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Online Fiber Optics Training Course

Syllabus/Course Competencies

Table of Contents

1.0 The Telecommunications Market

1.1 Trace the path of an internet network from an Internet Service Provider (ISP) to various points of connections (homes, businesses, LAN, MAN and WAN)

1.2 Identify using the ISO/OSI Model (International Organization for Standards) the 7 Layers of Networking/Telecommunication

1.3 Describe the evolution of copper networking technologies to include:

1.3.1 personal computer performance advances

1.3.2 network type/loading advances

1.3.3 the information capacity of a network type (data rate)

2.0 High Speed Telecommunications Systems (The Need for Speed)

2.1 Explain Moore's Law as it relates to computer processing power and costs

2.2 Discuss the role of fiber optic networking as the need for speed increases

2.3 Explain analog signal testing parameters to include:

2.3.1 amplitude (peak, peak to peak, cycles, waves and sinusoidal waves)

2.3.2 frequency (cycles per second, hertz, kilo, mega, giga)

2.4 Explain digital signal testing parameters to include:

2.4.1 bits, binary digits, cycle, bytes, 1 and 0

2.4.2 digital data rates in Mbps

2.4.3 square waves

2.5 Relate bandwidth to data rates using the following parameters:

2.5.1 line encoding schemes

2.5.2 line capacity in bits/Hz/MHz/GHz

2.6 Describe the evolution of local area networks (LANs) from voice/low speed data to data grade/high speed data to include:

2.6.1 Category cabling (CAT 1 to CAT 6 and beyond)

2.6.2 bandwidth capacities of each category cabling

2.6.3 data rate capability of each category cabling

2.6.4 application types of each Category cabling

2.6.5 encoding methods for each Category cabling

2.6.6 fiber optic cabling for high speed gigabit Ethernet networks

2.6.7 VCSEL development and parameters

3.0 Industry Standards and Codes

3.1 Demonstrate the ability to differentiate between Industry Standards and Codes to include:

3.1.1 purposes are to protect life, health and property, to ensure construction consistency and quality

3.1.2 Codes are considered “law” while Industry Standards are considered Industry-accepted “rules”

3.2 List common Industry Standards Acronyms and match them to their respective abbreviated titles

3.3 List common Industry key definitions and match them with acronyms to include:

3.3.1 attenuation

3.3.2 backscatter

3.3.3 bandwidth

3.3.4 bit error rate

3.3.5 dB

3.3.6 dBm

3.3.7 reflection index matching gel

3.3.8 index of refraction

3.3.9 insertion loss

3.3.10 mode

3.3.11 numerical aperture

3.3.12 optical loss test set

3.3.13 Optical Time Domain Reflectometer (OTDR)

3.3.14 power loss budgets

3.3.15 Rayleigh's scattering

3.3.16 refraction

3.3.17 total internal reflection

3.3.18 FC, ST, SC, LC, MT/RJ, MTP/MPO and SFF connectors

3.4 Explain why Industry Standards lag behind new technologies development including the use of Standards Committees / Consortiums, Technical Service Bulletins (TSBs), ANSI/TIA/EIA Standards and required Safety Codes

4.0 ANSI/TIA/EIA & TSBs (Standards Affecting Telecommunications)

4.1 Describe how the Telecommunications Industry Standards were developed

4.2 Explain the relationships of ANSI, TIA, and the EIA in Telecommunications Industry Standards development

4.3 Demonstrate the ability to correctly understand and apply Telecommunication Industry Technical Service Bulletins (TSBs) to cabling standard specifications

4.4 Match the ANSI/TIA/EIA-569 (Commercial Building Standard for Telecommunications Pathways and Spaces) to its applications

4.5 Match the ANSI/TIA/EIA-570 (Residential and Light Commercial Telecommunications Wiring Standard) to its applications

4.6 Match the ANSI/TIA/EIA-606 (Administration Standard for the Telecommunications Infrastructure of Commercial Buildings) to its applications

4.7 Match the ANSI/TIA/EIA-607 (Commercial Building Grounding and Bonding Requirements for Telecommunications) to its applications

4.8 Match the ANSI/TIA/EIA-568-B (Commercial Building Telecommunications Cabling Standard) to its applications

4.9 Match the ANSI/TIA/EIA-568-B.3 (Commercial Building Telecommunications

Cabling Standard which includes Optical Fiber Cabling Installation Standard) to its applications

4.10 Identify the following Installation-Specific Codes and match them to their respective related topics:

4.10.1 NFPA-70 (National Fire Protection Association Code)

4.10.2 NEC (National Electrical Code)

4.10.3 Chapter 8-Communications Systems, (Article 250-Grounding and Bonding), (Article 770-Optical Fiber Cables and Raceways), (Article 800-Communications Systems) and (Article 820-CATV)

4.11 Identify the following Institute of Electrical and Electronic Engineers (IEEE) Network-Specific Standards and match them to their respective related topics:

4.11.1 IEEE 802.3 “Ethernet” with Carrier Sense Multiple Access and Collision Detection (CSMA/CD)

4.11.2 IEEE 802.5 “Token Ring”

4.11.3 ATM “Asynchronous Transfer Mode”

4.11.4 X3T9.5 “TP-PMD” (Twisted Pair-Physical Medium Dependent or CDDI-LAN Backbone)

5.0 ANSI/TIA/EIA-568-B Commercial Building Telecommunications Wiring Standard

5.1 Explain the parameters of the ANSI/TIA/EIA-568-B Standard to include:

5.1.1 defines the topologies

5.1.2 defines horizontal and backbone cabling

5.1.3 identifies media types

5.1.4 provides some installation requirements with distances

5.1.5 connector interface is specified

5.1.6 transmission requirements are specified

5.2 List the five sections of the Commercial Building Telecommunications Wiring Standard (EF: Entrance Facility cabling, ER: Equipment Room cabling, Backbone cabling, TR: Telecommunications Room cabling, and HC: Horizontal cabling)

5.3 Draw simple line diagrams of the four common Network Topologies (Point-to-Point, “Bus”, “Ring” and “Star”)

5.4 Describe Entrance Facilities (EF) including the following considerations:

5.4.1 aerial entrances

5.4.2 underground entrances (direct buried and tunnel between buildings)

5.4.3 grounding and protection considerations

5.4.4 NEC requirements (50ft for fire-rated cable)

5.4.5 TMGB

5.4.6 optical fiber construction for entrance facilities is dependent upon the intended application and the environment

5.5 Define the term “Demarcation Point” and explain the following commercial/shared tenant terms:

5.5.1 MPOE (Minimum-Point-Of-Entry)

5.5.2 CO (Central Office)

5.5.3 physical space location point

5.5.4 termination requirements

5.5.5 primary protection (Voltage)

5.6 Define the term “Equipment Room” and explain the following related topic areas:

5.6.1 “Building serving”

5.6.2 Main Cross connect (MC), “first level” Intermediate Cross connect (IC), “second level” backbone

5.6.3 Houses main electronics for voice and data

5.6.4 environmental, power and protection requirements

5.6.5 may function as Telecommunications Room (TR) or second floor Work Areas (WA)

5.7 Define the term “Backbone Cabling” and explain the following related topic areas:

5.7.1 Intra-building or Inter-building cabling

5.7.2 “Distribution” cabling

5.7.3 “Vertical” cabling

5.7.4 “Riser” cabling

5.8 List the 5 types of Backbone Cabling accepted in the TIA/EIA 568-B Standard including:

5.8.1 UTP

5.8.2 ScTP

5.8.3 STP

5.8.4 Multimode fiber

5.8.5 Single-mode fiber

5.8.6 (coax cable is recognized for existing wiring only but is not recommended)

5.9 List the Backbone Media Distance Parameters as defined in the TIA/EIA 568-B Standard

5.10 Define “Telecommunications Room” as defined in the TIA/EIA 568-B Standard

5.11 Define “Horizontal Cabling” as defined in the EIA/TIA 568-B Standard including:

5.11.1 maximum distances (in meters and in feet)

5.11.2 four types of acceptable cables

5.11.3 topology considerations

5.11.4 plenum considerations (CMP vs. CMR)

5.11.5 maximum pull force allowable, minimum bend radius

5.11.6 routing restrictions, resting restrictions, approved support systems

5.11.7 minimum “Category-rated cable” allowable

5.12 Cite the maximum “Basic Link” Configuration length (in meters and in feet)

5.13 Cite the maximum “Channel” Configuration lengths of the following:

5.13.1 user patch cords (in meters and in feet)

5.13.2 maximum Channel length (in meters and in feet)

5.13.3 equipment patch cords (in meters and in feet)

5.14 List the 4 accepted Horizontal Cable Media to the Work Area including the accepted Category Ratings for each Cable Media (coax cable is recognized for existing wiring only but is not recommended)

5.15 Discuss and define the terms “Collapsed Cabling” and “Fiber to the Workstation”

5.16 Define the term “Centralized Optical Fiber Cabling”

5.17 Define the term “Work Area”

5.18 Define the term “Communications Outlets” and related types of mounting (flush-mount; surface-mount; tombstone-mount)

6.0 ANSI/TIA/EIA 606 Administration Standard for Telecommunication Infrastructures of Commercial Buildings

6.1 State the purpose of the ANSI/TIA/EIA 606 Administration Standard for Telecommunication

6.2 State the scope of the Terminations (color coding) to include:

6.2.1 telecommunications media located in Work Areas (WA)

6.2.2 Telecommunications Rooms/closets (TR)

6.2.3 Equipment rooms (ER)

6.2.4 Entrance facilities (EF)

6.2.5 telecommunications cabling media between terminations

6.2.6 pathways between terminations that contain media

6.2.7 bonding/grounding as it applies to telecommunications

6.2.8 as-built data

6.3 List the Administration Color Code to include:

6.3.1 demarcation point-orange

6.3.2 network connections-green

6.3.3 common equipment-purple

6.3.4 1st level backbone-white

6.3.5 2nd level backbone-slate (gray)

6.3.6 station-blue

6.3.7 inter-building backbone-brown

6.3.8 miscellaneous-yellow

6.3.9 key systems-red

6.4 Define the following Administration terms to include:

6.4.1 cut-over

6.4.2 cut-sheets

6.5 List the Fiber Optic Cable Color Code to include:

6.5.1 Blue, Orange, Green, Brown, Slate, White, Red, Black, Yellow, Violet, Rose, Aqua

7.0 NEC – National Electrical Code

7.1 State the purpose of the NEC

7.2 Discuss the scope of the NEC to include:

7.2.1 electrical conductors and equipment within or on public or private buildings or other structures including mobile homes, recreational vehicles, floating buildings and other premises (yards, carnivals, parking lots, etc.)

7.2.2 conductors of equipment that connect to the supply of electricity

7.2.3 other outside conductors and equipment

7.2.4 the premises' optical fiber cable

7.2.5 buildings used by the electric utility

7.3 Discuss the types of objects specifically not covered by the NEC to include: ships, water craft, aircraft, automobiles, underground mines and related equipment

7.4 Discuss the various NEC reference Sections and Articles to specifically include Article 770 (Optical Fiber and Pathways)

7.5 Explain the NEC (50 ft) limitation on the transition point from the demarcation/ Entrance Facility (EF) including:

7.5.1 intra-building cabling must have NEC listed fire-rated cable

7.5.2 any cable-type non NEC listed gel-filled cables

7.5.3 cables encased in metallic conduit

7.6 Discuss the NEC Cable Fire-Ratings to include:

7.6.1 Fire Resistance Levels (plenum, riser-LSZH, general purpose, residential)

7.6.2 applicable Flame Test Requirements (UL-910, NFPA 262, UL-1666, UL-1581, UW-1)

7.6.3 MP (Multi Purpose), CM (Communications Cables), Type CATV (Community Antenna, Television & Radio, Distribution Cables)

7.6.4 type OFN (Optical Fiber Non-conductive), Type OFC (Optical Fiber Conductive)

7.6.5 suffix-designation (P: Plenum rating, R: Riser rating, G: General Purpose rating, X: Residential rating, LSZH: Low Smoke Zero Halogen)

7.7 List and define the NEC Classification of Fiber Optic Cable Types including OFNP, OFCP, OFNR, OFCR, OFN (OFNG) and OFC (OFCG)

7.8 Explain the electrical characteristics of insulation materials per ASTM Standard D 4566-94 to include:

7.8.1 dielectric constant (the ratio of capacitance of insulated wire to the capacitance of the same wire unshielded in the air with air being the reference with a dielectric constant of 1.0)

7.8.2 dielectric strength (measures the maximum voltage an insulation can withstand without breakdown, measured in volts per millimeter)

7.8.3 insulation resistance (insulation's ability to resist the flow of current through it, in inside wire conductors insulation resistance (IR) is typically measured in meg-ohm/km)

7.8.4 dissipation factor (relative power loss in insulation for telecommunication circuits)

7.9 Describe UL Listed jacket material construction to include:

7.9.1 inside/Outside labeling

7.9.2 3 criteria of ratings (smoke resistance, flame spread, temp rating)

7.9.3 NEC Rating (plenum rated, UL 910, CSA FT6, Steiner Tunnel Test, riser rated, UL 1666, CSA FT4, Vertical shaft, tray rated, UL 1581, DP: Data Processing Raised Floors)

7.9.4 Materials used for jackets: FEP (Fluorinated Ethylene-Propylene), PTFEP (Pure Teflon FEP-DuPont), Halar (Ausimont), Kynar (Elf Autochem), PVC (Polyvinyl Chloride Plenum-rated), Fire guard, Smoke guard (Gary Chem/ allied), Flame Arrest (Belden), PEPVC (Polyethylene Polyvinyl Chloride, Foam PVC, Poly PVC (Union Carbide), FRPE (Flame Retardant Polyethylene), PP (Poly propylene), Thermoplastic, PU (Polyurethane), PE (Polyethylene), MDPE (medium density PE), LSZH (Low Smoke Zero Halogen), PVDF (Fluropolymers)

8.0 ANSI/TIA/EIA 607 GROUNDING & BONDING

8.1 Discuss the scope of Grounding and Bonding to include:

8.1.1 supports a multi-vendor, multi-product environment

8.1.2 encompasses grounding practices for various systems to be installed

8.2 Identify a Telecommunications Bonding Backbone (TBB), a Telecommunications Main Grounding Busbar (TMGB), a Telecommunications Grounding Busbar (TGB), and a Grounding Equalizer (GE) from a schematic

8.3 Demonstrate an understanding of the grounding and bonding requirements for the ANSI/TIA/EIA 607 Grounding and Bonding Standard and all applicable NEC Codes and required laws to safely ground and bond telecommunication lines

9.0 Fiber History / Advantages & Disadvantages of Fiber

9.1 Identify from a timeline significant developments in fiber optics history

9.2 List the advantages of fiber optics over copper cabling to include:

9.2.1 larger transmission capability/ wider bandwidth

9.2.2 lower signal attenuation

9.2.3 longer transmission distances with fewer repeaters

9.2.4 immune to EMI/RFI

9.2.5 secure and stable signal transmissions

9.2.6 extremely small, light and cost effective

9.2.7 no spark or fire hazard

9.2.8 non-obsolescent, non FCC-frequency dependent, decreasing costs

9.3 Explain how the demand and application for fiber optics has grown over time

9.4 Describe the American Digital Signal Hierarchy and identify its starting point of Digital Signal 0 (DS0) at 64,000 bits (64 Kb)

9.5 Describe the European Digital Signal Hierarchy and its starting point (DSO)

9.6 Identify attenuation to include:

9.6.1 loss of signal strength

9.6.2 measured in decibels (dB)

9.6.3 an increase in frequency or length increases the amount of attenuation

- 9.6.4 attenuation is algorithmic
- 9.6.5 cabling and not connectors is the reason for increasing attenuation in copper cabling
- 9.6.6 connectors relative to the cable is the reason for increasing attenuation in fiber optics

9.7 Identify the maximum insertion loss (attenuation) specified in TIA/EIA 568B for a fiber optic connector

9.8 Identify the maximum allowable splice loss (attenuation) specified in TIA/EIA 568B

9.9 Explain power and voltage reductions and increases relative to a decibel (dB) Scale to include that at 3db there is a 50% increase/decrease

9.10 Identify the three factors limiting bandwidth in fiber optics

9.11 Identify eight fiber characteristics which affect bandwidth

9.12 Match the following as additional advantages of fiber optics:

- 9.12.1 immune to EMI, EMP, RFI pulses and lightning strikes
- 9.12.2 it is dielectric and cannot easily be tapped so therefore is more secure
- 9.12.3 immune to florescent lighting/transformers, VHAC / Overhead High Voltage
- 9.12.4 no Electrostatic Discharge, does not radiate energy
- 9.12.5 no short circuits, no shielding requirements
- 9.12.6 no grounding or antenna effect
- 9.12.7 immune to normal heating / ac ducts
- 9.12.8 lower Bit Error Rates (BER), no "NEXT" (Near-end Crosstalk), and larger ACR (Attenuation-to-Crosstalk Ratio) "Headroom"

9.13 Define Attenuation-to-crosstalk Ratio (ACR), also called 'Headroom" to include that it is the difference expressed as a figure in decibels (dBs), between the signal attenuation produced by a wire or cable transmission medium and the Near-end Crosstalk (NEXT)

9.14 Relate that ACR is a quantitative indicator of how much stronger the attenuated signal is than the crosstalk at the destination (receiving) end of a communications circuit

9.15 Explain that the ACR figure must be at least several decibels for proper circuit performance and that if the ACR is not large enough, errors will be frequent

9.17 Explain that because of the much smaller size and weight of fiber cable, and the much greater information carrying capacities of fiber, significant design and installation cost savings can be realized

9.18 List the disadvantages of fiber to include:

9.18.1 initial costs are higher than copper cabling but these costs are decreasing

9.18.2 lack of universal industry standards and protocols in some SONET and WDM technologies

9.18.3 skilled “Certified” personnel are required to install, repair and maintain fiber optics systems and cabling

9.18.4 high levels of continuous nuclear radiation causes increased attenuation in fiber cable, but can clear within minutes

9.18.5 tool kits and test equipment are more expensive than copper-based tool kits and test equipment

9.18.6 when a fiber link goes down a lot of people may be affected for a longer period of time due to the complexity of repairs

9.19 Compare the performance capabilities of unshielded twisted pair (UTP) Category cabling to multimode fiber optic cabling

10.0 Understanding Metrics for Fiber Optics

10.1 Differentiate between the required metric units of measurement used for specific applications of fiber optics and light to include:

- 10.1.1 meter (m)
- 10.1.2 millimeter (mm)
- 10.1.3 micrometer (Micron) (um)
- 10.1.4 nanometer (nm)
- 10.1.5 angstrom (A)

10.2 Describe the place of the meter (m) in the International System of Units (SI)

10.3 Identify the micrometer (micron) as the correct metric unit of measurement used for the fiber core, cladding, coating and buffer dimensions/sizes

10.4 Identify the millimeter (mm) as the correct metric unit of measurement used for the fiber optic cable outside jacket dimensions/sizes

10.5 Identify the nanometer (nm) as the correct metric unit of measurement used for the measurement of wavelengths of light in fiber optics

10.6 Identify the angstrom (A) as the non-SI unit of measurement which is internationally recognized, represents 0.1 of a nanometer (nm) and is sometimes used in expressing the sizes of atoms, lengths of chemical bonds, visible-light spectra, and dimensions of parts of integrated circuits

10.7 Identify the decimal equivalents through the use of Scientific Notation Charts of:

- 10.7.1 positive Powers of Ten, E Notation, prefixes and symbols for tera, giga mega, kilo, hecto and deka values
- 10.7.2 negative Powers of Ten, E Notation, prefixes and symbols for deci, centi, milli, micro, nano, pico, femto, and atto values

10.8 Compare to scale the relationships in size of microns, human hair and fiber optic core diameter sizes and representations

10.9 Identify various metric and non-metric measurement terms through the use of Units of Measurement Charts

11.0 Optical Principles and Properties of Light

11.1 Identify the portion of the electromagnetic spectrum used for fiber optics

11.2 Identify the transmission windows of multimode and single mode transmitters

11.3 Explain the effects of dispersion upon wavelengths of light

11.4 Explain light wave propagation in fiber to include:

11.4.1 wave lengths

11.4.2 sine waves

11.4.3 measurement in nanometers

11.4.4 designated with the lambda symbol

11.4.5 frequency measurement in Hertz (Hz) or CPS (cycles per second)

11.5 Determine wavelengths of various radio frequencies by dividing frequency in Hertz by the speed of light

11.6 Identify the three common wavelengths used in fiber optics

11.7 Explain the principles of refraction and reflection as they are used in fiber optics

11.8 Explain Snell's Law as it applies to angles of incidence and refraction rays in similar substances and its importance in fiber optics

11.9 Explain the principles of a Fresnel Lens and how it maximizes refraction

11.10 Explain Rayleigh Scattering with respect to refraction and attenuation in nature

11.11 Explain critical angle in relation to the angle of incidence, reflection and refraction

11.12 Examine the refractive indices of various materials through the use of charts

12.0 Propagation of Light

12.1 Identify the three main parts of an optical fiber (core, cladding and coating)

12.2 Describe total internal reflection as it relates to fiber optics

12.3 Explain how light injected into an optical fiber at more than the critical angle is reflected and light injected into an optical fiber at less than the critical angle is absorbed into the jacket

12.4 Correctly define the term “mode” as used in fiber optics as “a light path”

12.5 Describe the three fundamental types of optical fiber to include:

12.5.1 Step Index Multimode

12.5.2 Graded Index Multimode

12.5.3 Step Index Single Mode

12.6 Define the term “Modal Dispersion” as used in fiber optics

12.7 Describe the bandwidth capabilities of the three fundamental types of optical fiber

12.8 List the core/cladding size ranges of the three fundamental types of optical fiber

12.9 Correctly identify the North American multimode fiber optic standard as “a fiber core of 62.5 microns and an outside diameter of 125 microns”

12.10 Describe high order, low order and fundamental modes traversing through an optical fiber

12.11 Define the term “Pulse Dispersion” as used in fiber optics, its unit of measurement (nanoseconds per kilometer), and its effects on bandwidth

12.12 Define the term “attenuation” as used in fiber optics as “loss”

12.13 Define the measurement of attenuation (loss) in fiber optics as “decibels (dB)” and dB per kilometer (dB/km)

12.14 Explain Intrinsic factors contributing to fiber attenuation to include:

12.14.1 Rayleigh Scattering

12.14.2 Hydroxyl (OH)

12.14.3 radical ultraviolet absorption

12.14.4 microbends

12.15 Explain the External factors contributing to fiber attenuation to include:

12.15.1 splices

12.15.2 connectors

12.15.3 macrobends

12.16 Explain the use of Fiber Optic Spectral Loss Charts in determining the transmission capacity of fiber and compiling loss budgets

12.17 Discuss structural and compositional imperfections in fiber to include:

12.17.1 microbends

12.17.2 cracks

12.17.3 core ovality and core concentricity

12.17.4 bubble penetrating the core

12.18 Define the term “Bend Radius” as used in fiber optics to include:

12.18.1 civilian “rule-of-thumb” bend radius is 5x the cable Outside Diameter (OD) during installation

12.18.2 civilian “rule-of-thumb” bend radius is 10x the cable Outside Diameter (OD) installed

12.18.3 civilian “rule-of-thumb” bend radius is 20x the cable Outside Diameter (OD) under tension during pulling

12.18.4 Military (per MIL-STD-2042) bend radius is 8x the cable Outside Diameter (OD) during installation

12.18.5 Military (per MIL-STD-2042) bend radius is 16x the cable Outside Diameter (OD) installed

12.18.6 Military (per MIL-STD-2042) bend radius is not specified for tension while pulling

12.18.7 when bend radius is unknown or not specified, the installer should use the formula for dynamic bend radius of 20x the diameter

12.19 Explain the various methods used to avoid twisting cable during installation to include:

12.19.1 roll the cable off spools instead of spinning it off the end of the spool

12.19.2 use a large “figure-8” when laying cable on the ground between pulling runs to prevent twisting

12.19.3 use a swivel pulling eye when required

12.20 Compare light sources used in fiber optic transmissions to include:

12.20.1 LASERs

12.20.2 LEDs

12.20.3 VCSELs

12.21 List the advantages and disadvantages of fiber optic light sources

12.22 Explain the Acceptance Angle of fiber optic cable in relation to its Critical Angle for fibers with large (higher) Numerical Apertures (NAs) and fibers with small (lower) Numerical Apertures (NAs)

12.23 Define Modal Dispersion as the spreading of a light pulse as it moves through a fiber

12.24 Define Material Dispersion as the effects of a light pulse reacting to imperfections in the fiber

12.25 Define Chromatic Dispersion as the combination of material dispersion and wavelength dispersion (the wavelength dependent effects upon the refractive index of the fiber and its relation to the NA and the core size)

12.26 Explain the Modal Dispersion characteristics of LASERs and LEDs

12.27 Describe the differences of multimode and single mode fiber in relation to their core to cladding sizes and information carrying capabilities

12.28 Explain signal processing in fiber to include:

12.28.1 Simplex Signal

12.28.2 Half Duplex Signal

12.28.3 Full Duplex Signal

12.29 Explain Wavelength Division Multiplexing (WDM) to include:

12.29.1 allows multiple channels in a single fiber by simultaneous transmission of multiple wavelengths

12.29.2 allows greatly increased amounts of data to be transmitted and received

12.29.3 susceptible to channel "crosstalk"

12.30 Describe the characteristics of Specialty Fiber to include:

12.30.1 Polarity Maintaining (PM) Fiber

12.30.2 Polarization-maintaining and Absorption-reducing (PANDA) Fiber

13.0 Optical Fiber Cable Construction

13.1 Describe the fiber cable fabrication process to include:

13.1.1 preform

13.1.2 fiber drawing tower

13.1.3 oven/furnace

13.1.4 automatic feedback system

13.1.5 polymer coating/extrusion process

13.2 Identify the Two General Cable Types:

13.2.1 Tight Buffered-generally for Indoor applications

13.2.2 Loose Tube-generally for Outdoor applications

13.3 Describe the Jacketing considerations for fiber cable to include:

13.3.1 Environmental Conditions:

13.3.1.a sunlight (UV)

13.3.1.b water/humidity

13.3.1.c temperature range

13.3.1.d chemical sensitive

13.3.1.e radiation

13.3.1.f rodents

13.3.2 Mechanical conditions:

13.3.2.a pull tension

13.3.2.b vertical support

13.3.2.c bending

13.3.2.d impact

13.3.2.e crush

13.4 Describe a typical Tight Buffered fiber optic cable configuration to include:

13.4.1 bare fiber is coated with plastic to a 900 micron diameter

13.4.2 surrounded with Kevlar® aramid yarn or other strength member

13.4.3 covered with one or more layers of jacketing

13.5 Identify typical Cordage Colors for fiber optic cables to include:

13.5.1 Single-mode fiber optic cables are designated as yellow

13.5.2 Multimode fiber optic cables are designated as orange or gray

13.6 Differentiate Loose Tube fiber optic cables from Tight Buffered fiber optic cables to include:

13.6.1 Loose Tube fibers float freely inside buffer tubes that are gel filled

13.6.2 Tight Buffered fibers have a buffer tube extruded directly over a bare fiber

13.7 Discuss the advantages and disadvantages of Tight Buffered cable to include:

13.7.1 Advantages:

13.7.1.a may be used indoors

13.7.1.b increased flexibility

13.7.1.c easy to handle

13.7.1.d easier to connectorize (no breakout furcation kits needed)

13.7.1.e no gel to contain or clean up

13.7.1.f may use jumpers, pigtails and splice to OSP cable

13.7.1.g Fire-rated

13.7.2 Disadvantages:

13.7.2.a limited temperature range

13.7.2.b limited moisture protection

13.8 Describe a Tight Buffered Duplex Cable to include:

13.8.1 two fibers in a “Zipcord” construction (2 jackets bonded together)

13.8.2 2 subunits sharing a common jacket

13.8.3 usually used in Risers and Patch Cords

13.8.4 application is generally equipment interconnection for transmit and receive

13.9 Describe a Tight Buffered Duplex Intrabuilding Non-Breakout Cable to include:

13.9.1 usually a MAC or MIC-type cable

13.9.2 used for indoor applications

13.9.3 consists of two tight buffered fibers in a single jacket

13.9.4 usually used for Plenum and Riser use

13.9.5 application is generally equipment interconnection and general building wiring

13.10 Describe a Tight Buffered Multifiber Breakout Cable to include:

13.10.1 may be used indoors or outdoors

13.10.2 constructed with tight buffered fibers stranded around a central member, then jacketed (simplex cables jacketed together)

13.10.3 used in general building wiring, as a Riser Cable (OFNR) & Plenum (OFNP), Indoor/outdoor point-to-point links (outdoor spans should be less than 2km, located below the frost line and in conduit)

13.10.4 does not require an enclosure box

13.11 Describe Loose Tube Cable construction to include:

13.11.1 design is especially important because contraction and expansion may occur outdoors

13.11.2 in normal conditions, fibers have slack within the gel filled tubes

13.11.3 buffer tube contracts and expands with temperature changes and allows fibers to adjust

13.11.4 fiber length remains constant with the fiber bundle to the outside of the cable in a stress-free state

13.11.5 core designs vary and may include concentric cores and fibers or ribbon cores in a square configuration

13.11.6 cables inside the Loose Tube may be jacketed or unjacketed

13.11.7 require a secondary buffer/breakout “furcation kit” to terminate the fibers

13.12 Describe the typical structure of a Loose Tube (OFN) Fiber Optic Cable to include:

13.12.1 central strength member

13.12.2 buffer tubes with fiber

13.12.3 binder tape

13.12.4 ripcord

13.12.5 outer strength member made of Kevlar®

13.12.6 outer jacket of black medium density, polyethylene (MDPE)

13.13 Describe the typical structure of a Loose Tube (OFC) Fiber Optic Cable for Direct Buried applications to include:

13.13.1 central strength member

13.13.2 buffer tubes with fiber

13.13.3 special steel tape armor

13.13.4 ripcord

13.13.5 outer strength member made of Kevlar®/steel tape armor

13.13.6 outer jacket of black medium density, polyethylene (MDPE)

13.14 Describe various Loose Tube designs and components for buried cables including LXE Metallic cables, LXE Dielectric Sheath Cable, Crossply Sheath, ECCS armor, AccuRibbon® core, corrugated jacketing, interlock armoring, BX and steel wire

13.15 Describe various Loose Tube designs and components for Aerial cables to include:

13.15.1 "All Dielectric Self Supporting" (ADSS) Fiber Optic Aerial cables

13.15.2 "Figure 8" Fiber Optic Aerial cables

13.16 List the advantages of All Dielectric Self Supporting (ADSS) Fiber Optic Aerial cables to include:

13.16.1 eliminate the need to install a messenger

13.16.2 superior grounding and bonding

13.16.3 no metallic elements

13.16.4 lower galloping (caused by low frequency vibrations)

13.16.5 longer pull lengths within conduit or duct applications

13.16.6 up to 216 fibers for Micro Span (MS) -200 feet (62 meters), Short Span (SS) -500 feet (152 meters), Long Span (LS) -1000 feet (302 meters) depending on NESC loading conditions

13.16.7 Indoor/Outdoor available tray rated (OFN)

13.17 Describe the design characteristics of All Dielectric Self Supporting (ADSS) Fiber Optic Aerial cables to include:

13.17.1 buffer tubes with fibers around a jacketed central strength member

13.17.2 interstitial gel filling

13.17.3 two layers of strength member Kevlar®

13.17.4 binder tape

13.17.5 ripcords

13.17.6 black medium density polyethylene (MDPE) outer jacket

13.18 Describe the design characteristics of Figure 8 Self Supporting cable to include:

13.18.1 typically 7 wire 1/4 inch galvanized steel strand top support

13.18.2 tube core

13.18.3 ECCS armor

13.18.4 HDPE inner jacket

13.18.5 LDPE outer jacket

13.19 List the various strength members used with Loose Tube Fiber Optic cable to include:

13.19.1 Fiberglass Epoxy Rod (FGE)

13.19.2 Glass Reinforced Plastic (GRP)

13.19.3 Stainless Steel (for “Toning”)

13.19.4 Aramid Yarn (Kevlar®)

13.19.5 Strength Members MUST be sized to meet pulling requirements

13.20 Explain the Color Coding for a 24 strand Loose Tube Fiber Optic Cables to include:

13.20.1 fibers 1 through 6 are in a Blue tube

13.20.2 fibers 7 through 12 are in an Orange tube

13.20.3 fibers 13 through 18 are in a Green tube

13.20.4 fibers 19 through 24 are in a Brown tube

13.20.5 fiber colors (six fibers per tube) are Blue, Orange, Green, Brown, Slate and White

13.20.6 individual fibers are identified by Tube Color/Fiber Color (the identifier Blue/White would mean: the individual White Fiber in the Blue Tube)

13.21 Identify various Slit, Ring and Stripping Tools used to strip, cut or slit cable jackets

14.0 Designing & Planning Fiber Optic Networks

14.1 List various fiber optic network configuration types to include:

14.1.1 Ethernet

14.1.2 Token Ring

14.1.3 Fiber Distributed Data Interface (FDDI)

14.1.4 ATM

14.1.5 Fibre Channel

14.1.6 Voice

14.1.7 Video

14.2 Describe typical Patch Panel sizes, port number options, mounting specifications, non-loaded or loaded options, coupler nomenclature, custom designs and pigtails

14.3 List various cable infrastructure support structures for networks to include:

14.3.1 cable trays

14.3.2 conduit

14.3.3 innerduct

14.3.4 aerial

14.3.5 buried

14.4 Describe typical Cable Tray sizes, location of placements and the use of innerduct for protection and cable separation

14.5 Describe typical Conduit infrastructures, sizes, color code specifications, placements, pull points, J-boxes, manholes and handholes for servicing

14.6 Describe typical Innerduct sizes, stand alone pathways, multiple cell configurations within a conduit, placements, pull points, J-boxes, color code specifications and ditch witch pull through

14.7 Describe typical Aerial designs including ADSS, Figure 8, sizes, strength member and anti-buckling member requirements, enclosure within a jacket, direct lashing, storage loops (snow shoes) and weatherproof splice closures

14.8 Describe typical Buried infrastructures including fiber optic cables are Optical Fiber Non-conductive (OFN) in conduit, Direct Buried- Optical Fiber Conductive (OFC), includes manholes and the cable types are dielectric, indoor/outdoor cables

14.9 Identify the purpose of Fiber Optic Splice Closures, locations commonly found, types of protections they afford, whether encapsulated or pressurized, National Electrical Manufacturers Association (NEMA) ratings and re-entry and expansion considerations

14.10 List two types of Fiber Optic Splice Trays to include:

14.10.1 metal trays

14.10.2 plastic trays

14.11 Describe design considerations involving Fiber Optic Splice Trays including type of splice trays, mounting inside the closures, organization of bare fibers and splices, minimum bend radius preservation, securing buffer tubes or tight buffer to trays, determining the number of trays, Fiber type (single-mode or multimode), hardware type and splicing methods

14.12 Discuss the various designs of metal splice trays including those used to house fusion splices, heat shrink and reduced length applications

14.13 Discuss the various designs of plastic splice trays to including those used for fusion or mechanical splices and splice chips located with the splice tray

14.14 List the placement of closures and enclosures for aerial, buried and inside building applications to include:

- 14.14.1 entrances for cable management
- 14.14.2 central splices
- 14.14.3 high density patching
- 14.14.4 telecommunications rooms
- 14.14.5 wall, rack and patch panels
- 14.14.6 fiber to the home
- 14.14.7 fiber to the desk

14.15 Discuss the applications of Plastic Fiber from a designer's view to include:

- 14.15.1 modest performance of a maximum 50 Mbps over 100 meters
- 14.15.2 have larger core/cladding sizes
- 14.15.3 considerably less expensive than ultra pure glass fibers
- 14.15.4 primarily use red light range of 660 nanometers for ease of troubleshooting
- 14.15.5 rugged, easier to terminate than glass fiber but much more loss
- 14.15.6 used in automobiles, trucks, music systems and consumer electronics

14.16 Describe Blown Optical Fiber Technology (BOFT) to include:

- 14.16.1 newer technology
- 14.16.2 used in new Naval Ship construction
- 14.16.3 used in commercial buildings and high rises

14.17 Explain Blown Optical Fiber Technology installation methods and materials to include:

- 14.17.1 microducts

14.17.2 high pressure air delivery systems

14.17.3 fibers blown through a 5 mm microduct can navigate up to 300 tight 90 degree bends of 1 inch radius

14.17.4 fibers can be blown up to 3,000 feet horizontally or up to 1,000 feet Vertically

14.17.5 BOFT fibers are lighter than conventional multi-fiber cable

14.17.6 BOFT fibers come in both multimode and single-mode and have special coatings

14.17.7 fibers cannot be broken during cable pulling because conventional cable pulling equipment and materials are not used

14.17.8 fiber stress and strain due to pulling is nonexistent

14.17.9 BOFT has lower signal losses due to reduced interconnection and fewer splices, fibers are “furcated” so that the ends can be connectorized like standard fiber cables, reduced training requirements and no specialized tool kit requirements, easily spliced, damaged fibers may be blown out and more easily replaced without the need for new cables to be pulled, associated costs for expansion of networks may be spread out over time

14.18 Describe the types of questions an installer should be able to ask regarding Fiber Optic Cable Assemblies to include:

14.18.1 core/cladding sizes for multimode and single-mode, number of fibers being installed, simplex, duplex, cable type being installed, Inside Plant (ISP), Tight Buffered Breakout, cable coatings (250 micron or 900 micron), riser or plenum rated material, simplex zipcord multiple fibers each in its own jacket or multiple fibers surrounded by one jacket, Tight Buffer Non-Breakout (ISP), MIC,MAC, LGBC, or ACCUMAX

14.18.2 Outside Plant (OSP) Loose Tube Gel Filled, each fiber having one 250 micron buffer coating, NEC restrictions on (OSP) use for entrance facilities, Riser Rated Loose Tube (RLT), cable manufacturer, connector types (Multimode: ST, SC, FC, MIC/FDDI, SMA, BICONIC, or Single-mode: ST, SC, FC, or APC)

14.18.3 connector ferrule type (stainless steel, ceramic, zirconia, polymer), manufacturer of connectors, jumper lengths, and whether the designs are scaled to feet or meters

15.0 Safety Guidelines and OSHA

15.1 Describe the inherent dangers of working with glass fibers which are extremely small and clear (nearly invisible) in appearance

15.2 Explain the safety considerations for the fiber optic work area to include:

15.2.1 do not eat or drink in the immediate working vicinity

15.2.2 fiber strands may be ingested (in a soda can or coffee cup) causing severe internal problems

15.2.3 always wear protective eye wear when working with fiber optics

15.2.4 dispose of fiber optic materials and waste ends in a covered container

15.2.5 working on a dark surface ensures visual verification of identifying loose fiber pieces

15.2.6 maintain good housekeeping methods (cleanup, labeling and order)

15.2.7 fiber pieces may become imbedded in the skin causing swelling and soreness, imbedded fiber pieces may not be seen and require Teflon®-tipped tweezers for removal and serious cases of imbedded fibers may involve surgical procedures for removal and treatment

15.3 Explain the safety considerations involving lasers to include:

15.3.1 lasers and LEDs used in fiber optics are operated in the infrared light range and are invisible to the eye

15.3.2 lasers and LEDs should always be considered “hot” or “energized”

15.3.3 prolonged exposure to lasers will cause irreparable damage to the eyes

15.3.4 there would be no pain prior to eye damage caused by lasers and no visible warnings that exposure to laser light has occurred

15.3.5 because laser light used for fiber optic transmissions is invisible, the iris of the eye will not close involuntarily as it would when exposed to a bright light

15.3.6 there will be no reflective responses when staring into a laser such as blinking or turning away

15.4 Describe the safety procedures an installer shall take to prevent eye damage from laser light sources and transmitters to include:

15.4.1 verify transmission circuits are not energized

15.4.2 use of a power meter (preferred) to test whether a laser source is being transmitted or use of an infrared detector card of the proper wavelengths before inspecting a fiber optic termination or fiber end with a microscope

15.4.3 do not look into the output ports of a laser transmitter from a tester or other active device

15.4.4 circuits shall be deactivated and tagged in accordance with all safety regulations and codes prior to splicing or terminating fiber ends

15.5 Describe the Four Classes of Lasers as rated by the Center for Devices and Radiological Health (CDRH) and IEC Regulations to include:

15.5.1 Class I Lasers - theses devices are considered “inherently safe”

15.5.2 the IEC requires a classification label for Class I lasers but the CDRH does not

15.5.3 Class I lasers are considered "eye safe" because they operate at low power levels

15.5.4 Class II Lasers: these lasers have power levels similar to Class I devices for an exposure of 0.25 second

15.5.5 eye protection for Class II Lasers is self provided and are considered "eye safe" (you do not need eye protection) by what is referred to as a "normal aversion response" (blinking or turning away by reflex)

15.5.6 Class III Lasers: both the CDRH and the IEC have defined two subclasses of Class III Lasers (Class IIIA and Class IIIB)

15.5.7 Class IIIA Lasers cannot injure a person's eyes under normal conditions of bright light

15.5.8 the CDRH classification of Class IIIA Lasers concerns only visible light wavelengths while the IEC classification of Class IIIA Lasers concerns all wavelengths

15.5.9 most Laser pointers are Class IIIA Lasers

15.5.10 Class IIIB Lasers can injure a person's eyes if the laser light is viewed directly

15.5.11 Class IV Lasers: these devices can injure the eyes of a person even when viewed indirectly

15.6 Define Lasers and LEDs used in Fiber Optic Technology as "OPERATED IN THE INFRARED RANGE", invisible to the eye AND EXTREMELY DANGEROUS

15.7 Describe the safety concerns of various powerful chemicals used in Fiber Optic connectorizations, splicing and installation to include:

15.7.1 solutions such as Methylene Chloride, Acetone, Isopropyl

Alcohol and various epoxies are sometimes used in the preparation of fibers and cables

15.7.2 chemicals used in Fiber Optics are flammable, poisonous and irritable

15.8 Identify chemical applications used in Fiber Optics to include:

15.8.1 acetone is used to clean off light buffer coatings after mechanical stripping to ensure a clean surface around the fiber

15.8.2 fingernail polish remover may be substituted for acetone (except non-acetone types) and is also used to clean off light buffer coatings after mechanical stripping

15.8.3 99% Isopropyl or Denatured Alcohol is commonly used for the cleaning of optical fiber endfaces and connectors

15.8.4 Methylene Chloride (MC) (not used much anymore in fiber optics) is carcinogenic and highly irritable to the skin (this chemical is also used as a paint remover)

15.8.5 various epoxies (all highly toxic) are used to adhere bare fiber to connectors and to treat and repair enclosures

15.9 Explain the importance of proper labeling of chemicals used in Fiber Optic Technologies and the importance of proper handling and storage procedures

15.10 Explain the role of the Occupational Safety and Health Administration (OSHA) Standards in Fiber Optic safety and the development of Material Safety Data sheets (MSDS) to include:

15.10.1 in 1985, OSHA (in its role for the Department of Labor) developed and issued Standards called the MSDS for chemical manufacturers, importers, distributors, employers and employee use

15.10.2 all manufacturers are subject to OSHA compliance to provide MSDS for their products

15.10.3 OSHA Standards establish uniform requirements to assure that hazards of all chemicals and products used by manufacturing employees in the U.S. are evaluated and that this hazard information is then transmitted to employers and employees

15.10.4 the MSDS is a Technical Bulletin detailing information about the physical or health hazards of a chemical mixture or product

15.10.5 OSHA identifies a hazardous chemical as one which has or poses a physical hazard, health hazard or both

15.10.6 MSDS addresses such concerns as flammability, combustibility, vapor or irritability

15.10.7 if a material contains 1% of an ingredient which is considered hazardous, then the entire mixture is considered hazardous under the definition

15.10.8 MSDS Procedures include: always know the location of the MSDS information at work or a job site, be aware of proper handling procedures and instructions in case of injury, content or swallowing, know how to store and the proper disposal of hazardous chemicals, think about your protection and the protection of others, wear appropriate clothing, safety glasses, shoes, etc. and maintain good housekeeping habits and always communicate with co-workers

15.11 Explain the need to maintain a culture of safety in Fiber Optics

16.0 Connector Types and Connector Components

16.1 Explain Fiber Optic Test Procedures (FOTP) to include:

16.1.1 Fiber Optic Test Procedures (FOTPs) are used when working with optical fiber cable connectors

16.1.2 each FOTP has specific requirements for visual testing, polishing and dB loss per insertion

16.1.3 growth in fiber optic technologies over time has produced a relative parity between single-mode connectors and multimode connectors

16.2 Define Fiber Optic Connectors (FOC) and connectorization as a precision mechanical means to terminate optical fibers which is designed to connect and disconnect optical fibers to another Fiber Optic Connector (FOC), a source (transmitter) or to a detector (receiver)

16.3 Discuss the requirements for FOC to include:

16.3.1 exact fiber alignment to yield low insertion and return loss (back reflection/reflectance)

16.3.2 easily field terminated

16.3.3 secure fiber cable to connector bonding and strain relief

16.3.4 good thermal characteristics

16.3.5 15+ years longevity (warranty)

16.3.6 moderate cost

16.3.7 ease of use and small foot print

16.4 List some common types of Fiber Optic Connectors (FOCs) to include:

16.4.1 ST Connector (Straight Tipped)

16.4.2 LC Connector (Lucent® Connector)

16.4.3 SC Connector (Subscriber Connector)

16.5 Explain the purpose of a Ferrule as the part of the Fiber Optic Connector that holds the end of the fiber and precisely aligns it to the socket

16.6 List the materials commonly used for Fiber Optic Ferrules to include:

16.6.1 ceramic

16.6.2 plastic

16.6.3 stainless steel

16.7 Discuss fiber end polish finishes to include:

16.7.1 GAP finish (non contacting surface and flat finish not currently used in fiber optic technology because it created too much back reflection)

16.7.2 PC or “Physical Contact” finish (domed end finishes with only the two fiber ends are physically touching instead of the end faces of the Connectors)

16.7.3 Zirconia PC Compliance finish (pre-domed and exhibit very little back reflection)

16.7.4 APC or “Angle Polish Physical Contact” (ferrules are keyed at 8 degrees with an angle polish, the ferrule key means you will always plug them in exactly the same way, the design is used in high-order modes, modes exceeding the critical angle or angle of incidence are reflected into the cladding and not back to the transmitter which reduces reflectance)

16.8 Explain the process of Scribing to include that it is the process of scoring the glass fiber using a Scribe to allow for a clean fiber break and that the Scribe is used for CONNECTORIZATION purposes

16.9 Explain the process of Cleaving to include that it is the planned, clean breaking of a fiber perpendicular to the fiber axis and that a Cleaver is used for SPLICING purposes

16.10 Describe the process of fiber end polishing to include:

16.10.1 after a fiber has been scribed and broken (for connectorizations) or after it has been cleaved (for splicing) the end face must be polished

16.10.2 the use of abrasive paper (after scribing and breaking or cleaving) to polish the fiber face to a smooth finish minimizes loss and maximizes light transfer

16.10.3 polishing is usually performed in stages starting with coarse grit paper to remove adhesive and excess fiber (grinding) then substituting finer grit paper (for final polishing)

16.10.4 polishing procedures, fixtures and materials vary widely between connector types

16.10.5 some connectors do not require polishing of fiber end faces

16.11 Explain fiber optic end polishing to include:

16.11.1 in the hand polishing process the fiber end is held in a special fixture called a "puck" because it glides over the polishing paper like a hockey puck

16.11.2 during the hand polishing process the polisher should always use a "figure-8" motion to evenly polish the fiber end face or the end face may end up with a slightly angled surface resulting in high loss

16.11.3 automatic polishers are available for many connectors, are very expensive but do produce exceptional polishing results

16.12 Describe common flaws in fiber end faces after cleaving and polishing to include:

16.12.1 chips

16.12.2 shards

16.12.3 cracks

16.12.4 hackles

16.12.5 scratches

16.12.6 pits

16.12.7 lint

16.12.8 dirt

16.13 Explain the use of a Fiber Scope as a visual inspection tool which magnifies the end face of fiber to visually check for imperfections

16.14 Discuss Light Loss Tolerance due to fiber misalignment to include:

16.14.1 angular misalignment

16.14.2 lateral displacement

16.14.3 fiber end separation

16.15 List the Extrinsic Factors that result in light loss to include:

16.15.1 surface roughness

16.15.2 lateral displacement

16.15.3 fiber end separation

16.15.4 angular misalignment

16.16 List the Intrinsic Factors that result in light loss to include:

16.16.1 mismatch of core

16.16.2 core diameter mismatch

16.16.3 core alignment

16.16.4 cladding

16.16.5 cladding diameter mismatch

16.17 List the three basic Fiber Optic Connector styles by their method of connect to include:

16.17.1 ST connectors have a bayonet style Twist connector: S - "T"

16.17.2 SC connectors have a Push-Pull Click connector: S - "C"

16.17.3 FC connectors are threaded

16.17.4 all three (ST, SC and FC connectors) have a 2.5mm ferrule

16.18 List the different methods to attach fiber to a connector to include:

16.18.1 epoxy

16.18.2 quick cure adhesives

16.18.3 hot melt

16.18.4 adhesiveless

16.18.5 crimplok

16.18.6 twist tie

16.19 Describe the common components of Fiber Optic Connectors to include:

16.19.1 ferrule

16.19.2 connector housing

16.19.3 crimp ring

16.19.4 boot

16.19.5 threaded latch

16.19.6 APC-Angle Polish Physical Contact (8 degree angle)

16.19.7 key

16.19.8 Simplex and Duplex couplings

16.20 Discuss the uses and required configurations of an Optical Patch Panel as to the importance of maintaining the correct positions of A and B cables for transmission and receiving data whether using Simplex connectors or Duplex Connectors

16.21 Describe the characteristics of 568 SC Connector Optical Patch Cords as being polarized with the requirement that their positions must be maintained based on color coding

16.22 Describe the characteristics of FC Connector as being APC (Angle Polished Physical Contact) and designed with Male and Female couplings which may require an adapter, sleeve or coupling to join two connectors

16.23 Describe Fiber Optic Connector Couplings to include:

16.23.1 a Latch Mechanism Coupler matches the connector style with a thread, bayonet or push-pull mechanism

16.23.2 materials used for Couplings are metal, plastic (composite) and ceramic

16.24 List the various Ferrule Alignment Sleeves designs and materials for ST, SC and FC connectors to include:

16.24.1 clover leaf

16.24.2 silica-filled epoxy

16.24.3 inverted clover leaf

16.24.4 split zirconia

16.24.5 material properties are ceramic, copper, bronze and plastic

16.25 Discuss the procedures for Preparing Fiber for Connectors to include:

16.25.1 strip and remove the jacket to expose the strength member, Kevlar®, buffer and glass fiber

16.25.2 hold Kevlar® back with your fingers while stripping buffer

16.25.3 strip the acrylate coating from the fiber (sometimes it comes off with the buffer)

16.25.4 cut the Kevlar® to length

16.26 Discuss the characteristics of Adhesive Bonded connectors and include that Adhesive Bonded connectors are the most commonly used connectors

16.27 Explain “Fiber Stub” Technology connector design characteristics as it includes a splice inside of an already pre-polished ferrule

16.28 Explain Non-Adhesive (Epoxyless) Technology connector design characteristics to include:

16.28.1 Plastic Coating Gripping Connectors

16.28.2 Low energy Gripping Connectors

16.28.3 High Energy Gripping Connectors

16.28.4 “Crimplok” Connectors

16.28.5 Twist Tie Connectors

16.29 Discuss through the use of a Connector Reference Sheet the various design and application data associated with the following connector types:

16.29.1 ST, SC and FC Connectors

16.29.2 MIC (Medium Interface Connector)

16.29.3 SMA (Subminiature A Connector)

16.29.4 BICONIC Connector

16.29.5 FDDI “ESCON” Connector

16.29.6 NEC D4 Connector

16.29.7 APC (Angle Polished Physical Contact Connector) -various

17.0 Testing and Troubleshooting

17.1 Explain the importance of testing as it relates to Fiber Optics and provide examples of test procedures used in network construction, the fabrication of fiber itself, creating connectors and jumpers, patch panels, cable pulling and how testing is a critical part of every level of Fiber Optic installation

17.2 Explain the Generic Lightwave Communication System to include:

17.2.1 the Driver

17.2.2 the Source

17.2.3 the Source to Fiber Connection

17.2.4 the Optical Fiber

17.2.5 the Fiber to Detector Connection

17.2.6 the Detector

17.2.7 the Output Circuit

17.2.8 any of these points could be a potential problem and can be tested

17.3 Explain how a Light Source and Power Meter are used to test Fiber Optic Circuits to include:

17.3.1 Light Source - where optical light is injected into fiber - done with a Laser or LED

17.3.2 Power Meter - measures optical power loss in mW (milliwatts), in dB (decibel units) and dBm (absolute power referenced to 1 milliwatt)

17.3.3 Attenuator - reduces the amount of light between input and output ports, simulates lengths of fiber and may be fixed or variable

17.3.4 Attenuator is used when B.E.R. (Bit Error Rate) testing or in Power Meter calibration

17.3.5 An Optical Loss Test Set (OLTS) is the combination of a Light Source and Power Meter - may be one unit or separate units and measures optical power - OLTS injects optical light into fiber, measures loss in fibers and measures loss in connectors - OLTS measure dBm, milliwatts, and decibel units in one (or a combination of two) testing device(s)

17.4 Explain how an Optical Time Domain Reflectomer (OTDR) is used to test Fiber Optic Circuits to include:

17.4.1 an Optical Time Domain Reflectometer (OTDR) - locates flaws in fiber, measures distance to faults, measures splice and connector loss, measures fiber lengths and qualifies (Certifies) a system

17.4.2 it is possible for one technician to troubleshoot using an OTDR

17.4.3 most OTDRs have a print feature for permanent record keeping and can graphically display a Fiber Optic Circuit's footprint

17.5 Explain how an Optical Fault Finder is used to test Fiber Optic Circuits to include:

17.5.1 Optical Fault Finder locates flaws in fiber

17.5.2 measures fiber lengths

17.5.3 quick & simple way to troubleshoot

17.6 Explain the use of an Optical Fiber Identifier to test Fiber Optic Circuits to include:

17.6.1 identifies live vs. spare fiber optic cable

17.6.2 identifies the direction of traffic on a fiber optic cable

17.6.3 identifies light presence in fiber

17.7 Explain through the use of a chart showing the ANSI/TIA/EIA 568B Standard Backbone Distances, the options for increasing or decreasing distances between the Main Cross-connect (MC), Intermediate Cross-connect (IC), Telecommunications Room (TR) and Work Area (WA)

17.8 Explain the advanced functions of an Optical Loss Test Set (OLTS) to include:

17.8.1 used for system continuity tests for attenuation

17.8.2 when used for "actual to budget loss" tests, Bi-Directional testing is required

17.8.3 the Light Source is placed on one end of the link and the Power Meter is placed on the other end of the link

17.8.4 the Light Source output power must be stabilized to prevent drifting

17.8.5 if the Light Source output power drifts, the end measurement at the Power Meter will also drift

17.8.6 Light Sources may use either Lasers, LEDs or VCSELs at wavelengths required by the user

17.8.7 usually a multimode Light Source has an 850nm and a 1300nm Light Source while a single-mode Light Source usually has a 1310nm and

1550nm Light Source (individual manufactured Light Sources may vary)

17.8.8 most Light sources have fixed connectors which allow for optimum alignment of the Test Jumper to the Light Source

17.8.9 Power Meters are built and calibrated against National Institute of Standards and Technology (NIST) Standards

17.8.10 calibration testing of Power Meters are required annually to assure that the meter is in proper calibration

17.8.11 Power Meters may be single or multi-wavelength measurement instruments and can be used for multimode and single-mode measurements through the use of selectable wavelength settings which atomically adjust the instrument to calibrated NIST Standards

17.8.12 many power meters come with various adapter caps for use with different connector types

17.8.13 (OLTS) Power Meter and Light Sources have a Dynamic Range and a Maximum Distance Usage Range

17.8.14 to determine the Dynamic Range and Maximum Distance Range of a Light Source and Power Meter (OLTS) you will need to find the Output Power of the Light Source and the Receiver Sensitivity of the Power Meter

17.8.15 Dynamic Range is the difference between Output Power and Input Receiver Sensitivity expressed in dB

17.8.16 Signal Power is determined by the ratio between the Transmitted Power and the Received Power

17.8.17 in optical and telephone communications systems, power is referenced to 1 milliwatt so 0 dBm is 1 milliwatt

17.8.18 in Fiber Optic applications, a range of +10 dBm to -90 dBm is typical

17.9 Convert milliwatt values to dBm values using a Conversion Chart or Conversion Program

17.10 Describe the properties of various Photo Diodes used in Detectors to include:

17.10.1 Silicon (Si), Germanium (Ge) and Indium Gallium Arsenide (InGaAs) have spectral ranges anywhere from as low as 400 nanometers up to as high as 1800 nanometers

17.10.2 the most common types of Photo Diodes are Silicon and Germanium

17.11 Compare typical Photo Diodes using a Comparison Chart to include:

17.11.1 Silicon, Germanium and Indium Gallium Arsenide spectral ranges

17.11.2 Positive-Intrinsic-Negative Diodes (PIN Diodes) - less sensitive, low power and more expensive

17.11.3 Avalanche Photo Diodes (APD) - more sensitive, high power and less expensive

17.12 Perform a simulated Optical Fiber Loss Measurement calculation using readings from an Optical Loss Test Set (OLTS) which consists of a Light Source and Power Meter (Bi-Directional Test)

17.13 Describe items listed on a typical Customer Documentation Power Meter Light Source Test Documentation Form while using a sample Form

17.14 Describe the functions of an Optical Time Domain Reflectometer (OTDR) to include:

17.14.1 an OTDR determines the length of an optical fiber, locates fiber breaks, anomalies, splices and a connector's "fingerprint"

17.14.2 an OTDR measures the attenuation of fibers, splices and connectors

17.14.3 an OTDR when used by itself provides an INDIRECT method of attenuation measurement

17.14.4 an OTDR, when used with a companion Receiver (may be sold separately), can be used to measure attenuation DIRECTLY

17.14.5 an OTDR assesses fiber uniformity and maintains the cable system by periodic comparisons to initial signal traces

17.14.6 technicians are warned to USE EXTREME CAUTION when using an OTDR as the laser output is invisible and you should NEVER look directly into the OTDR output or turn on the laser unless certain that no one is looking at the other end of the fiber under test

17.14.7 an OTDR measures backscatter levels and not the level of transmitted signal (opposite direction of light) - and these levels should be linear

17.14.8 OTDR readings are expressed as a ratio (in percent) of the backscatter coefficient

17.14.9 OTDR measurement will find Fresnel reflections 40 thousand times more (4%) more than backscatter saturation or Rayleigh Scattering (1%) (also called "Fog")

17.15 Define the "Dead Zone" when referring to Optical Time Domain Reflectometer (OTDR) measurements as an area of "blindness" or undetermined pulse duration

17.16 Perform a simulated Optical Time Domain Reflectometer (OTDR) Measurement calculation using readings from a simulated Optical Time Domain Reflectometer (OTDR) which consists of various lengths of fiber cable and various loss readings from such common items as splices and connectors

17.17 Describe various types of issues and situations that may arise to cause losses of power during testing to include:

17.17.1 Index of Refraction differences at testing ranges (1310 nm and 1550 nm for example)

17.17.2 Dispersion Shifting for various single-mode and multimode cables dependent upon manufacturer

17.17.3 Refraction considerations (Refraction is the change in direction of a light wave due to a change in its speed) such as dirt, damage, and improper termination or splicing techniques causing degraded performance (loss) by changing the refraction angles and/or increasing the amount of light reflected back from the interface which allows less light (loss) through to its intended destination

17.17.4 Network configurations and applications have an impact on loss levels as Fiber To The Desktop (FTTD) becomes easier to install, becomes less expensive and provides advantages such as greater bandwidth, immunity to EMI, RFI and Crosstalk which is why it's important to maintain acceptable power levels for origination to the desktop

17.18 Describe a problem of fiber Reflection caused by an air gap between two fibers and provide a solution is to this problem

17.19 Describe applications, equipment and recommended types of testing to perform while using a Testing and Troubleshooting Reference Sheet

18.0 Mechanical and Fusion Splicing

18.1 Describe the procedures for producing a Mechanical Splice to include:

18.1.1 after stripping the fiber cables to be joined down to the bare fiber, the two ends of the fibers to be mechanically spliced are precisely cleaved by a cleaver

18.1.2 the two cleaved fiber ends are visually inspected using a Fiber Scope to insure each has a smooth, clean surface with no burrs, hackles, cracks, chips or scratches

18.1.3 there are a variety of mechanical splicing equipment on the market but they all have a similar function which is to hold the two fibers together using a mechanical fitting

18.1.4 an example of a Mechanical Splicer is the crimp lock fitting “FibrLok®” which has a splice cap, a splice fitting, an end cap and a fiber entry point

18.1.5 the cleaved fiber ends are put inside of the fitting and carefully lined up

18.1.6 the fiber is lined up on each side of the fitting

18.1.7 once the fibers are lined up, they are crimped in place by the crimp lock fitting

18.1.8 the inside is filled with index matching gel which reduces the amount of back reflection on the spliced glass

18.2 Describe the procedures for producing a fusion splice to include:

18.2.1 fusion splices physically fuse each end of the glass into the other

18.2.2 fibers are aligned and fused by electric arc at the fiber joint

18.2.3 fusion splicers have relatively low splice loss and they are used typically for small core, single-mode fibers

18.2.4 no epoxy is needed, no index matching gel is needed but the equipment is relatively expensive

18.2.5 be sure to refer to the manufacturer’s instructions for fiber cleave length requirements which varies between fusion splicers as proper cleave length is CRITICAL in fusion splicing

18.2.6 splice protector sleeves come in a variety of types and lengths, including conductive and non-conductive types

18.2.7 be sure to change fusion splicer heater settings according to the splice protector sleeves being used

18.3 Discuss the operation of a fusion splice machine to include that each fusion splice machine includes instructions on cleaving, setting up the machine and putting the fibers into the chucks

18.4 Describe the higher learning curve involved with fusion splicing in that it requires practice and special care in handling and maintenance

18.5 Discuss the advantages of Mechanical Splicing to include:

- 18.5.1 can be used in all environments
- 18.5.2 small and portable
- 18.5.3 quick learning curve
- 18.5.4 no significant machine maintenance
- 18.5.5 no calibration required
- 18.5.6 require a less precise cleave compared to Fusion Splicing
- 18.5.7 capital investment is low
- 18.5.8 have a broad geographical deployment

18.6 Discuss the disadvantages of Mechanical Splicing to include:

- 18.6.1 higher splice power loss as compared to Fusion Splicing
- 18.6.2 may suffer degradation over time

18.7 Discuss the advantages of Fusion Splicing to include:

- 18.7.1 much lower splice power loss as compared to Mechanical Splicing
- 18.7.2 permanent connectivity of two fiber ends with no degradation

18.8 Discuss the disadvantages of Fusion Splicing to include:

- 18.8.1 must be used in a clean, controlled environment
- 18.8.2 not as portable as Mechanical Splicing
- 18.8.3 requires a much more significant learning curve
- 18.8.4 require very precise cleaving
- 18.8.5 are a significant capital investment
- 18.8.6 not as broadly deployed as Mechanical Splices