



High School Makerspace Tools & Materials

April 2012

Makerspaces are collaborative workshops where young people gain practical hands-on experience with new technologies and innovative processes to design and build projects. They provide a flexible environment where learning is made physical by applying science, technology, math, and creativity to solve problems and build things.

Every Makerspace is different, reflecting the available resources and the needs of the young makers who use it. It can be any kind of physical space from a classroom to a shed, from a storage room to a freestanding building. It can support a handful of young makers to dozens of students, focused on a particular activity such as electronics, or offering a broad range of equipment and materials.

Given this range of possibilities it would be impossible to make a one-size-fits-all template for developing a Makerspace. Instead this document is an outline providing an à la carte approach to selecting equipment, tools, and materials for a new Makerspace, allowing it to best serve the needs of its makers. It covers outfitting a space from the floor up and the walls in including space requirements, workbenches, storage, and maintenance materials. We chose tools and materials to be easy-to-use and useful on a broad range of projects. The amounts we suggest you purchase are to support the work of up to 25 makers at once in a space, for a semester's worth of projects. The quantities should be adjusted to match the number of makers and length of projects for your particular space.

The equipment is divided into modules, but each module amplifies the usefulness of the others. For example, combining metalworking with electronics allows very capable robotics.

For updates and more information visit our companion web site makerspace.com

Overview

Each section of this document covers a particular Makerspace module or specialization and includes a description, notes on safety, considerations such as space or utilities, and lists of tools and materials appropriate to be used with the tools.

Workspace	The working environment of the space creating the foundation for a safe, comfortable and clean working environment
General	Tools and materials common among and across modules that are useful on a wide range of projects
Woodworking	Working primarily with wood
Metalworking	Working primarily with metal
Electronics	Using electricity from the basics of circuit design through more advanced microcontrollers, robotics other electromechanical creations
Textiles	Working with flexible materials such as cloth, vinyl, leather, rope and string, including soft circuits and wearable electronics
Computers	The hardware and software necessary for modern planning, design and fabrication
3D Printing	Additive manufacturing ability known as 3D printing which allows makers to create detailed, complex objects
Laser Cutting	The requirements for a laser cutter, which would provide the ability to cut and etch materials quickly and with high precision
CNC Cutting	The requirements for Computer Numerical Controlled (CNC) machines, which accurately cut and sculpt various materials

Lists of equipment, tools, and materials constitute the bulk of this document. These lists include the common name of each tool, general pricing information, and often a more specific description of what kind of tool would work best in this context. We welcome feedback on our recommendations. Lists are arranged by price/performance allowing you to choose cost and capabilities that match your space.

We have chosen tools and materials specifically for young people ages 14 to 18 working within a shared environment like a Makerspace. The tools are generally easy to maintain. We avoid listing parts that are easily lost or broken. We also try to take into account that these tools might be used by smaller hands with less strength than an adult, while still wanting to choose tools which work reliably. The lists are broken down by *Tools & Equipment* and *Materials & Parts*.

Tools & Equipment covers the tools for this module. The number of each tool is estimated for a group of up to 25 students to work simultaneously. This list is further broken down into:

- **Safety:** the equipment necessary for safe operation of the tools.
- **Accessories:** support items for the tools, including storage and maintenance materials.
- **Consumables:** items needing regular replacement such as hot glue sticks, saw blades, etc.

Materials & Parts lists the generally most common and useful materials to keep on hand that can be broadly useful for projects, using the recommended tools. The quantities are the suggested useful amount for a wide range of projects and will need occasional replenishing depending on use.

Note: The example links provided are to show an *example* of this kind of tool, equipment, or material, and are not purchase recommendations or endorsements. Prices given are estimates.

Basic The recommended equipment and materials to introduce this module into your Makerspace. We selected items that keep the cost low while making sure that the tools are the most useful and the materials are easy to work with.

Intermediate This level allows Makers to create more ambitious projects and work with a wider range of materials with greater precision. In most modules the Intermediate tools and materials are added to the Basic set allowing a space to advance over time. When an identical Item is listed twice, additional numbers are suggested for an Intermediate space.

Key

		Basic Makerspace Only
		Intermediate Makerspace Only
		Both Basic and Intermediate .

Class Size

The tool count, workspace size, and material totals are for a typical class of 25 students. When outfitting your space, add or subtract equipment appropriate to your class size. Consumables and upkeep costs are estimates for 25 students using the space for 70 to 100 hours. This is roughly a semester of two 2-hour sessions per week, plus some individual extracurricular time.

Costs

We assume you will start your Makerspace from bare walls and will buy all equipment and materials new. We do not account for existing, built, donated, or salvaged equipment or materials. Upkeep covers the cost of replenishing consumables and materials plus wear and tear for a single class of 25. We do not include infrastructure costs such as utilities or staffing. This chart shows the estimated costs for each module and level.

Module	Basic	Startup	Subtotal	Upkeep	Intermediate	Startup	Subtotal	Upkeep
Workspace		\$3,326	\$3,326	\$50	Tools	\$3,644	\$3,644	\$75
General	Tools	\$1,830	\$2,559	\$350	Tools	\$2,830	\$3,820	\$550
	Materials	\$729			Materials	\$990		
Woodworking	Tools	\$1047	\$1,135	\$120	Tools	\$1,894	\$2,058	\$200
	Materials	\$88			Materials	\$164		
Metalworking	Tools	\$766	\$1,468	\$160	Tools	\$3,702	\$4,656	\$400
	Materials	\$702			Materials	\$954		
Electronics	Tools	\$596	\$1,402	\$80	Tools	\$1,395	\$3,008	\$300
	Materials	\$211			Materials	\$302		
	Microcontrollers & Robotics	\$595			Microcontrollers & Robotics	\$1,311		
Textiles	Tools	\$332	\$538	\$60	Tools	\$821	\$1,031	\$100
	Materials	\$140			Materials	\$278		
	Soft Circuits	\$66			Soft Circuits	\$232		
Computers			\$3,883	\$30		\$4,773		\$60
3D Printing						\$2,240		\$50
Laser Cutting					Tools	\$11,812	\$12,142	\$400
					Materials	\$330		
CNC Cutting					Tools	\$5740	\$5816	\$250
					Materials	\$76		

Workspace

Create a safe, comfortable and creative space for making by individuals and teams.

Safety

The workspace needs to be organized and spacious enough to provide enough room to move around working makers freely and without danger. Keep clear all pathways to tools, exits, and safety equipment. Make it easy to remove trash and debris regularly. Provide adequate ventilation and lighting. Everyone should know where the first aid kits and fire extinguishers are. Drop cords can quickly become a work and tripping hazard, so place outlets around the perimeter of the room and/or drop them from the ceiling for each work area. Similarly we generally discourage the use of power strips with the exception of a few specific modules listed below.

Building It Yourself

Many elements of the workspace such as workbenches, storage, shelving, and whiteboards can be made for significantly less money, and sometimes more sturdily, than buying ready-made. This has the advantage of engaging students in meaningful acts of creation while tamping down your overall startup budget.



Considerations

- Large workbenches allow makers to work comfortably while allowing them to build cooperatively.
- Keep it tidy: shelves give participants a place to keep their projects when they're not in the space, and there are supplies for cleaning up when done.
- We recommend a sealed concrete floor.
- **Basic:** 1000 square feet or more. (For 25 makers)
- **Intermediate:** 1200 square feet or more. (For 25 makers) A sink is preferred but not required.

Workspace Tools & Equipment

Equipment	Description	Example*	Quantity	\$ Each	\$ Total
Workbench	6' x 3' Wooden top, standing height.	Example	6	\$160	\$960
Worktable	6' x 3' wooden top, sitting height (28")	Example	1	\$160	\$160
Tool bench	Bench for stationary tools such as a drill press and bench vise.	Example	1	\$210	\$210
Stool	30" round	Example	26	\$55	\$1430
Chair	Standard chair, without arms.		4	\$45	\$180
Whiteboard	4' x 8'		2	\$80	\$160
Project storage shelves	Shelving at least 24" deep, 30+ linear feet of shelves. (Can be built)	Example	-	-	\$300
Accessories					
Dry erase marker set			2	\$4	\$8
Whiteboard eraser			2	\$3	\$6
Wet/Dry vacuum	5 gallon or larger capacity. With wheels.	Example	1	\$45	\$45
Push broom	24" or wider.	Example	1	\$30	\$30
Broom	Standard lobby broom		2	\$10	\$20
Dust pan			2	\$8	\$16
Bench brush	8" to 10"	Example	6	\$2	\$12
Trash Can	30 gallon or larger. Wheeled preferred.		2	\$25	\$50
Consumables					
Trash Bags	Matching the trashcan above.		1 box	\$12	\$12
Paper towels			6 rolls	\$2	\$12
All purpose cleaner	Spray bottle.		2 bottles	\$3	\$6
Vacuum collection bags	Matching the wet/dry vacuum above.		6 bags	\$3	\$18
Vacuum filter	Matching the wet/dry vacuum above.		1 filter	\$9	\$9
				Basic Total:	\$3326
				Intermediate Total:	\$3644

General

Outfit a workshop with tools for cutting, fastening, shaping, marking, measuring, taking apart, and putting together a large variety of maker projects.

Safety

The tools listed are safe when used responsibly. All power tools should be used after training and with supervision, and only by students who have the strength to control the tool.

Wear safety glasses when...

- working with any power tool
- hammering and working with any tool that could possibly generate flying debris
- working with chemicals that can splash or create fumes.

Wear respirators (masks) when sawing, sanding, working with aerosols, or any other tool that creates airborne particles.

Wear ear muffs or foam ear plugs when working with power tools or regular hammering.

When using any power tool long hair should be tied up, and loose clothes and jewelry should be secured.



Considerations

- These tools take from a few seconds to a few minutes to learn to use.
- These tools support the capabilities of other modules.
- The materials are non-specialized and can be worked easily with the tools in this module.
- Several feet of open wall [or a tool magazine or foldout organizer (as above)] are needed to store tools.

General: Tools & Equipment

Tool	Description	Ex.*	Quantity	\$ Each	\$ Total
Electric Drill/Driver	Variable speed, 1/2" keyless chuck. Rechargeable preferred.	Example	4	\$120	\$480
Rotary tool	"Dremel" or similar. Corded (not cordless) Variable speed. Add a "keyless chuck" accessory if not included in your model.	Example	2	\$75	\$150
Bench top drill press	Multiple speed, 1/2" chuck. 8" or longer swing.	Example	1	\$120	\$120
Drill bit set	Multipurpose bits in sizes from 1/16" to 1/2" with case.	Example	3	\$15	\$45
Claw hammer	16oz, smooth face.	Example	4	\$15	\$60
Mallet	18 oz rubber	Example	1	\$12	\$12
Screwdriver Assortment	10 screwdrivers in various sizes, both straight and Phillips head.	Example	-	-	\$20
Small screwdriver assortment	10 Small screwdrivers with both straight and Phillips heads.	Example	-	-	\$20
Combination wrench set (SAE)	Sizes from 1/4" to 3/4"	Example	2 sets	\$15	\$30
Combination wrench set (Metric)	Sizes from 10mm to 24mm		1set	\$25	\$25
Socket set (SAE)	3/8" drive. Sockets from 5/16" to 3/4"		1 set	\$24	\$24
Adjustable wrench	"Crescent" wrench 6" and/or 8" length	Example	4	\$10	\$40
Hex wrench set (SAE)	Folding set of imperial (SAE) 5/64" to 1/4"	Example	2	\$9	\$18
Hex wrench set (Metric)	Folding set. Sizes from 1.5mm to 8,,		1	\$9	\$9
Star wrench set	aka "Torx" wrenches. Folding set preferred.	Example	1	\$9	\$9
Slip joint pliers		Example	4	\$5	\$20
Needle nose pliers		Example	2	\$4	\$8
Square nose pliers		Example	2	\$5	\$10
Locking pliers	aka "Vise-grips"	Example	2	\$6	\$12
Utility knife	Retractable blade.	Example	7	\$3	\$21
Pull saw	"Japanese style" 10" double sided with ripping and crosscut blade	Example	2	\$16	\$32
Miter box	Plastic or wood	Example	2	\$15	\$15
Hack saw	Open frame	Example	2	\$10	\$20
Utility Scissors	aka "EMT Scissors"	Example	7	\$3	\$21
Pry bar	Flat, 8" to 12"	Example	1	\$10	\$10

	Putty knife	3" wide, flexible steel		2	\$4	\$8
	Tape measure	16 foot or longer	Example	2	\$8	\$16
	Yardstick	made of wood		6	\$1	\$6
	Caliper set	Include inside and outside caliper	Example	1 set	\$20	\$20
	Vernier caliper	Digital, 6"		1	\$20	\$20
	Carpenter's square	Steel 16" x 24"	Example	4	\$5	\$20
	C clamp	2 each, 4", 8" and 10"	Example	6	\$6	\$36
	Spring clamp	3" to 4" size		6	\$3	\$18
	Staple gun	Heavy duty, manual	Example	2	\$18	\$36
	Hot glue gun	Full size, not "mini" or "craft" size.	Example	7	\$7	\$49
	Heat gun	300w or more power	Example	1	\$18	\$18
	Paint brushes - wide	Between 1" to 4" wide, synthetic bristle		10	\$1	\$10
	Paint brushes - detail	Less than 1" width		20	\$0.50	\$10
Safety						
	Safety glasses	With adjustable length temples	Example	30	\$2	\$60
	Safety goggles	Adjustable headband. Impact resistant lenses	Example	5	\$3	\$15
	First aid kit	Appropriate for workshops	Example	2	\$18	\$32
	Fire extinguisher	Class ABC. 5lb.		2	\$20	\$20
	Work gloves	Cloth with rubberized/nitrile palm coating. 5 pair each small, medium, large	Example	15 pair	\$4	\$60
	Disposable gloves	Nitrile (not latex) 100 each, small, medium, large				\$45
	Disposable respirators	AKA "dust mask" Rated N95 or higher		30+ masks	\$0.75	\$23
	Earmuffs	Adjustable, sound insulating. Noise Reduction Rating (NRR) 30 dB or more	Example	4	\$10	\$40
	Foam ear plugs	Disposable. Noise Reduction Rating (NRR) 30 dB or more		1 pack of 50+ pair	\$10	\$10
Accessories						
	Heavy duty drop cord	25 foot. High visibility (Yellow or orange)		3	\$15	\$45
	Sharpening stone	Double sided (medium and fine grit) at least 2" wide.		1	\$16	\$16
	Apron	Denim or canvas	Example	12	\$10	\$120
	Pegboard	4' x 8' sheets, with mounting hardware.	Example	2	\$22	\$44
	Pegboard	(Additional)		1	\$22	\$22
	Hook assortment	For the pegboard: 200 pieces total, various sizes and functions	Example	200 pegs	-	\$40

	Large rolling tool box	Steel, 4+ drawers with wheels.	Example	1	\$140	\$140
	Tool cabinet	Freestanding metal cabinet with lock and shelves.	Example	1	\$360	\$360
Consumables						
	Utility knife blades	Blades to match utility knives above.		25 blades	\$0.25	\$7
	Coping saw blades			20 blades	\$0.15	\$3
	Hack saw blades	Match hack saw above.		10 blades	\$0.35	\$4
	Rotary tools bit set	Various grinding, sanding, polishing and cutting bits to fit rotary tool above. With storage case.	Example	1 set	\$25	\$25
	Sandpaper assortment	9" x 11" Sheets, various grit from 80 (medium) to 240 (very fine) grit		100 sheets	-	\$20
	Sanding pad/sponge	Medium to fine grit	Example	1 case of 12	\$35	\$35
	Staples	Match staple gun above.		1 box	\$5	\$5
	Hot glue sticks	10" clear		50 sticks	-	\$15
	White glue	4 oz bottle or bigger		7 bottles	\$2	\$14
	Wood glue	8 oz bottle		4 bottles	\$3	\$12
	PVC cement	4 oz bottle or bigger		1 bottle	\$4	\$4
	Super glue			2 bottles	\$4	\$8
	Super glue remover	5 gram brush-on		1 bottle	\$3	\$3
	Epoxy	General purpose, quick-set two-part epoxy syringe	Example	4 syringes	\$3	\$12
	Spray adhesive	16 oz. bottle. 3M Super 77 or similar multipurpose adhesive		1 bottle	\$12	\$12
	Duct tape	2" width, 60-yard roll, silver		4 rolls	\$4	\$16
	Masking tape	3/4" width 60 yard rolls		6 rolls	\$2.50	\$15
	Electrical tape	1/2 or 3/4" width. 20 yard or longer rolls. Black.		4 rolls	\$3	\$12
	Pens	Ballpoint		50	\$0.15	\$8
	Pencils	#2, wood		50	\$0.10	\$5
	Marker assortment	Various colors		50	\$0.50	\$25
					Basic Total:	\$1830
					Intermediate Total:	\$2830

General: Materials & Parts

Material/Part	Description	Quantity	\$ Each	\$ Total
Plywood	1/4" thick 2' x 4' sheets. (Can be cut to size)	6	\$4	\$24
Lumber	1" x 2" x 4'	8	\$1.75	\$14
Lumber	1" x 4" x 4'	8	\$1.75	\$14
Lumber	2" x 4" x 4'	8	\$2	\$16
PVC pipe	1/2" diameter 5' length	12	\$1.50	\$18
PVC connector	1/2" diameter 90 degree slip elbow	12	\$0.30	\$4
PVC connector	1/2" diameter Tee slip connector	12	\$0.25	\$3
PVC connector	1/2" diameter 45 degree slip connector	6	\$0.50	\$3
PVC connector	1/2" diameter 4-way slip connector	6	\$1	\$6
PVC connector	1/2" diameter end cap	12	\$0.75	\$9
Popsicle sticks	wood, box of 1000+	1 box	\$12	\$12
Toothpicks	wood, box of 1000+	1 box	\$6	\$6
Basswood assortment	assorted sizes. Example	-	-	\$20
Dowel	1/4" diameter 36" round	6	\$0.25	\$2
Dowel	1/2" diameter 36" round	6	\$0.50	\$3
Dowel	1" diameter 36" round	6	\$2	\$12
Machine screws	10-24 size, 3" or longer, fully threaded. Pan or round head. Phillips or slotted head. Box of 50 or more.	1 box	\$14	\$14
Machine screws	10-24 size, 1 1/2" length. Pan or round head. Phillips or slotted head. Box of 50 or more.	1 box	\$12	\$12
Nuts	10-24 size, hex.	1 box	\$14	\$14
Washers	10-24 size. Flat washers. Box of 100 or more.	1 box	\$10	\$10
Nails	2" galvanized	1 box	\$6	\$6
Nails	1 1/4" brads	1 box	\$3	\$3
Screws	3/4" flat head wood screws	1 box	\$10	\$10
Screws	2" flat head wood screws	1 box	\$12	\$12
Swivel casters	2" wheels with plate mount.	8	\$3	\$24
Thumb tacks	flat metal head	1 box	\$2	\$2
Rubber bands	Various sizes	1 package	\$5	\$5
Craft paper	Roll 36" or 48" wide. White or "natural" color	1 roll	\$22	\$22
Corrugated cardboard	Various sizes and shapes. Can be upcycled or scavenged.	4 pounds	\$12	\$12
Paperboard	aka "chipboard". Various sizes and shapes. Can be upcycled or scavenged.	1 pound	\$6	\$6

	Foam board	Brand name "Foamcore". 1/4" thick 36" sheets. White.	8 sheets	\$3	\$24
	Dense polystyrene foam	2" thick. 4' x 8' sheet. (Can be cut smaller to store) Available from hardware stores and home centers. Example.	1 sheet	\$24	\$24
	Zip tie assortment	Various lengths	1 package	\$8	\$8
	String	Cotton, 16-ply, 500 feet	1 roll	\$3	\$3
	Rope	Cotton 1/4" or 3/8", 50 feet	1 roll	\$6	\$6
	Cheesecloth	2 yards or more	-		\$4
	"Hand moldable" plastic	Brand names "Shapelock", "InstaMorph" 1 pound (500 grams) or more.	1 bag	\$25	\$25
	Paint - Acrylic	4oz tubes or larger, multiple colors	8 tubes	\$3	\$3
	Storage shelf	Open shelves, 24" deep. At least 4 shelves 5' long. (15 total feet of shelves.)	-	\$160	\$160
	Storage shelf	(Additional 10 feet of shelves)		\$100	\$100
	Storage cabinet	Metal cabinet, 36" x 24" x 72"	1	\$315	\$315
				Basic Total:	\$729
				Intermediate Total:	\$990

Woodworking

Wood is a fantastic material—cheap, durable, attractive, renewable, and readily available in many standard sizes. This module builds on the General module’s most basic tools to cut and shape wood allowing higher precision, greater complexity, and larger projects.

Safety

The safety equipment from the General tool module will provide adequate protection for this module.

Splinters and cuts are the most common injuries when working with wood.

Wear safety glasses and gloves at all times.

Wear respirators while sanding.

When working with power tools, wear hearing protection.

Secure long hair and loose clothes to keep them from getting pulled into the tools.



Considerations

- Woodworking tools take a few minutes to learn to use safely.
- Basic Woodworking recommendations include the hand tools, both powered and unpowered, to handle many projects including building workbenches, shelving and other workspace equipment.
- Intermediate Woodworking recommendations add more power and specialty tools to tackle more ambitious projects with more precision.
- Stationary power tools such as the drill press and scroll saw should have their own dedicated space.

Woodworking: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Circular Saw	7¼" blade. Corded. Bevel adjustment. Storage case.	Example	1	\$100	\$100
Jig Saw	Variable speed with orbital action	Example	1	\$50	\$50
Scroll Saw	Bench-top, variable speed	Example	1	\$250	\$250
Router	Fixed base, variable speed. 2HP or more	Example	1	\$160	\$160
Forstner bit set	Bits ranging from ½" to 1½" or more	Example	1 set	\$35	\$35
Countersink bit set			1 set	\$25	\$25
Random orbit sander	With dust collector/vacuum attachment	Example	1	\$70	\$70
Belt sander	With dust collector/vacuum attachment		1	\$160	\$160
Wood chisel set	Set of 4 or more. Hardened steel square blade in various widths		1	\$25	\$25
Block plane	At least 1½" width	Example	1	\$45	\$45
Nail punch set			1 set	\$18	\$18
Bradawl			1	\$5	\$5
Rasp assortment	Set of 6, half-round and flat		1 set	\$30	\$30
Bar clamp	24" or longer bar	Example	4	\$8	\$32
90° clamp	aka "framing clamp"		4	\$6	\$24
Woodworker's vise	Bench mounted		1	\$180	\$180
Accessories					
Heavy duty drop cord	25 foot. High visibility (Yellow or orange)		3	\$15	\$45
Saw horses			2	\$20	\$40
Sharpening stone	Double sided (medium and fine grit) at least 2" wide		1	\$16	\$16
Tool cabinet	Freestanding metal cabinet with lock and shelves	Example	1	\$360	\$360
Storage shelf	10 shelf-feet of storage		-	\$100	\$100
Consumables					
Circular saw blade	7¼" ripping (24 teeth)		1	\$12	\$12
Circular saw blade	7¼" cross-cut (40+ teeth)		1	\$12	\$12
Circular saw blade	7¼" plywood (100+ teeth)		1	\$12	\$12
Jigsaw blade assortment	At least 12 blades with fine, medium and rough wood blades and fine metal blade. Matching jigsaw above.		1 set	\$25	\$25

	Scroll saw blades	Matching the scroll saw above		6 blades	\$1	\$6
	Block plane blade	Matching the block plane above		1 blade	\$9	\$9
	Orbital sander sanding discs	Matching the orbital sander above. Medium and fine grit.		2 boxes	\$12	\$24
	Belt sander belts	Matching the belt sander above. Medium and fine grit		4 belts	\$3	\$12
	Wood glue	8 oz bottle		4 bottles	\$3	\$12
					Basic Total:	\$1047
					Intermediate Total:	\$1894

Woodworking: Materials & Parts

	Material/Part	Description	Quantity	\$ Each	\$ Total	
	Plywood	1/2" thick 4' x 8' sheets.	2	\$6	\$12	
	Lumber	2" x 4" x 4'	8	\$2	\$16	
	Lumber	1" x 6" x 8'	8	\$3	\$24	
	Lumber	2" x 6" x 8'8	6	\$4	\$24	
	Eyelet screw	1/4" eyelet.	1 box	\$5	\$5	
	Angle bracket	aka corner brace. 90° 4 hole, galvanized.	6	\$1.50	\$9	
	Hinge	2" long door hinge	6	\$2	\$12	
	Hinge	4" long door hinge	6	\$2	\$12	
	Piano hinge	48" or longer.	1	\$18	\$18	
	Pulley	1 1/2" to 2" diameter	2	\$4	\$8	
	Swivel casters	2" wheels with plate mount.	8	\$3	\$24	
					Basic Total:	\$88
					Intermediate Total:	\$164

Metalworking

Make everything from delicate jewelry to durable, heavy-duty projects. These tools can create stable platforms for robots or the finest chainmail. They can be used to make attractive metal project cases or to build replacement parts for cars, bicycles and other machines.

Safety

Working with metal typically requires working with tools that apply a lot of force or a lot of heat. Using these tools safely requires attention to the tool and the surrounding work area. Take special care needs to prevent harm from flying debris, not only for those who are using the equipment, but also for anyone near the work area. Dedicate a space clear of flammable materials for tools that generate heat such as torches and welders, as well as tools that generate sparks such as grinders. Isolate welding areas with welding shields to prevent eye damage to those nearby and to contain any flying debris.

For most activities, the gloves, masks, safety glasses and hearing protection from the General Tools module will protect the makers adequately. However, when working with a torch or welder, use more serious safety equipment. A torch requires heat-resistant gloves and goggles specifically for torch work. Welding requires full body protection including a face shield, welding gloves, and a sleeved bib to protect clothes, high-top shoes, and pants without cuffs. Use a mask to prevent inhalation of metal fumes.



Considerations

- The Basic level focuses mostly on hand tools and smaller projects while the Intermediate level adds more power tools and a welder, dramatically increasing the scale and capability of projects.
- Most tools take a few minutes to learn to use. Welding, brazing, and soldering each take at least half an hour to learn safety and basic fundamentals.
- Ventilation for working with torches or welders.
- Intermediate: 120+ square feet with concrete floor.

Metalworking: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Band saw			1	\$800	\$800
Bench grinder	With grinding wheel and brush. With eye sheilds	Example	1	\$130	\$130
Angle grinder	4 ½" disks.	Example	1	\$80	\$80
Sheet metal nibbling sheers	Manual	Example	1	\$45	\$45
Hacksaw	Open frame 10" high tension.		2	\$10	\$20
Jeweler's saw	Adjustable frame		1	\$10	\$10
Pipe/tubing cutter	Able to cut up to 2" pipe.		1	\$22	\$22
Sheet brake	30" or longer bench top model able to handle 18 gauge or larger material.	Example	1	\$120	\$120
Hand torch	Butane. Electric ignition.	Example	1	\$30	\$30
MIG welder	110v unless your space is wired for 220v. "gas or no gas"	Example	1	\$600	\$600
Welding clamp			2	\$30	\$60
Magnet square	25 lb or stronger magnets.		1	\$12	\$12
Welding pliers			1	\$16	\$16
Carbide drill bit set	Bits from 1/16" to		1	\$24	\$24
Step drill bit	1/8" increments		1	\$22	\$22
Drill vise	4" or larger jaws		1	\$40	\$40
Diamond needle file set	Assorted small files		1 set	\$20	\$20
Machinists file set	Assorted large files with handles.		1 set	\$50	\$50
Ball peen hammer	aka "machinist's hammer". 16 oz weight.		1	\$10	\$10
Brass hammer	2 oz. head.		1	\$14	\$14
Center punch		Example	1	\$6	\$6
Desktop anvil	5-10 lb		1	\$20	\$20
Anvil	50 lb or more.		1	\$90	\$90
Tap and Die set (SAE)	Threads from from 4-40 to ½"		1 set	\$45	\$45
Bench vise	4" or larger jaws		1	\$35	\$35
Locking pliers	aka "vice grips"	Example	2	\$6	\$12
Pipe wrench	2" jaw or 10" handle		1	\$26	\$26
Diagonal cutter	6" heavy duty.		1	\$12	\$12
Crimping pliers			1	\$10	\$10
Wire wrapping pliers	3 step rounded nose		1	\$16	\$16

	Feeler gauge set			1	\$25	\$25
	Thread pitch gauge set	SAE and metric		1	\$8	\$8
	Pipe bender	Manual hydraulic, bench top, with die assortment.		1	\$250	\$250
	Wire brush	Assortment from 1" to 4" of bristles.		4	\$3	\$12
Safety						
	Fire extinguisher	CO2 5lb.		1	\$20	\$20
	Torch goggles	Shade number 5. Flip-up style. Adjustable		3	\$12	\$36
	Welding face shield	Shade number 12. Auto-darkening is optional but very nice to have		1	\$60	\$60
	Welding gloves			1 pair	\$15	\$15
	Welding bib/cape	With sleeves		1	\$75	\$75
	Welding screen	6' x 6' or bigger. Enough to cover exposed sides of welding area.		2	\$70	\$140
Accessories						
	Large rolling tool box	Steel, 4+ drawers with wheels.	Example	1	\$140	\$140
	Small welding table	All metal construction. Able to hold at least 800lbs.		1	\$280	\$280
Consumables						
	Steel wool	"0" or "fine" size. Package of 12 or more pads.		1 pack	\$5	\$5
	Emory cloth	cloth backed metal sandpaper. 30' roll. Medium (120) and fine (320) grit		2 rolls	\$8	\$16
	Steel Epoxy	J-B Weld or similar "cold weld" high strength epoxy.		2	\$5	\$10
	Degreaser	Hand-spray bottle.		1	\$12	\$12
	Cutting fluid	Non-aerosol. 8-16 ounce bottle with applicator tip.		1	\$12	\$12
	Cutting fluid	Non-aerosol. 8-16 ounce bottle with applicator tip.		2	\$12	\$24
	Butane	5oz or larger bottle with standard lighter refill connector.		1 bottle	\$10	\$10
	Hacksaw blades			6 blades	\$0.50	\$3
	Jewelers saw blades			6 blades	\$0.50	\$3
	Band saw blades	Matching band saw above.		2	\$20	\$40
	Welding wire	Self shielding, flux core 0.030" dia. 10 LB spool		1 spool	\$45	\$45
	Cutoff disk	For Angle Grinder above. Pack of 25		1 pack	\$25	\$25
	Grinding wheel	For Angle Grinder above		2 wheels	\$6	\$12
	Cup brush	For Angle Grinder above		1 brush	\$25	\$25
	Soapstone pencil	aka Welder's pencil, soapstone chalk.		1	\$2	\$2
					Basic Total:	\$766
					Intermediate Total:	\$3702

Metalworking: Materials & Parts

Material/Part	Description	Quantity	\$ Each	\$ Total
Steel pipe	¾" x 60" Black or galvanized.	4	\$12	\$48
Steel tube - square	1" x 60"	4	\$12	\$48
U-bolt	¾" inner diameter.	8	\$2	\$16
Steel pipe flange	¾" inner diameter floor/wall flange. Example	4	\$6	\$24
Steel 90° fitting	¾" Female/Female threaded. Example	6	\$6	\$36
Steel Tee fitting	¾" Female threaded. Example	4	\$6	\$24
Steel cross fitting	¾" Female threaded. Example	2	\$10	\$20
Sheet steel	Galvanized 26-30 gauge. 12" x 24" sheets.	4	\$10	\$40
Slotted angle steel	1 ¼" to 1 ¾" width. 4 foot lengths. Example .	4	\$6	\$24
Brass sheet	6" x 12" sheets. Assorted thickness	4	\$6	\$24
Copper sheet	6" x 12" sheet. Assorted thickness.	4	\$7	\$28
Brass rod	12" length Assorted diameter.	-	\$12	\$12
Threaded rod	½" diameter 2 foot or longer lengths. Example	4	\$5	\$20
Wire	20-16 gauge, galvanized, solid, bare wire.	1 spool	\$8	\$8
Artists wire	Any color, 45' spools	2 spools	\$5	\$10
Jewelry clasp assortment	Various sizes, hook & eye, Lobster-claw, etc.	-	\$12	\$12
Jewelry mount assortment	Pins, earring backs, brooch backs, etc.	-	\$18	\$18
Nuts	½" hex. Box of 50 or more.	1 box	\$8	\$8
Bolts	3/8" diameter 3" length, fully threaded. Coarse (20) thread. Hex head. Box of 20 or more.	1 box	\$16	\$16
Bolts	3/8" diameter 1 ½" length. Coarse (20) thread. Hex head. Box of 20 or more.	1 box	\$13	\$13
Nuts	3/8" hex. Box of 50 or more.	1 box	\$7	\$7
Washers	3/8" inner diameter flat washers. Box of 100 or more.	1 box	\$6	\$6
Bolts	¼" diameter 3" length, fully threaded. Coarse (20) thread. Hex head. Box of 20 or more.	1 box	\$15	\$15
Bolts	¼" diameter 1 ½" length. Coarse (20) thread. Hex head. Box of 20 or more.	1 box	\$12	\$12
Nuts	¼" hex. Box of 50 or more.	1 box	\$6	\$6
Washers	¼" inner diameter flat washers. Box of 100 or more.	1 box	\$6	\$6
Machine screws	10-24 size, 3" or longer, fully threaded. Pan or round head. Phillips or slotted head. Box of 50 or more.	1 box	\$14	\$14
Nuts	10-24 size, hex.	1 box	\$14	\$14
Washers	10-24 size. Flat washers. Box of 100 or more.	1 box	\$10	\$10
Storage shelf	(Additional 10 feet of shelves)		\$100	\$100
Storage cabinet	Metal cabinet, 36" x 24" x 72"	1	\$315	\$315
			Basic Total:	\$702
			Intermediate Total:	\$954

Electronics

Learn about electricity, electronics, integrated circuits and microelectronics. Read and create schematic diagrams and troubleshoot circuits.

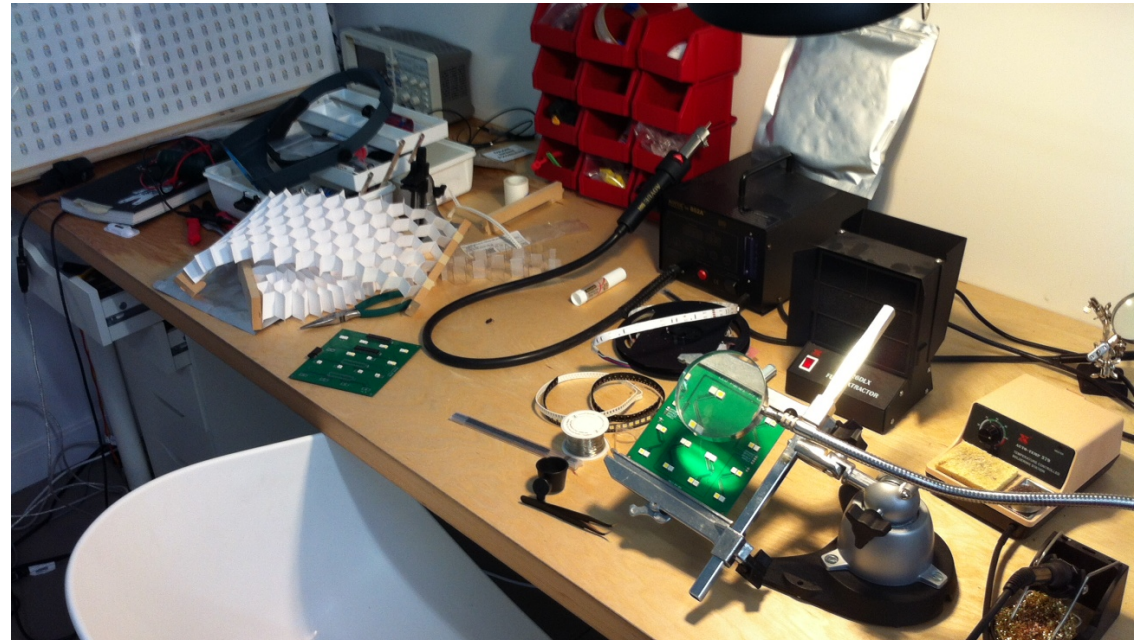
Submodule:

Microcontrollers & Robotics

Microcontrollers allow makers to create advanced electronics and electromechanical systems including robots. The Microcontrollers & Robotics submodule adds the capability to build and experiment with robotics, microcontrollers, and other electromechanical creations. The capability of this module is largely limited by mechanical construction, and benefits from the capability that other modules offer, especially metalwork. The basic selection of materials is for simple robots that are capable of following lines or avoiding obstacles. The intermediate selection adds more advanced functionality allowing competition-ready robots.

Safety

Electronics at this level are low-power and safe. The tip of a soldering iron heats to about 400°F, hot enough to cause burns and should be handled attentively. Under normal soldering conditions, solder containing lead poses no health risk, though makers should be encouraged to wash their hands after a long period of handling leaded solder. Lead-free solder is available but not recommended because the flux core gives off much more toxic fumes, is more corrosive to soldering tips, requires higher soldering temperature, and is generally harder to work with. Any kind of soldering generates fumes from the flux core of the solder, so ventilate the area.



Considerations

- Solderless breadboards allow makers to quickly and nondestructively explore circuits while soldering allows makers to assemble circuits more permanently, either from kits or original designs.
- The equipment here can be quickly set up when needed and easily stored when not in use.
- It takes around 10 minutes to learn to solder, an hour to become proficient at using an oscilloscope, and about 15 minutes to master the rest of the tools.
- Compared to the Basic level, the Intermediate level has higher-quality and easier-to-use soldering irons, encourages more complex projects including robotics, and suggests more advanced tools for troubleshooting and problem solving.
- If upgrading from the Basic Electronics level, you can use the temperature-controlled soldering irons to either replace or augment the pencil irons in the Basic level.
- Provide grounded outlets for each power strip.
- Ventilate the work area while soldering.
- The Robotics and Electromechanics submodule and Intermediate level require access to computers. (See Computers below.)

Electronics: Tools & Equipment

Tool		Description	Example*	Quantity	\$ Each	\$ Total
	Pencil soldering iron	30w	Example	13	\$6	\$78
	Basic temperature-controlled soldering station	with replaceable/interchangeable tips.	Example	13	\$20	\$260
	Soldering stand	with sponge (may be included with more advanced soldering irons)	Example	13	\$5	\$65
	Helping hands		Example	13	\$6	\$78
	Digital multimeter		Example	2	\$15	\$30
	Oscilloscope	2 or more channel, 500MS/s or better.	Example	1	\$400	\$400
	Power Supply	Bench-top, adjustable 0-18v or more. 1 Amp or more.	Example	1	\$150	\$150
	Wire stripper	for 22- to 30-gauge wire	Example	7	\$7	\$49
	Needle-nose pliers	smooth jaw	Example	7	\$3	\$49
	Flush diagonal cutters		Example	7	\$8	\$49
	Solder vacuum	aka "solder sucker"	Example	2	\$5	\$10
	Solderless breadboard	"half size" 400 point	Example	25	\$5	\$125
	Solderless breadboard	"full size" 800+ point	Example	8	\$8	\$64
Accessories						
	Power strip	6 outlet grounded		6	\$5	\$30
	Storage box	Plastic, 4-gallon or larger, with lid		1	\$19	\$19
Consumables						
	Solder	¼ pound of 60/40 0.031" diameter, rosin core (to be divided into smaller spools)	Example	1	\$6	\$6
	Solder wick	5-ft spool	Example	1 spool	\$3	\$3
	Tip cleaner		Example	1	\$8	\$8
					Basic Total:	\$596
					Intermediate Total:	\$1395

Electronics: Materials & Parts

Material/Part		Description		Quantity	\$ Each	\$ Total
	Hookup Wire	22 gauge, solid core, 25-foot rolls, multiple colors	Example	5	\$3	\$15
	Heat shrink assortment	From 1/16" to 3/8" diameter.	Example	2	\$5	\$10
	AA battery			20	-	\$15
	9v Battery			10	-	\$15
	Coin cell battery	3 volt CR2032. Dangerous if swallowed (warn students with young siblings)		20	-	\$12

	9v Battery clip		Example	10	\$1	\$10
	AA x 2 battery holder		Example	5	\$2	\$10
	AA x 4 battery holder		Example	5	\$2	\$10
	Resistor assortment	¼" watt. Assortment of at least 250 pieces	Example	–	–	\$8
	Capacitors (electrolytic)	Assortment of at least 50 pieces	Example	–	–	\$15
	Capacitors (ceramic)	Assortment of at least 50 pieces	Example	–	–	\$5
	Diodes	Assortment of at least 50 pieces	Example	–	–	\$2
	Transistors	Assortment of at least 50 pieces	Example	–	–	\$15
	Potentiometers	Assortment of at least 10 pieces	Example	–	–	\$5
	LEDs	Assortment of at least 100 pieces	Example	–	–	\$10
	Switches	Assortment of at least 10 pieces	Example	–	–	\$8
	Motors	Assortment of at least 10 small "hobby" DC motors	Example	–	–	\$10
	Photoresistors	Assortment of at least 10 pieces	Example	–	–	\$3
	555 timer	8-pin "DIP" package	Example	5	\$2	\$10
	Piezo buzzer	½" to ¼" enclosed	Example	5	\$3	\$15
	Speaker	Small 8 ohm, 0.5 watt	Example	5	\$2	\$10
	Gear reduction motors	140:1 reduction or higher (slower)	Example	6	\$6	\$36
	Wheels	Hub matching gear motors above	Example	6	\$3	\$18
	Storage cabinet for parts	24 or more drawers	Example	1	\$35	\$35
					Basic Total:	\$211
					Intermediate Total:	\$302

Electronics Submodule: Microcontrollers & Robotics

Material/Part	Description	Example*	Quantity	\$ Each	\$ Total
Arduino Uno		Example	6	\$30	\$180
Arduino Mega		Example	2	\$65	\$130
USB Cable	3' with full size "A male to B male" plugs on both ends.		8	\$3	\$24
9v wall plug	5.5x2.1mm barrel connector to match Arduino above	Example	8	\$6	\$48
Motor shield	Control motors, servos, etc from an Arduino (above)	Example	2	\$20	\$40
WaveShield	Play music and sounds from an Arduino (above)	Example	2	\$23	\$46
Ultrasonic distance sensor		Example	2	\$30	\$60
3 axis accelerometer	In a breadboard compatible breakout form.	Example	2	\$10	\$20

	PowerSwitch tail	Control household voltage with low voltage microcontroller	Example	2	\$28	\$54
	Solenoid - small	Less than 12v. "Push" type, with return spring.	Example	4	\$5	\$20
	Solenoid - medium	More than 12v. "Push" type, with return spring.	Example	4	\$12	\$48
	Micro servo	Small, 5v servo. Often blue and with "9g" in the product number.	Example	6	\$5	\$30
	Servo	High torque "standard" hobby servo.	Example	4	\$12	\$48
	IR Emitter/receiver pair	aka "Line sensor"	Example	12	\$1	\$12
	Temperature sensor	Analog, 3 pin.	Example	6	\$1.50	\$9
	Tilt sensor		Example	4	\$2	\$8
	Force sensitive resistor		Example	4	\$7	\$28
	Flex sensor		Example	4	\$8	\$32
	Motion sensor	PIR (Passive Infrared) sensor	Example	2	\$10	\$20
	Humidity and temperature sensor		Example	2	\$10	\$20
	Lever switch	aka "Snap action" or "whisker" switch	Example	6	\$2	\$12
	Pushbutton	Momentary tactile switch	Example	10	\$0.50	\$5
	Basic robot chassis	2 wheel drive, with motors.	Example	1	\$50	\$50
	Advanced robot chassis	4 wheel drive with geared motors.	Example	1	\$60	\$60
	Miniature T-Slot assortment	MicroRax, MakerBeam, OpenBeam, etc. Various lengths, with hardware.	Example	-	-	\$150
	Stepper motors - small		Example	6	\$7	\$42
	Stepper motor - medium		Example	4	\$15	\$60
	Solar panel	Small, 5v, 1w. 10 square inches or so.	Example	2	\$10	\$20
	Storage cabinet for parts	24 or more drawers	Example	1	\$35	\$35
					Basic Total:	\$595
					Intermediate Total:	\$1311

Textiles

Work with cloth, vinyl, leather, yarn and other flexible materials. Quilt, knit, crochet, and knot. Sew, repair, and alter clothes. Create home decor, utility (aprons, gloves, toolbelts, etc), jewelry. With additional tools, create furniture, fiberglass, soft circuits and other projects.

Submodule: Soft Circuits

The materials in the soft circuits module allow makers to explore the world of wearable electronics with the addition of lights, sensors and microcontrollers to create clothes that react to the world around them. Having access to the basic Electronics module vastly expands the capability of this module.

Safety

Sewing is generally a safe activity with very little risk of more than a small prick from a needle.

Steam irons do get hot enough to cause burns.

Sergers have blades that can cut a careless finger.

Sewing machines and sergers both have enough power to put a needle through a finger when used carelessly.

There is no danger of shock from the soft circuits submodule because they are very low power.



Considerations

- The Basic level equipment could be quickly set up and put away when not needed, while the Intermediate level would have a dedicated worktable for larger projects.
- The Intermediate level allows makers to work with a wider range of materials and adds a serger which cuts and sews at the same time easily creating professional seams as well as decoration.
- Basic requires two grounded outlets, while intermediate needs three grounded outlets.
- For the Intermediate level we recommend a 6' x 3' area for a sewing table.
- Soft Circuits submodule requires access to computers. (See Computers below.)
- Time to set up and learn the basic use of a sewing machine is half an hour.
- Time to set up and learn the basic use of a serger is an hour.

Textiles: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Sewing Machine	Basic name-brand, multi-stitch sewing machine	Example	1	\$100	\$100
Serger	Also called an "overlocker" or "overlock machine"	Example	1	\$230	\$230
Fabric Shears	8-10" blade		2	\$11	\$22
Embroidery scissors	4" blade	Example	1	\$12	\$12
Seam ripper		Example	1	\$4	\$4
Cloth tape measure		Example	1	\$3	\$3
Hand sewing needles	Assortment of at least 12 needles		–	\$3	\$3
Heavy-duty hand needles	Assortment of at least 6 needles for upholstery and leatherwork			\$5	\$5
Steam iron	Includes auto-off feature		1	\$18	\$18
Ironing board	Freestanding, collapsible	Example	1	\$19	\$19
Crochet hooks	Assortment of at least 8 aluminum hooks of various sizes		–	\$15	\$15
Leather Punch		Example	1	\$20	\$20
Snap setter	with multiple sizes of bits/dies	Example	1	\$15	\$15
Sewing awl			1	\$5	\$5
Embroidery hoops	10" and 6"		2	\$3	\$6
Knitting needles	Assortment of at least 4 pair of different sizes		–	\$12	\$12
Pins	Box of 100 or more		–	\$2	\$2
Safety pins	Box of 50 or more		–	\$2	\$2
Thimble			5	\$1	\$5
Accessories					
Sewing Table	3' x 6' worktable. Can be same as the workshop workbenches		1	\$160	\$160
Cutting Mat	Self healing 36" x 48"			\$65	\$65
Sewing Machine storage case	Match the make and model of sewing machine above (often included)		1	\$23	\$23
Sewing bobbins	Match the make and model of sewing machine above		Box of 10	\$3	\$3
Craft storage box		Example	1	\$16	\$16
Consumables					
Sewing machine needles	70/10 or 80/12 size, packs of 5. Matching make and model above.		3 packs	\$2	\$6
Serger needles	14/90 or 12/80, packs of 5. Matching make and model above		3 packs	\$8	\$24
Serger blades	Matching make and model above		1 set	\$12	\$12

	Fabric marking pen		2 pens	\$5	\$10
	Fabric glue	4 oz. or bigger bottle, machine-washable (not water soluble)	1 bottle	\$4	\$4
				Basic Total:	\$332
				Intermediate Total:	\$821

Textiles: Materials & Parts

Material/Part	Description	Quantity	\$ Each	\$ Total	
Cloth - muslin		6 yards	\$2	\$16	
Cloth - muslin	(Additional)	6 yards	\$2	\$16	
Cloth - cotton	Lightweight cotton, 2 yards each of different colors/patterns	8 yards	\$4	\$48	
Cloth - cotton	(Additional)	6 yards	\$4	\$24	
Felt	9" x 12" craft felt sheet, various colors	100+ sheets	-	\$12	
Sewing Thread assortment	12 or more spools, various colors with at least 250 yards per spool	12 spools	\$1	\$12	
Conductive thread	With stainless steel. 30+ feet. Example	1 spool	\$8	\$8	
Fusable bonding tape	aka "Stitch Witchery" 5/8" width 12 + yards	1 spool	\$6	\$6	
Upholstery Thread	large 1000+ yard spools. Mix of black and white spools	4 spools	\$5	\$20	
Nylon webbing/strapping	1" width. 5+ yards.	-	-	\$12	
Elastic ¼" wide	3+ yards	-	-	\$3	
Elastic 1" wide	3+ yards	-	-	\$3	
Button assortment	Various sizes and colors. At least 100 buttons	-	\$5	\$5	
Hook and Loop fastener	Velcro or other brand, ¾" wide tape, without adhesive backing	2 yards	\$6	\$12	
Snaps	Package of 10 sets or more, small or medium size		\$7	\$7	
Ribbon	Fabric ribbon. ¼" to 1½" width. Various colors	3 spools	\$9	\$27	
Leather cord	5 or more yards		\$12	\$12	
Yarn	Acrylic worsted, various colors	4 skeins	\$4	\$16	
Fabric Glue	4 oz., washable.	1	\$7	\$7	
Storage bin	10- to 12-gallon, plastic, with lid	1	\$12	\$12	
				Basic Total:	\$140
				Intermediate Total:	\$278

Textiles Submodule: Soft Circuits

Material/Part	Description	Example*	Quantity	\$ Each	\$ Total
Conductive thread	sewable stainless steel. 50' or more.	Example	-	-	\$10
LED assortment	Assorted color, 5mm and/or 10mm LEDs.		50	-	\$10
Coin cell batteries	CR2032 size		20	\$0.30	\$6
Sewable coin cell battery holder	Single cell with holes for sewing.	Example	6	\$1.50	\$9
EL wire	6 feet, single color.	Example	6 feet	-	\$15
EL wire inverter	Small, powered by 2AA or 2AAA batteries. With connector.	Example	2	\$8	\$16
Arduino Lillypad Beginners Kit	With Arduino Lillypad sensors, LEDs and other modules.	Example	3	\$75	\$150
Conductive fabric	1 square foot or more.	Example	-	-	\$10
			Basic Total:		\$66
			Intermediate Total:		\$232

Computers

Access information as well as digital tools to design, create, and collaborate on projects. Program robots and use other programming tools. Add a printer to produce patterns, designs, decorations, and explanatory materials.

Along with Internet access, computers offer access to reference information, project ideas, expert help, instructional videos and safety information as well as data files to modify or replicate with digital fabrication tools. Documenting and sharing projects is an important part of making. Adding cameras and access to blogging tools accelerates the process.

Ultraportables, netbooks, and tablets and even smartphones can be used to do research and documentation, but are not recommended for 3D modeling and other more demanding tasks. Newer laptops are capable of handling these tasks, with the main limitation being the size of the screen. Working with complex 3D models and professional design tools require more powerful computers.

Safety

Introduce the practice of ergonomic workstations to your students. Make sure that they don't hunch over their work, and that they get up frequently to stretch and assume a healthy posture again.

When using the Internet, students should be careful not to disclose identifying information such as their city, school, address, phone number, email address, or real names.



Operating Systems

In general any operating system (Windows, OS X, Linux) is acceptable. If the space is associated with another organization with computers, such as a school or library, we recommend you use what the organization supports. One exception is if you are using an Epilog laser cutter, the software required to operate it is Windows only. In addition, some professional engineering tools are Windows only.

Considerations

- Compared to the Basic level, Intermediate has more powerful computers capable of running more advanced software. Screens are larger to make design easier, and the Intermediate setup has a larger format printer allowing makers to print larger plans and full-size patterns.
- Computers are absolutely necessary for working with digital fabrication tools such as 3D printers, laser cutters and CNC machines.
- We recommend Internet access. Wireless Internet (WiFi) preferred.
- Provide 6 grounded outlets.

Software

A great selection of software is available to makers as freeware and shareware, running on a variety of operating systems. Some examples: [Gimp](#) for creating and manipulating images. [Inkscape](#) for creating and manipulating line drawings. [Blender](#), [Sketchup](#), [Tinkercad](#), and [123D](#) for creating and working with 3D objects. However free software is often not what the professionals use. Professional engineering and image-creation software is expensive, but it is often more powerful and easier to use. Most professional software companies—including [Adobe](#), [Autodesk](#) and [Corel](#)—offer educational discounts.

Computers: Tools & Equipment

Tool		Description	Example*	Quantity	\$ Each	\$ Total
	Laptop	15" or larger screen. 2GB or more RAM. 200 GB or more hard drive.	Example	6	\$500	\$3000
	Laptop	17" or larger screen. 4GB or more RAM . 500 GB or more hard drive.	Example	6	\$600	\$3600
	Printer	Black and white laser printer. Wireless.	Example	1	\$110	\$110
	Larger format printer	Laser printer with support for 12x18 or larger print size	Example	1	\$390	\$390
	Digital camera	Able to shoot video as well as stills. Removable SD card.		1	\$100	\$100
Accessories						
	Table	Round "activity" table capable of seating 4.	Example	2	\$165	\$330
	Chair	Folding chair or wheeled office chair		6	\$22	\$132
	USB thumb drives	2 GB or larger		6	\$5	\$30
	SD Card	2GB or larger		6	\$5	\$30
	Mouse	3 button with scroll wheel		6	\$4	\$24
	Mousepad			6	\$2	\$12
	Printer stand	Capable of storing several reams of paper.	Example	1	\$45	\$45
Consumables						
	Printer toner	Cartridge to match your printer		1	\$30	\$30
	Paper 8½ x 11 (Letter size)	White 20# 500 sheets		1	\$10	\$10
	Paper 11x17 (Tabloid size)	White 20# 500 sheets		1	\$10	\$10
	Colored paper	Various colors 500 sheets total. 8½" x 11"		1	\$15	\$15
	Cardstock	White 110# 250 sheets		1	\$15	\$15
					Basic Total:	\$3883
					Intermediate Total:	\$4773

3D Printing

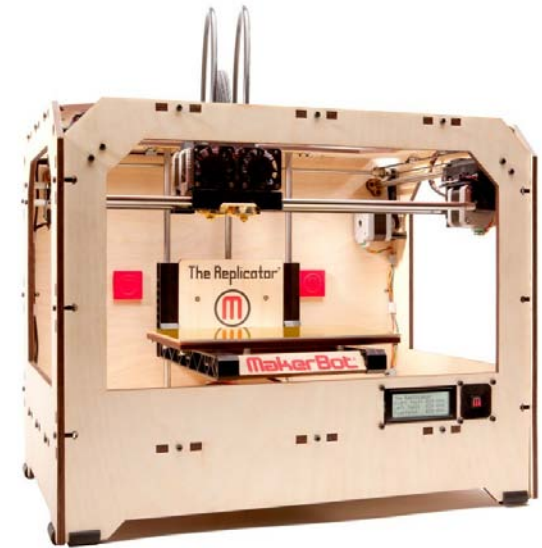
Create complex 3D shapes from plastic or other materials. Extrusion-based 3D printers build objects by squeezing out thin layers of plastic, one on top of the other. Many different kinds and colors of plastics can be used, including ABS (the same plastic used by LEGO) and PLA (a biodegradable plastic). There is even glow-in-the-dark material! Add other items such as [windup motors](#) to create motion or other interesting capabilities.

Safety

3D printers are generally very safe. The print extruder does heat to several hundred degrees and should not be touched. There will be a slight "hot plastic" smell when printing with ABS plastic. It's non-toxic but can be an irritant and the printer should be placed in an open area or near ventilation.

Software

There are a large number of applications that can create 3D models for printing. Popular free offerings include [Google Sketchup](#), [Blender](#), [Wings 3D](#), [tinkerCAD](#), and [Autodesk 123D](#). Commercial packages include [Rhino](#), [Autodesk Inventor](#), and [Solidworks](#). The price varies from several hundred to thousands of dollars, though many software publishers offer educational discounts.



Considerations

- You need a minimum 24" x 24" of dedicated table or desk space.
- If buying a kit, you'll need 12-16 hours and skills in assembly and soldering.
- Certain models may require a computer to operate the printer.
- A 3D printer requires a grounded outlet.
- 3D printing is not a particularly fast process. Speed almost entirely depends on the volume of plastic needed for the project. For example, a small whistle is mostly hollow and will print in around 5 minutes, while larger pieces can easily take hours.
- The output of extrusion printers often requires a bit of cleanup by hand after printing.
- While a computer is not required to print, makers will need access to one to create or download the files for printing.
- Advanced printers can have more than one print head (extruder) that can print in multiple plastics at the same time. This allows printing in multiple colors or printing with more than one material in an object. When one material is water-soluble much more complex shapes can be printed. One example would be printing a wheel on an axle with water-soluble material separating them. When the material is dissolved the wheel can spin freely on the axle.
- In lieu of a full 3D printer setup, consider sending your students' work to service bureaus like [Shapeways](#) and [Ponoko](#). They can print with more detail and in other materials such as metal, ceramics, and in full color. Price depends on material and the volume of the object.
- It takes 1 to 3 hours to learn to use and maintain 3D printer. Initial setup and calibration takes several hours.
- In addition to creating original 3D models, designs can also be freely downloaded from sites like [Thingiverse.com](#).

3D Printing: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Extrusion-based 3D Printer		Example	1	\$2000	\$2000
Accessories					
SD Card	1GB or larger SD card for transferring student models to the printer		25	\$2	\$50
Consumables					
Plastic filament	1kg ABS 1.75mm. Any color.	Example	1	\$50	\$50
Plastic filament	(Additional roll/color)	Example	1	\$50	\$50
PVA (water soluble) filament	1kg PVA 1.75mm	Example	1	\$90	\$90
				Intermediate Total:	\$2240

Laser cutting

Quickly and accurately cut complex shapes from flat materials such as paper, wood, acrylic, cardboard, and felt. Then assemble these flat cutouts to create 3D structures if you'd like. Or etch designs into the surface of materials.

Safety

The primary risk when using a laser cutter is of fire within the cutter itself. The laser cutter should *never* be run unattended, as even a small fire can cause costly damage to the equipment. A CO₂ or halon fire extinguisher should be accessible near the cutter. Both halon and CO₂ extinguishers can be used to quench fires without causing more damage to the laser cutter.

A secondary risk is of fumes. As the laser vaporizes material, gases are released. If the cutter cannot vent to the outdoors then use a comprehensive filter. While most recommended materials do not release hazardous gases, they can still cause irritation.

Unapproved materials such as vinyl and PVC release chlorine gas when laser-cut. Chlorine is very *toxic* and also corrosive. It will damage your health and the laser.

While the laser itself is invisible, a properly maintained laser cutter has a number of interlocks and safety systems to prevent the laser from escaping the cabinet and causing damage or harm. If the lid or access panels are opened during operation the laser should turn off immediately. The glass in the cabinet is designed to filter out the reflected rays of the laser so cutting can be observed without danger.

Software

There are a number of applications that can create two-dimensional files for laser cutting. In general any application that can generate vector drawings can be used. The standard is [Corel Draw](#), a commercial vector drawing application that costs around \$400, though educational discounts are available.

[Inkscape](#) is a free option that also allows makers to create dimensional drawings for cutting and etching. In addition software like [123D Make](#) can generate 2D files from 3D models. There are also downloadable files available on the internet, as well as tools that automatically create custom files for things such as boxes or gears.



Considerations

- Space: Minimum 60" x 60"
- Power: 3 grounded outlets.
- A computer is required to create designs and to manage the laser cutter.
- Laser cutting and etching can be done directly by makers or can be submitted to a supervisor to cut outside of class time.
- It takes up to an hour to learn the basics of laser cutter use. Since conceptually it works much like a printer, students often understand its uses more quickly and easily than those of a 3D printer.
- Learning to fully maintain a laser cutter will take several hours. Training to use a laser cutter includes selecting material that can be safely and effectively cut, creating patterns on the computer, choosing the correct settings to cut effectively, as well as care, maintenance, and calibration of the laser cutter.

Laser Cutting: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Laser Cutter	30-watt laser with 24" x 12" cutting area.	Example	1	\$7995	\$7995
Accessories					
Compressor	Provides air assist, which prevents flare-ups and fires.	Example	1	\$80	\$80
Air filtration system	Removes debris, toxic fumes, and odors from cutting. At least 450cfm, 3-stage filter including HEPA filter (Optional if you have access to external ventilation.)	Example	1	\$2500	\$2500
Fire extinguisher	CO2 or Halon to stop fires without causing more damage to the laser cutter. 5 lb.		1	\$65	\$65
Computer	Windows XP/Vista/7 required to send files to the cutter		1	\$600	\$600
Table	At least 60"x30" With shelves for material storage		1	\$190	\$190
Chair			1	\$25	\$25
Consumables					
Filter replacements	Matching the 3 different filter elements for the air filter above				\$275
				Intermediate Total:	\$11,812

Laser Cutting: Materials & Parts

Material/Part	Description	Quantity	\$ Each	\$ Total	
Card Stock	12" x 12" 100 sheets, various colors	100	-	\$15	
Acrylic sheet 1/8" or 3mm	12" x 24" or smaller. Transparent. Various colors	5	\$8	\$40	
Acrylic sheet 1/4" or 5mm	12" x 24" or smaller. Transparent. Various colors	5	\$12	\$60	
Corrugated Cardboard	12" x 24" 100 sheets (Can be upcycled/salvaged and cut to size)	100	-	\$5	
Felt	12" x 12" 50 sheets, various colors. Wool.	50	-	\$25	
Hardboard or MDF 1/8"	12" x 24" Can be cut to size.	20	-	\$35	
Hardboard or MDF 1/4"	12" x 24" Can be cut to size.	20	-	\$45	
Plywood 1/8"	12" x 24" Birch, sanded. Can be cut to size.	20	-	\$60	
Plywood 1/4"	12" x 24" Birch, sanded. Can be cut to size.	10	-	\$45	
NOTE: DO NOT USE VINYL OR PVC ON A LASER CUTTER. The fumes are TOXIC.					
				Intermediate Total:	\$330

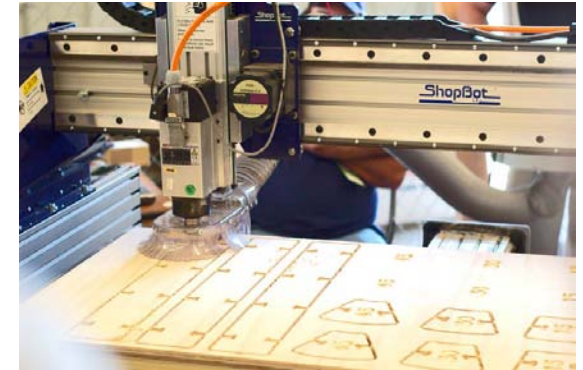
CNC Cutting

Computer Numerical Control (CNC) routers allow precise control of rotating cutters that can cut, carve and shape a wide variety of materials in three dimensions.

This differs from a laser cutting in two ways: it carves two- or three-dimensionally, and it cuts a wider range of materials and thicker materials.

Safety

A CNC router is still a router, so the same precautions apply, including wearing hearing protection for everyone in the area and safety glasses to protect from flying debris. Most CNC routers have an open frame, making it possible for fingers, loose clothing, long hair, etc. to get caught in the gantry.



Considerations

- Minimum of 60" x 60" desktop or bench-top space.
- Power: a grounded outlet
- For casual use, a wet-dry vacuum can be used to collect dust. Install a dedicated dust collection system if you expect heavy use.
- Some models may require a dedicated computer to use. A variety of 2D and 3D software can be used to generate cutting patterns.
- CNC routers may come as kits and require a number of hours to assemble and calibrate.

CNC Cutting: Tools & Equipment

Tool	Description	Example*	Quantity	\$ Each	\$ Total
Desktop CNC	24" x 12" x 2" cutting area or larger. With dust skirt.	Example	1	\$5500	\$5500
Accessories					
Wet-dry vacuum	aka "Shop-vac" 5 gallon or larger capacity.	Example	1	\$45	\$45
Vacuum adapter	To adapt dust skirt outlet to vacuum.		1	\$15	\$15
Consumables					
Cutting Bit Set	Assorted bits matching the router for the CNC above.		1 set	\$180	\$180
Intermediate Total:					\$5740

CNC Cutting: Materials & Parts

Material/Part	Description	Quantity	\$ Each	\$ Total
MDF	1/2" cut to size to fit cutting area.	10	\$4	\$40
Foam Board	aka "Pink insulating foam" Polystyrene insulating foam sheets. Cut to fit cutting area. 2" thick.	12	\$3	\$36
Intermediate Total:				\$76