### Revision Control

<table>
<thead>
<tr>
<th>Version</th>
<th>Date of Revision</th>
<th>Author(s)</th>
<th>Description of Changes</th>
</tr>
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<tbody>
<tr>
<td>A1.01</td>
<td>10-Jan-19</td>
<td>J. Berez</td>
<td>Initial draft</td>
</tr>
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<td>11-Jan-19</td>
<td>J. Berez</td>
<td>Pilot version used for TA training, 11-Jan-19.</td>
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<td>B1.02</td>
<td>12-Jan-19</td>
<td>J. Berez</td>
<td>Revisions based on TA training, mostly for clarity and brevity</td>
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<td>C1.01</td>
<td>23-Aug-19</td>
<td>Z. Klesmith, P. Jung</td>
<td>Addition of training items for miter saw, jigsaw, standard/impact power drills, IDEA laboratory layout updates</td>
</tr>
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<td>D1.01</td>
<td>20-Aug-20</td>
<td>C. Saldana</td>
<td>Modification of general rules and procedures for COVID-19 mitigation and modified laboratory/classroom layout, addition of training items for laser cutter, 3D printer</td>
</tr>
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<td>Modified laser cutting safety protocols</td>
</tr>
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<td>C. Saldana</td>
<td>Modification of rules/procedures for COVID-19 mitigation for FA21 semester</td>
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This laboratory training and reference manual is available on request from the TA on duty within the IDEA Laboratory or by request to the course coordinator.
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About This Guide
All content in this guide is intended to be reviewed and understood by GTAs and UGTAs that staff ME2110 and the IDEA Lab. Portions of this guide are noted as “TA Lesson Plans” that are intended for training students to utilize the IDEA Lab. Finally, internal procedures for IDEA Lab staff are outlined.

TA Training Procedure:
1. This guide, and all appendices, is to be reviewed with all TAs by a senior TA.
2. TAs independently review this guide and all appendices.

ME2110 Student Training Procedure
1. Students receive a lecture on safe lab practices (referenced in the appendix).
2. Students review and agree to the GWW user agreement (referenced in the appendix), this is logged on the SUMS system.
3. All portions of this guide identified as a “TA Lesson Plan” are should be reviewed with ME2110 students in a hands-on training session.
4. Once training is completed, the training GTA logs each student who was trained in the SUMS system for the equipment they are now trained to use.
   a. Note: Students who are late, leave early, or miss portions of the training session can not be logged as ‘trained’. They must attend another training session to address this lapse.
**Formatting of this Document**

TA Lesson plans come with the below header:

<table>
<thead>
<tr>
<th>TA Lesson Plan</th>
</tr>
</thead>
</table>

Portions of lesson plans that are supplementary (i.e. not intended for communication to the students) and intended to as reference material for TA’s understanding are in *gray-ed out text.*

Cues to the TA are written in *italics.*

**General Lab Safety Rules and Procedures**

**PPE and Proper Shop Wear**

IDEA lab rules and procedures pertaining to PPE and proper shop wear are clearly displayed in the Lab, and shown during an ME2110 to the students of the course prior to any lab use by said students. It is the studio TA’s responsibility to review these rules, as posted, with their students and ensure a proper understanding.

<table>
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<th>TA Lesson Plan:</th>
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1. Review posted rules and procures with students, in-person. Accompanying explanation of rules with examples as to how they protect the user is suggested.
2. Demonstrate proper and improper wear using examples (such as the TA’s appearance at the moment and that of the students present, etc.).

**General Lab Use and Safety & General Equipment Operation Safety**

IDEA lab rules and procedures pertaining to General Lab Use and Safety & General Equipment Operation Safety are clearly displayed in the Lab, and shown during an ME2110 to the students of the course prior to any lab use by said students. It is the studio TA’s responsibility to review these rules, as posted, with their students and ensure a proper understanding.

<table>
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1. Review COVID-specific conditions of entry with students, in-person. Accompanying explanation of rules with examples as to how they protect the user is suggested.
   a. Key items: symptom overview, decision tree overview, SUMS-required reservation (outside studio), safety glasses
2. Review posted rules and procures with students, in-person. Accompanying explanation of rules with examples as to how they protect the user is suggested.
3. Review the lab layout, and physically point out all important safety equipment around the lab. The lab has fire extinguishers (3), first aid kits (2), eye-wash station (1), fire blanket (1), safety glasses location, and bag/coat drop location.
4. Demonstrate proper and improper adherence to the rules around the lab.
   a. Power cable drops can be a tripping hazard. Drops should be used such that cables do not create tripping hazards on the floor. Shop air is not intended for use by students.
   b. Show where cleaning equipment can be found, and point out how messes can create an unsafe lab.
5. Lab staff are not just supervisors or safety police, but dedicated to teaching. Students should never feel inappropriate or fear a negative response to questions that address how to use equipment in the lab properly.

Emergency and Reporting Procedures
These procedures document how the staff that run the IDEA lab must handle emergencies and incident reporting. These procedures need not be communicated to the student users of the lab.

Student User Procedures
If the IDEA Laboratory is not actively staffed by TAs or instructors, students are not allowed in the Laboratory and equipment/tools are not allowed to be used.

1) In case of injury:
   • Immediately notify the TA/staff on-duty, if you are unable to do that ask another student to notify the TA/staff on-duty
   • If serious – call GTPD @ 404.894.2500 or 911 on a landline. The IDEA laboratory is located in the MRDC building on the second floor in MRDC 2101.
   • If not serious, utilize the first-aid resources immediately available.
   • If it is required to visit a health care facility and the student can bring themselves or another student can bring them safely:
     o Graduate students go to the nearest emergency room (see link below) or the medical center at Concentra (730AM-7PM M-F)
     o Undergraduates can go to Stamps Health Center on GT’s campus 8AM-5PM
       ▪ Stamps Health Services (https://health.gatech.edu/after-hours-care) is open from 8a to 5p Monday through Friday. If your condition is not urgent or an
emergency, please make an appointment with Stamps Health Services during our normal business hours. See the Stamps website for details.

- If you feel you are experiencing a life or limb threatening emergency and need an ambulance, please call 911. If you need care when we are not open, please see the list of hospitals and urgent care centers at the link above.

2) In case of equipment problems (e.g., crashes, malfunctions, tool breakage, etc.):
   - Immediately put the machine in emergency stop (or a powered off state if no emergency stop is available)
   - Immediately notify the TA/staff on-duty, if you are unable to do that ask another student to notify the TA/staff on-duty

3) If you notice another student/user operating equipment or tools improperly or unsafely:
   - Cordially notify the student/user the safety issues with the way they are operating the equipment or tools
   - If you feel uncomfortable doing this, immediately notify the TA/staff on-duty of the issue
   - Stop work authority (SWA): students and users of the facility
     - SWA gives ALL workers the right to stop work that puts someone in imminent danger
       - Imminent danger is any condition, activity, or practice in the workplace that could cause: (1) death/serious physical harm, (2) significant environmental harm
     - To use SWA:
       - Stop the unsafe work. Under SWA, employees are obligated to initiate a stop-work intervention with colleagues who are potentially at risk. Just tell them: “I’m using stop-work authority to pause this job, and let’s talk about it.” The stop-work action should be clearly identified and initiated in a noncombative manner. Don’t panic, but come across in a helpful way.
       - Investigate the cause for intervention. Affected personnel should discuss the situation and come to an agreement on the behavior or action in question.
       - Correct the hazard.
         - If the hazard cannot be corrected, notify the TA on duty.
         - If the hazard is corrected, resume work.
     - If someone tells you to stop work, you need to stop the job immediately. Remember, your coworkers are trying to help keep you safe, not punish you

Internal Staff Procedures
All incidents and near-misses reported to or witnessed by staff must be recorded immediately (or as soon is safely possible). The incident date, time, place, persons involved, reporting staff member, and relevant details must be recorded. Synchronously the incident must be reported to the head TA(s) and lead instructor(s).

1) If an incident results in no TA/staff available to support laboratory monitoring:
   - The IDEA laboratory must be shut down and closed to student users until a trained TA or staff is available to monitor the space.
   - Notify the head TAs and instructor immediately.

2) In case of any staff/student injury:
   - If serious — call GTPD @ 404.894.2500 or 911 on a landline. The IDEA laboratory is located in the MRDC building on the second floor in MRDC 2101.
• If not serious, utilize the first-aid resources immediately available.
• If it is required to visit a health care facility and the student can bring themselves or another student can bring them safely:
  o Graduate students go to the nearest emergency room (see link below) or the medical center at Concentra (730AM-7PM M-F)
  o Undergraduates can go to Stamps Health Center on GT’s campus 8AM-5PM
    ▪ Stamps Health Services (https://health.gatech.edu/after-hours-care) is open from 8a to 5p Monday through Friday. If your condition is not urgent or an emergency, please make an appointment with Stamps Health Services during our normal business hours. See the Stamps website for details.
    ▪ If you feel you are experiencing a life or limb threatening emergency and need an ambulance, please call 911. If you need care when we are not open, please see the list of hospitals and urgent care centers at the link above.
3) In case of equipment problems (e.g., crashes, malfunctions, tool breakage, etc.):
   • Immediately put the machine in emergency stop (or a powered off state if no emergency stop is available)
   • Replace tools or return to service if you are trained to do so
   • If you are unable or untrained to replace tools or return to service
     o Mark the equipment as inoperational with signage
     o Notify the head TAs and lead instructor
4) If you notice a student/user operating equipment or tools improperly or unsafely:
   • Inform the student/user the safety issues with the way they are operating the equipment or tools, provide suggestions for improving the safety issues
   • Issue a demerit through the electronic system in case of violations indicating clear negligence or lack of awareness (e.g., leaving a mess, leaving machines when powered and running, distracting other users while operating equipment, etc.)
5) To allow students to earn credit to offset lab stewardship demerits:
   • Students may do simple housekeeping chores to support the laboratory such as cleaning up or sweeping floors. Guidelines should be a 15-20 minute activity to support simple lab upkeep and tidiness.
   • Issue a credit to the electronic system.
Dimensional Inspection

Anatomy of the Caliper

TA Lesson Plan

General Use

- Treat with care – lay down carefully and check for damage
- Tactilely inspect jaws and hold jaws up to the light to make sure they close fully
- Zero frequently (especially after jarring drops, etc.)
- Measuring over burrs and non-flat/parallel surfaces will not return a useful reading
- Checking caliper against a gauge measures caliper scaling error (assuming properly zeroed)
- Sine error – not measuring perpendicularly across parallel surfaces
- Error due to material stiffness. *TAs should consider demonstrating by measuring their finger width, and showing how size changes with measuring force.*

Measuring dimensions of size

- Outside Jaws
  - Use the flats whenever possible. They self-align and reduce error due to measuring force.
  - The sharps are susceptible to depressing the material and returning a false measurement (they are also likely to be damaged/not flat and/or mar the work)
Technique: rocking the jaws (side-to-side, then up-and-down) around a dia. or width while looking for a minimum measurement

- Inside jaws
  - Technique: rocking the jaws (side-to-side, then up-and-down) inside a bore or slot while looking for a maximum measurement

- Depth Measurement
  - Two methods – depth probe or caliper butt
    - The greater bearing surface of the butt can be helpful
  - Some imprecision is expected

**Students:** all students practice measuring a known piece of delrin using the calipers

Anatomy of the Tape Measure and Scale

**General Use**

- Measurement resolution
  - Tape measure measures out to 1/16” resolution.
  - Scales and rules might measure to 1/8” resolution depending on the graduations.

- Tape measure hook
  - Tape measure hook on end is designed to move and be loose. Its movement is accounted for on the scale so the thickness of the hook (1/16”) isn’t included on outside or inside measurements.
  - Can be used as a scribe on a piece of wood, can be used to grab onto fasteners

**Students:** all students practice measuring a known piece of wood using the tape measure
Manual Lathe
Anatomy of the Lathe

IDEA Laboratory Lathe

Engine Lathe (geared, 3 hp, 105-2000 RPM)
https://www.mscdirect.com/product/details/09517350

Safety Training

<table>
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<tr>
<td>• Always have the spindle disengaged and motor off while setting-up a work-piece, measuring a work-piece, cleaning the machine or work-piece, or changing tools</td>
</tr>
<tr>
<td>o Note: these E-stops are not be used as an off switch</td>
</tr>
<tr>
<td>o The footbrake functions as an E-stop and can be used to stop the lathe in an emergency without disengaging the spindle first</td>
</tr>
<tr>
<td>• Keep fingers clear of all moving parts – be aware that shafts across the bed of the lathe spin as well as on the left side of the lathe</td>
</tr>
<tr>
<td>o The lead screw is disconnected on the IDEA Lab machines, but the warning should be issued nonetheless</td>
</tr>
<tr>
<td>• NEVER LEAVE THE CHUCK KEY IN THE CHUCK – always immediately remove it after use</td>
</tr>
<tr>
<td>• Do not handle metal chips or pull at them with bare hands – use a brush or pliers, if necessary</td>
</tr>
<tr>
<td>• Do not let large chip strings (bird-nests) gather around a tool or part</td>
</tr>
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</table>
Stop the machine, and brush them off

- Keep your eyes on your work at all times while the machine is on
- Use proper work-holding techniques – the lathe WILL throw your work-piece if not held properly
  - Choke up on the workpiece as much as possible – at a minimum ~.75in must be gripped in the 3-jaw chuck
  - Inspect for burrs, chips, and grime on the workpiece and chuck before clamping – they will prevent the work from being held with sufficient force
  - Not confident in your work-holding? Stop and talk to Lab staff to work out a solution
- Deburr sharp edges on the work-piece immediately after completing work, they will cut you

Proper Operation

- Clean before and after use – keep the ways, chuck, and lead screws clear of chips
- These are geared transmissions, only change speeds while the machine is off
- Peck drill
  - The drill should be pulled out after cutting 1/2 dia. deep to allow chips to clear and heat to dissipate – re-enter slowly
- Always check that the chuck will not crash into the carriage (over the entire length of your cut) before starting the machine – it often helps to spin the chuck once by hand to be sure
  - Remove the tool while using the tail stock for drilling and other operations
- Do not adjust tool height, position, stick-out, compound angle, etc. without working with Lab staff – always return the tool and machine to its normal position afterwards if you do
- Always face and center-drill before drilling
- Do not engage the powerfeeds without Lab staff approval
  - Even if engaged, the carriage/cross-slide will not move, since the lead screw is disengaged, but the warning stands nonetheless
- Do not swap chucks without Lab staff assistance
- Do not clean with water degreaser or soap – only mild solvents are to be used and the machine must be properly oiled with way oil immediately afterwards

Standard Operating Procedures

*These procedures outline how to approach a generalized task on the lathe. They reiterate safety pointers in addition to emphasizing proper operation and technique. The TA should first review this generalized process, then review specific operations.*

Generalized Process

1. Plan out your machining operations
   a. Create a drawing
   b. Consider order of operations and tooling required
   c. Consider safety and treatment machine capability for all operations
   d. Consult with IDEA lab staff for advice and approval, as needed
2. Check out your tools and tooling, choose your machine, and MAKE SURE THE MACHINE IS OFF
3. Clean the machine
   a. Remove any extraneous tools, parts, material, and drawings that are not needed for your operation
b. All surfaces that are relied upon to be true, flat, and square should be clear of chips, grime, surface rust, etc. (such as the lathe bed, carriage and cross-slide ways, chuck jaws, tail-stock taper, and any other work-holding tools)
   i. Brush-off/vacuum up all chips off the machine and surrounding floor area
   ii. Mild solvent and fine scotch Brite is all that is needed to clean off surface rust DO NOT USE ANYTHING MORE AGGRESSIVE
   iii. If you clean surface rust off a surface with a solvent the surface must have a light coating of way oil applied to prevent future rusting – lightly wipe on a few drops with a rag – no standing pools of oil should be left behind

4. Install your tool
   a. If your tool is not already in a tool holder, insert it. Clean off chips and grime first, then press the tool against the floor and back of the tool holder while tightening hold down screws – ideally, three screws should be used. NEVER use only one screw.
      i. Inspect the insert for chipped and worn edges, and get help from Lab staff to replace/re-orient it as needed
   b. Install the tool holder onto the tool post – push the tool post handle counter-clockwise to loosen, slide on the tool holder, then pull the handle clockwise to tighten – no great physical force is needed to do so
      i. Inspect dove tail joint and tool post for chips, wear, burrs, etc. and clean as needed
   c. Check tool height
      i. The cutting edge of the tool should be on the center of the horizontal plane that intersects the spindle axis – check this visually on your work and get help from Lab staff, if needed, to adjust the tool

5. Install your part
   a. Debur your part – if a burr is between your part and the chuck jaws it will not be held with holding force
   b. Inspect your workpiece and chuck surfaces for chips, burrs, wear, and grime and clean as necessary
   c. Choke up on the work-piece as much as possible – at least ~.75” should be held in the chuck – consult with Lab staff if this cannot be done

6. Get ready to run the machine
   a. Choose an appropriate speed. In the IDEA Lab, the machines can be used at a pre-set speed with the Delrin material used in the machining assignment
   b. Plan your cut – ensure that over the entire planned tool path the tool will not crash into the chuck or any other machine components

7. Make your cut
   a. Depth of cut should not exceed .050 (dia.) and normally should be closer to .035-.020 (dia.)
      i. Note that a diametrical depth of cut is twice a radial depth of cut
   b. LISTEN to your machine and MONITOR your cut
i. Chatter and heavy vibration is not to be tolerated – stop your cut and ask for help

ii. Chips should be well managed – if machining steel chips should not come off colored blue or purple – straw colored chips signify you are operating at the top limit of speed for a HSS end mill on a steel work-piece

iii. Keep an eye on your work piece and work-holding – the work should not shift

iv. If there are too many chips to see your cut stop the machine and brush the work area clean

8. Make your measurements as needed

9. Change tools as needed, following the earlier stated steps

10. Finishing your work
   a. Return all tools, work-holding devises, and measurement devices used
   b. Deburr your work-piece IMMEDIATELY – sharp parts cut hands!

11. Clean the machine
   a. Follow the instructions form Step 1 – your peers deserve a clean and well-maintained machine to operate
   b. Be sure to vacuum the machine, chip tray, and sweep/vacuum the surrounding area

Common Operations on the Lathe

- DRO use
  o X = radial direction = cross-slide
  o Z = axial direction = carriage
  o The compound can swing in a compound X-Z direction, when loosened and set to an angle.
  o Review the DRO use instructions from the “Machining and Mechatronics Studio Assignment” (see appendix)

- Facing
  o Touch-off, approximately, then use the DRO to roughly estimate depth of cut.
  o Dial in a depth-of-cut, marking this on the DRO. Face one sawcut face of the work using slow, consistent feed at a proper depth of cut.

- Turning
  o Touch-off, approximately, then use the DRO to roughly estimate depth of cut.
  o Dial in a depth-of-cut, marking this diameter as on the DRO. Turn a portion of the work down using slow, consistent feed at a proper depth of cut.

- Turning a shoulder
  o Use this as an opportunity to show how to achieve dimensional accuracy both the X and Z directions using the DRO (and the previously set zeros)
    ▪ You will need to demonstrate measuring the dia. in the chuck
    ▪ Emphasize how this could also be used to bring the work to length (demonstrate measuring the length of the work in the chuck)
  o Take successive turning passes (having already marked a X and Z point on the DRO), leaving .015-.010 on the shoulder each time. Take a final turning pass at final diameter, and move to the final shoulder location. The face outwards.

- Drilling
- Proper drilling technique – center or spot drill, then twist drill. Explain how this prevents ‘walking’. The web of a drill is not a cutting edge, and often somewhat blunt. The drill will center on a spotted hole better than not.
- Tighten a tool in the chuck, use considerable torque but one should not overtighten by using all the strength available to them, this is not needed
- Touch-off on the face of the work, to use the quill feed dial or markings to gauge hole depth
- Demonstrate peck-drilling

Students: all students practice taking a facing cut and a turning cut
Miter Saw

Anatomy of the Miter Saw

TA Lesson Plan

- **Hazards**
  - Potential for severe cuts and limb loss
  - Users must wear safety glasses and can wear hearing protection (earplugs) as well

- **General use**
  - Clean any sawdust that you create immediately after using the equipment, the shop vacuum does not capture all the sawdust.
  - Never operate the Miter Saw with another person within the marked active work zone boundary. Do not allow others to distract you while using this equipment.
  - **Always keep the saw off** while setting-up a workpiece, measuring a workpiece, cleaning the machine or workpiece. Wait for the blade to stop spinning before raising the blade after a cut.
  - **Keep fingers clear of the saw and out of the ‘no finger zones’ marked above. Do not wear gloves, loose clothing, jewelry or other dangling objects when operating the saw.**
  - Keep hands out of path of saw blade. Avoid contact with any coasting blade. It can still cause severe injury. Never reach around saw blade.
  - Do not operate saw without guards in place. Check blade guard for proper closing before each use. Do not operate saw if blade guard does not move freely and close instantly. Never clamp or tie the blade guard into the open position. Do not touch the blade guard.
  - Workpieces must be clamped to work platforms before cutting. Long material must be supported at the same height as the saw table.
  - Workpieces should have their longest side resting against the vertical guides.
- Do not use the tool in the presence of flammable liquids or gases. The electrical operation of the tool could create an explosion and fire when exposed to flammable liquids or gases.
- Make sure that the turn base is properly secured so it will not move during operation.
- NEVER use tool where operator positioning would be awkward.
  - **Only your right hand can be used to lower the miter saw.**
  - NEVER hold workpiece on right side of blade with left hand or vice versa.
  - ALWAYS use vise to secure workpiece.
- Avoid cutting nails. Inspect for and remove all nails from the workpiece before operation.
- **Be sure that the blade does not contact the turn base or the vertical guides in the lowest position.** Hold the handle firmly. Be aware that the saw moves up or down slightly during start-up and stopping.
- **Do not adjust the vertical guides.**
- Before using the tool on an actual workpiece, let it run for a while. Watch for vibration or wobbling that could indicate poor installation or a poorly balanced blade.
- Do not attempt to lock the trigger in the "ON" position.

**Common operations**
- Simple straight down cut
  - Check active work zone boundary
  - Place wood piece on work platform, push against vertical guide, use a height support for longer wood pieces so it is fully supported across the length of the board
  - Clamp wood piece to work platform
  - Turn on light switch
  - Without depressing power trigger, check saw blade alignment by bringing saw blade down using cut handle
  - Adjust wood piece position if needed and secure clamping, ensure nothing is in the way of the saw (e.g., clamping, etc.)
  - Return saw to top resting position
  - Make sure the blade is not contacting the workpiece before switch is turned on.
  - When ready to cut, depress power trigger and lower miter saw using manual cut handle, return to top position
  - Turn off tool and wait for saw blade to stop before moving workpiece or changing settings
- Cross cut or combined down/cross cut
  - A **cross cut involves translation of the saw blade in/out in the Y-direction (toward the user), this is a function of the miter saw that is NOT ALLOWED for students to use**
  - Contact a TA if a cross cut is desired.

**Students:** all students practice clamping a board, position for 60 deg angle cut, take 60 deg angle cut, rotate to 0 deg cut, take 0 deg cut, unclamp board
Laser Cutter

Anatomy of the Laser Cutter

The Trotec Speedy 300 laser cutter is a computer-controlled tool that is used to cut or engrave flat sheets of material. The laser cutter works by local ablation of material due to the laser source. The laser itself is a class 4 device, but with machine interlocks and other safety features the laser system we have is a class 2 laser. We will limit materials in this class to MDF and perhaps other wood-based materials, and those that are less than at most 0.375” (3/8”) thick. We have developed cut settings for 0.25” MDF, which will make it easier for students to fabricate from those materials. Caution must be exercised in focusing the laser or any Z-moves. **STUDENTS MUST NOT CRASH THE LASER HEAD INTO WORK MATERIALS.** Also, students should not abuse or manipulate the carriage physically by pushing/pulling it without oversight by a TA. Students must monitor all cutting and not leave the machine unattended. **The exhaust system must be running during operation of the laser, if it appears to be malfunctioning the machine should not be used.**

Hazards:

- Fires are rare when cutting approved materials in the laser cutter, but it’s possible that the laser may ignite materials, which is why the you can never leave the laser cutter. Identify the fire extinguisher and fire blanket.
- Small fire (< 2” flame) – **momentary flames** – usually self extinguish within seconds. If not, a small flame can usually be extinguished using the fire blanket. Stop the laser cutter. Throw the blanket over the flame (if needed, push the laser nozzle out of the way first). Close the cabinet.
- Large fire (> 2” flame) - **persistent or large flames** – the preferred method of putting out a fire would be to use the fire blanket. If you were to use a fire extinguisher it would put out the fire, but the laser cutter would most likely be rendered useless. If a fire cannot be controlled by the blanket, a fire extinguisher should be used. After use, evacuate the room and call the Fire Department.
- If at any point you need to immediately stop the laser, you have multiple options including: (1) stopping the machine in Job Control with the stop button on the bottom right of the screen, (2) turning off the laser cutter with the physical on off switch at back left of the machine, (3) activating...
the pause button on the machine controller panel on the top right of the machine. Situations that might require stopping of the laser cutter during process include the following:

- If the material in the laser bed catches on fire (*brief tongues of flame while the laser is firing are acceptable, but if a constant flame is started, abort the job*)
- If the smoke from the material is building up in the machine and not being evacuated by exhaust system.

**General Use:**

1. Preparation for use:
   - Load saved .pjx file in Job Control (or send to Job Control by printing from Inkscape)
   - Turn on machine (switch on back left panel)
   - Connect Laser to Job Control
     - Click USB symbol button on bottom right of Job Control
     - After successfully connected, a crosshair should appear in the Job Control Window indicating location of the laser head in the machine.
   - Open machine
   - Place workpiece material on work bed (must be smaller than 29" x 17" x 3/8")
   - Focus the laser using the focus tool
     - Place the focus tool on the ledge of the head as in below
     - Use Z-axis control buttons to raise and lower the build plate
     - Raise the build plate until the focus tool rests on top of the work material or until it just gently falls over due to contact
     - Replace the focus tool in it’s housing. DO NOT MISPLACE THE FOCUS TOOL.
   - Position the job in job control
Double click or drag the job onto the build plate in Job Control
Cursor snaps to the corners or the midpoint of the job
Move the job as needed on the build plate
  • Verify (or set) power and speed settings under materials template tab in Job Control
  • Hit Eyeball logo in case you can’t preview your job
  • Preview outline of Job Control on workpiece, verify that part to be cut is fully contained by the workpiece as positioned

2. Make the cut
  • Run the job by pushing the start button on the bottom right of the Job Control screen
  • Monitor for any persistent flames, if present, abort job by slightly lifting lid, adjust laser parameters and contact TA if needed

3. Check the job
  • When the job finishes, do not immediately remove material
  • Open the lid of the machine
    i. If engraving and you are unsatisfied with quality of engrave, you can try engraving over it again to achieve different finish
    ii. If cutting, gently apply pressure to material with one hand and use other to push down your part. If it doesn’t fall through, repeat the cut until it does.

4. Cleanup
  • Remove workpiece
  • Clean up any debris

**Students:** demo what to do, then ask students to actually load material and run part under guidance
3D Printer

Anatomy of the 3D printer

The Ultimaker 2+ 3D printer is a computer-controlled tool that is used to deposit plastic-based materials using fused deposition modeling (FDM). The machine works by locally heating and feeding filament through a nozzle that is guided by a gantry style system to deposit material on a heated build plate. Adhesion of the material to the build plate is dependent on the geometry of the part, the material used, print parameters and use of any additional adhesive material on the build plate (e.g., glue stick). We will be using PLA/PHA with known good print parameters, so that should simplify parameter setting. TAs will be responsible for filament changes and build plate leveling. If these operations need to be done, students should notify TAs, otherwise they will be done at the start of the workday.

Hazards:

- Risk of burns: There is a potential risk of burns, as the print head can reach temperatures of up to 260°C and the heated bed of up to 120°C. The nozzle of the print head is mostly surrounded by an aluminum cover to prevent contact, but we advise against reaching in machine when print head and/or heated bed are hot.
- Pinch points: The Ultimaker 2 contains many moving parts, but the stepper motors do not have enough power to cause serious injuries and moving gears have been covered. Still, it is advised to only reach in the machine when it is turned off.
- Exhaust: Printing pure PLA is considered safe, although good ventilation is still advised for possible unknown vapors released from coloring dyes in colored PLA.
- Build removal: When using putty knives to remove builds, use work gloves to protect against slippage and cuts. Use nitrile gloves underneath work gloves for sanitary reasons.

General Use:

1. Preparation for use:
   - Turn on machine (switch on back left panel)
• Insert SD card
• Select ‘print’ from the screen using the thumbwheel (press to select), navigate to Job file

2. Start the print
• Machine starts when you select the print using the thumbwheel press
• Wait for the machine to go through a heating cycle
• Monitor first several layers to confirm that the print is adhering to the build plate
  o Pause print if the layers are failing or not adhering to the build plate
  o Navigate to ‘tune’ in the menu, select ‘abort’.

3. Cleanup
   a. Exercise caution removing prints as build plate and nozzle can be hot
   b. Wearing work gloves with nitrile gloves underneath, use a putty knife to remove workpiece from build plate. Be careful not to slip and potentially cut/slice your supporting hands.
   c. Clean up any debris, clean build plate as needed.

**Students:** demo what to do, then ask students to actually load material and run part under guidance
Vertical Wood Bandsaw

Anatomy of the Bandsaw

The vertical wood bandsaw is a flexible tool most suited for small to medium sized sheet and dimensional lumber. The saw can be used to make square and angled cuts. No curved or freeform cuts are allowed. Laying out cut lines beforehand is extremely important to ensure an accurate cut. Do note that the best suited tool for the job is not always the bandsaw. It will often be advantageous to plan out cuts and utilize the table saw in the woodshop. Longer dimensional lumber (i.e. 2x4s) should be roughly broken down with a hand saw and miter box. Do not push with great force – slight force is all that is needed (needing to use excessive force may indicate that the blade needs to be changed – if so, make sure the students contact a TA to do so). Students should never adjust any setting or open the machine.

DO NOT CUT METALS!

General Use:

4. Preparation for use:
   - Adjust guard height to 1/8" to 1/4" above workpiece height
   - Loosen guard locking screw on back
   - Adjust guard height with adjustment wheel
   - Tighten locking screw
5. Make the cut
• Fingers should always stay 1.5” in clear of the blade (e.g., no finger zone)
• Use a push-stick or sacrificial piece if necessary

6. Press the red “off” button then use footbrake to bring the blade to a full-stop

Fixtures:
• Miter sled (not w/work fence) – guided straight cuts and angled cuts
• Work fence (not w/miter sled) – guided straight cuts
• Push block and/or stick – support for keeping fingers out of ‘no finger zone’
• Students: all students practice take test cuts on piece of wood
• Review the posted safety/use rules with the students. Be sure to demonstrate examples of what is not safe/proper use (i.e. hands too close, blade guard adjustment, how to quickly make/use a push-stick, etc.)
• Hazards: significant cut and/or loss of limb

Students: all students practice doing a simple 1” cut with the fence and a push stick/block
Drill Press
Anatomy of the Drill Press

Primary use: small/large holes

Fixtures:

Work Platform (use clamps)
Vise (use clamps)
Drilling Jigs (use clamps)

Primary motion: tool

Caution: do not drill the work platform, report any issues or maintenance needs! Drill can be hot after use! If you have a long workpiece, make sure that the excess material is on the left side of the drill press so that if the clamps fail, the workpiece will be rotated into the machine and away from the user.

All safety requirements for mill and hand-drill apply – see other sections.

Students: all students practice load tool, make hole, unload tool
Portable Jigsaw
Anatomy of the Jigsaw

TA Lesson Plan

• Rules
  o Clean any sawdust that you create immediately
  o Make sure your body is clear of the jigsaw blade path if workpiece were to slip or fail
  o Workpieces must be clamped to worktables and should overhang to not cut the table
  o Make sure jigsaw platform is resting flat on your piece of wood to improve stability of cut (reduce vibrations), **KEEP your hands/fingers/body free of the jigsaw blade**

• Wood cut use cases
  o Simple cuts, cornering and profile cuts

• Typical product use cases
  o Load jigsaw blade
    ▪ Remove battery if it is inserted
    ▪ Activate toggle lock by trigger
    ▪ Rotate load/unload lever on topside of jigsaw
    ▪ Insert jigsaw blade
    ▪ Verify jigsaw blade is secure
    ▪ Insert battery and activate toggle unlock
    ▪ Use trigger to verify the jigsaw blade is secure while operating in air

• Unload jigsaw blade
  ▪ Be CAREFUL, jigsaw blade might be hot after use
  ▪ Remove battery if it is inserted
  ▪ Activate toggle lock by trigger
  ▪ Rotate load/unload lever on topside of jigsaw
  ▪ Remove jigsaw blade
• Adjust jigsaw bevel angle if needed (lever is on underside of jigsaw). Before adjusting bevel angle make sure the battery is pulled out or the saw is locked.
  ▪ Rotate angle adjustment lever on bottom of jigsaw
  ▪ Rotate jigsaw platform to appropriate cut angle (marked on back lower portion of jigsaw)

**Students:** all students practice loading/unloading blades, take test cuts on piece of wood
Portable Drill/Drivers
Anatomy of the Drill/Driver

- **Rules**
  - Clean any sawdust that you create immediately
  - Do not operate manual drill chuck using the drill power
  - Make sure your body is clear of the tool path if workpiece were to slip or fail
  - **Primary use**: drilling, fastening
  - **Drill/Driver**: drilling holes, driving smaller fasteners
  - **Impact Driver**: driving large or long fasteners, limits torque input to user
  - **Combo Driver**: both
  - **Primary motion**: tool
  - **Caution**: use the right tool, report batteries that need to be charged, be careful not to drill any worktables and other fixtures

**Students**: all students practice driving a fastener using a drill and using an impact driver
Hand Drill Safety

Only use drills to hold tools meant for drills
Utilize proper work-holding
  • Never hold your work by hand ALWAYS use clamps
  • Always be aware of where your and other hands are – NEVER behind a workpiece
Use a sacrificial backing piece
  • Prevents tear-through, damage to work tables
Apply light force only
Put the drill into neutral when not in use
Smoke, excessive/irregular noise, heavy vibrations, etc. are all signals to stop and figure out what is wrong
Hand Tools, Heat-Generating Tools

General Awareness

Your actions have the potential to affect those around you
Consider the radius of effect
  • Where is/are the debris/dust/chips going?
  • If you loose purchase/miss/etc. what’s in the way?
Every tool is a potential hazard – treat it as such

Hand Tools, Tools that Generate Heat

Hand tools do have the potential for danger
Always be conscious of how much load you are applying – never apply so much load that if you lost grip or slipped you would be out of control
Who’s in the path of danger?
Soldering irons, heat guns, hot glue guns
  • Always assume hot
  • Never use to melt materials they are not designed for
  • Do not place near paper, cloth, other flammables
  • Unplug when not in use
Students: students will not be trained on the IDEA Laboratory Mill, if they wish to use the Mill, they will get trained separately outside of the studio section

Safety Training

- **Always turn off the motor and engage the E-stop** while setting-up a workpiece, measuring a workpiece, cleaning the machine or workpiece, or changing tools
- **Keep fingers clear of the spindle while it is rotating**
- **Do not handle chips or pull at them with bare hands** – use a brush or pliers, if necessary
- Do not let large chip strings (bird-nests) gather around a tool
  - Stop the machine, and brush them off
- **Use proper work-holding techniques** – the mill WILL throw your workpiece if not held properly
The workpiece must be held along the centerline of the vice to prevent jaw-jacking – if your workpiece is too short use a dummy piece on the other end of the vise. The dummy piece must be a dimensional match, or the work piece could slip. Demonstrate what jaw-jacking is (see graphic in appendix)

Over-clamping the work will bow it (see table in appendix)

Inspect for burrs, chips, and grime on the workpiece and vise before clamping – they will prevent the work from being held with sufficient force

Choose parallel surfaces on your workpiece to face the vise jaws – non-parallel surfaces will prevent the work from being held with sufficient force

Not confident in your work-holding? Stop and talk to Lab staff to work out a solution

- When handling machine tools and cutting/abrading tools use caution, rags, and gloves as needed to avoid being cut
- Deburr sharp edges on the workpiece immediately after work, they will cut

**Proper Operation**

- Clean before and after use – keep the ways and vise clear of chips
- The mill table IS NOT a worktable – it is a precision surface to be treated with care
  - Do not hammer, strike, or abrade (file or sand) work on the table
- These are geared transmissions, only change speeds while the machine is off
- Plan your cut – be sure the tool will not crash into the vise, part, or machine over its entire travel
- Take care not to drill into the parallels or vise beneath the workpiece
  - Parallels do shift while working, sometimes
- Only plunge with the quill feed handle, do not use the head stock travel
- Peck drill
  - The drill should be pulled out after cutting 1/2 dia. deep to allow chips to clear and heat to dissipate – re-enter slowly
- Hold endmills and tools (with a rag) while removing them – don’t let them drop on the table
- Tilt the head? Remove the vise? Get Lab staff approval and help to return them to tram and square
- Do not clean with water degreaser or soap – only mild solvents are to be used and the machine must be properly oiled with way oil immediately afterwards

**Standard Operating Procedures**

**Generalized Process**

1. Plan out your machining operations
   a. Create a drawing
   b. Consider order of operations and tooling required
   c. Consider safety and treatment machine capability for all operations
   d. Consult with IDEA lab staff for advice and approval, as needed
2. Check out your tools and tooling, choose your machine, and MAKE SURE THE E-STOP ON YOUR MACHINE IS ENGAGED
3. Clean the machine
   a. Remove any extraneous tools, parts, material, and drawings that are not needed for your operation
b. All surfaces that are relied upon to be true, flat, and square should be clear of chips, grime, surface rust, etc. (such as the machine table, vise jaws and bed, spindle taper, collet outer taper and inner bore, tool shank, parallels, and any other work-holding tools)
   i. Brush-off/vacuum up all chips off the machine and surrounding floor area
   ii. Mild solvent and fine scotch Brite is all that is needed to clean off surface rust
       DO NOT USE ANYTHING MORE AGGRESSIVE
   iii. If you clean surface rust off a surface with a solvent the surface must have a light coating of way oil applied to prevent future rusting – lightly wipe on a few drops with a rag – no standing pools of oil should be left behind

4. Install your tool
   a. Choose the correct collet size – R8 style collets can ONLY accommodate tools corresponding with their labeled size, there is no compatibility for oversized and undersized tools. ER collets (the ones we are using) have a slight tolerance for oversize or undersize (+/- .015 max)
      i. Inspect collet for chips, wear, burrs, etc. that will prevent the collet from gripping the tool properly
   b. Install the collet into the collet nut (DO NOT install your tool, yet)
      i. Inspect threads for chips, wear, burrs, etc. what will prevent easy threading
   c. Slide in your tool
      i. Hold your tool carefully (maybe using a rag) to avoid being cut
      ii. If the tool does not slide in with ease (only light hand force) the collet is too small. If it has play, the collet is too large.
      iii. Tools should be gripped using the full area of their shank but do not grip the tool on the flutes!
   d. Install the collet/collet nut/tool assembly onto the spindle
      i. Hold the assembly carefully, maybe with a rag. to avoid being cut
      ii. Hand-tighten; if the tool is still able to fall out at this point your collet is too big
      iii. Make sure the machine is in low gear, and tighten with a collet wrench

5. Install your part
   a. Deburr your part – if a burr is between your part and the jaws it will not be held with proper holding force
   b. Inspect your workpiece and vise surfaces for chips, burrs, wear, and grime and clean as necessary
   c. Choose parallel and square surfaces of the workpiece to face the jaws – gripping non-parallel surfaces will not produce proper holding forces
   d. Use parallels to raise your work to a proper working height
   e. Place your workpiece on the parallels, and make sure there is material between the centerline of the vise
      i. If this is not possible, a second identically sized dummy work piece will have to be used to prevent jaw jacking
   f. Lightly tighten the vise
   g. Tap the work lightly to ensure it is seated on the parallels and the parallels into the vise bed
h. Tighten the vise – no great physical effort is needed – consider that soft materials and thin workpieces WILL deflect under high holding forces.

6. Get ready to run the machine
   a. Choose an appropriate speed. in the IDEA Lab, for machining Delrin, a single pre-set speed suffices.
   b. Make sure the machine tables are not locked in place.
   c. Lock the head stock assembly to the vertical ways.
   d. Plan your cut – ensure that over the entire planned tool path the tool will not crash into the vise, table, or any other machine components.

7. Make your cut
   a. Tool engagement should not exceed \( \frac{1}{4} \) the dia. of the endmill.
   b. Depth of cut should not exceed \( \frac{1}{2} \) the dia. of the endmill.
   c. Endmills should not be plunged more than 1.5 the dia. of the endmill.
      i. This applied to slotting operations, as well.
   d. Do not edge mill with the tool contact length being a depth of than 1.5 the dia. of the endmill.
   e. LISTEN to your machine and MONITOR your cut.
      i. Chatter and heavy vibration is not to be tolerated – stop your cut and ask for help.
      ii. Chips should be small – if machining steel chips should not come off colored blue or purple – straw colored chips signify you are operating at the top limit of speed for a HSS end mill on a steel work-piece.
      iii. Keep an eye on your work piece and work-holding – the work should not shift.
      iv. If there are too many chips to see your cut stop the machine and brush the work area clean.

8. Make your measurements as needed... WITH THE MACHINE OFF AND THE E-STOP ENGAGED.

9. Change tools as needed.
   a. WITH THE E-STOP ENGAGED hold the tool carefully, maybe with a rag, and untighten the collet nut with the collet wrench – a quick sharp pull on the wrench may be needed to loosen the nut.
   b. If the nut does not loosen, ask for help from IDEA lab staff.
   c. Once the collet nut is loose, while holding the tool carefully, take the nut off by hand.
      i. You don’t want to let the tool fall!
   d. Return your collet and tool after cleaning them.
   e. Install a new collet and tool as needed.

10. Finishing your work
    a. Return all tools, work-holding devises, and measurement devices used.
    b. Deburr your workpiece IMMEDIATELY – sharp parts cut hands!

11. Clean the machine
    a. Follow the instructions form Step 1 – your peers deserve a clean and well-maintained machine to operate.

Common Operations on the Mill

1. DRO use
a. X = right/left
b. Y = back/forward
c. Z = up/down
d. Make note of sign convention
e. Review the DRO use instruction from the “Machining and Mechatronics Studio Assignment” (see appendix)

2. Side milling
   a. Square one saw-cut face of the work by touching-off on the side of the work, then use the DRO to roughly gauge the tool engagement for a side-milling pass. Use visual and tactile senses to identify a smooth, flat surface.
   b. Mark this as an X position on the DRO
   c. Discuss how this zero, along with measurement of the work in the vise, could be used to bring the work to length. Referring to the graphic in the Machining Assignment to explain this is recommended.

3. Facing
   a. Face one cantilevered edge of the work by touching-off on the face, then using the DRO to roughly gauge a small initial pass.
   b. Mark this as a Z zero on the DRO
   c. Discuss how this zero, along with measurement of the work in the vise, could be used to bring the work to a certain height/thickness. Referring to the graphic in the Machining Assignment to explain this is recommended.

4. Plunging/slotting
   a. As this is not necessary for the students to complete their assignment, verbal review is all that is needed
   b. Plunging and slotting in tough materials is dangerous and difficult, consult with Lab staff before attempting (chip clearance is the issue)

5. Drilling
   a. Proper drilling technique – center or spot drill, then twist drill. Explain how this prevents ‘walking’. The web of a drill is not a cutting edge, and often somewhat blunt. The drill will center on a spotted hole better than not.
   b. Tighten a tool in the chuck, use considerable torque but one should not overtighten by using all the strength available to them, this is not needed
   c. Touch-off on the face of the work, then use the DRO to gauge hole depth.
   d. Demonstrate peck-drilling

6. Edge-finding
   a. Refer to documentation in appendix
   b. Slowly approach, watch at an angle diagonal to X and Y axis, double check, offset by radius of .100”. Consider repeating to ensure accuracy.
Appendix
Posted PPE/proper shop wear and general Lab use/equipment use safety rules
Posted bandsaw use/safety rules
Posted lab layout and emergency procedures
ME2110 safety lecture
Machining assignment
DRO instructions
Edge finding/touching-off methods
Part drawings, and process plan notes/graphics
Documentation on 4” Kurt vise