Vanderbilt University

Mech. Engineering Techniques and Best Practices Manual

Guidelines for quality and efficient handwork

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Contents

Soldering

Definition:

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal. Soldering differs from welding in that soldering does not involve melting the work pieces. [wikipedia]

Resources:

THIS IS A MUST WATCH BEFORE YOU BEGIN:

1. https://www.youtube.com/watch?v=BLfXXRfRIzY [colderstart user youtube]
   Very basic soldering guide. Less than 5 min.

2. https://www.youtube.com/watch?v=J5Sb21qbpEQ [EEVblog youtube channel]
   https://www.youtube.com/watch?v=fYz5nIHH0iY [EEVblog youtube channel]
   https://www.youtube.com/watch?v=b9FC9fAlfQE [EEVblog youtube channel]
   A 3 part quite in-depth tutorial. 1st link is dedicated to soldering tools. 2nd link is soldering through hole components to PCB boards. 3rd link is soldering surface mount components. Quite detailed and is a great source if you'll be doing a lot of solder work or are interested in creating your own circuit boards.

3. The Art of Electronics by Paul Horowitz and Winfield Hill
   Not a book on soldering, but instead a very thorough guide on electronic components and the functions they serve in circuits. Widely recognized as *the* reference on electronic circuits. Great for learning as well as a very useful reference. As a side note, at the time this is written, this book is highly recommended in the graduate level mechatronics class.

Quick tips:

1. Always tin (touch the solder to the iron's tip such that it flows onto it and coats it) your iron before heating the components you want to solder as this will DRASTICALLY improve the heat transfer and therefore solder flow.

2. Use a **WET** sponge instead of the flick method to remove excess solder. That being said, still use safety goggles.

3. When possible, make use of a third hand. Keeping the work pieces that are to be joined stationary and in direct physical contact to each other makes the job much easier.

Third hand

4. Ensure there is a good physical connection between the wires/components prior to soldering

5. Avoid touching the soldering iron with the solder once it is tinned- Use the iron to heat the wire and then melt the solder on to the heated joint.

6. Try not to breath in solder fumes by working in a well-ventilated area or by working next to a fan. Even if the solder is lead-free (which, as a side note, tends to be more difficult to work with), the fumes may be hazardous to your health and prolonged exposure should be avoided.

7. Always wash your hands after soldering.

8. When soldering small components or metal that's close to plastic (e.g., leads of a linear potentiometer, operational amplifiers), don't hold the iron on the component you are soldering for too long or you may damage the component. Use the coolest setting on the iron that will melt the solder for better results (660 °F or 350 °C is good for most general purpose soldering, 750 °F or 400 °C should be used for large components and heat sinks, higher temperature should be reserved only for lead-free soldering with large components and rework).

9. You can always test the quality of your joints by using your multimeter's continuity mode. The figure below shows the symbol to which you should set your multimeter. When you touch the probes together, you should hear a beep indicating a sound electrical connection. When you join two conductive paths using solder, you can check whether current can run freely through the newly formed connection by placing the probes at the two location of your circuit which you now expect to be electrically joined.

Multimeter in continuity mode with probes touching
(you should hear a continuous beep as long as the probes are in contact)

10. Soldering is **not** used to make mechanical connections. Solder should not be viewed as glue and will not join parts in such a way that the join can be stressed. **Use it only to make electrical connections**.

11. Never try to use a soldering iron to melt or cut plastic. NEVER. It will just ruin the soldering iron.

Drilling

Definition:

A cutting process that uses a drill bit to cut or enlarge a hole of (almost always) circular cross-section in solid materials. The drill bit is a rotary cutting tool, often multipoint. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the workpiece, cutting off chips (swarf) from the hole as it is drilled. [wikipedia].

Resources:

1. Machining Fundamentals by John R. Walker. The Goodheart-Willcox Company Inc., 2004. Tinley Park, Illinois. p.153-182. Wide overview of drill and drill machine types, clamping devices, basic safety, different drilling operations and good practices.
2. Shop Reference for Students and Apprentices 2nd ed. compiled by Edward G. Hoffman. Industrial press Inc., 2000. New York. p. 361-369. Quick tips on drilling. Large collection of recommended cutting speeds for different materials.
3. https://www.youtube.com/watch?v=zqtO3NnixwQ [doitbestcorp user youtube] Basic guide on hand-held drills, tools, and techniques. < 4 min.
4. https://www.youtube.com/watch?v=VBSAqU8aunI [Ray LeBel user youtube] < 1 min video on what peck drilling looks like.
5. https://www.youtube.com/watch?v=6JyIR5nwRho [Kenneth Finnegan user youtube] 16 min video covering the basics of using a drill press. Numerous tools for drilling operations are shown and discussed. **NOTE:** This fine gentleman, despite being knowledgeable in the use of a drill press, decided to hold his work piece. This is NOT something you should EVER do, so -20 pts for him, and please don't follow this bad example. Use a c-clamp or a vise.

Quick Tips:

1. As with all machining, always wear safety goggles and secure/tuck-in loose clothing, jewelry, long hair, or anything else that can get caught in the spindle.

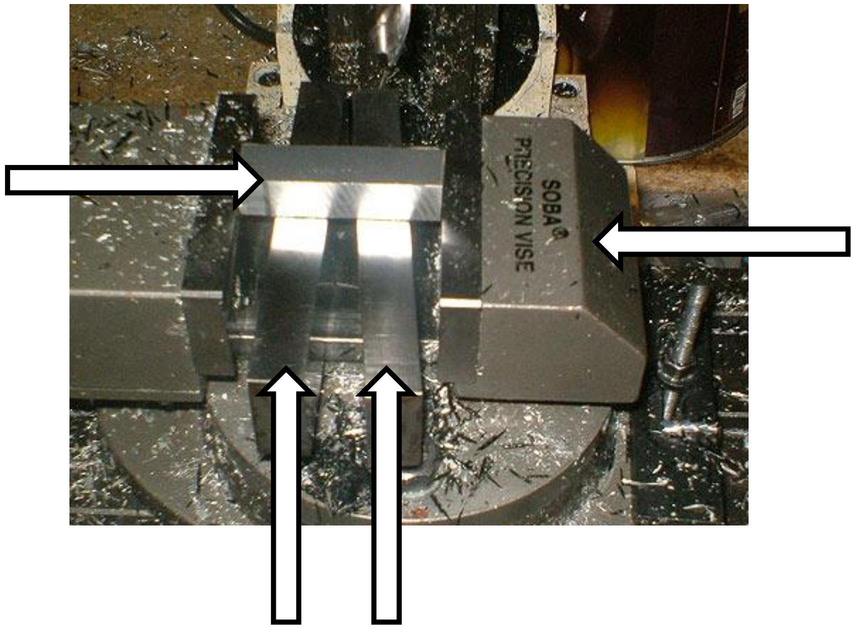
2. Use a center punch and center finder before drilling to ensure accurate hole placement. If even more accuracy is desired, consider using a mill with digital position readout in conjunction with an edge finder.

3. Always clamp the work piece solidly using a vise or a set of solid c-clamps (several is better). Never hold the work piece with your hand. A properly held work piece should not move

4. Parallels are often used in conjunction with a vise to level your work piece and lift it off the vise base to drill through holes (see picture on next page).

5. Always check the drill diameter before drilling a hole using either calipers or a micrometer. New drills are checked across the drill margins (i.e., largest diameter of the fluted section of the drill), worn drills are checked on the shank at the end of the flutes.

6. Remember to always remove the key from the chuck before turning the drill on.



7. Check that the drill runs true after tightening it in the chuck. Drill bits get warped during improper use and may not be able to make good straight holes.

8. To locate your initial hole location after using a center punch, use a center drill to begin the drilling process.

9. If drilling a hole larger than 0.25" start with at least a 0.25" drill bit or a similar sharp drill bit about that size.

10. Cutting fluid **<u>should always</u>** be used in steel and Aluminum. Cutting fluid prolongs drill bit life while simultaneously making the drilling operation easier by reducing friction at the cutting edges and improving hole finish. Use a cutting fluid whenever possible **EXCEPT** when drilling cast iron or other brittle materials. When working with those types of materials, use compressed air intermittently. Always thoroughly wash your hands after using cutting lubricants and read the warning on the container to know what to do should some get in your eye.

11. Use the correct cutting speed for the material you are working on. Speeds that are too slow or too high decrease tool life and increase chance of drill bit breakage (which, if you don't care so much about drill bits that are not your own, can, and most likely will, destroy your work piece). For the correct cutting speed for your specific material, check the Resource 2 (Shop Reference…) in the section above. Here is a rough guideline for cutting speeds for common materials:

$$\text{RPM for cutting operation} = \frac{12 \times speed\ from\ table\ (feet/min)}{3.14 \times diameter\ of\ drill\ bit\ (inches)}$$

Cutting Speed Selection Guide

Material	Cutting speed using a high-speed steel cutter (feet/min)
Plain carbon steel	40-50
Alloy steel	40
Cast steel	55 (down to 30 for higher carbon content)
Stainless steel	40
Wrought and cast aluminum alloys	350
Brass	160
Gray cast iron	60-100
Malleable iron	45

12. A dull drill bit will squeak and overheat. Also, watch for blue, rough chips and drill press slow down as signs of a dull drill bit.

13. When removing a drill from a drill press, place a piece of wood not far below it. Small drills can be damaged if dropped and larger ones can cause injury.

14. Clean chips off using a brush instead of your hands. Splinters are not pleasant, independent of constituent material.

15. Use peck drilling to drill small diameter holes. Drill in 0.25” increments, letting the drill bit completely emerge from the work piece between each ‘peck’, completing the hole through incremental cutting (see Resources (4) video). This will help clear the chips from the hole, which can otherwise cause the drill bit to get jammed and break. You can also apply cutting fluid intermittently during peck drilling to aid the drilling operation, cool the drill bit, and increase its lifetime.

16. Never rapidly cool drill bits by plunging them into water. The shock of sudden cooling can crack them.

Sawing

<u>Definition:</u>
A material cutting process that uses a blade with a series of teeth on its edge to cut a narrow opening in a workpiece. Sawing may be used to produce slots or grooves or to separate the workpiece into two pieces. [http://www.toolingu.com/]

<u>Resources:</u>

1. https://www.youtube.com/watch?v=AcA-ReT3EHA [Toms Techniques user youtube] Excellent 6 min safety video on band saw use. Definitely watch this if you're just starting to use this machine or if you need a refresher. Also shows how to safely cut round stock on a vertical band saw.
2. https://www.youtube.com/watch?v=ZYlLIp5urJQ [IUSculpture's channel user youtube] Great 10 min video demonstrating the versatility of the band saw and some best practices. **NOTE:** The user does have his hands a little too close to the blade, AVOID doing this. Use a push stick or clamp your work piece with a vise grip to distance your hands from the fast-traveling, serrated metal band of destruction.

<u>Quick Tips:</u>

1. Never test the sharpness of any saw by running your finger along the teeth. Find a small scrap piece of material or visually inspect the teeth.

2. Always wear safety goggles with all saws. Even a hacksaw blade can shatter and produce flying metal shrapnel.

3. Choose the correct saw for the job. Here are some common types:

Hand Saw Type Selection Guide

<table>
<tr><th>Saw Type</th><th>Material</th></tr>
<tr><td>Crosscut saws and ripsaws

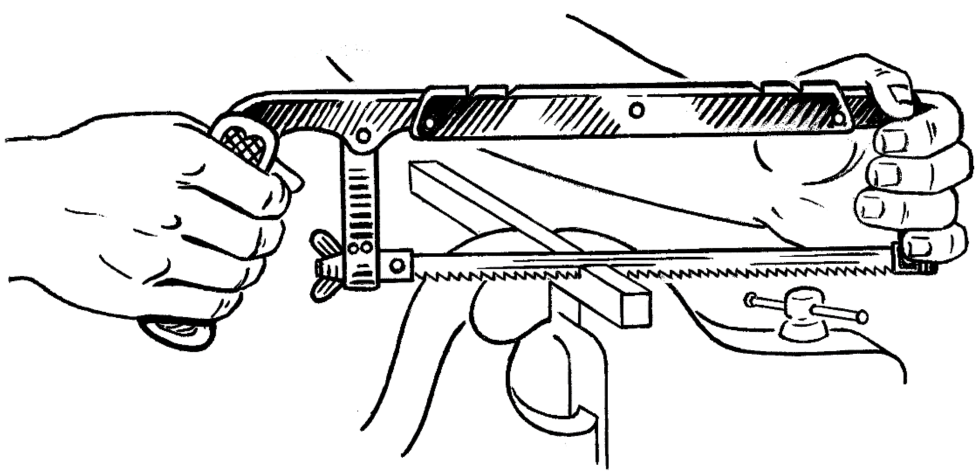

</td><td>Wood</td></tr>
<tr><td>Keyhole saw


</td><td>Wood, drywall</td></tr>
</table>

Saw Type	Material
Coping saw 	Wood (contoured or smooth line cuts)
Hacksaw  	Metal and plastic

Hacksaw

1. When mounting a new hacksaw blade, make sure the teeth are facing away from the handle such that the saw cuts on its forward motion.



Hacksaw (note the blade teeth orientation and the proximity of the cut to the vise)

2. A hacksaw blade should “ping” when snapped with your finger. Frequently a blade must be retightened after the first few strokes as it will stretch slightly from the head produced while cutting.

3. Use a vise or a c-clamp to tightly secure your work piece and cut as close to the vise/c-clamp as practically possible to limit chatter.

4. The first cut should be started on a flat side as opposed to a corner or edge. It is also good practice to notch the work with a file.

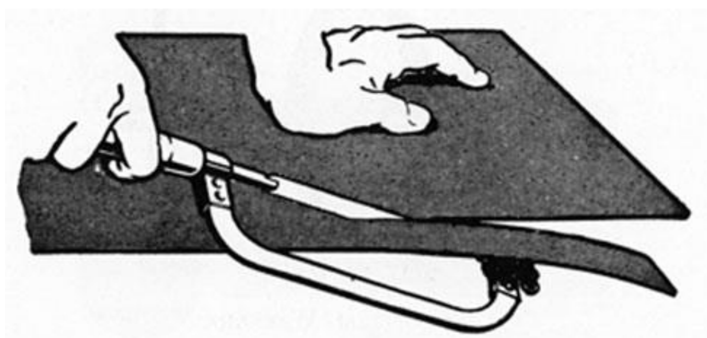
5. Hold the hacksaw by the handle and the front of the frame. Apply enough pressure on the forward stroke and lift the saw slightly on the return stroke. Cut with the full length of the blade.

6. If you break or dull a hacksaw blade, do not continue with a new blade in the same cut as the new blade will often bind and be ruined. Rotate the work and start the cut on the opposing side.

7. When the blade has almost cut through the work, saw carefully and support the piece being cut off with your free hand.

8. For mild materials and hard steels, use coarse blades with plenty of chip clearance. For tubing, angle iron and sheet metal work use fine pitched blades. 2-3 teeth should be in contact/cutting at all times.

9. Cutting long narrow strips from thin metal can be done by setting the blade at a right angle to the frame as shown below. Also, thin metal can be cut more easily and precisely by sandwiching it between two pieces of wood and cutting through both wood and metal.



Band Saw

1. If you're installing a new band saw blade, wear heavy leather gloves.

2. Adjust the band saw guides to be about 1/4"-1/2" above the piece that you're going to cut. Make sure that the piece can clear under the guides along its cutting path.

3. Lubricate the band saw blade on both sides to increase tool life and reduce noise while cutting. Carefully (with your hands out of the blade's path, and the stick on the band saw table) holding a wax stick up to a running blade is a common method for lubrication but cutting fluid can also be used.

4. Use a push stick or vise grip to make sure your fingers are **never** in the path of the blade behind your work piece.

5. Be careful cutting round stock or any work piece that tends to rotate. Special precautions need to be made, watch Resource # 1 (Toms Techniques) to see how this can be done safely.

6. When cutting a long piece/creating a long cut, be weary that the blade can be “pinched” by the recently cut region as material is removed. This can be addressed by applying a gentle pulling force on both side of the cut BEHIND the running blade. Ask someone to assist you as opposed to reaching around the blade.

Using a Rotary Tool ("Dremeling")

Definition:

A rotary tool is a hand held power tool with a variety of rotating accessory bits and attachments that can be used for cutting, carving, sanding, polishing and many other applications.

The smaller rotary tools use high RPMs to maintain the correct cutting conditions for the tool bits. They have low torque which makes them safer for freehand use than the larger higher powered models or similar power tools. A wide variety of accessories are available for applications such as cutting, carving, sanding, polishing, and grinding. The carving (or cutting) bits are referred to as burrs and are similar to those used by dentists.

Rotary tools are sometimes called "Dremels" because of the market strength of Dremel, a particular brand. But the Dremel name is still protected and is far from legally genericized. [wikipedia]

Resources:

1. https://www.youtube.com/watch?v=7pL-2LaLyUM [Engineering Lab Safety user youtube] A quick (less than 4 min) overview of basic rotary tool safety. Brief examples of grinding jobs.
2. http://www.dremel.com/en-us/videosandhowto/Pages/default.aspx [official Dremel website] A plethora of DIY videos for all sorts of projects involving cutting, sanding, engraving, grinding, etc., etc., Most videos are quite short.

Quick Tips:

1. Many rotary tool jobs produce a large amount of debris and, when cutting hardened metals, sparking is not uncommon. Therefore, rotary tools should be operated while wearing both, safety goggles and adequate gloves (for working with hard metals, thick fabric which won't limit your dexterity is preferred).
2. Never position your hand such that if the rotary tool slips, your hand is along its cutting/grinding plane.
3. Always, always, make sure that whatever you are using a rotary tool on is <u>very</u> securely clamped.
4. 3 common rotary tool grips:

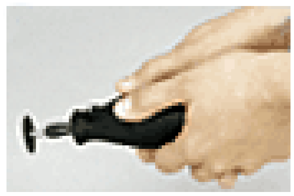
   THE PENCIL GRIP
   This grip offers the best control for fine detail work. Use this only once you got comfortable with the tool and if you're engraving a very soft material (such as a pumpkin) at low speeds.

Pencil Grip

   THE PARING KNIFE GRIP
   Use this grip with cutters when making longer, smoother cuts. This grip offers good control for cutting depth. This grip is probably used most often. Remember that even though a rotary tool has relatively low torque, if the spinning bit seizes up in/on the work piece, you'll have very little time to react, which may lead to all sorts of injuries. Remember to always use a light touch with a rotary tool. You're just guiding the tool. Let the high speed do all the work.

Paring Knife Grip

THE GOLF GRIP
One and two hands. When you want to keep the tool parallel to the work surface for sanding or grinding, use the one-handed grip. Use the two-handed grip every time you use a cut-off wheel. Cut-off wheels can stick and cause kickback. Two hands offer better control. However, just as with the paring grip, don't apply too much force towards the workpiece, and instead, let the high RPM do the work.

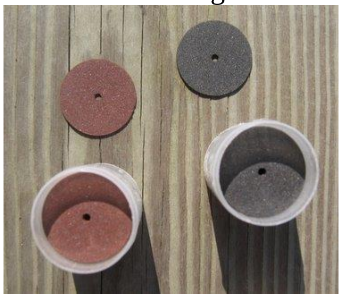
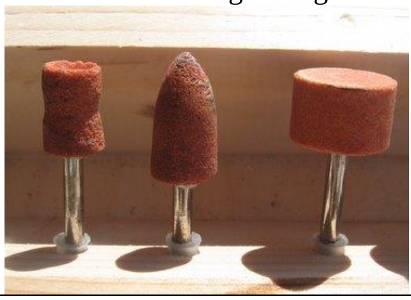


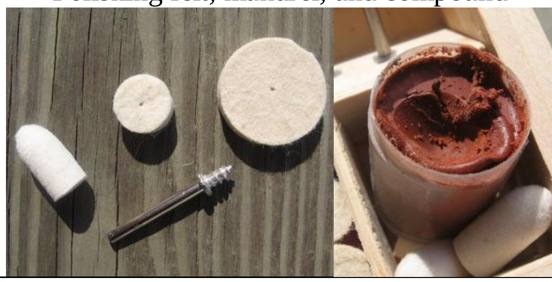
Golf Grip

5. Common rotary tool bits and their uses:

Rotary Tool Bit Selection Guide

Attachment	Use	Material
Diamond bits 	Carving and engraving	Metals Bookboard Ceramic tile Glass Mirror
High-speed cutters 	Carving and engraving	Bookboard Linoleum Polymer clay Wood

Attachment	Use	Material
Sanding bands and drums 	Sanding	Metals Bookboard Plexiglass Polymer clay Wood
Abrasive cutting wheels 	Cutting	Mostly metals Wood Plastic
Fiberglass cutting wheels 	Cutting	Metals including hardened steel Ideal for shortening fasteners and making slots in stripped ones
Aluminum oxide grinding tools 	Grinding	Metals Castings Welded joints Rivets Rust General purpose
Aluminum oxide grinding tools (higher grade) 	Grinding	Use on harder steels than the orange tools above

Attachment	Use	Material
Polishing felt, mandrel, and compound 	Cleaning and polishing	Aluminum Ceramic tile Glass Mirror
Carbon steel brushes 	Polishing Removing rust and corrosion Cleaning electrical components	Pewter Aluminum Stainless steel

6. Recommended cutting speeds for cut-off wheels:

Rotary Tool Cutting Speeds

Fiberglass Reinforced Cut-off Wheels

MATERIAL	RPMs (1000s)
Aluminum	35
Brass	35
Ceramic	35
Copper	35
Hardwood	20-35
Plastic	10-15
Softwood	20-35
Stone	35
Shell	35
Steel	35

Cut-off Wheels

MATERIAL	RPMs (1000s)
Aluminum	35
Brass	35
Ceramic	35
Copper	35
Hardwood	20-35
Plastic	10-15
Softwood	20-35
Stone	35
Shell	35
Steel	35

Cutting/Shaping Wheel

MATERIAL	RPMs (1000s)
Hardwood	30-35
Plastic	10-15
Softwood	35

MultiPurpose Cutting Bit

MATERIAL	RPMs (1000s)
Aluminum	20-35
Brass	35
Copper	35
Drywall	35
Hardwood	20-35
Plastic	10-15
Softwood	20-35

Drywall Cutting Bit

MATERIAL	RPMs (1000s)
Drywall	35

Carbide Grout Removal Bit

MATERIAL	RPMs (1000s)
Grout	20

Tile Cutting Bit

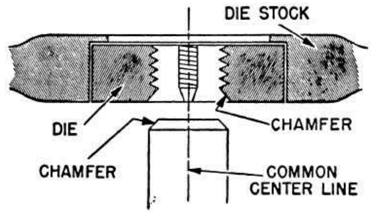
MATERIAL	RPMs (1000s)
Ceramic wall tile	35

Tapping and Threading

Definition:
Taps and dies are cutting tools used to create screw threads, which is called threading. A tap is used to cut the female portion of the mating pair (e.g., a nut). A die is used to cut the male portion of the mating pair (e.g., a bolt). The process of cutting threads using a tap is called tapping, whereas the process using a die is called threading. Both tools can be used to clean up a thread, which is called chasing. [wikipedia]

Resources:
1. https://www.youtube.com/watch?v=KVnN4jiB7Gk [youtube user NewMetalworker] < 4 min video introduction to tapping and threading. Best starting place if you have never used a tap or a die.
2. https://www.youtube.com/watch?v=gVcwjjBAT4Q [youtube user diplocraterion] < 3 min Small demonstration of using a die to cut external threads. Good introduction, not the best quality video, but the British accent will keep you entertained.
3. https://www.youtube.com/watch?v=0MyzdVGQXkg [youtube user Ultimate Handyman] < 4 min video on tapping threads using a drill. Advanced technique that should be used only if you're comfortably with tapping by hand.

Quick Tips:
1. The first step in creating a well-tapped hole for a fastener is to create a well-drilled, correctly-sized hole to work with. Refer to the section on drilling for proper technique.
2. Refer to the thread/screw drill & tap charts for both imperial and metric fasteners (p.17-18) to make sure the drilled hole is of the correct diameter. As a simple, quick check, ensure that your chosen drill's diameter is smaller than the diameter of the fastener for which you'll be tapping.
3. Using tapping fluid (or cutting fluid, e.g., Tap Magic) makes tapping MUCH easier in metals.
4. When you start tapping your hole, after the first couple of threads are cut, make sure to follow the one turn forward, half a turn back technique shown in Resources 1 (NewMetalworker video). If you feel the tap is straining quite a bit during the cutting motion, reduce the forward motion to half a turn. DO NOT forcibly turn taps that are providing quite a bit of resistance as it is unfortunately quite easy to break them. You can easily destroy the tool as well as your work piece.
5. When using a die to cut the external thread, it is necessary to chamfer the round stock on all sides such that the die can engage the stock easily as shown below.



The chamfer helps the die engage the round stock
to start the external thread cutting

6. Use the technique of going a turn forward and half a turn back when cutting external thread with a die as shown in Resources 2 (diplocraterion video)

Imperial Drill & Tap Chart

Size		Threads Per Inch	Minor Dia	Tap Drills				Clearance Hole Drills			
				Alum, Brass, & Plasitcs		Stainless Steel, Steels & Iron		All Materials			
				75% Thread		50% Thread		Close Fit		Free Fit	
# or Dia	Major Dia			Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.
0	0.0600	80	0.0447	3/64	0.0469	55	0.0520	52	0.0635	50	0.0700
1	0.0730	64	0.0538	53	0.0595	1/16	0.0625	48	0.0760	46	0.0810
		72	0.0560	53	0.0595	52	0.0635				
2	0.0860	56	0.0641	50	0.0700	49	0.0730	43	0.0890	41	0.0960
		64	0.0668	50	0.0700	48	0.0760				
3	0.0990	48	0.0734	47	0.0785	44	0.0860	37	0.1040	35	0.1100
		56	0.0771	45	0.0820	43	0.0890				
4	0.1120	40	0.0813	43	0.0890	41	0.0960	32	0.1160	30	0.1285
		48	0.0864	42	0.0935	40	0.0980				
5	0.1250	40	0.0943	38	0.1015	7/64	0.1094	30	0.1285	29	0.1360
		44	0.0971	37	0.1040	35	0.1100				
6	0.1380	32	0.0997	36	0.1065	32	0.1160	27	0.1440	25	0.1495
		40	0.1073	33	0.1130	31	0.1200				
8	0.1640	32	0.1257	29	0.1360	27	0.1440	18	0.1695	16	0.1770
		36	0.1299	29	0.1360	26	0.1470				
10	0.1900	24	0.1389	25	0.1495	20	0.1610	9	0.1960	7	0.2010
		32	0.1517	21	0.1590	18	0.1695				
12	0.2160	24	0.1649	16	0.1770	12	0.1890	2	0.2210	1	0.2280
		28	0.1722	14	0.1820	10	0.1935				
		32	0.1777	13	0.1850	9	0.1960				
1/4	0.2500	20	0.1887	7	0.2010	7/32	0.2188	F	0.2570	H	0.2660
		28	0.2062	3	0.2130	1	0.2280				
		32	0.2117	7/32	0.2188	1	0.2280				
5/16	0.3125	18	0.2443	F	0.2570	J	0.2770	P	0.3230	Q	0.3320
		24	0.2614	I	0.2720	9/32	0.2812				
		32	0.2742	9/32	0.2812	L	0.2900				
3/8	0.3750	16	0.2983	5/16	0.3125	Q	0.3320	W	0.3860	X	0.3970
		24	0.3239	Q	0.3320	S	0.3480				
		32	0.3367	11/32	0.3438	T	0.3580				
7/16	0.4375	14	0.3499	U	0.3680	25/64	0.3906	29/64	0.4531	15/32	0.4687
		20	0.3762	25/64	0.3906	13/32	0.4062				
		28	0.3937	Y	0.4040	Z	0.4130				
1/2	0.5000	13	0.4056	27/64	0.4219	29/64	0.4531	33/64	0.5156	17/32	0.5312
		20	0.4387	29/64	0.4531	15/32	0.4688				
		28	0.4562	15/32	0.4688	15/32	0.4688				
9/16	0.5625	12	0.4603	31/64	0.4844	33/64	0.5156	37/64	0.5781	19/32	0.5938
		18	0.4943	33/64	0.5156	17/32	0.5312				
		24	0.5114	33/64	0.5156	17/32	0.5312				
5/8	0.6250	11	0.5135	17/32	0.5312	9/16	0.5625	41/64	0.6406	21/32	0.6562
		18	0.5568	37/64	0.5781	19/32	0.5938				
		24	0.5739	37/64	0.5781	19/32	0.5938				
11/16	0.6875	24	0.6364	41/64	0.6406	21/32	0.6562	45/64	0.7031	23/32	0.6562
3/4	0.7500	10	0.6273	21/32	0.6562	11/16	0.6875	49/64	0.7656	25/32	0.7812
		16	0.6733	11/16	0.6875	45/64	0.7031				
		20	0.6887	45/64	0.7031	23/32	0.7188				
13/16	0.8125	20	0.7512	49/64	0.7656	25/32	0.7812	53/64	0.8281	27/32	0.8438
7/8	0.8750	9	0.7387	49/64	0.7656	51/64	0.7969	57/64	0.8906	29/32	0.9062
		14	0.7874	13/16	0.8125	53/64	0.8281				
		20	0.8137	53/64	0.8281	27/32	0.8438				
15/16	0.9375	20	0.8762	57/64	0.8906	29/32	0.9062	61/64	0.9531	31/32	0.9688
1	1.0000	8	0.8466	7/8	0.8750	59/64	0.9219	63/64	1.0156	31/32	1.0313
		12	0.8978	15/16	0.9375	61/64	0.9531				
		20	0.9387	61/64	0.9531	31/32	0.9688				

Metric Drill & Tap Chart

Metric Tap & Clearance Drill Sizes		Tap Drill				Clearance Drill			
		75% Thread for Aluminum, Brass, & Plastics		50% Thread for Steel, Stainless, & Iron		Close Fit		Standard Fit	
Screw Size (mm)	Thread Pitch (mm)	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill	Drill Size (mm)	Closest American Drill
M1.5	0.35	1.15	56	1.25	55	1.60	1/16	1.65	52
M1.6	0.35	1.25	55	1.35	54	1.70	51	1.75	50
M 1.8	0.35	1.45	53	1.55	1/16	1.90	49	2.00	5/64
M 2	0.45	1.55	1/16	1.70	51	2.10	45	2.20	44
	0.40	1.60	52	1.75	50				
M 2.2	0.45	1.75	50	1.90	48	2.30	3/32	2.40	41
M 2.5	0.45	2.05	46	2.20	44	2.65	37	2.75	7/64
M 3	0.60	2.40	41	2.60	37	3.15	1/8	3.30	30
	0.50	2.50	39	2.70	36				
M 3.5	0.60	2.90	32	3.10	31	3.70	27	3.85	24
M 4	0.75	3.25	30	3.50	28	4.20	19	4.40	17
	0.70	3.30	30	3.50	28				
M 4.5	0.75	3.75	25	4.00	22	4.75	13	5.00	9
M 5	1.00	4.00	21	4.40	11/64	5.25	5	5.50	7/32
	0.90	4.10	20	4.40	17				
	0.80	4.20	19	4.50	16				
M 5.5	0.90	4.60	14	4.90	10	5.80	1	6.10	B
M 6	1.00	5.00	8	5.40	4	6.30	E	6.60	G
	0.75	5.25	4	5.50	7/32				
M 7	1.00	6.00	B	6.40	E	7.40	L	7.70	N
	0.75	6.25	D	6.50	F				
M 8	1.25	6.80	H	7.20	J	8.40	Q	8.80	S
	1.00	7.00	J	7.40	L				
M 9	1.25	7.80	N	8.20	P	9.50	3/8	9.90	25/64
	1.00	8.00	O	8.40	21/64				
M 10	1.50	8.50	R	9.00	T	10.50	Z	11.00	7/16
	1.25	8.80	11/32	9.20	23/64				
	1.00	9.00	T	9.40	U				
M 11	1.50	9.50	3/8	10.00	X	11.60	29/64	12.10	15/32
M 12	1.75	10.30	13/32	10.90	27/64	12.60	1/2	13.20	33/64
	1.50	10.50	Z	11.00	7/16				
	1.25	10.80	27/64	11.20	7/16				
M 14	2.00	12.10	15/32	12.70	1/2	14.75	37/64	15.50	39/64
	1.50	12.50	1/2	13.00	33/64				
	1.25	12.80	1/2	13.20	33/64				
M 15	1.50	13.50	17/32	14.00	35/64	15.75	5/8	16.50	21/32
M 16	2.00	14.00	35/64	14.75	37/64	16.75	21/32	17.50	11/16
	1.50	14.50	37/64	15.00	19/32				
M 17	1.50	15.50	39/64	16.00	5/8	18.00	45/64	18.50	47/64
M 18	2.50	15.50	39/64	16.50	41/64	19.00	3/4	20.00	25/32
	2.00	16.00	5/8	16.75	21/32				
	1.50	16.50	21/32	17.00	43/64				
M 19	2.50	16.50	21/32	17.50	11/16	20.00	25/32	21.00	53/64
M 20	2.50	17.50	11/16	18.50	23/32	21.00	53/64	22.00	55/64
	2.00	18.00	45/64	18.50	47/64				
	1.50	18.50	47/64	19.00	3/4				

Proper Use of Adhesives

Definition:

An adhesive is any substance applied to the surfaces of materials that binds them together and resists separation. Adjectives may be used in conjunction with the word "adhesive" to describe properties based on the substance's physical or chemical form, the type of materials joined, or conditions under which it is applied. The use of adhesives offers many advantages over binding techniques such as sewing, mechanical fastening, thermal bonding, etc. These include the ability to bind different materials together, to distribute stress more efficiently across the joint, the cost effectiveness of an easily mechanized process, an improvement in aesthetic design, and increased design flexibility. Disadvantages of adhesive use include decreased stability at high temperatures, relative weakness in bonding large objects with a small bonding surface area, and greater difficulty in separating objects during testing. [wikipedia]

Resources:

1. https://www.youtube.com/watch?v=3eh0u2FDzwQ [youtube user ubcengphysprojectlab] ~ 1 min video introduction to using epoxy. Very brief and basic, but an excellent introduction.

Quick Tips:

1. Use of safety goggles and gloves are strongly encouraged. Many adhesives are chemically dangerous compounds that can cause serious problems with physical exposure.
2. Some adhesives give off toxic fumes. Make sure to read the warning label and work in either a well-ventilated area or use a respirator.
3. Selecting the right adhesive for the job is the first step in a achieving a good quality bond. Here is a rough guide to choosing the proper adhesive for the job. Remember, reading the directions/description of suitable materials on the specific adhesive itself is a better way of ensuring a good bond.

Adhesive Selection Guide

Adhesive	Material candidates	Bond strength	Drying Time/Curing Time Notes
PVA (polyvinyl acetate, e.g., Elmer's)	Plastic, paper, fabric, styrofoam, organic materials	Weak	Dries in 1 hr, Cures in 24 hrs. Hold in place for first 30 min.
Wood glue (e.g., Titebond Wood Glue)	Wood (surprise)	Strong	Dries in 1 hr. Cures in 24 hrs. Good clamping for first 30 min. Coat both surfaces to be joined.
Cyanoacrylates (super glue, e.g., Krazy Glue)	Metals, glass, ceramics, plastics, organic materials	Strong	Often dries in < 5 min. Cures in 24 hrs. Apply to both surfaces to be joined.
Silicone adhesives (e.g., Permatex RTV Silicone)	Plastics, ceramics, glass, metals.	Weak to moderate	Sets in ~ 5 min, dries in 1 hr. Cures in 24 hrs. Flexible, waterproof bonds.
Epoxies (e.g., Loctite Epoxy)	Plastics, ceramics, wood, glass, metals (J.B. Weld is a good choice), organic materials.	Strong	Setting and drying times vary greatly, check directions. Usually cures in 24-48 hrs.

Adhesive	Material candidates	Bond strength	Drying Time/Curing Time Notes
Hot glue (used with hot glue gun)	All except metals. Usually a better candidate exists.	Weak	Sets in about 15-30 sec, dries in 5-10 min. Cures in 24 hrs. Usually used in crafts and does not provide structurally sound bonding.
Expandable glue (polyurethane adhesives e.g., Gorilla Glue)	Mostly used on wood. Can also work on plastics, glass, ceramics, metals, and organic materials.	Strong	Dries in 1-2 hrs. Cures in 24 hrs. Often water-activated, so surface needs to be slightly moistened. Expands, filling cracks but possibly seeping out of originally intended bonding area. Make sure to use tight clamping.

4. Always clean and prep the surfaces you want to join. Remove dust, debris, grease, oil, moisture (unless glue calls for wet surfaces) and/or oxide film from the surfaces which are to be joined. Poor surface preparation is one of the most common reasons for bond failure. Use the following as a guideline:
    a. Clean the surface from any dust, dirt, any loose particulates. If you use a detergent, make sure to use plenty of water to ensure no amount of it remains after the cleaning process.
    b. Use acetone or isopropyl alcohol to degrease the surface. Although the surface may appear clean, even oil from your fingerprints can undermine the strength of your bond. (**Note:** when adhering plastics, be aware that acetone and isopropyl alcohol may damage certain types of plastics. Make sure you check the plastic's chemical compatibility chart before using either of these substances on it.)
    c. For best bonds/those that require plenty of strength, abrading the surfaces is highly recommended. Not only does this make the surfaces even cleaner, but it also increases the surface area over which the adhesive will be able to grip. Use fine grain (120-200) sand paper, steel wool, emery cloth, or grit blasting. Remember to repeat steps a. and b. from above after finishing as abrading will create particles and may introduce dirt.
5. Improper clamping is another common reason for poor bond strength. Make sure to use c-clamps when possible to apply a good amount of pressure between the two pieces that are being joined as the adhesive cures.
6. Be patient. Just because the pieces are holding together does not mean the bond has achieved its full strength. Check the directions as to how long you should wait to ensure the bond is as strong as it will get.

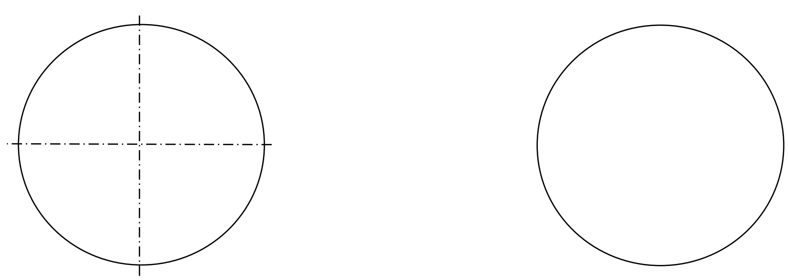
Laser Cutting Prerequisites

<u>Requirements:</u>
If you wish to use the Featheringill senior design Full Spectrum Laser laser cutter, be aware of the following:

1. Before preparing a file and purchasing your material, ensure that the intended material is suitable for cutting. The Full Spectrum Laser Start-up Guide (one copy is located next to the Full Spectrum Laser laser cutter and another one can be found in the Design Studio) includes a table of materials that can and cannot be cut. This guide also includes step-by-step instructions on how to op
2. You will need to ask a trained person to do the laser cutting for you. You are **not** permitted to use the laser cutter by yourself unless you have received the appropriate training and have the explicit permission of Tom Withrow.
3. You will need to provide your own material to cut. Some good sources for basic materials are Lowes and Home Depot for plywood and MDF and McMaster-Carr (http://www.mcmaster.com/) for plastics, rubbers, foams, fabrics, etc.,
4. You will need to prepare your files ahead of time and have them on a USB flash drive (see next section to see how files are prepared). The computer controlling the laser cutter does **not** have internet access, therefore you will **not** be able to simply email the files to yourself.

<u>Preparing files to cut:</u>
Note: This is not the only way to prepare a laser cutting job, but is the most common. The use of Creo/CAD software is encouraged to prep your file as you can use assemblies to ensure your laser cut parts are to scale/the size you need for interaction with other components.

1. Create the piece(s) that you wish to cut out as an extrusion using your choice of CAD software. Remember that the laser cutter can cut only 2D pieces. The thickness of your extrusion does not matter as the thickness of the material you will be cutting will determine the height of the cut piece. However, it would be wise to set the extrusion height to the thickness of the material you will use to get a good sense of the overall shape of your piece.
2. Create a new drawing (.drw in Creo) based off of your created part.
3. In the CAD's drawing mode, remove any lines on the piece that are not explicit cut lines. This includes center lines, datums, reference points, coordinate systems, etc., Your piece should appears in such a way, that every line that is a part of it is a line along which the laser cutter will cut, as is shown with the circle example below.



Not correct

Correct

4. Save your drawing file as a ".dxf" on to a USB flash drive. When saving, make sure to check "export all splines as polylines" option.

Future Sections

Rapid Prototyping/Additive Layer Manufacturing

Working with Materials:
Wood
MDF
PVC
Acrylic
Carbon Fiber Reinforced Polymer (CFRP)
Aluminum
Steel

Painting and coatings
Appropriate primers
Latex paints
Acrylic
Oil based
Spray paint
Enamel
Other coatings
- Hard Chrome
- Anodizing
- Powder coating
- Parkerizing

Working with Circuits
Basic circuit components
Building circuitry
Bread boards
Printed circuit boards (PCBs)
Wire wrapping

Working with motors
- Motor controllers
- DC
- Brushless DC
- AC

Microcontroller Basics
Arduino
Tinyduino
Gumstix
- Tiny AVR – can program in Arduino
- https://www.sparkfun.com/products/11801

PC104
“little bits”
Orangutan family of robotic controllers
Orangutan X2 is by far the most powerful Orangutan, and it is intended for small and medium-sized robots