|-------|-----------|
| 1. | Describe the Ridley- Watkins-Hilsum (RWH) theory and explain the two-valley model using RWH theory.                                                                                                                                                                 | (16) | CO2 | BTL 4 | Analyzing |
| 2. | A reflex klystron is operated at 8 GHz with AC beam voltage of 600V for 1.75 mode, Repeller space length of 1mm, and dc beam current of 9 mA. The beam coupling coefficient is assumed to be 1. Calculate Repeller voltage, electronic efficiency and output power. | (16) | CO3 | BTL 4 | Analyzing |

|     |                                                                                                                                                                                                                                                                                                         |            |     |       |           |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-----|-------|-----------|
|     |                                                                                                                                                                                                                                                                                                         |            |     |       |           |
| 3.  | Explain the construction and working of IMPATT diode with neat diagrams.                                                                                                                                                                                                                                | (16)       | CO2 | BTL 3 | Applying  |
| 4.  | Explain the operation of PIN diode in detail and mention its applications.                                                                                                                                                                                                                              | (16)       | CO2 | BTL 4 | Analyzing |
| 5.  | Discuss the working principle of Gunn diode as a transferred electron device with two valley model, Also draw the structure, equivalent circuit and V-I characteristics of Gunn diode.(13)                                                                                                              | (16)       | CO2 | BTL 3 | Applying  |
| 6.  | Illustrate with interaction region diagram the mechanism of operation of TWT amplifier, its applications and the expression for the gain of a TWT.                                                                                                                                                      | (16)       | CO3 | BTL 4 | Analyzing |
| 7.  | (i) Comparison between the Gunn, IMPATT and TRAPATT diodes.<br>(ii) Discuss the voltage current waveform with respect to time of a TRAPATT diode and write its characteristics.                                                                                                                         | (8)<br>(8) | CO2 | BTL 4 | Analyzing |
| 8.  | Discuss the working principle of Gunn diode as a transferred electron device with two valley model, also draw the structure, equivalent circuit and V-I characteristics of Gunn diode.                                                                                                                  | (16)       | CO2 | BTL 3 | Applying  |
| 9.  | Discuss the working principle of Gunn diode oscillator and its modes.                                                                                                                                                                                                                                   | (16)       | CO2 | BTL 3 | Applying  |
| 10. | A TWT operates under the parameters: beam voltage = 3 KV, beam current = 30 mA, characteristics impedance of helix =10 $\Omega$ , circuit length = 50, frequency = 10 GHz. Calculate gain parameter, output power gain in dB, four propagation constants.                                               | (16)       | CO3 | BTL 4 | Analyzing |
| 11. | (i)Discuss the working principle of reflex klystron oscillator with necessary diagrams.<br>(ii)Derive velocity modulation, transit time of reflex klystron oscillator.                                                                                                                                  | (8)<br>(8) | CO3 | BTL 3 | Applying  |
| 12. | Examine the operation mechanism of two-cavity Klystron amplifier with neat sketch and write the expression for its output power.                                                                                                                                                                        | (16)       | CO3 | BTL 3 | Applying  |
| 13. | An identical two cavity Klystron amplifiers operates at 4GHz with $V_0=1$ kV, $I_0=22$ mA, cavity gap 1mm, drift space 3 cms. Calculate beam coupling coefficient, d.c. transit angle in drift space and input cavity voltage magnitude for maximum output voltage.                                     | (16)       | CO3 | BTL 3 | Applying  |
| 14. | A reflex klystron is operated at 9 GHz with dc beam voltage 600V, beam current 10mA, repeller space length of 1mm for $1\frac{3}{4}$ mode, Beam coupling coefficient is assumed to be 1. Calculate the repeller voltage, RF power output, electronic efficiency and the bandwidth over $\Delta VR=1V$ . | (16)       | CO3 | BTL 4 | Analyzing |

|     |                                                                                                                                                                                                                                                                                                                            |      |     |       |           |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|-------|-----------|
| 15. | A helix TWT operates at 4GHz under a beam voltage 10KV and beam current 500mA. If the helix impedance is $25 \Omega$ and the interaction length of 20cm, Find the O/P power gain in dB.                                                                                                                                    | (16) | CO3 | BTL 4 | Analyzing |
| 16. | Draw a neat sketch showing the constructional features of a cylindrical magnetron and derive an expression for cut off magnetic field.                                                                                                                                                                                     | (16) | CO3 | BTL 3 | Applying  |
| 17. | A pulsed cylindrical magnetron is operated with the following parameters:<br>Anode voltage=25kV, Beam current = 25A,<br>Magnetic density = $0.34 \text{ Wb/m}^2$ , Radius of cathode cylinder = 5 cm, Radius of anode cylinder = 10 cm<br>Calculate the angular frequency, cut off voltage, cut off magnetic flux density. | (16) | CO3 | BTL 4 | Analyzing |

### UNIT III MICROSTRIP LINES AND MICROWAVE MEASUREMENTS

Microstrip Lines and Filter Design: Microstrip lines, Losses in Microstrip lines, Quality factor of Microstrip lines, Microstrip line low pass and high pass filters.

Microwave Measurements: S parameters, Impedance, Frequency, Wavelength, Power, VSWR, and Attenuation.

#### PART A

| Q.No | Questions                                                                                                                                                                     | CO  | BT Level | Competence    |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|----------|---------------|
| 1.   | Define a strip lines.                                                                                                                                                         | CO4 | BTL 1    | Remembering   |
| 2.   | Identify the various configurations of planar transmission line.                                                                                                              | CO4 | BTL 1    | Remembering   |
| 3.   | Why are microstrip lines called as open strip lines?                                                                                                                          | CO4 | BTL 1    | Remembering   |
| 4.   | Write the characteristic impedance of microstrip lines.                                                                                                                       | CO4 | BTL 1    | Remembering   |
| 5.   | State the advantages of microstrip lines.                                                                                                                                     | CO4 | BTL 1    | Remembering   |
| 6.   | List the approximations considered for the radiation losses in a microstrip lines.                                                                                            | CO4 | BTL 2    | Understanding |
| 7.   | What are the different types of losses in microstrip lines?                                                                                                                   | CO4 | BTL 1    | Remembering   |
| 8.   | Summarize the significance of quality factor in microstrip lines.                                                                                                             | CO4 | BTL 2    | Understanding |
| 9.   | Name the types of microstrip filters.                                                                                                                                         | CO4 | BTL 1    | Remembering   |
| 10.  | A certain microstrip line has the following parameters $\epsilon_r = 5.23$ , $h = 7$ mils, $t = 2.8$ mils, $W = 10$ mils. Calculate the characteristic impedance of the line. | CO4 | BTL 2    | Understanding |
| 11.  | How did you determine the characteristics of the microstrip lines?                                                                                                            | CO4 | BTL 2    | Understanding |
| 12.  | Write the expression relating the skin depth and the ohmic losses.                                                                                                            | CO4 | BTL 1    | Remembering   |
| 13.  | What is the significance of VSWR measurement?                                                                                                                                 | CO4 | BTL 1    | Remembering   |
| 14.  | List any two methods used to measure impedance.                                                                                                                               | CO4 | BTL 1    | Remembering   |
| 15.  | Define reflection coefficient.                                                                                                                                                | CO4 | BTL 1    | Remembering   |
| 16.  | Distinguish between low-frequency measurements and microwave measurements.                                                                                                    | CO4 | BTL 2    | Understanding |
| 17.  | List the sensors used for measuring microwave power.                                                                                                                          | CO4 | BTL 1    | Remembering   |
| 18.  | Write down the relationship of guide wavelength, cutoff wavelength and free space wavelength of a waveguide.                                                                  | CO4 | BTL 2    | Understanding |
| 19.  | What is meant by VSWR?                                                                                                                                                        | CO4 | BTL 1    | Remembering   |
| 20.  | Distinguish between a thermistor and a barretter.                                                                                                                             | CO4 | BTL 2    | Understanding |

|        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |     |       |               |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----|-------|---------------|
| 21.    | Mention the possible errors in VSWR measurements.                                                                                                                                                                                                                                                                                                                                                                                                                                        |                          | CO4 | BTL 2 | Understanding |
| 22.    | Classify the power measurements.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                          | CO4 | BTL 2 | Understanding |
| 23.    | Define insertion loss.                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          | CO4 | BTL 1 | Remembering   |
| 24.    | What are the errors that occur in attenuation measurement?                                                                                                                                                                                                                                                                                                                                                                                                                               |                          | CO4 | BTL 1 | Remembering   |
| PART B |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |     |       |               |
| 1.     | Determine the characteristic impedance of the microstrip line and mention its limitations.                                                                                                                                                                                                                                                                                                                                                                                               | (16)                     | CO4 | BTL 4 | Analyzing     |
| 2.     | Elaborate on the field distribution in a strip line and explain the cross-sectional view of a microstrip line.                                                                                                                                                                                                                                                                                                                                                                           | (16)                     | CO4 | BTL 4 | Analyzing     |
| 3.     | Discuss the various losses in a microstrip line.                                                                                                                                                                                                                                                                                                                                                                                                                                         | (16)                     | CO4 | BTL 3 | Applying      |
| 4.     | Derive the quality factor of microstrip lines,                                                                                                                                                                                                                                                                                                                                                                                                                                           | (16)                     | CO4 | BTL 3 | Applying      |
| 5.     | Draw and explain the schematic diagram of a microstrip line and determine the dielectric and ohmic attenuation constant.                                                                                                                                                                                                                                                                                                                                                                 | (16)                     | CO4 | BTL 3 | Applying      |
| 6.     | Explain the dielectric losses and radiation losses of a microstrip line.                                                                                                                                                                                                                                                                                                                                                                                                                 | (16)                     | CO4 | BTL 4 | Analyzing     |
| 7.     | Derive the dielectric attenuation constant of a microstrip line which is approximately the reciprocal of the dielectric loss tangent.                                                                                                                                                                                                                                                                                                                                                    | (16)                     | CO4 | BTL 4 | Analyzing     |
| 8.     | A lossless parallel strip line has a conducting strip width $w$ . The substrate dielectric separating the two conducting strips has a relative dielectric constant $\epsilon_{rd}$ of 6 and a thickness $d$ of 4mm. calculate<br>(i) The required width $w$ of the conducting strip in order to have a characteristic impedance of $50\Omega$ .<br>(ii) The strip line capacitance<br>(iii) The strip line inductance<br>(iv) The phase velocity of the wave in the parallel strip line. | (4)<br>(4)<br>(4)<br>(4) | CO4 | BTL 3 | Applying      |
| 9.     | Explain the procedure for measuring the impedance of a load using the slotted-line and reflectometer methods.                                                                                                                                                                                                                                                                                                                                                                            | (16)                     | CO4 | BTL 3 | Analyzing     |
| 10.    | Explain the measurement of low & high VSWR with the help of a block diagram.                                                                                                                                                                                                                                                                                                                                                                                                             | (16)                     | CO4 | BTL 4 | Analyzing     |
| 11.    | Discuss the power sensors used for microwave power measurement.                                                                                                                                                                                                                                                                                                                                                                                                                          | (16)                     | CO4 | BTL 3 | Applying      |
| 12.    | With a neat diagram, explain the measurement of S parameters using network analyzer.                                                                                                                                                                                                                                                                                                                                                                                                     | (16)                     | CO4 | BTL 3 | Applying      |
| 13.    | Draw the experiential setup to find the attenuation and explain the procedure.                                                                                                                                                                                                                                                                                                                                                                                                           | (16)                     | CO4 | BTL 3 | Applying      |
| 14.    | A slotted line is used to measure the frequency and it was found that the distance between the nulls is 1.85 cm. Given the guide dimension as $3\text{ cm} \times 1.5\text{ cm}$ , calculate the frequency.                                                                                                                                                                                                                                                                              | (16)                     | CO4 | BTL 3 | Applying      |
| 15.    | With a neat diagram, explain how to measure frequency and wavelength using the slotted line technique.                                                                                                                                                                                                                                                                                                                                                                                   | (16)                     | CO4 | BTL 3 | Applying      |
| 16.    | Describe how the power of a microwave generator can be measured using the bolometer and calorimeter technique.                                                                                                                                                                                                                                                                                                                                                                           | (16)                     | CO4 | BTL 4 | Analyzing     |
| 17.    | Explain the double minimum method of measuring VSWR.                                                                                                                                                                                                                                                                                                                                                                                                                                     | (16)                     | CO4 | BTL 4 | Analyzing     |

| UNIT IV – OPTICAL FIBER STRUCTURES AND DIGITAL TRANSMISSION SYSTEMS                                                                                                                                                                                         |                                                                                                                                                                                                     |      |          |               |           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------|---------------|-----------|
| Elements of an optical fiber transmission link, Total internal reflection, Acceptance angle, Numerical aperture, Single mode fibers, Graded index fiber structure, Indoor and outdoor fiber cables, Fiber fabrication techniques, Linearly polarized modes. |                                                                                                                                                                                                     |      |          |               |           |
| PART A                                                                                                                                                                                                                                                      |                                                                                                                                                                                                     |      |          |               |           |
| Q.No                                                                                                                                                                                                                                                        | Questions                                                                                                                                                                                           | CO   | BT Level | Competence    |           |
| 1.                                                                                                                                                                                                                                                          | Draw the basic block diagram of an optical fiber communication system.                                                                                                                              | CO5  | BTL 2    | Understanding |           |
| 2.                                                                                                                                                                                                                                                          | What are the advantages of optical fiber?                                                                                                                                                           | CO5  | BTL 1    | Remembering   |           |
| 3.                                                                                                                                                                                                                                                          | State the reasons to opt for Optical fiber communication.                                                                                                                                           | CO5  | BTL 1    | Remembering   |           |
| 4.                                                                                                                                                                                                                                                          | What are the conditions for light to propagate inside a fiber?                                                                                                                                      | CO5  | BTL 1    | Remembering   |           |
| 5.                                                                                                                                                                                                                                                          | Define Numerical Aperture                                                                                                                                                                           | CO5  | BTL 2    | Understanding |           |
| 6.                                                                                                                                                                                                                                                          | State Snell’s Law.                                                                                                                                                                                  | CO5  | BTL 2    | Understanding |           |
| 7.                                                                                                                                                                                                                                                          | Why is partial reflection of light occurring in an optical fiber?                                                                                                                                   | CO5  | BTL 1    | Remembering   |           |
| 8.                                                                                                                                                                                                                                                          | What is total internal reflection in a fiber?                                                                                                                                                       | CO5  | BTL 1    | Remembering   |           |
| 9.                                                                                                                                                                                                                                                          | The refractive indices of the core and cladding of a silica fiber are 1.48 and 1.47 respectively. Find the Numerical Aperture (NA) of the fiber.                                                    | CO5  | BTL 2    | Understanding |           |
| 10.                                                                                                                                                                                                                                                         | Calculate critical angle of incidence between two substances with different refractive indices $n_1 = 1.5$ and $n_2 = 1.46$ .                                                                       | CO5  | BTL 2    | Understanding |           |
| 11.                                                                                                                                                                                                                                                         | Compare single-mode and Multimode fibers.                                                                                                                                                           | CO5  | BTL 2    | Understanding |           |
| 12.                                                                                                                                                                                                                                                         | Write the expression for the refractive index in graded index fibers.                                                                                                                               | CO5  | BTL 2    | Understanding |           |
| 13.                                                                                                                                                                                                                                                         | What is the necessity of cladding for an optical fiber?                                                                                                                                             | CO5  | BTL 2    | Understanding |           |
| 14.                                                                                                                                                                                                                                                         | Assume that there is a glass rod of refractive index 1.5, surrounded by air. Find the critical incident angle.                                                                                      | CO5  | BTL 2    | Understanding |           |
| 15.                                                                                                                                                                                                                                                         | Consider a parabolic index waveguide with $n_1 = 1.75$ , $n_2 = 1.677$ and core radius $25\mu\text{m}$ . Calculate the numerical aperture at the axis and at a point $20\mu\text{m}$ from the axis. | CO5  | BTL 1    | Remembering   |           |
| 16.                                                                                                                                                                                                                                                         | Mention the necessity of cladding for an optical fiber.                                                                                                                                             | CO5  | BTL 2    | Understanding |           |
| 17.                                                                                                                                                                                                                                                         | Why do we prefer step index SM fiber for long distance communication?                                                                                                                               | CO5  | BTL 1    | Remembering   |           |
| 18.                                                                                                                                                                                                                                                         | Why is sintering not needed in plasma chemical vapor deposition?                                                                                                                                    | CO5  | BTL 1    | Remembering   |           |
| 19.                                                                                                                                                                                                                                                         | A step-index fiber has a normalized frequency $V = 26.6$ at a 1300-nm wavelength. If the core radius is 25 mm, what is the numerical aperture?                                                      | CO5  | BTL 2    | Understanding |           |
| 20.                                                                                                                                                                                                                                                         | A SI fiber with silica core refractive index of 1.458, $V=75$ and $NA=0.3$ is to be operated at 820 nm. Determine its core size.                                                                    | CO5  | BTL 1    | Remembering   |           |
| 21.                                                                                                                                                                                                                                                         | Classify the fibers based on the index of refraction and modes.                                                                                                                                     | CO5  | BTL 2    | Understanding |           |
| 22.                                                                                                                                                                                                                                                         | A manufacturing Engineer wants to make an optical fiber that has a core index of 1.480 and cladding index of 1.478. Identify the core size for single mode operation at 1550 nm.                    | CO5  | BTL 2    | Understanding |           |
| 23.                                                                                                                                                                                                                                                         | Mention the characteristics of graded index fiber.                                                                                                                                                  | CO5  | BTL 2    | Understanding |           |
| 24.                                                                                                                                                                                                                                                         | Why should we prefer step-index single-mode fiber for long-distance communication?                                                                                                                  | CO5  | BTL 1    | Remembering   |           |
| PART B                                                                                                                                                                                                                                                      |                                                                                                                                                                                                     |      |          |               |           |
| 1.                                                                                                                                                                                                                                                          | With a neat block diagram, explain the elements of an optical fiber communication system.                                                                                                           | (16) | CO5      | BTL 3         | Applying  |
| 2.                                                                                                                                                                                                                                                          | Explain the phenomenon of total internal reflection using snell’s law with figures and calculations.                                                                                                | (16) | CO5      | BTL 4         | Analyzing |
| 3.                                                                                                                                                                                                                                                          | (i) Derive the expression for numerical aperture of the fiber.                                                                                                                                      | (8)  | CO5      | BTL 3         | Applying  |

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |            |     |       |           |
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|     | ii) A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50 $\mu\text{m}$ . The fiber has a numerical aperture of 0.2. Calculate the total number of guided modes propagating in the fiber when it is operating at a wavelength of 1 $\mu\text{m}$ .                                                                                                                                                                                                                                                                                                                                                                                                                          | (8)        |     |       |           |
| 4.  | (i) A step index fiber with suitably large core diameter for ray theory considerations has core and cladding refractive indices of 1.44 and 1.42 respectively. Calculate the acceptance angle for skew rays which change direction by 150 degrees at each reflection.<br>(ii) An optical fiber in air has a numerical aperture of 0.4. Compare the acceptance angle for meridional rays with that for skew rays which change direction by 100 degrees at each reflection and also comment on the result.                                                                                                                                                                                                                   | (8)<br>(8) | CO5 | BTL 3 | Applying  |
| 5.  | (i) A silica fiber with core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and cladding refractive index of 1.47. Determine (a) The critical angle at the core cladding interface (b) The NA for the fiber (c) The acceptance angle in air for the fiber.<br>(ii) Consider a multimode fiber that has a core refractive index of 1.480 and a core cladding index difference of 2%. Find the numerical aperture, the acceptance angle and the critical angle of the fiber                                                                                                                                                                                               | (8)<br>(8) | CO5 | BTL 3 | Applying  |
| 6.  | Explain the following fiber configurations with neat index profile diagrams.<br>(i). Step-Index (SI) fiber<br>(ii). Graded Index (GI)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | (8)<br>(8) | CO5 | BTL 4 | Analyzing |
| 7.  | (i) Consider a fiber with 25 $\mu\text{m}$ core radius, core index $n_1 = 1.48$ and $\Delta = 0.01$ . If $\lambda = 1320$ nm, what value of V and how many modes propagate in the fiber. What percent of optical power flows in the cladding? If the core cladding difference is reduced to $\Delta = 0.003$ , how many modes does the fiber support and what fraction of the optical power flows in the cladding.<br>(ii) Consider a multimode step index fiber with a 62.5 $\mu\text{m}$ core diameter and a core cladding index difference of 1.5%. If the core refractive index is 1.480, estimate the normalized frequency of the fiber and the total no of modes supported in the fiber at the wavelength of 850 nm. | (8)<br>(8) | CO5 | BTL 3 | Applying  |
| 8.  | Describe with the aid of simple ray diagrams.<br>(i). Single mode step index fibers<br>(ii). Multimode step index fibers                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | (8)<br>(8) | CO5 | BTL 4 | Analyzing |
| 9.  | A step-index silica fiber with a core radius much longer than the operating wavelength of light has a core refractive index of 1.50 and a cladding refractive index of 1.48. Estimate the values of<br>a) Numerical aperture of the fiber.<br>b) Maximum acceptance angle in air.<br>Maximum acceptance angle in water having a refractive index of 1.33.                                                                                                                                                                                                                                                                                                                                                                  | (16)       | CO5 | BTL 4 | Analyzing |
| 10. | Contrast the advantages and disadvantages of step index and graded index, single mode propagation and multimode propagation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | (16)       | CO5 | BTL 4 | Analyzing |
| 11. | List the various types of optical fiber cables explain each in brief with neat diagrams.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | (16)       | CO5 | BTL 4 | Analyzing |

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| 12. | (i) A multimode step index fiber with a core diameter of 80 $\mu\text{m}$ and a relative index difference of 1.5% is operating at a wavelength of 0.85 $\mu\text{m}$ . If the core refractive index is 1.48, estimate: (a) the normalized frequency for the fiber; (b) the number of guided modes.<br>(ii) A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50 $\mu\text{m}$ . The fiber has a numerical aperture of 0.2. Estimate the total number of guided modes propagating in the fiber when it is operating at a wavelength of 1 $\mu\text{m}$ . | (8)<br><br>(8) | CO5 | BTL 4 | Analyzing |
| 13. | (i) Explain the fiber fabrication method without involving preforms.<br>(ii) Write the advantages of optical fiber communication in detail.                                                                                                                                                                                                                                                                                                                                                                                                                                                             | (8)<br>(8)     | CO5 | BTL 4 | Analyzing |
| 14. | (i) A step-index fiber has an acceptance angle of $18^\circ$ in air. The fiber has a relative refractive index of 2.5%. Estimate the value of the critical angle at the core-cladding interface of the fiber and also the numerical aperture of the fiber.<br>(ii) A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47. Determine: (a) the critical angle at the core-cladding interface; (b) the NA for the fiber; (c) the acceptance angle in air for the fiber.             | (8)<br><br>(8) | CO5 | BTL 3 | Applying  |
| 15. | Explain in detail about fabrication process of preform and also explain about how fiber is pulled from a preform.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | (16)           | CO5 | BTL 3 | Applying  |
| 16. | Explain the following fiber fabrication techniques.<br>(i) Vapor Phase Axial Deposition (VAD).<br>(ii) Modified Chemical Vapor Deposition (MCVD)                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (8)<br>(8)     | CO5 | BTL 4 | Analyzing |
| 17. | Elaborate on the Linearly Polarized Modes in optical fibers.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | (16)           | CO5 | BTL 3 | Applying  |

#### UNIT V - OPTICAL SOURCES AND RECEIVERS

Direct and indirect band gap materials, LED structures: SLED, ELED, Concept of LASER diode, Operation of PIN diodes and Avalanche Photo diodes (APD), Probability of error and Error sources in optical systems, Point to point link system considerations, Link power budget and rise time budget.

##### PART A

| Q.No | Questions                                                                                         | CO  | BT Level | Competence    |
|------|---------------------------------------------------------------------------------------------------|-----|----------|---------------|
| 1.   | Why indirect band gap material is preferred for optical sources.                                  | CO6 | BTL 1    | Remembering   |
| 2.   | Draw the energy level diagram of P & N type semiconductor.                                        | CO6 | BTL 2    | Understanding |
| 3.   | Calculate the band gap energy for an LED to emit 850 nm,                                          | CO6 | BTL 1    | Remembering   |
| 4.   | Define internal quantum efficiency of LED.                                                        | CO6 | BTL 2    | Understanding |
| 5.   | What is meant by hetero junction? Give it advantages.                                             | CO6 | BTL 1    | Remembering   |
| 6.   | The carrier recombination lifetime for an LED is 10ns. Estimate the optical bandwidth of the LED. | CO6 | BTL 2    | Understanding |
| 7.   | Why is silicon not used to fabricate LED or Laser diodes?                                         | CO6 | BTL 2    | Understanding |
| 8.   | Mention the various types of LED structures.                                                      | CO6 | BTL 1    | Remembering   |
| 9.   | What are the several drawbacks of LED when compared to the injection lasers?                      | CO6 | BTL 2    | Understanding |

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| 10. | State the mechanisms behind the lasing action.                                                                                                                                                   | CO6 | BTL 1 | Remembering   |
| 11. | Give the expression for laser diode rate equation.                                                                                                                                               | CO6 | BTL 2 | Understanding |
| 12. | Classify the Laser structures.                                                                                                                                                                   | CO6 | BTL 2 | Understanding |
| 13. | Differentiate the optical sources LED and Laser.                                                                                                                                                 | CO6 | BTL 2 | Understanding |
| 14. | What is meant by population inversion?                                                                                                                                                           | CO6 | BTL 1 | Remembering   |
| 15. | A GaAs optical source with a refractive index of 3.6 is coupled to a silica fiber that has a refractive index of 1.48. what is the reflectivity for normal incidence of a plane wave.            | CO6 | BTL 1 | Remembering   |
| 16. | Contrast the advantages of PIN diode with APD.                                                                                                                                                   | CO6 | BTL 2 | Understanding |
| 17. | List the advantages of pin photodiodes.                                                                                                                                                          | CO6 | BTL 1 | Remembering   |
| 18. | Point out the drawbacks of avalanche photodiode.                                                                                                                                                 | CO6 | BTL 1 | Remembering   |
| 19. | Define bit error rate.                                                                                                                                                                           | CO6 | BTL 2 | Understanding |
| 20. | Illustrate the factors that determine the response time of the photodiode.                                                                                                                       | CO6 | BTL 2 | Remembering   |
| 21. | Calculate the photo generated current. Photons of energy $1.53 \times 10^{-19}$ J are incident on a photodiode which has the responsivity of 0.65 A/W. if the optical power level is 10 $\mu$ W. | CO6 | BTL 2 | Understanding |
| 22. | What are the error sources of the fiber optical receiver?                                                                                                                                        | CO6 | BTL 1 | Remembering   |
| 23. | What is meant by responsivity of photodiode?                                                                                                                                                     | CO6 | BTL 1 | Remembering   |
| 24. | A digital fiber-optic link operating at 1310 nm requires a maximum BER of $10^{-8}$ . Calculate the required average photons per pulse.                                                          | CO6 | BTL 2 | Understanding |

#### PART B

|    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |             |     |       |           |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----|-------|-----------|
| 1. | (i) What are direct band gap and indirect band gap semiconductors? Explain it with necessary diagrams.<br>(ii) Select the appropriate materials used for preparation of LED.                                                                                                                                                                                                                                                                                    | (10)<br>(6) | CO6 | BTL 3 | Applying  |
| 2. | Explain the N-type semiconductor and P-type semiconductor with relevant diagrams.                                                                                                                                                                                                                                                                                                                                                                               | (16)        | CO6 | BTL 4 | Analyzing |
| 3. | With a neat diagram explain the surface emitting LED.                                                                                                                                                                                                                                                                                                                                                                                                           | (16)        | CO6 | BTL 3 | Applying  |
| 4. | Explain the working principle of Edge emitting LED with necessary diagrams.                                                                                                                                                                                                                                                                                                                                                                                     | (16)        | CO6 | BTL 4 | Analyzing |
| 5. | (i) Derive the expression for internal quantum efficiency and the internal power generated in the LED.<br>(ii) A double hetero junction InGaAsP LED emitting at a peak wavelength of 1310 nm has radiative and non-radiative recombination times of 30 and 100 ns resp. The drive current of 40mA. Find bulk recombination time, the internal quantum efficiency, internal power level.                                                                         | (8)<br>(8)  | CO6 | BTL 4 | Analyzing |
| 6. | Express about external quantum efficiency and the external power generated in the LED with necessary equation.                                                                                                                                                                                                                                                                                                                                                  | (16)        | CO6 | BTL 3 | Applying  |
| 7. | The minority carrier recombination life time for an LED is 5ns.when a constant d.c current is applied to the device the optical power is 300 $\mu$ W. Calculate the optical output power when the device is modulated with an rms drive current corresponding to the d.c drive current at frequencies of (a) 20 MHz (b) 100MHz. Further determine the 3dB optical bandwidth for the device and estimate the 3dB electrical bandwidth assuming Gaussian response | (16)        | CO6 | BTL 3 | Applying  |
| 8. | Classify the various structures of laser diode and its radiation pattern with neat diagram.                                                                                                                                                                                                                                                                                                                                                                     | (16)        | CO6 | BTL 4 | Analyzing |
| 9. | A given GaAlAs laser diode has an optical cavity length of                                                                                                                                                                                                                                                                                                                                                                                                      | (16)        | CO6 | BTL 3 | Applying  |

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |      |     |       |           |
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|     | 300 $\mu$ m and 100 $\mu$ m width. At a normal operating temperature, the gain factor $\beta = 21 \times 10^{-3} \text{ A cm}^3$ and loss coefficient $\alpha = 10 \text{ cm}^{-1}$ . Assume the reflectivity is $R_1 = R_2 = R = 0.32$ for each end face. What is the threshold current density and threshold current for the device?                                                                                                                                                                                                                                                                                                                                                                         |      |     |       |           |
| 10. | Explain the working principle of PIN diodes with a neat diagram                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | (16) | CO6 | BTL 4 | Analyzing |
| 11. | An InGaAs pin photo diode has the following parameters at a wavelength of 1300 nm. $I_D = 4 \text{ nA}$ , $\eta = 0.90$ , $R_L = 1000 \Omega$ and the surface leakage current is negligible. The incident optical power is 300 nW and the receiver bandwidth is 20 MHz. Find the various noise terms of the receiver.                                                                                                                                                                                                                                                                                                                                                                                          | (16) | CO6 | BTL 3 | Applying  |
| 12. | Describe the working principle of Avalanche photodiode.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | (16) | CO6 | BTL 3 | Applying  |
| 13. | With a schematic diagram, explain the blocks and their functions of the major elements of a point-to-point optical fiber link, and the system considerations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | (16) | CO6 | BTL 4 | Analyzing |
| 14. | Derive the probability of error of the fiber optic receiver.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | (16) | CO6 | BTL 4 | Analyzing |
| 15. | Describe the various error sources in the optical receiver.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | (16) | CO6 | BTL 3 | Applying  |
| 16. | Elaborate the Link power budget and rise time budget.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | (16) | CO6 | BTL 4 | Analyzing |
| 17. | <p>(i) A transmitter has an output power of 0.1 mW. It is used with a fiber having <math>NA = 0.25</math>, attenuation of 6 dB/km and length 0.5 km. The link contains two connectors of 2 dB average loss. The receiver has a minimum acceptable power (sensitivity) of -35 dBm. The designer has allowed a 4 dB margin. Calculate the link power budget.</p> <p>(ii) For a multimode fiber link, the following parameters are recorded. LED with drive circuit has a rise time of 15 ns; LED spectral width is 40 nm; material dispersion-related rise-time degradation is 21 ns over a 6 km link; receiver bandwidth is 25 MHz; modal dispersion rise time is 3.9 nsec. Calculate the system rise time.</p> | (8)  | CO6 | BTL 3 | Applying  |