Essential Tools and Techniques for Nanofab Engineering Students

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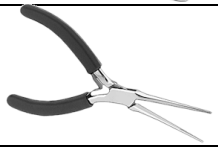
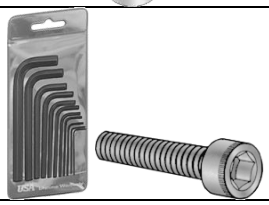
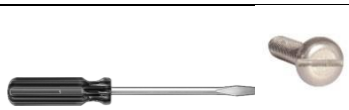
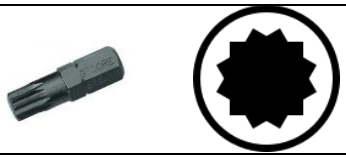
Basic hand tools

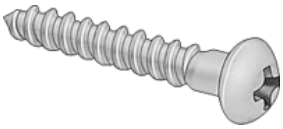
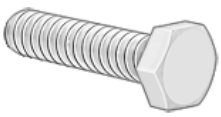
Adjustable wrench: The jaw opening can be adjusted to fit a continuous range of sizes. It is used for turning square or hexagonal shaped nuts, bolts and fittings.	
Fixed wrench: The fixed wrenches have a smaller head, so in tight spaces they work better than adjustable wrenches. They can be open-ended or closed-ended. Some fixed wrenches contain both. Closed-end wrenches can grip the part better, but they need access from the top which may not always be possible in a busy area. Some of the closed end wrenches have a ratcheting style grip so that they can be turned repeatedly without taking them off the part.	
Pipe wrench: This is used for turning round objects such as pipes that don't have a hexagonal or square grip. The jaws are angled so that they can dig into the pipe to prevent it from slipping. The downside of this wrench is that it will scar the pipe surface. The wrench only works in one direction of rotation due to the angle of the teeth.	
Torque wrench: This wrench will indicate the torque being applied with a mechanical indicator or a digital display. The torque value is important in applications where nuts and bolts have to be tightened to a specified value.	
Combination pliers: These are the most common pliers. They have a serrated grip and also a wire cutter.	
Needle nose pliers: These have a pointed tip and are useful for reaching small parts in confined areas.	
Socket wrench: A socket is attached to the handle and then fitted over the nut or bolt being turned. The socket grabs all sides of the item being turned, so there is less chance of the nut slipping and deforming. Sockets are most commonly hexagonal in shape, but can also be a 6-pointed or 12-pointed star. A switch on the wrench handle allows it to turn in either direction for tightening or loosening.	

August 7, 2013

Deep sockets: These are the same as the regular sockets, but have extra clearance inside for a longer reach. These are useful for turning a nut from the long end of a bolt.	
Allen keys: Also known as hex keys, they are used to turn screws with a hexagonal socket in its head.	
Philips Screwdriver: This is used for turning screws with a crossed slot.	
Flat Screwdriver: This is used for turning screws with a straight slot.	
6-point (Torx) Screwdriver: The screw head has 6-pointed slot in a star shape. Due to the greater number of points, this screwdriver can exert a greater torque without damaging the slots.	
12-point (triple square) Screwdriver: The screw head as 12-pointed slot, similar to the Torx.	

<u>Screws, Nuts and Bolts</u>

The general term for all kinds of nuts and bolts is “fasteners”.

Screws: Screws have a tapered thread that allows them to be driven into wood and sheet metals. The screw can cut its own thread as it is driven. This is also known as self-tapping screws. The head can be a hexagonal, straight slot or a crossed slot. Different head profiles are also used, ranging from pan, flat, round etc..	
Bolts: These are designed to be driven into a threaded hole. The head can be hexagonal, straight slot or a crossed slot.	
Nuts: These are designed to hold the other end of the bolt. The majority of nuts have a hexagonal exterior shape. A socket wrench, fixed wrench or adjustable wrench can be used to turn the nut.	

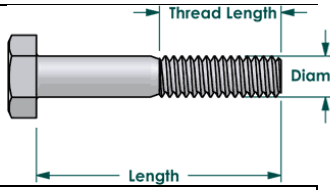
Washers: Washers are used with nuts and bolts to distribute the load, although they also serve many other functions depending on their type. Examples include split-ring lock washers, conical washers etc..	

Tool sizes

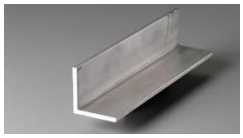
Fractional inch: Tools made in the U.S. mostly use fractional inches, with the denominator in multiples of two, such as ½”, ⅜”, ⅝”, ¼”, 1/16”, 1/32” etc..	
Metric: In the metric system, sizes are typically in whole integer values of millimeters.	

Screw sizes

Screws and bolts have at least three numbers. First one is the diameter of the shaft, and the second is the pitch of the thread. The third number is the length of the screw. Additional numbers could be used for the threaded length and shoulder length. This is the nomenclature used in machining. Different standards are used in other industries such as aviation and military.

Fractional inch: In the fractional system, the diameter of the shaft is given in fractional inches, and the pitch is given in threads per inch. For example, ¼-20 x 1 refers to a bolt with a ¼” diameter shaft and a 20 turn thread per inch and one inch total length. Standard bolt sizes are: ¼-20, ¼-28, ⅜-16, ⅜-24, etc..	
Numbered size: For diameters smaller than ¼”, a numbering system is used. For example, 8-32 refers to a screw size of #8 with 32 threads per inch. The #8 is actually 0.164”, but the actual size is not as important as much as the relative scales. Smaller numbers represent smaller diameters. Common numbered sizes are: 8-32, 6-32, 4-40, 0-80 etc..	
Metric: In the metric system, the pitch is standardized, so only the diameter is specified. M5 means the diameter is 5mm, but a pitch of 0.8mm is implied but rarely stated. Standard metric sizes are: M1.6, M2, M3, M4, M5 etc..	

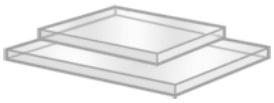
Metals

Aluminum: This is a cheap light-weight metal, but it is soft and has a high thermal expansion coefficient. A lot of parts around the lab are made of aluminum because it can be easily machined. Some tubes are also made of aluminum. Aluminum will oxidize but does not corrode significantly.	
Steel: Steel is an alloy with many different elements. It is very strong, but it is also very heavy. Steel can corrode over time, so it is not used much in the laboratory.	
Stainless steel: This is a different type of steel that resists corrosion due to its high chromium content. This is extensively used in the laboratory. High-purity gas lines, tables and equipment surfaces are normally made of stainless steel.	
Copper: This is used mostly in water supply lines because copper can be easily soldered. Copper is also used in electrical wiring and in circuit boards.	
Forged steel: This is a heat treated steel with extreme hardness and strength. This is the steel used in tools such as wrenches, hammers and sockets. It is also known as tool steel.	

Plastics

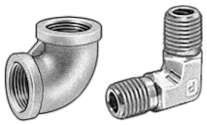
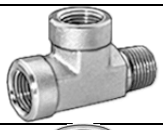
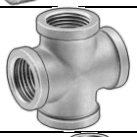
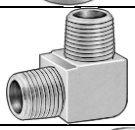
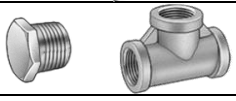
Plastics are lighter than metals, and can be shaped easily by machining or molding or even 3D printing. But they are not as strong as metals and will soften at high temperatures. Plastics are unsuitable in high vacuum systems because they will outgas. With a few exceptions, most plastics will dissolve or swell in organic solvents, but have good resistance to many acids. In contrast, metals have good resistance to organic solvents but will corrode in acids. The resistance of different plastics should be verified from chemical compatibility charts.

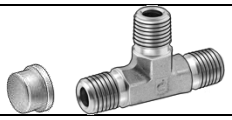
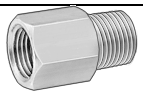
Polypropylene: This is an opaque white plastic that has excellent chemical resistance. Many plastic chemical bottles are made of polypropylene, especially for use with solvents such as acetone. The bottles may have an embossed “PP” sign on the bottom to identify it as polypropylene.	
PTFE: Also known as Teflon, this is chemically extremely inert and can withstand relatively high temperatures. It is very slippery and nothing will stick to it. However, PTFE is very expensive, so only the most demanding parts are made with this material.	
Polyethylene: This comes in high density polyethylene (HDPE) or low density polyethylene (LDPE). It has a lower resistance to chemicals, but it can be used with many inorganic chemicals such as acids.	

Acrylic: These are sold under the name Plexigas. They are optically clear, and mostly used as windows. They have poor chemically resistance. They are typically sold in sheets, but they can also come in other shapes like tubes and rods.	
Polycarbonate: These are also optically clear plastics, and sold under the name Lexan. They have high impact strength, but their chemical resistance is poor.	
Nylon: Nylon is used in mechanical fixtures because it is relatively strong, but its chemical resistance is poor.	
PVC: Polyvinyl chloride is used in rigid plastic pipes. They are widely used in residential drain piping. They do have some resistance to certain chemicals.	

Pipe Fittings

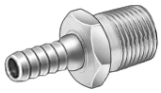
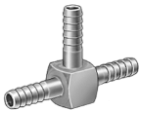
In plumbing fixtures, a fractional inch system is used. What may be confusing is that the specified sizes do not correspond to the actual size of the part. Nevertheless, this is a widely used and well-understood system. The threads on the pipes are standardized and is known as the National Pipe Thread Taper (NPT).

Thread: In the NPT system, the thread is standardized to each diameter, so it is not specified in the designation. Common pipe sizes are ⅛", ¼", ⅜", ½" etc.. A common source of confusion is that the designated size is not the actual diameter of the pipe. The actual diameter is significantly larger than the specified number. For example, ⅛" NPT has a diameter close to ⅜".	
Male & Female fittings: In pipe fittings, one part screws into another. The part that goes inside the other one is called the male fitting, and the part that accepts it is the female fitting.	
Tee: Tee fittings contain three branches. The size and gender of each branch can be the same or they can all be different.	
Cross: These fittings contain four branches. The size and gender of each branch can be the same or they can all be different.	
Elbow: This is a right-angle turn. Instead of bending the pipe, this fitting allows one to make a sharp small-radius turn.	
Plug: A plug screws into a female pipe fitting to close it off.	

Cap: In contrast to a plug, a cap screws onto a male pipe fitting.	
Coupling: A coupling fitting allows two threaded ends to be connected. The ends can be male or female.	
Bushing: A bushing is a male fitting with a female thread inside in the same housing. A bushing is used whenever a smaller size male has to be fitted into a larger size female.	
Adapter: While a bushing only allows a smaller male to fit inside a larger female, an adapter allows any size male to be fitted inside any size female.	
Valves: Valves allow the flow to be turned on and off. There are many different types of valves, but the most widely used type is the ball valve. A ball with a hole aligns parallel or perpendicular to the flow to turn the flow on or off.	

Tube fittings

A tube fitting allows a plastic or metal tube to be attached to a fixture.

Barb fitting: These are used with soft plastic tubes. The tube is pushed over the ribbed nipple. The ribs are angled such that the tube can slip on the nipple easily, but won't slip out easily. A hose clamp is normally used to strengthen the grip. The other end of the barb fitting can be an NPT thread or some other tube fitting. They can also be in the form of tees, crosses and couplings. Because the tube fits over the nipple, the dimension specified is the inside diameter (I.D.) of the tube. Generally, the tube cannot be easily removed from the barb fitting. The tube has to be cut along its length to retrieve the fitting. Barb fittings are used in low-pressure fluid applications.	 
Hose clamp: The hose clamp is a metal strap which is tightened with a worm gear screw. Hose clamps are most commonly used with barb fittings. Excessive tightening of the hose clamp can be harmful because it can cut into the tube.	
Compression fittings: These are most commonly used with metal tubes and hard plastic tubes. The tube is inserted into the body, and the nut is tightened. As the nut tightens, it compresses a metal ring around the tube. The face of the ring is designed to fit perfectly inside the body of the fitting. Because the ring fits over the tube, the dimension specified is the outside diameter (O.D.) of the tube. Once the ring is compressed onto the tube, it cannot be extracted. The tube with the ring has to be cut and discarded before using the tube with another fitting. Compression fittings are strong, therefore they can be used in high-pressure applications.	 

Push-to-connect fittings: These are most commonly used with plastic tubes. As the tube is inserted into the hole, and a ring inside tightens around it to create a seal. The nice thing about these fittings is that the tube can be easily removed by pressing the release ring on the front face of the fitting. Because the tube fits into a hole, the dimension specified is for the outside diameter (O.D.) of the tube. These are mostly suitable for low-pressure applications.	

Soldered pipe fittings

Copper fittings: Soldering is done mostly with copper pipe fittings. The fittings have openings that are exactly sized to accept the outside diameter (O.D) of the pipe. Heat is applied with a torch at one end of the joint, and solder is applied from the opposite end. The solder is never directly heated. When the pipe and the fitting get hot enough, the solder will flow between the gaps by capillary action to create a seal. In order for the solder to wet the copper surfaces, they must be thoroughly cleaned and pretreated with flux.	 
Propane torch: This torch is commonly used to solder copper pipes. Propane is used as fuel, although butane is also used in some torches to reach a higher flame temperature.	

High-purity/hazardous line fittings

These are similar to the other tube fittings, but are designed for extremely low leak rates and high pressure capability.

Swagelok™ tube fittings: These are nearly identical to compression fittings, but are designed with greater precision. The threads are also different from the standard compression threads. These tube fittings also come in elbows, tees and crosses. The most typical configuration is a tube fitting on one end and a male NPT on the other end.	
Swagelok™ VCR fitting: These are used in systems that flow gases and liquids inside a high vacuum chamber. It seals two gland faces on the tube ends by crushing a metal gasket between them. These fittings have better sealing capability than the tube fittings, but the disadvantage is that the tube ends must be welded with the VCR glands, male and female nuts. The fitting can be easily removed and reconnected, but the metal gasket has to be replaced every time. The female nut also contains a hole for use with leak detection equipment.	

Tubes

Plastic and metal tubes will have a specified inside diameter (I.D) and outside diameter (O.D). Which one is relevant depends on the intended fitting. For barb fittings, the inside diameter of the tube should be used. For compression fittings, it is the outside diameter. Metal tubes can withstand greater pressure. Plastic tubes are more flexible.

Copper tube: These tubes are used largely in water supply lines because copper is safe for drinking water. The fittings are typically soldered but compression fittings can also be used. They are typically rigid, although small diameter tubing can be somewhat flexible.	
Aluminum tube: Aluminum tubes are cheaper than copper. They can be used for non-drinking water, oil or compressed air. Aluminum tubes are difficult to solder, so they are most commonly used with compression fittings.	
Stainless steel tube: These are used with high-pressure gases. In high-purity applications, the inside of the tube has a polished surface to reduce entrapment of contaminations. These are known as electro-polished tubes. These tubes can be welded, although most commonly they are used with Swagelok™ fittings.	
Plastic tubes: Plastic tubes can be made of polyethylene, polypropylene, polyvinyl chloride (PVC), nylon, polyurethane, Teflon etc.. depending on the pressure, chemical compatibility and flexibility.	

Cutting & bending tubes

Metal tube cutter: Metal tubes should never be cut with saws or snips. Doing so will deform the circular shape of the tube. A tube cutter is like a C-clamp that is tightened around the tube, and then rotated to cut equally from all directions.	
Plastic tube cutter: If a plastic tube is cut with scissors, it will collapse the tube and make it difficult to use in subsequent fittings. A plastic tube cutter looks essentially like a pair of scissors, except it has only one cutting blade. The other side consists of a wide support to prevent the tube from kinking, and contains a slot to allow the blade to slide in.	
Metal tube bender: Bending a metal tube by hand is imprecise, and can cause it to kink or pinch off, and cause leaks. A tube bender allows one to make a smooth bend with a constant radius.	

Vacuum fittings

Vacuum fittings are designed for high conductance. Therefore, these fittings are generally much larger in diameter than other types of fittings. The fittings are categorized by the flange type and diameter. Also, there is no male or female end - both ends of these fittings are identical.

KF flange: Two flat flanges are connected with a soft o-ring seal, and all three parts are tightened with a clamp. As the clamp screw is tightened, the flanges are pulled together until they crush the o-ring seal. The flanges are specified in millimeters, which measures the outside diameter of the tube that is attached to the flange. Standard sizes are KF16, KF25, KF40, which are 16mm, 25mm and 40mm respectively.	
CF flange: Also known as conflats, two flat flanges are joined with a metal gasket (usually copper) and compressed with a number of bolts around the circumference. Compared to KF, CF flanges take more time to remove and reassemble. However, because they use metal gaskets they work better in vacuum because they don't outgas as much as the rubber gaskets used in KF. The flanges are specified by the diameter of the connecting tube in inches. Standard sizes are 1.33 CF, 2.75 CF, 4.5 CF etc.. for 1-⅓", 2-¾" and 4-½" respectively. They also come in sizes as large as 14" diameter.	
Vacuum feed-through fittings: Feed-throughs allow electrical wires, fluid connections or mechanical motion to be connected between the outside and the inside of vacuum chambers. The feed-throughs are design to fit standard vacuum flanges (KF, CF etc..), and will have connections on the vacuum-side and the air-side of the fitting.	

Seals

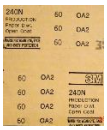
Two hard surfaces will generally not produce a leak free interface unless a collapsible seal is used at the interface. Seals can be in the form of o-rings, gaskets or tapes.

O-rings: These are typically circular rings with a circular cross-section, but they can also have square and other cross-sections. The o-ring is placed inside a specially designed groove between the two parts being mated. When the parts are pulled together by tightening, the o-ring will collapse and seal the interface. O-rings are typically made of synthetic rubbers such as Buna-N (also known as nitrile), silicone or Viton (which is a fluoropolymer).	
Gaskets: These are flat seals which are compressed between flanges and manifolds. They could be made of synthetic rubbers, metals or even paper. Copper gaskets are used in CF vacuum flanges. Stainless steel gaskets are used in VCR fittings. Silicone lined paper flanges are used in rotary vacuum pump bodies.	
Shaft seals: Rotating parts such as vacuum pumps and mechanical feed-throughs require the shaft to be sealed while allowing the shaft to rotate with low friction. The	

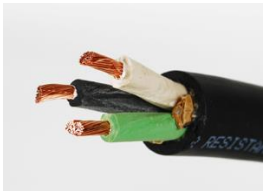
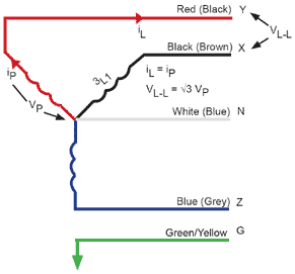
seals typically have a face seal made of a slippery material like PTFE, and a double-seal o-ring that grabs around the shaft.	
PTFE sealant tape: This is a very thin tape that is wrapped over the pipe thread to improve the sealing capability of the thread. It should be wrapped in the direction of turn so that it does not unravel during tightening.	

Abrasive sheets

These are also known as sandpaper, and are used in grinding and polishing. It is basically a sheet of paper or cloth with embedded abrasive particles, which can be aluminum oxide, silicon carbide or diamond. Large particles are suitable for rapid removal of material and smaller particles are better for polishing finishes. The particle size of the abrasive is indicated by the grit number. Larger numbers indicate a smaller particle size.

Grit size 60 corresponds to a particle size of 265μm. Grit numbers smaller than 60 (particles larger than 265μm) are only suitable for very coarse work and for rapid removal of material.	
Grit size 220 corresponds to a particle size of 68μm. This is suitable for slow removal of material, and for preparing surfaces for bonding. However, it will leave visible scratches behind.	
Grit size 400 corresponds to a particle size of 23μm. This can leave a relatively smooth matt-like finish. Mirror-like finishes will require particle sizes smaller than 1μm.	
Semiconductor grade sheets are not designated with grit numbers. Instead, the particle sizes are used in the designation, and they are color coded. These sheets are generally made of diamond abrasives because that is the only material that will cut silicon.	

Electrical Voltages

Single phase 120V: The most common AC outlets are 120V at 60Hz. Typically there will be three wires. The black wire is the power line, white wire is the neutral and green wire is ground. The ground and the neutral are tied together at the power distribution panel, so they are essentially the same line. Many appliances only use the black and white wires. The green ground wire is used in appliances where there is a risk of electrical exposure. Any current that flows through the green wire can be used to trigger a safety device that shuts off the power. These are known as ground fault circuit interrupters (GFCI).	
Two phase 240V: Most residential power also contains an additional 120V line that is 180-deg out of phase. When the two phases are connected across a load, it will produce 240V. In homes, 240V is used with cooking stoves and laundry dryers. Some commercial buildings also contain two-phase 240V. The wiring contains four wires: a black and a red wire that are 120V but out of phase, a white neutral wire and a green ground wire.	
Three phase 208V: Power generation and distribution is actually done in a 3-phase configuration. The single-phase and two-phase outputs are derived from the 3-phase distribution system. In commercial buildings, three phase power is used to drive high power motors. There are three 120V power lines, each 120-deg out of phase with the other. The power lines are black, red and blue. A white neutral wire and a green ground will also be provided, for a total of five wires. When any two of the power lines are connected across a load, the voltage will be 208V. This comes from $120\sqrt{3}$.	

Electrical wires

Most electrical wires are made of copper or aluminum due to their high conductivity.

Wire thickness: Wire thicknesses are measured using a standardized system known as the American Wire Gauge (AWG). The numbers range from 0 to 40. AWG 40 corresponds to an extremely thin wire of diameter 3 mils. One mil is defined as 1/1000". Therefore, 3 mils is about 75μm. Smaller numbers indicate larger diameters. AWG 20 corresponds to 32mils (or 800μm). The required wire thickness is determined by the maximum current that flows through the wire, not the voltage. The voltage only determines the type of insulation for preventing arcing. In most electronics, AWG 20 – 26 is used. In 120 V electrical wiring, AWG 10 is used for 20 amp wiring.	
Solid wire: A solid wire is a single strand of metal. When bent, they hold their shape well, and they are also easy to terminate with crimped or screwed connectors.	

Stranded wire: Stranded wire contains a bundle of many thin wires. Compared to solid wire, these are more flexible, so they can be routed easier.	

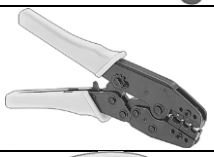
Wire connectors

When connecting electrical wires, it is poor practice to simply twist the wires together and wrap some electrical tape. The tape will come off sooner or later, and the joint will fail when pulled. Wires are terminated and spliced using a number of different ways, depending on application:

Twist-on wire connectors: This is plastic cap with a tapered thread inside. The two wires to be spliced are held together and the cap is screwed on the joint. The threads inside the cap will dig into the wire surfaces to prevent the wires from slipping out. It is also common practice to apply insulation tape to secure the splice. Since no part of the wire is exposed, this is commonly used in 120V electrical wiring.	
Ring terminals: These connectors allow a wire to be attached to some fixture using a screw. The wire is inserted into a hole on the side, and the metal around it is compressed with a crimping tool. Since the screw terminal is exposed, this connection is typically used in low voltage applications.	
Quick-connect terminals: These connectors allow a wire to be connected and disconnected easily by simply inserting the male terminal into the female terminal. The wires are attached by crimping. Since the connection is exposed, this is also only used in low voltage applications. They come in flat or cylindrical plugs, or a variety of other shapes.	
Screwed terminal block: These are plastic blocks with a row of many screw terminals that allow pairs of wires to be connected. Wires with ring terminals are attached to each screw terminal.	
Butt splice: This is a small metal tube used for joining two wires together. The wires are inserted into the holes and crimped to create a permanent splice. The splice typically comes insulated with a plastic sleeve, so it can be used in high voltage applications. Compared to the twist-on connector, the butt splice is more compact and more robust. But unlike the twist-on connector, this splice cannot be separated.	
Alligator clips: The wire is attached using a screw terminal or a crimp style connection. The spring loaded jaws allow the terminal to be clipped to many surfaces.	

Banana plugs: These are commonly used in electronics test benches. The plugs can be inserted and extracted easily.	
D-sub connectors: These are typically found in computers, but can be used in any low voltage application where a large number of wires need to be connected and disconnected at once. The easiest way to connect the wires is by using crimped male and female pins, and then inserting these pins into the plug holes.	
BNC connectors: These are for connecting coaxial wires, and are used for carrying high frequency signals. Oscilloscope and signal generators typically use this type of connector.	
Patch cord: A patch cord is a piece of wire with plugs on either end. They are used in electronics test equipment for connecting various pieces together. The most common patch cord is the one with banana plugs on both ends.	
Heat shrink tube: This is a plastic tube that shrinks when heat is applied with a heat gun. It can be used to create a tight wrapping around exposed parts of the wires or terminals, or simply to hold multiple wires together in a bundle.	

Electrical tools

Wire stripper: This is used for removing the plastic insulation. The sliding screw can be used to adjust for different wire thicknesses.	
Crimping tool: This tool will squeeze the metal tube around a wire to create a permanent crimped connection. The tool has different claws for various crimp diameters.	
Digital Multimeter: This is for measuring connectivity, resistance, AC and DC voltages and currents.	
Soldering: Copper or aluminum wires can be soldered. A common mistake made in soldering is to melt the solder and spread it like a glue. This will result in dry joints. Instead, the joint should be heated first from one side, and then the solder should be applied from the other side of the joint to allow it to flow by capillary action.	

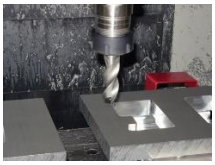
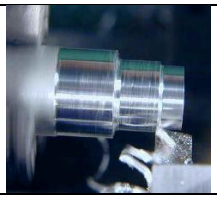
Thermal paste: This is a thermally conductive paste that is applied to improve the thermal contact between high power electronic components such as CPU's, LED's and a heat sink. These are just pastes, not adhesives.	
Desoldering: The joint can be reheated to remove the part easily. However, cleaning out the remaining solder requires the use of a desoldering pump or wick. The wick is a braided material. It is placed over the solder and heated. As the solder melts, it will get sucked into the wick by capillary action.	

Adhesives

Epoxies: Epoxies come in two parts – part A and part B, sometimes also referred to as resin and hardener. The two parts are mixed and then applied to the surface being bonded. After some time, the epoxy will become a gel. This is known as the working time of the epoxy. Then it will harden. Working time of the epoxy can range from 1 minute to 1 hour. The advantage of epoxies is that they can be stored for a very long time. They don't harden unless the two parts are mixed. Most epoxies will soften at high temperatures, in the range of 100C.	
One-part adhesives: These adhesives start curing by exposure to moisture, UV light or heat. Superglue, for example, is activated by moisture in the air.	
Thermally conductive epoxies: These are silver-filled two-part epoxies that are used to bond an electronic component to a heat sink. Unlike a thermal paste, the epoxy bonded interface is permanent and cannot be easily removed.	

Machining

Even if you are not going to do machining, it is important to know the common techniques so that the parts you design can be machined easily. The three basic tools used in machining are drills, mills and lathes.

Drill bits: Drilling is for making holes. The cutting blade is at the bottom of the drill bit, not the sides. The sides have a spiral shape, known as flutes, to allow the loose material to flow upwards. Drill bits come in fractional inches and metric. There is also numbered sizes (1 through 80) and lettered sizes (A through Z). Most drill bits are made from high-speed steel (HSS). Some drill bits are coated with titanium nitride for durability. These have a golden color. Cobalt steel is used when drilling into hard materials like steel.	
Hand drill: Hand drills are easy to use, but they are not used for precise applications because everything will move and wobble during drilling. The drill bit is held by the chuck that tightens around the shaft.	
Drill press: A drill press does the same thing as a hand drill, except both the drill and the part can be held rigidly for a precise operation.	
Milling: Milling looks very similar to a drilling, and the cutting tool also looks similar to a drill bit, but the process is different. In milling the material is removed by laterally translating the work piece against the cutting tool. Slots and steps can be cut this way. Unlike a drill bit, a milling tool has cutting blades along its edges and the bottom.	
Lathe: In a lathe, the cutting tool is kept stationary and the part is rotated. The process automatically results in a cylindrically symmetric cut. This is ideal for making shafts and sockets, as well as threads.	

Taps and Dies

These are used for cutting screw threads.

Tap: A tap looks very similar to a drill bit, but its sides are shaped like a tapered screw with sharp cutting blades along its edges. They are used to cut the inside threads of a hole. They come in all the different screw thread specifications. The tap is mounted on a handle and turned by hand. Hence they are also known as hand taps.	

Die: A die is used for cutting an outside thread, such as on a shaft. These are also mounted on a handle and turned by hand.	

Compressed gases

The quantity of gas in a cylinder is normally measured in pounds. A tall gas cylinder typically contains 132 lbs of gas. The pressure may vary depending on the gas type. Pressure is most commonly measured in psi (pounds per square inch) above atmospheric pressure. Zero pressure is the same as atmospheric pressure. The pressure in a gas cylinders can be as high as 2500 psi. The pressure in your car tires is 30 psi. Atmospheric pressure is 14 psi (compared to vacuum). Therefore, there is enough energy contained inside a compressed gas cylinder to cause a serious explosion. These cylinders must always be used with a step-down pressure regulator.	
Process gases: Gases are used for a variety of needs such as etching, purging, venting etc.. In semiconductor processes we use high-purity gases (sometimes as high as sometimes as high as 99.9999%). This is different from standard industrial gases. Gas cylinders are color coded to indicate their purity levels.	
Gas regulators: Since gas cylinders are filled to extremely high pressure, they need to be regulated down to lower pressures before being delivered to an equipment. Typical delivery pressures are 15-20psi. Regulators normally have two gauges, one showing the inlet pressure and the other showing the outlet pressure.	
Gas flow rates: The flow rates are typically measured as sccm (standard cubic centimeters per minute), or lpm (liters per minute). As an example, a 132 lb Argon cylinder translates to 36 m^3 of gas. If the flow rate is 1 lpm, the tank will last for 600 hours. Gas flow rates can be measured with a rotameter (which contains a float inside a tube), or a mass flow controller (MFC). Mass flow controllers are used in very precise applications but are significantly more expensive than rotameters.	

Compressed air

Air compressors: An electric pump is used to compress ambient air and deliver at about 100 psi. The primary application of compressed air is to drive pneumatic tools. Compared to electric tools, pneumatic tools can deliver a greater force and is more suitable in flammable environments (i.e. no sparks). In a research	

laboratory, compressed air is used to move valves and various actuators. Compressed air should not be used on ultra clean surfaces because it contains oil, water and numerous other contaminations.	

Recirculating Chilled water

Cooling fluid for various equipment is performed by flowing cold water. However, the used water is not thrown away. Instead, it is returned back to the pump, and re-chilled, in a closed loop configuration. Therefore, the water has a supply line and a return line.	

Units of measure

Weight is most commonly measured in the following units: • pounds (abbreviated as lb) • ounces (abbreviated as oz. 16 oz = 1lb) • grams • ton (1000 lb = 1 ton)	
Volume is most commonly measured in the following units: • gallons • quart (4 quarts = 1 gallon) • pint (8 pints = 1 gallon) • liters • cubic centimeters (abbreviated as cc. 1000 cc = 1 liter) • fluid ounces (abbreviated as fl.oz. 29.6 cc = 1 fl.oz)