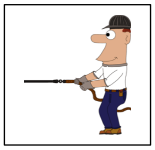
The Fiber Optic Association Inc.
www.foa.org info@foa.org Tel/Text: 760-451-3655



Fiber U Basic Skills Workbook

Splicing Optical Fibers

What Students Learn:
How mechanical and fusion splicing works
How to prepare fibers for splicing
Making mechanical and/or fusion splices
How to optimize the mechanical splice

Exercises:
Preparing the Cable
Stripping and Cleaving
Inspection
Inserting the Fiber into the Splice
    Finishing the Splice
    Testing the Splice
    Optimizing the Splice
Placing the splice in a splice closure (see section after splicing exercises)

Visual Aids
The following visual aids show the processes described in these exercises.

- FOA Instructional YouTube Videos: Fusion Splicing
    - https://foa.org/tech/ref/contents.html#YT
    - http://www.youtube.com/watch?v=qUdQzFaTWyM&list=PLC7CC6B17EF009849&index=22&feature=plpp_video
    - http://www.youtube.com/watch?v=kfYNj3nIPV8)
- FOA Online Guide To Fiber Optics: Splicing VHOs
    - mechanical https://foa.org/tech/ref/termination/VHO-mechspl/VHO-Splice-mech.pdf
    - fusion https://foa.org/tech/ref/termination/VHO-fuspl/VHO-Splice-fusion.pdf
    - ribbon https://foa.org/tech/ref/termination/VHO-ribspl/VHO-Splice-ribbon.pdf

Manufacturers of most splicing components have online videos that should also be used for showing students how to perform the appropriate tasks.

Splicing VHO (mechanical, fusion and ribbon) Download and use the appropriate VHO for the splices you make in your exercises.

Safety:
All students and instructors must wear safety glasses in this lab.
Follow all safety rules for working with fiber.
Safely dispose of all fiber scraps and cables after use.

Tools And Materials Needed

Safety Glasses
ST patch cord
Fiber Optic stripper
Test equipment: VFL and OLTS, reference test cables
Scribe
Miller Jacket stripper
Trash bin
Mechanical Splice consumables: 3 Ultra-splices:
Cleaning wipes or lint-free pads and 99% isopropyl alcohol
Power meter and Source
Bare fiber holder
Fiber cleaver
Aramid Yarn scissors

Splicing

Generally, splices are used to connect two fibers permanently. There are two basic categories of splices: Mechanical and Fusion. Fusion splicing uses a machine to “weld” fibers together in an electric arc. Mechanical fibers clamp two fibers into alignment with index matching gel between them to reduce loss and reflectance.

Fusion splice on the left and a variety of mechanical splices

Fusion splicing is the preferred method for splicing long distance singlemode cable plants, as it’s low loss and reflectance maximizes cable plant performance. Multimode fiber is more often spliced by mechanical splices, as the higher loss is acceptable, reflectance is not a problem, and fusion splicing sometimes has strange effects on multimode bandwidth when it melts the numerous layers in the core of the multimode fiber.

Mechanical Splices

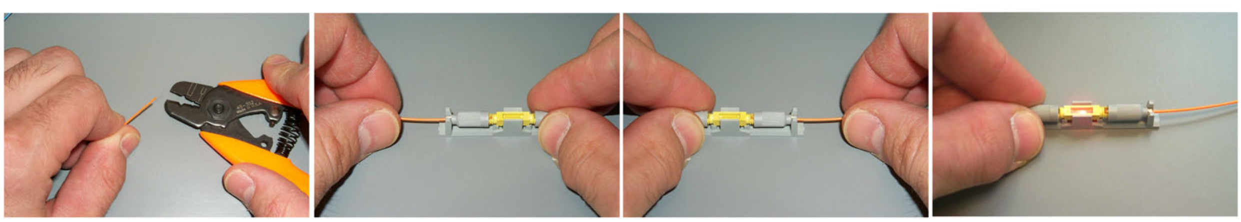
Mechanical splices use some alignment mechanism to align two fibers with index matching fluid between to fiber ends. Then some type of clamp grabs the fibers and/or buffers to hold the fibers in place.

There are many styles of mechanical splices. However, they all share some common characteristics. All mechanical splices use an index matching gel or oil to reduce loss and reflections. They are simple to install, requiring only a few basic tools. Typical mechanical splice losses are 0.5dB or less.

While mechanical splices require little in terms of specialized tools or fixtures, the splices themselves may be expensive, due to the critical nature of aligning the fiber ends to sub-micron precision. If you only have a small number of splices to install, mechanical splices may still be less expensive than fusion splicing.

Splice Installation

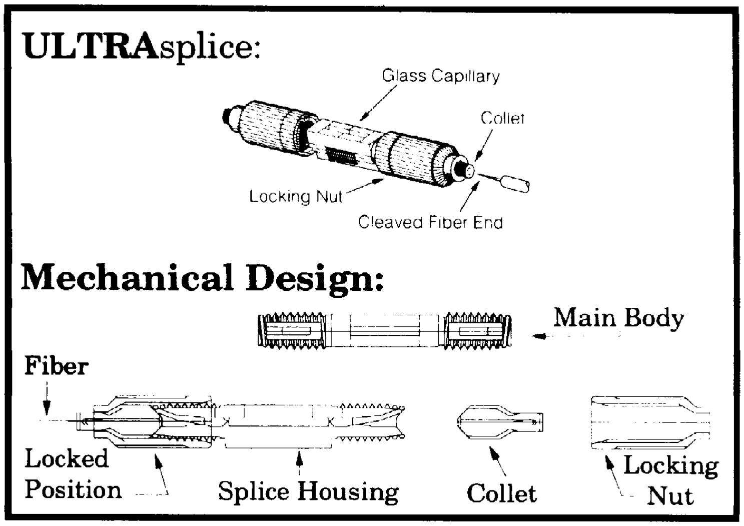
Note: *For the purposes of this manual, we will show the process using a splice called the "Ultrasplice." This splice appears to have gone out of production although some may still be available from distributor stock. We have used it for years because it has a glass alignment sleeve and a window to allow viewing the fiber ends and seeing the light lost at the splice when illuminated with a VFL. The VFL allows the splice to be tuned by moving one fiber and looking at the amount of light lost. Other splices may allow similar tuning. Different splices also have different methods of clamping the fibers in place so get copies of the manufacturer's instructions to use with them.*



Specific installation instructions will vary slightly between manufacturers for their different styles of mechanical and fusion splices. However, every splice, fusion and mechanical, follows this same basic procedure:

- Preparing the cable ends
- Stripping and cleaving the fiber
- Aligning and optimizing the splice
- Fixing the splice to hold the fiber permanently
- Testing the splice for loss

The Ultrasplice



Drawing courtesy of ACA

Preparing the Cable

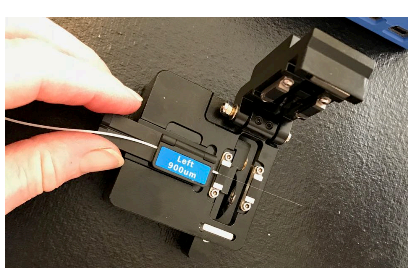
Wear Safety Glasses for this exercise!!

Note: If cutting a patchcord and splicing it, record the loss reading of the cable before beginning.

Cut the cable in half.
Remove approximately 6 inches of the jacket from each end leaving the buffered fiber. (See the cable or termination exercise for procedures)

Stripping and Cleaving

You should have developed skills in stripping fibers in the lesson on fiber and cables. Cleaving fibers is done using a special tool called a cleaver that comes in two versions, a simple hand-held cleaver (L below) and a more precise table-top cleaver ®.



Wear Safety Glasses for this exercise!!

Do not strip both fibers to be spliced at once. Strip one side, cleave it, insert it into the splice, then strip the other fiber.   This is safer and avoids breakage and contamination from dirt.

1. With the fiber stripper, strip away the buffer coating exposing approximately 1-1/2 to 2 inches of the glass fiber.
2. Clean the fiber with fiber cleaner or a lint-free wipe and pure alcohol.
3. Cleave the fiber with the cleaver

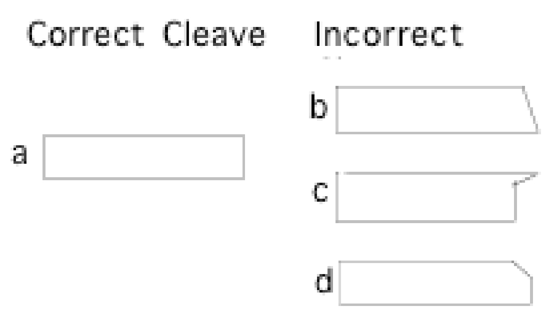
Inspection

Inspect the cleave using a bare fiber fixture in a microscope if available.

Note: A bare fiber fixture for a regular microscope can be made from a flat piece of metal, plastic or thin cardboard. Tape or hold the fiber on the fixture to view.

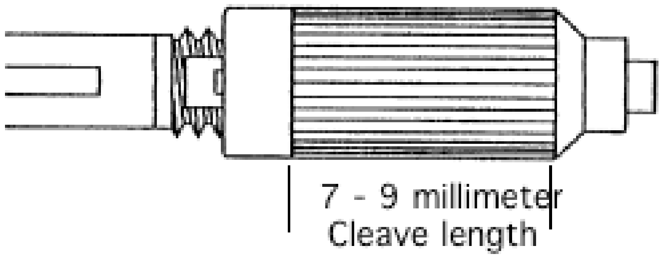
A low loss splice depends on a well-made cleave (see termination section for details). Using the microscope and bare fiber stage view the cleave. It should be a clean square cut (figure a). Excessive losses will be caused by an angle cleave (figure b), a cleave with overhanging material (figure c) or a cleave with missing material (figure d). Re-strip, scribe and cleave again if the cleave is not adequate.

When cleaving always wear protective eye wear.



Inserting the Fiber into the Splice

Insert the cleaved fiber into one end of the splice. The cleave length should be 7-9 millimeters. The knurled section of the locking nut represents the exact cleave length.



1. If using fiber with a buffer size larger than 500micron, it is necessary to remove the Blue Tube and open locking nut one half turn. Remove the blue tube.
2. Carefully insert the fiber into the spice, do not force it.
3. The fiber should be visible in the capillary tube.
4. Center the fiber in the capillary tube.
5. Lock the fiber in the splice by tightening the locking nut with a clockwise rotation. (The fiber is held in place by the collet. The collet acts like a drill chuck. When the locking nut is tightened down, the collet grips the buffer of the fiber. The locking nut is designed to strip if too much force is used.)

Finishing the Splice

1. Cleave the other fiber in the same manner as before.
2. Insert the second fiber and gently butt up against the first fiber. Do not force the fibers together, this will cause them to break.
3. Secure in place with the locking nut.

Testing the splice

Use the meter, source and one of the reference test cables to test the cable which now has a splice in it.
Record the loss.
Calculate the additional loss of the splice.

Optimizing the Splice

You can sometimes improve the loss of a mechanical splice by gently withdrawing one of the fibers a slight amount, rotating it slightly and reinserting it. Try this with your splice.

1. Attach the spliced cable to the meter and source
2. Record meter reading
3. Unlock one splice locking nut
4. Pull that fiber out by 1mm (about 1/16 inch)
5. Rotate the fiber 30 degrees and gently reinsert
6. Note the power meter reading. Did the loss increase or decrease?

7. Try the process again and note the results on the worksheets.

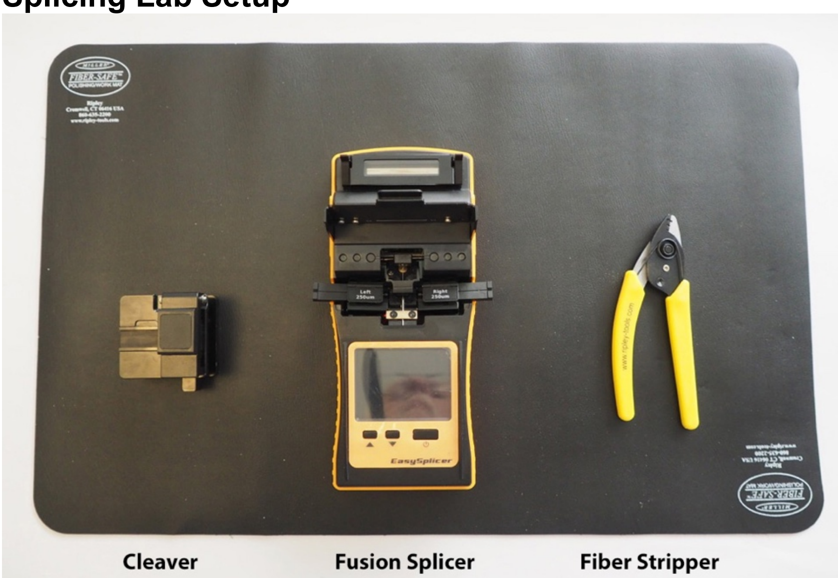
Fusion Splicing

What Students Learn:
How to prepare fibers for fusion splicing
The process of fusion splicing
How to protect fusion splices

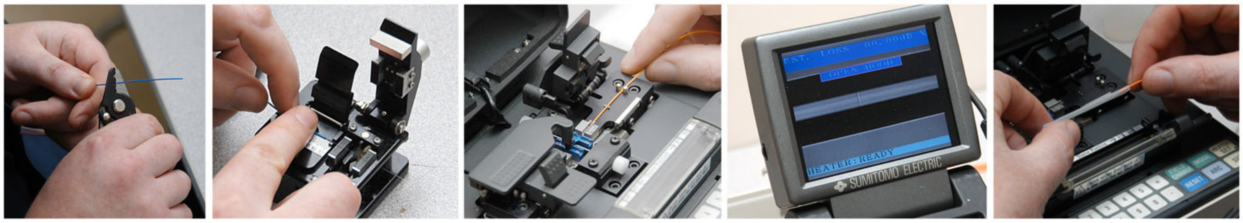
Exercises:
Preparing the Cable
Stripping fibers
Cleaving
Fusion splicing
Attaching splice protector
Placing the splice in a splice closure (see section after splicing exercises)

Safety:
All students and instructors must wear safety glasses in this lab.
Follow all safety rules for working with fiber.
Safely dispose of all fiber scraps and cables after use.

Splicing Lab Setup



This lab is designed to introduce the student to the theory and practice of fusion splicing fiber optics. The student will learn what a fusion splice is, what equipment is needed and how it is done. They will practice making single fiber splices and perhaps ribbon fiber splices, including testing each splice as made with an OTDR. The splice is then sealed in a splice protector usually by heat shrinking using a heater on the splicer. Finally, students should practice placing splices into a splice tray, mirroring actual field installation practices.

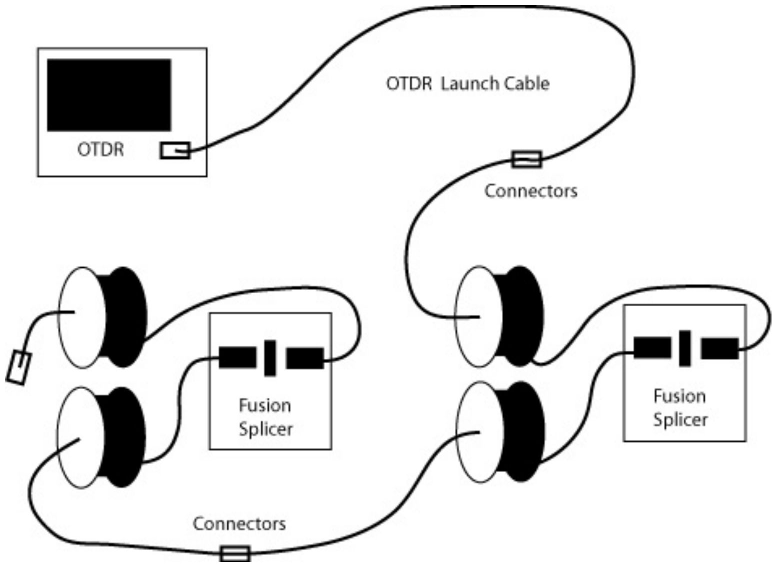


Fusion splicing starts with preparing the cable for splicing by stripping sufficient jacket length to expose the proper length of buffer tubes (if loose tube cable) and buffered fiber for the splice closure chosen. Then the fibers are stripped, cleaned and cleaved before insertion in the splicing machine. The FOA PPT on Splicing from the CFOS/S curriculum and the Online VHOs cover these processes step by step in great detail using typical splicers.

Fusion splicers have become highly automated so the first thing students must learn is how the splicing machine works. Teaching fusion splicing requires training material specific to the splice machine chosen, so if you intend to teach fusion, get the manufacturer of the chosen machine to assist you and provide training materials if available.

It is assumed that the instructor teaching a fusion splicing lab will be familiar with the equipment and its use and has available training aids like the FOA PPT on splicing and/or Internet access and can project the VHOs. An advanced lab should have access to several spools of fiber of lengths greater than 1 km for splicing and an OTDR to test the splices made in class. Students should be introduced to the OTDR before using it to verify splices.

Typical Lab Setup



The lab is divided into separate stations, with one station set up with an OTDR that will be used to test the finished splices, and one or more splicing stations. For example, a typical lab might include both single fiber and ribbon fiber splicing. The lab session has the students split into 3 groups with one group starting at the fusion splicer, one at each splicing station. Each group rotates to get at least one turn on each setup, learning how to splice and test each splice.

Wear Safety Glasses for this exercise!!

Lab Sessions

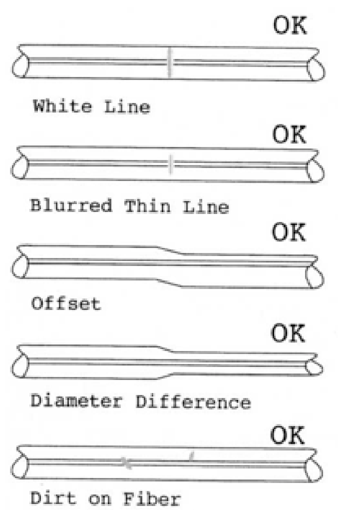
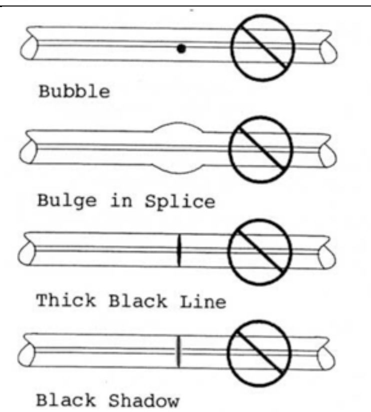
Students may participate in a lab consisting of three or more stations depending on the number and type of splicing machines that are available:
Single fiber splicing (2 stations or one station may be used for ribbon fiber splicing)
Testing splices with an OTDR (optical time domain reflectometer) and/or VFL (visual fault locator)
Students will be divided into 3 groups, each assigned to one station
Students should be shown the process by the instructor, then each student will participate in the activity of the station.
Students at each station will rotate using the equipment and watching and helping the other students
Each student will fill in a worksheet which includes:
Single fiber splicing – estimated loss from splicer and actual OTDR loss
Ribbon fiber splicing – estimated loss from splicer and actual OTDR loss for one fiber
Testing: OTDR data or trace for one completed link (4 spools and 2 splices)
Students should rotate through each station

Determining Splice Acceptance

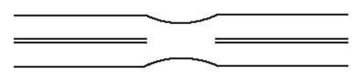
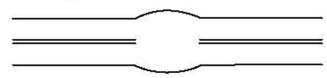
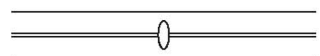
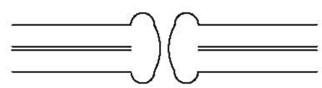
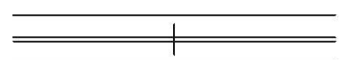
If you have an older fusion splicer with manual controls, you may actually see bad splices. Modern splicers are automatically controlling the parameters so the faults you see here are probably not going to happen, but you can learn more about fusion splicing by understanding what can happen.

Visually inspect each splice, using both X and Y views in the splicer video screen. Today's splicing machines are so well set up that making bad splices is difficult. They automatically check the quality of the cleaves, align fibers and fuse them according to the program selected. Making a bad slice is difficult; even if a cleave is bad, the machine will not try to splice the fiber but tell you to redo the cleave.

However, older splicers with more manual programs can cause problems, so it's important to understand how bad splices look in the machine's display. Here are some drawings from Sumitomo from early splicing machines that explain the possible problems.

Possibly Acceptable Some flaws that do not affect optical transmission (that is are low loss) are acceptable, as shown in the drawing to the right. Some fibers (e.g. fluorine-doped or titanium coated) may cause white or black lines in splice region that are not faults.	
Unacceptable Some flaws such as those shown in the drawing to the right are unacceptable and require starting the splicing process over. Some, like black spots or lines, can be improved by repeating the ARC step, but never more than twice. For large core offsets, bubbles or bulging splices, always redo the splice.	

Troubleshooting Splice Problems

Current too high Feed rate too slow Prefusion time too long Prefusion current too high Gap too wide Contaminated electrodes	Constriction 
Autofeed too fast Incorrect current	Enlargement 
Contaminated fiber end faces Poor cleave Fusion current too high Prefusion current or time too low	Bubble or inclusion 
Contaminated electrodes Fusion current much too high Prefusion time much too long Prefusion current much too high Autofeed too small Gap too large	Matchheads 
Fusion current too low Prefusion time too short	Not fused through 

Testing Fusion Splices

Every fusion splicer makes an estimate of the loss of the splice using calculations based on the alignment method. This is just an estimate based primarily on the alignment of the fibers so it can be inaccurate on some splices. The lab setup recommended has the advantage that each splice can be tested with an OTDR and the loss of the splice verified. If possible, use a single fiber that has been broken and then spliced to avoid the directional variations in loss of different fibers. If different fibers are used for one or more splices, test in each direction with the OTDR and note differences - good practice for the testing labs. If a directional difference is noted, you can measure the attenuation coefficient of each fiber and see if the relationship of fiber attenuation coefficient and loss differences at the splice are as predicted.

Protecting Splices

Splice Trays and Closures

For protection against the outside plant environment and damage, splices require placement in a protective case. They are generally placed in a splice tray which is then placed inside a splice closure for OSP installations or a patch panel box for premises applications. Indoors, splice trays are often integrated into patch panels to provide for connections to the fibers.

There are probably thousands of different types and options on splice closures. Some are designed for concatenation of long distance cables where two identical cables are spliced together. Some closures are designed for connecting several smaller cables to a larger one for breaking out the larger cable to several destinations. Closures can be used for midspan entry also, where the cable jacket is stripped but most of the buffer tubes are coiled inside without opening, while one or more tubes will be opened and spliced to other cables. Some have cables entering into one end, some have cable entries on both ends.

There are splice closures designed to be buried, mounted on walls, hung from cables or poles. Some are small pedestals themselves. Each type has a particular application and probably every application has a special closure. Even special hardware may be necessary for handling different cable or splice types, so make certain you have the right hardware before using the closure. It is recommended that you work with vendors to find the best closure for your applications then follow their instructions.

Preparing cables for splice closures involves several steps that should be followed in the exact sequence specified by the manufacturer to ensure the cables are properly secured and the closure will seal. For every splice closure, it is important to follow the manufacturer’s instructions on stripping the cable to ensure proper lengths of strength members to secure the cable to the closure and proper lengths of buffer tubes to connect to the splice trays. The proper length of fiber is needed to allow splicing and then neatly storing fiber in the splice tray. Inside splice closures and at each end, cables with metallic shielding or strength members must be properly grounded and bonded.

Care should be taken when arranging fibers and splices in splice trays and buffer tubes in the splice closure to prevent stress on the fibers. Arranging fibers inside splice trays may require twisting the fiber but following the closure manufacturer’s instructions will minimize the stress on the fiber.

Often the fibers are broken as the trays and closure are assembled or re-entered for troubleshooting and repair. Cables must be secured to the splice closure and sealed properly. Generally loose tube cables will have the tubes extending from the entrance of the closure to the tray, where they are secured, then approximately 1 meter of bare fibers are organized in the tray after splicing. Care must be taken to properly bond electrical conductors such as the armor on some cables or center metallic strength members to the closure and at each end.

All closures must be sealed to prevent moisture entry. Closures must be properly secured, with the location being determined by the installation type, and excess cable properly coiled and stored. This may be in a pedestal or vault, on a pole or tower or buried underground.

Exercise

Using the splice closure and an OSP loose tube or armored cable you have for practice, follow the instructions for the closure to prepare the cable, attach it to the closure, attach a buffer tube to a splice tray. Repeat for a second cable, then follow directions for the closure to splice two tubes of fibers together and dress the fibers properly in the trays. Then close the tray cover, place it in the closure and close and seal the closure.

The Fiber Optic Association Inc.
www.foa.org info@foa.org Tel/Text: 760-451-3655

Splicing Worksheet

Name:________________________________

1. On the following table, answer the questions by choosing the correct splice for each statement.

	Fusion Splice	Mechanical Splice
Lowest Loss		
Best reflectance		
Best for singlemode		
Best for multimode		
Least equipment cost		
Least inexpensive for high volumes of splices		
Least inexpensive for low volumes of splices		

2. What is the typical loss for each type splice?	dB	dB

Mechanical Splicing
3. What loss did you get when you tested your splices?

#1____dB

#2____dB

#3____dB

Fusion Splicing
4. What loss did you get when you tested your splices?

#1____dB

#2____dB

#3____dB

Mechanical Splicing Scorecard

Below is a “scorecard” for mechanical splicing. Check off “√” when you have correctly completed each step; repeat the step if it is a “X” until it is done correctly. If you have a mentor or instructor, have them provide feedback.

Mechancial Splicing Scorecard. (Print this page & duplicate for each exercise)

Process Step	Completed		Comments or Mentor/Instructor Feedback
	√	X	
Set up tools and components for exercise			
Prepare cable for splicing			
Strips fiber to appropriate length			
Checks for fiber integrity after stripping			
Cleans fiber			
Cleave fiber			
Discards glass shard			
Inserts fiber into one side of splice			
Repeat with second fiber			

Use VFL to verify splice			
Secure both fibers into splice			
Place completed splice in tray of splice closure			
Test splice with OLTS or OTDR if available			

Fusion Splicing Scorecard

Below is a "scorecard" for fusion splicing. Check off "√" when you have correctly completed each step; repeat the step if it is a "X" until it is done correctly. If you have a mentor or instructor, have them provide feedback.

Fusion Splicing Scorecard. (Print this page & duplicate for each exercise)

Process Step	Completed		Comments or Mentor/Instructor Feedback
	√	X	
Set splicer program and run calibration if needed			
Prepare cable for splicing			
Strips fiber to appropriate length			
Checks for fiber integrity after stripping			
Cleans fiber			

Inserts fiber into holder if required			
Cleave fiber			
Discards glass shard			
Place fiber in splicer & clamp			
Repeat with second fiber			
Close cover on splicer			
Run splicing program and verify results			
Remove spliced fibers			
Slide splice protector over splice point Insert protector in heater and run program Remove completed splice Place completed splice in tray of splice closure Test splice with OTDR if available			