TRINITY-AREA SCHOOL DISTRICT

FABLab

HIGH SCHOOL CURRICULUM

2023

Washington, Pennsylvania

ACKNOWLEDGMENTS

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REDEVELOPMENT AUTHORITY of the COUNTY of WASHINGTON

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Trinity High School
Fab Lab

Message to the Teacher

The purpose of the Fab Lab curriculum is to create a multidiscipline enterprise program that moves high school students through a process of planning, design, analysis, production, and fiscal examination through "real life" applied activities. This task supports both hard and soft skills using a traditional and high tech process that is integrated into academics and electives. Because engineers use technology to solve problems, many of the sections included in each unit relate to a field of engineering or artistic design and has been designed to be activity oriented.

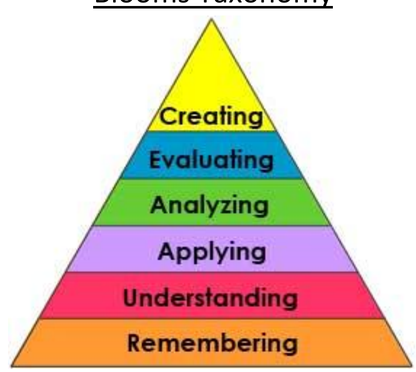
The **Fab Lab** contains two units; the first one is to be taught in a period of 18 weeks, and the second taught in a period of 36 weeks. The units provide students hands-on experience in developing prototypes and implementation models, enabling them to push future projects on their own.

- Digital Fabrication (1 Semester)
- Advanced Digital Fabrication (1 Year)

Performance objectives have been established for each of the sections. In each case there will be a different set designed to fulfill the goals and standards of the section.

Bloom's taxonomy is especially useful in developing performance objectives, activities, and assessments such as rubrics. In teaching we need to maintain congruency between instruction and assessment. The taxonomy can also assist the teacher in selecting and planning meaningful learning challenges for all students.

Blooms Taxonomy



FAB LAB NETWORK

PREFACE

The Fab Lab network is an open, creative community of fabricators, artists, scientists, engineers, educators, students, amateurs, professionals, of all ages located in more than 90 countries in approximately 1,500 Fab Labs. From community based labs to advance research centers, Fab Labs share the goal of democratizing access to the tools for technical invention. This community is simultaneously a manufacturing network, a distributed technical education campus, and a research laboratory working to digitalize fabrication, inventing the next generation of manufacturing and personal fabrication. Learn more on www.fabfoundation.org.

The following represents the specifications that the Fab Lab incorporates:

- Provide instruction in the specific skills and concepts related to each section.
- Be developed in concert with the latest standards for STEM (science, technology, engineering, & mathematics).
- Offer appropriate learning challenges to students at all levels of ability.
- Place emphasis on a project approach to learning – learning by doing, a hands-on approach that is exciting to students.
- Appeal to students from all backgrounds – females, males, racial, ethnic, and socio-economic populations.
- Provide opportunities for self-directed and extended learning activities.
- Promote skill development in the areas of design and personalized fabrication.
- Relate technology to the student's daily life.

A Message to Teachers about Rubrics

A comprehensive model of assessment would include the traditional assessments such as written tests, along with alternative assessments such as performance assessment and authentic assessment.

Many activities developed in the **Fab Lab** lend themselves to performance and authentic based assessment. These approaches to assessment use measures, called rubrics, to provide specific criteria to assess the level of attainment of individual objectives related to a given topic or activity.

We can identify five steps in developing rubrics:

1. Identify desired outcomes.
2. Include, where possible, student input.
3. Set a performance range.
4. Check for alignment.
5. Check for understanding of the criteria.

In planning to use a set of rubrics, a series of questions related to the above steps should be completed including the following:

- What specific content will you teach that lends itself to a performance task?
- What are the important understandings/skills that you expect the students to use?
- What is the “target” performance level that you want students to demonstrate?
- How would you define each additional level of performance above and below this target level?

The following model denotes four levels of achievement (performance range) as follows:

Distinguished	Demonstrates exemplary performance or understanding; shows creativity; goes beyond the target; shows initiative and independence in learning. (4 points)
Proficient	Demonstrates solid performance or understanding; is proficient in the learning; has reached the target goal. (3 points)
Apprentice	Performance and/or understanding is emerging or developing; makes errors; has a grasp of the material that is not thorough. (2 points)
Novice	Might attempt the work; has made minimal progress, and have serious errors or misconceptions about the work. (1 point)

On the next page you will find a fully developed rubric suitable for assessing the quality of a broad student performance for a wide range of authentic projects/activities. It can be used throughout the program with minor adjustments for each specific situation. This message about rubrics and the examples of them in the **Fab Lab** will be useful in developing others as teachers create new rubrics to meet their student evaluation needs.

Rubric for Project/Activity Performance

Outcome Category	Distinguished 4 Points	Proficient 3 Points	Apprentice 2 Points	Novice 1 Point
Required Elements	Thoroughly and clearly states the main points and percise details that are accurately focused on the designed project.	Adequately states the main points and details that are accurately focused on the design project.	States most of the main points and details that focus on the design project. May include some unnecessary information.	States few main points and details that focus on the design project, or information does not relate to topic.
Accuracy	Dimensions and all of the correct fittings are perfectly represented with little error.	Dimensions are precise and fittings are adequate.	Sizing and precision of project(s) show multiple errors.	Sizing and precision are incorrect and have a lot of errors.
Creativity	Appearance and uniqueness of the project is exceptionally attractive.	Project is mostly attractive and shows multiple aspects in being unique.	Project shows some promise of uniqueness but is not shown in the design.	Appearance of the project is not attractive and wasn't exceptional work.
Design	Clearly and completely describes the design and the design process, including all the necessary information in the most appropriate order.	Adequately describes the design process, including most of the necessary information in the correct order.	The design and design process is not clearly described and includes most necessary information.	The design and design process is not described and includes very few pieces of information.
Participation	Student was on task and followed instructions well. He/she had an excellent understanding of the criteria and class effort.	Student was somewhat on task and followed instructions. He/ she understood most of the criteria and class effort.	Student showed minimal effort and instruction. He/ she understood some of the criteria and class effort.	Student was distracted a lot, showed little effort, and didn't follow the criteria or class effort.

ITEEA Standards

Standards for Technological Literacy

STL 1. Characteristics and Scope of Technology

J. The nature and development of technological knowledge and processes are functions of the setting.

L. Inventions and innovations are the results of specific, goal-directed research.

STL 2. Core Concepts of Technology

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.
J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.
J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
L. The process of engineering design takes into account a number of factors.

STL 10. Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.
J. Technological problems must be researched before they can be solved.
L. Many technological problems require a multidisciplinary approach.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.
N. Identify criteria and constraints and determine how these will affect the design process.
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
Q. Develop and produce a product or system using a design process.
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.
N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
O. Operate systems so that they function in the way they were designed.
P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

STL 19. Develop an Understanding of and be able to Select and Use Manufacturing Technologies

M. Materials have different qualities and may be classified as natural, synthetic, or mixed.
N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.

Pennsylvania Standards

Technology/Engineering PA Standards

3.4.C. Technology and Engineering Design
- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World
- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.
- 3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World
- 3.4.10.E6. Illustrate how manufacturing systems may be classified into types such as customized production, batch production, and continuous production.
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

SCOPES-DF Standards

Fab I Can Statements

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Electronics.1 - I can follow instructions to build a simple electrical circuit using conductive material basic components and power.
Electronics.2 - I can follow a schematic diagram and create a circuit including a microcontroller with electronic components.
Electronics.3 - I can create my own schematic diagrams and use them to build electronic circuits including microcontrollers.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab’s capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Curriculum Outline

The expanded curriculum outline is intended to help the instructor who may not be familiar with all aspects of this field of study with an overview of topics which are included in sub-headings. Heading names may be unfamiliar to an individual and the expanded version will give you a more in-depth listing of topics that an instructor may want to study before presenting a unit or section. The allocation of time to each of the topics may be found in the weekly planners that are included in each unit overview.

UNIT 1 DIGITAL FABICATION

Section 1.1 Intro to Fab Lab

1.1.1 The Engineering Design Process

1.1.2 Fab Lab Workflow

- Design - Prepare - Fabricate
- CAD vs CAM
- CNC Fabrication

Section 1.2 Vector Design

1.2.1 Vector Design Software

- Raster vs Vector
- Shape & Node Editing
- Tracing Bitmaps

1.2.2 Vinyl Cutting

- Adhesion Vinyl
- Heat Pressed Vinyl

1.2.3 Laser Engraving

1.2.4 Laser Cutting

- Pressure-Fit Tolerances

Section 1.3 CNC Tool-Pathing

1.3.1 Vcarving Tool-Paths

1.3.2 Profile Cutting Tool-Paths
- Makercase Generator
- Tool Speeds & Feed Rates
- Preparing Vectors

Section 1.4 3D Design

1.4.3 3D Design Software
- 2D Sketch/3D Extrusion Features
- .STL Format

1.4.2 3D Printing (Fused Deposition Modeling)
- Slicing 3D Models
- Supports & Adhesions

Section 1.5 Soldering & Electronics

1.5.1 Soldering Techniques

1.5.2 Through-Hole Circuit Board Kits
- LED Torch Kit
- Easy Build Timer Kit
- Light Activated Switch Kit

Section 1.6 Project Development

1.6.1 Project 1: Enclosure Design

1.6.2 Project 2: Innovative Design

UNIT 2 ADVANCED DIGITAL FABRICATION

Section 2.1 Metal Fabrication

2.1.1 Waterjet Cutting
- Vector Design Software
- Fabrication Workflows

2.1.2 Metal Marking (Fiber Laser)
- Anneal, Polish, & Etch

Section 2.2 3D Modeling

2.2.1 3D Design Software
- Form Editing/Sculpting

2.2.2 3D Printing (Stereolithography)
- Slicing 3D Models
- Supports & Adhesions
- Rinsing & Curing Processes

2.2.3 3D Milling
- 2.5D vs 3D
- Converting Bitmaps into 3D
- Roughing & Finishing Tool-Paths

2.2.4 3D Scanning
- Principle of Laser Triangulation

2.2.5 Rotary Design
- 4^{th} & 5^{th} Axis Machines

Section 2.3 CNC Machining

2.3.1 Manufacturing (CAM) Software
- Tool Libraries
- Stock Setups
- 2D/3D Milling Tool-Paths
- Post Processing (G-Code)

2.3.2 CNC Milling Operations
- Tool/Work Offsets
- Conversational CNC Programming
- Active G-Code

Section 2.4 Molding & Casting

2.4.1 Vacuum Forming
- Thermoplastics (Sheets)
- Positive vs Negative Molds
- Pouring Molds

2.4.2 Sand Casting
- Foundry Tools
- Flask Assembly
- Pouring Aluminum

2.4.2 Plastic Injection Molding
- Thermoplastics (Pellets)
- Cavity Mold Features
- Machine Operations

Section 2.5 Electronics Production

1.5.1 Electronic Design Software
- Schematic vs Board View
- Routing Circuits

1.5.2 CNC Milling PCBs
- Fab Modules (CAM Software)
- Machine/Material Setup

1.5.3 Surface-Mount Devices (SMD)
- Soldering Techniques
- Component Polarities

Section 2.6 Project Development

1.6.1 Project 1: MP3 Speaker Design

1.6.2 Project 2: Advanced Innovative Design

Unit 1 Overview

Digital Fabrication

Description

This course provides the basic skills related to design and fabrication. Students will develop the ability to select and correctly use tools, materials, and processes to answer questions, understand explanations, and solve problems presented in real life situations. Classroom equipment includes a computer design lab with up-to-date 2D/3D software tools, and a complete fabrication lab that includes laser cutters, CNC milling machines, vinyl cutters, and 3D printers.

Unit Goals:

Upon the completion of this unit, students will learn:

- Awareness of engineering requirements and mechanical design influencing Fab Lab
- The impact of digital fabrication on today’s society
- To safely select and use fabrication tools and machines
- Proper drafting and design techniques
- The use of 2D/3D modeling software for creative applications
- Circuit assemblies and soldering techniques
- To select and apply proper resources to conduct a successful and innovative design

Weekly Planner:

Week 1	– Orientation of new groups – Introduction to Fab Lab workflow, CAD vs CAM software, & CNC fabrication – Students review & practice the engineering design process

Week 2	– Quiz: Fab Lab Workflow – Introduce vector design using CorelDRAW software – Demonstrate vinyl cutter operations – Activity: Adhesive Vinyl
Week 3	– Activity: Heat Pressed Vinyl – Continue work on CorelDRAW applications
Week 4	– Demonstrate laser engraving operations – Activity: Laser Engraving – Continue work on CorelDRAW applications
Week 5	– Refine vector design features – Demonstrate laser cutting operations – Activity: Laser Cutting
Week 6	– Quiz: Vector Design – Introduce CNC tool-pathing using Aspire software – Demonstrate CNC machine operations – Activity: Vcarving Tool-Paths
Week 7	– Continue work on Aspire applications – Demonstrate machine setup for CNC milling – Activity: Profile Cutting Tool-Paths
Week 8	– Continue work on Aspire applications – Students laser mark & build projects – Quiz: CNC Tool-Pathing
Week 9	– Introduce 3D design using Fusion 360 – Introduce 3D slicing using CURA software – Activity: 3D Printing (FDM) Workflow

Week 10	– Demonstrate (FDM) 3D printer operations – Introduce more 3D modeling features using Fusion 360
Week 11	– Continue work on Fusion 360 applications – Activity: 3D Design Challenge
Week 12	– Continue work on Fusion 360 applications – Quiz: 3D Design
Week 13	– Introduce how to solder electrical components – Activity: LED Torch Kit
Week 14	– Activity: Easy Build Timer Kit – Activity: Light Activated Switch Kit – Activity: Enclosure Design Challenge
Week 15	– Students finalize & submit their enclosure designs – Activity: Innovative Design Challenge
Week 16	– Students document, design, & prototype their innovative design project
Week 17	– Students continue to tweak & improve their prototypes for their innovative design project
Week 18	– Design & fabrication time needed to submit final innovative design project

SECTION 1.1

Intro to Fab Lab

Background Narrative

Digital fabrication is an emerging byproduct of the computer age. It is becoming more accessible for small scale production through the use of 2D/3D design software and additive/subtractive manufacturing. For example, a router is an electric driven cutting tool that is usually used for wood or plastic applications; but combined with computer numerical control (CNC) of the work piece table, it becomes a digital fabrication device.

Digital fabrication has a somewhat complex set of operations to achieve. First, a design is created with a sort of specialized CAD software (Computer Aided Design). The geometric information from the digital design is then computed into instructions for tool paths and related CAM information (Computer Aided Manufacturing). Any tooling or material setup is then prepared and the instructions are communicated to the tool to begin operation. Each type of computer controlled tool has its own particular approach; but most rely on a robotic head that negotiates a spatial grid based on coordinate directions that either deposits, cuts, or manipulates material.

To start this course, we will first introduce the concept in using the engineering design process to create a mock product. The sketching of a model is the essential starting point for manufacturing and analysis. By the end of this section, students will have the basic understandings in identifying fabrication processes and machine operations to imagine a Fab Lab workflow in creating their own unique designs.

ITEEA Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.
- L. Inventions and innovations are the results of specific, goal-directed research.

STL 2. Core Concepts of Technology

- W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

L. The process of engineering design takes into account a number of factors.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

PA State Standards:

3.4.C. Technology and Engineering Design

- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.

Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.

Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Performance Objectives:

1. Students will understand what a fabrication lab is & how they can utilize the space in creating future projects.
2. Students will apply the engineering design process to create a mock product.
3. Students will create models and documentation that represent solutions to problems.

Activities:

- ➢ The students follow the engineering design process to plan, create, evaluate and improve a design.

Resources:

- Cardboard and/or Paper
- Scissors, tape, & other craft materials

Assessment

- ➢ Students will be evaluated by instructor and rubric.
- ➢ Written quiz follows at the end of this section

Activity

Section 1.1

NAME(S) ____________________________________ **DATE**_____________

The Engineering Design Process

Instructions: Follow through each step in order to create a unique product.

STEP 1: Define the Problem:

STEP 2: Plan (Sketch) Possible Solutions:

STEP 3: Create A Prototype

STEP 4: Evaluate & Present Your Model

STEP 5: Reflect & Document Improvements as Needed:

Quiz

Section 1.1

NAME ____ **SCORE**____________

1-3. **Describe <u>in detail</u> what a CNC machine is. Give examples and show the significance and usage of them.**

4-5. **Describe <u>in detail</u> what the differences between CAD & CAM software.**

Match the following CNC vocabulary terms

6. _____ **Stepper Motor**	**A.** Programming language that is used in CAM software to control CNC machines
7. _____ **G-Code**	**B.** File format of an 2D or 3D object generated and used by a CAD software
8. _____ **Limit Switch**	**C.** Specifies each point uniquely in a multi-axis plane using a set of numerical positions
9. _____ **Cartesian Coordinates**	**D.** Made of energized coils to achieve very precise positioning and/or speed control
10. _____ **Digital Design**	**E.** Sends a signal that will stop the axis from trying to move past the end of its travel range

SECTION 1.2

Vector Design

Background Narrative

Vector design is graphical artwork comprising of points, lines, and curves that are based on mathematical formulas. It involves a creative plan to solve a problem with the use of images, symbols, or even words. It is visual communication of concepts and ideas using multiple graphic elements and tools.

Although much of vector design work is done on the computer, it can also be multimedia in nature. Some common specialties can include vinyl plotting, heat pressing, laser engraving, and laser-cut crafting. People interested in graphic design are visual thinkers who spend most of their time utilizing specialized graphic design software. This section understands this information and exposes high school students to these kinds of career paths.

The goal in this section is to show some of the basic elements of rastering and vectoring when going through the Fab Lab workflow. It merges information learned from the previous section and gives it more utilization of the fabrication lab. Students will use this portion of the course to produce multiple graphics; whether it's images, shapes, or text editing applications to gain further knowledge from the different fabrication software and machines.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

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STL 2. Core Concepts of Technology

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

CC. New technologies create new processes.

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P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

Q. Develop and produce a product or system using a design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.

3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

Fab I Can Statements:

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Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.

Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.

Safety.2 - I can operate equipment in a Fab Lab following safety protocols.

Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will understand the different features of 2D vector software and how it can be easily used to their needs.
2. Students will analyze the different material and software setup features to carry out tasks.
3. Students will apply the ability to and manipulate 2D geometry to produce a 3D model.

Activities:

- Students create a vinyl adhesive decal
- Students create a heat-transfer vinyl design
- Students create a laser-engraved graphic
- Students create a laser-cut silhouette that’s pressure-fitted

Resources:

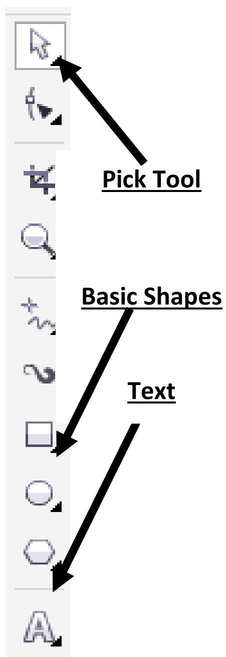
- Vectoring Software (CorelDRAW)
- Vinyl Cutter
- Heat Press
- Laser Cutter
- Tweezers, Scissors, Box Cutter
- Materials (Adhesive Vinyl, Heat-Transfer Vinyl, Rally Towels, 1/8” Thick Wood & Acrylic)

Assessment

- Students will be evaluated by instructor/student critiques and rubric.
- Written quiz follows at the end of this section

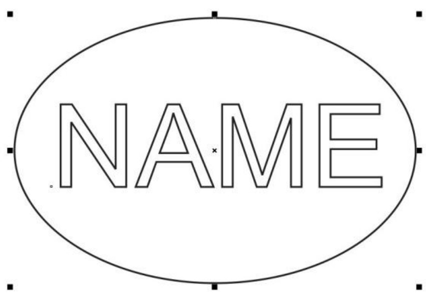
Activity

Section 1.2



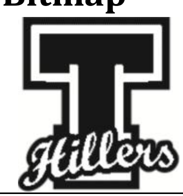
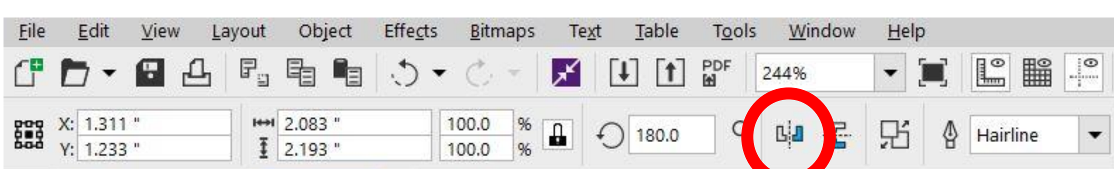
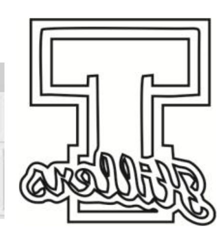
Adhesive Vinyl

To introduce **CorelDRAW** and vinyl cutting, we are going to start by creating a simple text. First create a 5”x5” new document. Draw a 3” wide, 2” tall oval and type your first name (in all capital letters).



Heat-Pressed Vinyl

Continuing with **CorelDRAW**, we will properly convert and trace a bitmap image into a vector outline. Once completed, remember to “mirror” your design from the toolbar menu shown on step 5.

1) Copy & Paste Google Image Document Size: 6”x6” 	**2) Convert to Black/White Bitmap** Bitmap > Mode > Black/White 
3) “Trace Bitmap” Manipulate Detail, Smoothing, & Corner Smoothness 	**4) No Fill / “Hairline” Outline** Go to Object Properties to Change an Object’s Fill & Outline 
5) Mirror Horizontally for Heat Transfer Application  	

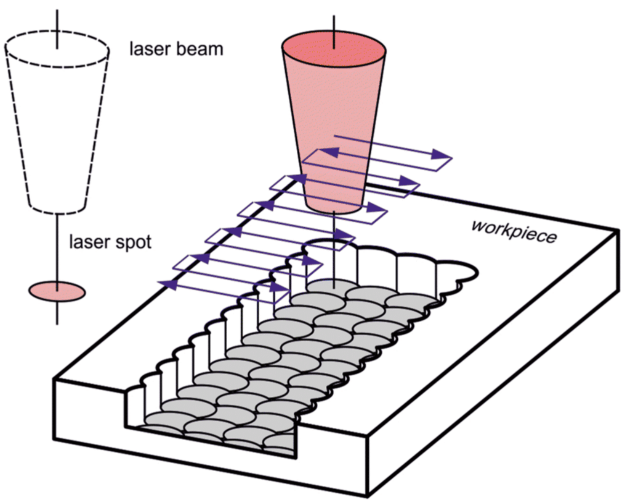
Activity

Section 1.2

Laser Engraving

(Rastering)

Rastering involves the laser performing a printer-like function. It moves back and forth across the material while the laser engraves a surface image. A vector image can also be used for raster engraving, but it must have a fill rather than consisting solely of outlines in order to be engraved.

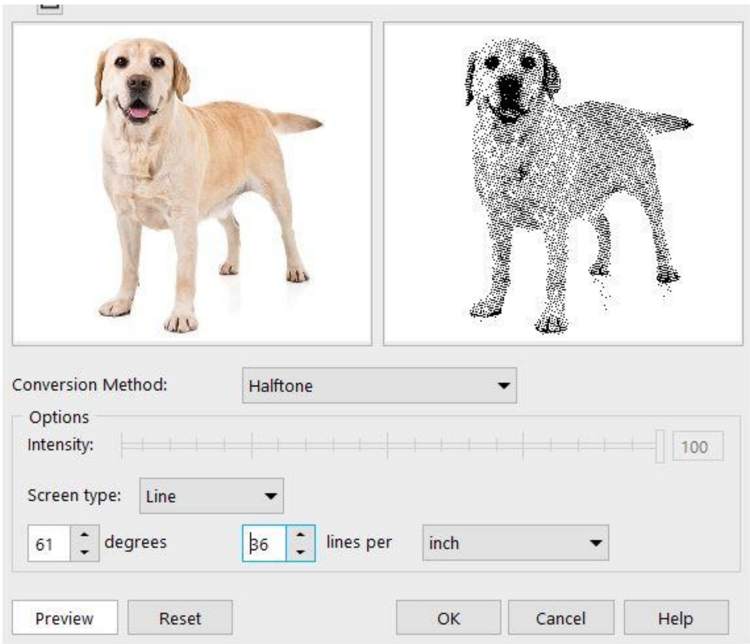


Create a Wood Engraving

Find a photograph image from Google with a white background.

Document Size: 6”x6”

Black/White Conversion Method: Haftone

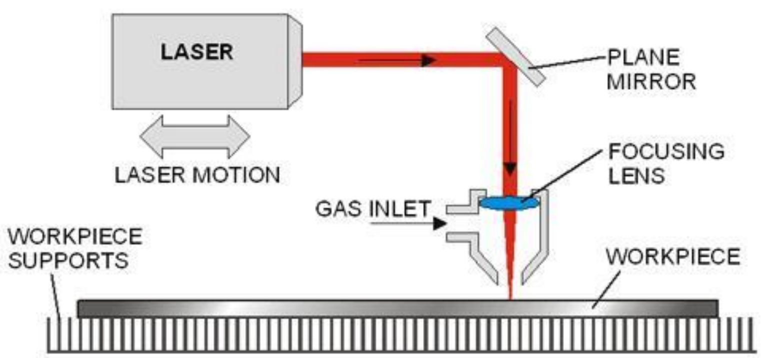


Activity

Section 1.2

Laser Cutting
(Vectoring)

Vectoring involves the action of cutting an outline and a shape from a piece of material. **CorelDRAW** interprets this functionality through a specific vector thickness labeled as "Hairline" outline.



Create a Pressure-Fitted Silhouette

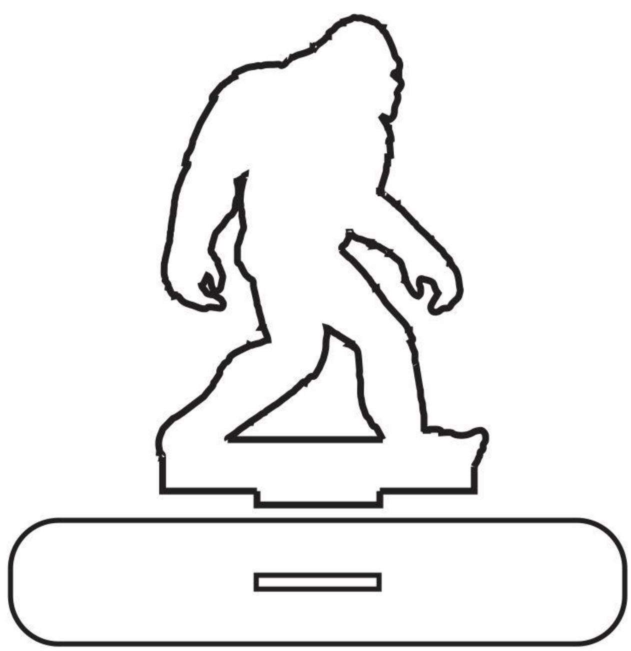
Find a silhouette image from Google & convert it into an outline.

Document Size: 6"x6"

Base Size: 5"x 1"

Slot/Finger Joint Size: 1"x 0.12" (Material Thickness -0.05" or more)

Cropping Method: Virtual Segment Delete (CorelDRAW)



Quiz

Section 1.2

NAME ____ **SCORE**_____________

Match the following CorelDRAW vocabulary terms

1. _____ **Pick Tool**	**A.** A graphics image file that's defined by the color of each of its pixels (or bits)
2. _____ **Vector**	**B.** Made up of points, lines, and curves that are based upon mathematical equations
3. _____ **Bitmap**	**C.** Used to select and manipulate objects which includes moving, resizing, & rotating
4. _____ **Node**	**D.** Can be used to trim overlapping lines and shapes
5. _____ **Virtual Segment Delete**	**E.** A point where lines or pathways intersect or branch; a connecting point

6-7. Explain the differences between raster and vector on the laser engraver.

8-10. Briefly describe everything that needs to be edited for a standard JPEG image (like the one shown above) so it can have a vector cut out using **CorelDRAW** and the laser engraver.

SECTION 1.3

CNC Tool-Pathing

Background Narrative

Computer numerical control (CNC) is a manufacturing process which typically employs computerized controls and machine tools to fabricate a custom-designed part. This process is suitable for a wide range of materials; including metals, plastics, wood, glass, foam, and composites, and finds application in a variety of industries. The automated nature of CNC machines enables the production of high precision and high accuracy in fabricating simple parts. However, while CNC machines demonstrate certain advantages over other manufacturing processes, the degree of complexity and intricacy for these kinds of part designs are limited.

This section is a continuation of vector design, by having the students take simple vectors and then converting them into CNC tool-paths. The class begins with an introduction to CAM software (**Aspire**) and the information needed for a CNC machine to Vcarve graphics. They will be able to examine the speeds, feeds, and cutting parameters associated with CNC tool-paths for a milling machine to follow digitally. By the end of this section, students will successfully operate a CNC milling machine to produce a small storage crate, which will hold future Fab Lab projects in this unit.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

CC. New technologies create new processes

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

3.4.10.C1. Apply the components of the technological design process.

3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.

3.4.D. Abilities for a Technological World

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.

Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.

Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will demonstrate the ability to create and manipulate geometry in 2.5 dimensions.
2. Students will apply the proper tools/material setups to operate a CNC milling machine.
3. Students will create manufactured products to utilize in future sections.

Activities:

- Students create a v-carved graphic into wood
- Students create a pressure-fitted crate design out of plywood

Resources:

- CAM Software (Aspire)
- CNC Milling Machine
- 0.5”- 60° V-Bit & 0.25” - End Mill Bit
- 4’ x 8’ Plywood (0.75” Thick)

Assessment

- Students will be evaluated by instructor/student critiques and rubric.
- Written quiz follows at the end of this section

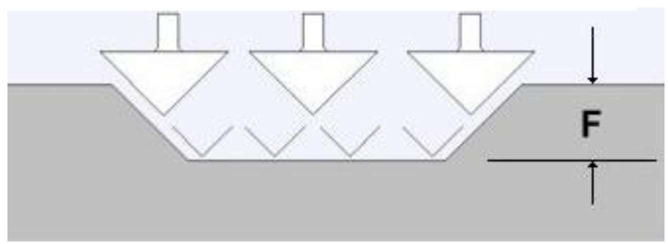
Activity

Section 1.3

V-Carving Tool-Paths

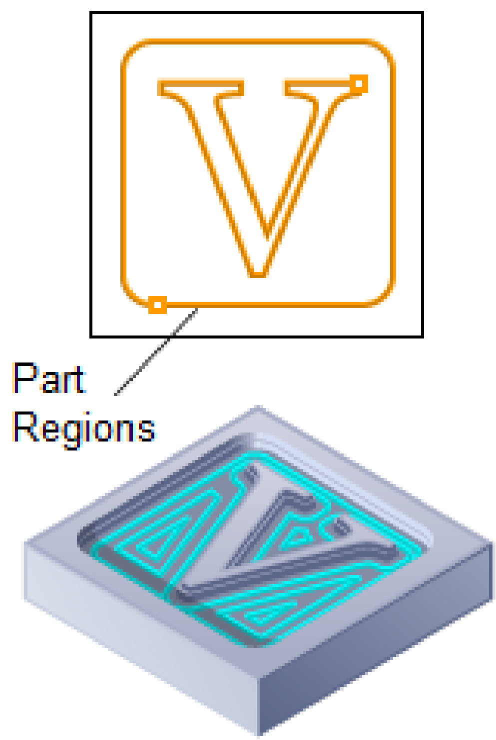
Vcarving is the action of carving with a v-shaped bit to generate designs with varied width. The unique shape of v-bits create carves that are narrow at the deepest part of the carve (created by the tip of the bit) and wider at the top of the material.

Flat Depth (F)
Checking this option limits the depth that the V-bit will machine to, and is used for Flat Bottomed Carving.



Import Vectors
For this activity, we will create all of our vectors in **CorelDRAW** & then import them into **Aspire** using a .SVG file format.

Sometimes you can have what looks to be a closed vector but is in fact an open vector. This may cause problems when setting up Vcarve tool-paths because of how it treats open vectors differently.



Create a V-Carve Tool-Path Operation

Use **CorelDRAW** to design an outlined vector-image & import the .SVG file into **Aspire**

Job Setup: 6”x6”x0.75”

Flat Depth: 0.5”

Toolbit: 0.5” - 60° V-Bit

Activity

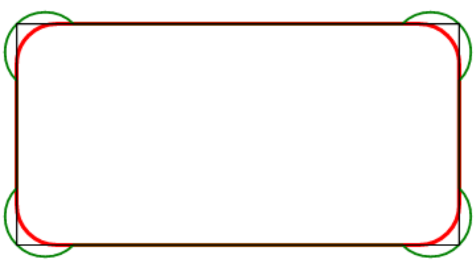
Section 1.3

Profile Cutting Tool-Paths

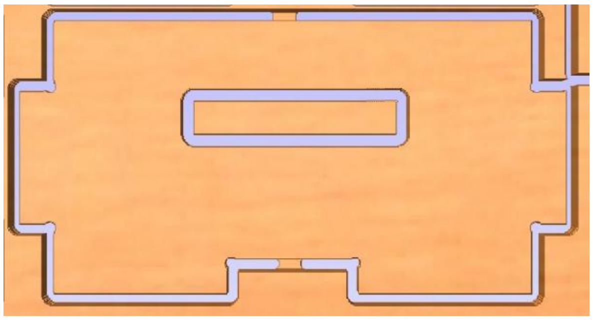
Profile cutting is used to cut around or along a vector using an end mill tool bit. This option provides the flexibility for cutting shapes out with optional Tabs / bridges.

Tool Info	
Diameter	Width or size of cutting tool
Pass Depth	How deeply a tool cuts down into your material on each pass
Stepover	Space between passes of a tool during operations
Spindle Speed	Rate of rotation of the tool
Feed Rate	Speed at which the cutter engages the part
Plunge Rate	Speed at which the cutter is driven down into the material

Create Fillets
A normal fillet is the rounding of a corner of a part design (shown below in red). However, we will be using the "Dog-Bone Fillet" option for all pressure-fit designs (shown below in green). This style of fillet creates a circular cut-out for our milling bit size (Radius-0.125") to fit in all corners.



Edit Tabs
Tabs or what are sometimes called "bridges" are added to vector designs to hold parts in place when cutting them out of the material.



Create a Pressure-Fitted Crate

Use www.makercase.com to design an **open box** design & import the .SVG file into **Aspire**

MAKERCASE	**Dimensions:** 12" wide, 6" high, & 12" deep **Material Thickness:** 0.75" **Edge Joints:** Finger
ASPIRE	**Job Setup:** 38"x14"x0.75" **Handle Size:** 5"x1.25" **Tab Size:** 0.5"x0.125" **Toolbit:** 0.25" – End Mill

Quiz

Section 1.3

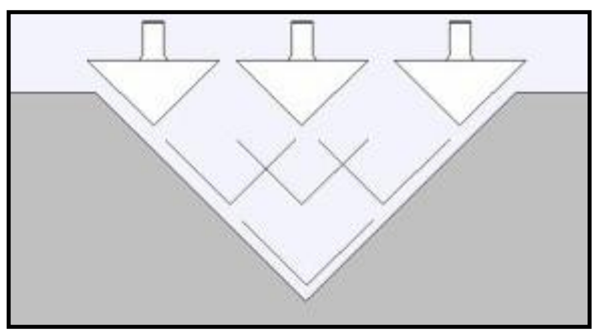
NAME ____ SCORE______________

Match the following CNC milling vocabulary terms

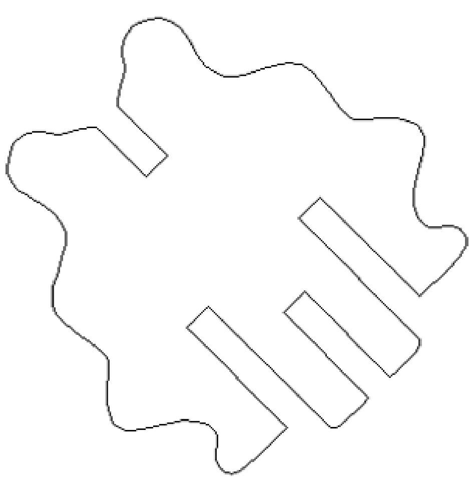
1. _____ **Diameter**
2. _____ **Pass Depth**
3. _____ **Stepover**
4. _____ **Spindle Speed**
5. _____ **Feed Rate**
6. _____ **Plunge Rate**

A. Space between passes of a tool during operations
B. Rate of rotation of the tool
C. Width or size of cutting tool
D. Speed at which the cutter is driven down into the material
E. How deeply a tool cuts down into your material on each pass
F. Speed at which the cutter engages the part

7. The image shown onto the right is an example of what Vcarving style?



8-10. Use the illustration below to draw the fillets needed & what they specifically are.



SECTION 1.4

3D Design

Background Narrative

3D design is the process of using software to create a 3-dimensional object or shape. The created object is called a 3D model and they're used in a variety of industries to help artists or designers shape, communicate, document, analyze, and share their ideas. These 3D models prove to be a great basis for physical devices that are built with 3D printers or CNC machines.

In this section, students are given the opportunity to use 3D design tools to create more complex models in fabrication. This design software is a suite of 3D editing tools created by Autodesk to use more drawing and modeling capabilities. This section also focuses on fused deposition modeling (FDM) by "slicing" design files, which makes students more suited towards creating physical objects by using 3D printing technology.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
- BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
- CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

- H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
- J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

L. The process of engineering design takes into account a number of factors.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

STL 19. Develop an Understanding of and be able to Select and Use Manufacturing Technologies

M. Materials have different qualities and may be classified as natural, synthetic, or mixed.

N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.

PA State Standards:

3.4.C. Technology and Engineering Design

- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World

- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will understand the different features on 3D printing technologies and how it can be easily used to their needs.
2. Students will apply the design process using a 3D design software package.
3. Students will create 3D models and documentation that represent solutions to problems.

Activities:

- Students create a basic keychain design to walk through the (FDM) 3D printing workflow.
- Students accurately replicate a part file by using different 3D modeling features.

Resources:

- 3D Design Software (Fusion 360)
- Slicing Software (CURA)
- 3D Printers (UltiMaker)
- PLA Filament

Assessment

- Students will be evaluated by instructor/student critiques and rubric.
- Written quiz follows at the end of this section

Activity

Section 1.4

3D Printing Workflow

Design (CAD)

AUTODESK® FUSION 360™

Features Learned

Parametric Modeling – The process used to change the shape of model geometry as soon as the dimension value is modified.

Component – A part that is capable of motion and has its own unique origin.

Origin – The surface or axis plane from which your design starts from.

Sketch – This is where the design starts in modeling to create 2D CAD drawings.

Extrude – Pushing or pulling a 2D sketch into a 3D model.

***Export the finished design as a stereolithography file (.STL) to use in CURA**

Slicing (CAM)

Ultimaker Cura

Features Learned

Material – Preloaded profile surfaces to preview the part accurately without printing.

Infill – The percentage of density that defines the amount of plastic used on the inside of the print.

Shell – Represents the outer walls of a 3D print that is adjusted by its thickness.

Supports – Removable structures that are made to bridge any overhangs in a design.

Adhesion – Options that add the ability of 3D printed plastic to “stick” better to the build plate while printing.

Create a Personalized Keychain

Use the different features shown to you in Fusion 360 & CURA in order to 3D print a design.

Keychain (Max) Size: 3” x 3” x 0.25”

Text/Graphic Extrusion: 0.125”

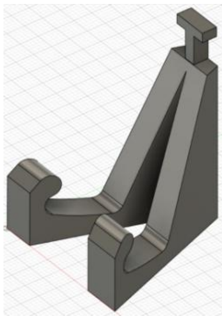
Hole Diameter: 0.5”

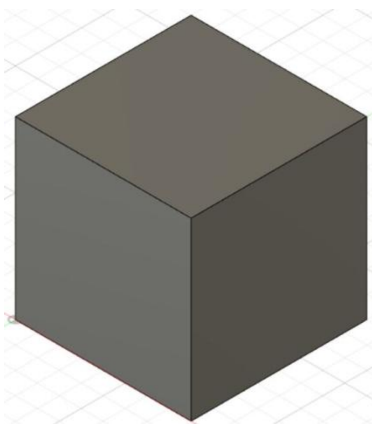
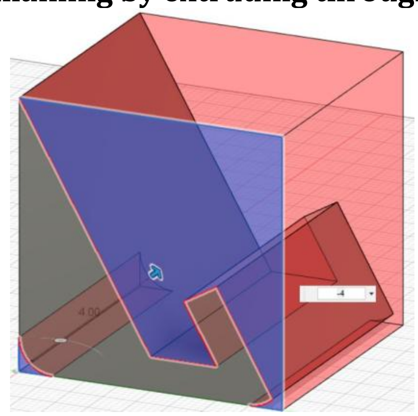
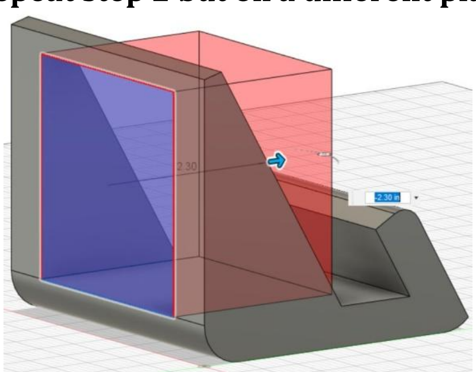
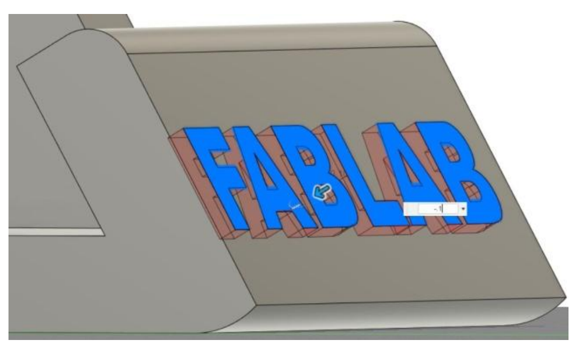
Activity

Section 1.4

3D Design Challenge

Design & Create a Custom Phone Stand



1. Sketch/extrude a 3" Cube 	**2. Choose a side to sketch and remove the remaining by extruding through** 
3. Repeat step 2 but on a different plane 	**4. Modify edges & surfaces** 

5. Save your file and also export a stereolithography file (.STL) to use in CURA

Quiz

Section 1.4

NAME ____ SCORE____________

Fill in the Blanks

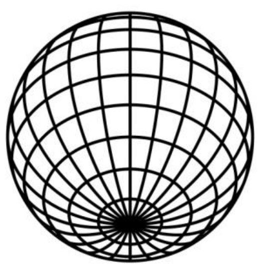
1. __________________________is the process to change the shape of model geometry as soon as the dimension value is modified.

2-3. In Fusion 360, _________________________ are parts that can have motion relationships with other parts and has its own ______________ planes.

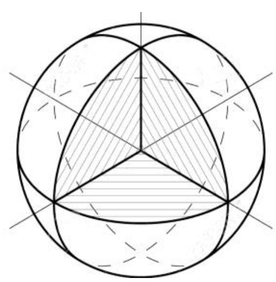
4. CURA is a ______________ software that is used in 3D printing processes for the conversion of a 3D model to specific instructions (G-Code) for the printer.

5. Which of the following spheres is represented as a .STL format?

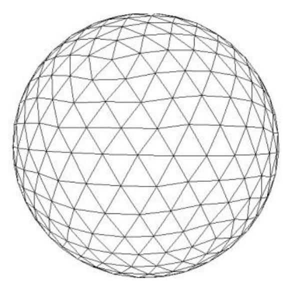
A



B

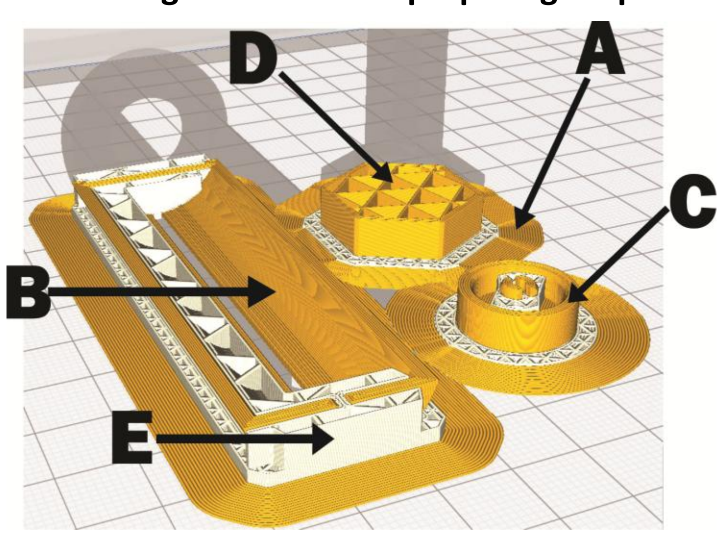


C



Match the following terms to the diagram below for preparing 3D print files.

6. _____ **Infill**
7. _____ **Shell**
8. _____ **Support**
9. _____ **Adhesion**
10. _____ **Material**



SECTION 1.5

Soldering & Electronics

Background Narrative

The Fab Lab has a well equipped electronics workbench that includes soldering stations, circuit components, and hand tools needed for engineering projects. Soldering is used in a wide variety of applications and does not require any particular skill. Examples include electronic components, plumbing, or jewelry making with easy-to-follow instructions found on several websites. The soldering stations in the Fab Lab are designed for electronic components soldering and exposes students to the essentials in electrical engineering.

The field of electrical engineering is the design, building and maintenance of electrical control systems, machinery and equipment. The term electrical engineering often includes electronics engineering. While electrical engineers mainly focus on large-scale production and distribution of electrical power, electronics engineers are concerned with smaller electronic circuits and often also work with computers and other modern technologies.

In this section, students will be a given multiple circuit board kits that they will solder themselves. Students will understand component features like polarity, voltages, ohm resistance, and more. By following the step-by-step instructions, students properly examine the circuits and what makes each component important in its design.

Technology Content Standards:

STL 2. Core Concepts of Technology

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

J. Technological progress promotes the advancement of science and mathematics.

STL 10. Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

J. Technological problems must be researched before they can be solved.

L. Many technological problems require a multidisciplinary approach.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.

3.4.E. The Designed World

3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Electronics.1 - I can follow instructions to build a simple electrical circuit using conductive material basic components and power.

Electronics.2 - I can follow a schematic diagram and create a circuit including a microcontroller with electronic components.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will create a variety of electronic devices by using different soldering techniques.
2. Student will understand the essential properties and features with electronic components.
3. Students will analyze schematics/board layouts in circuit design.

Activities:

- Students are introduced to soldering joints by completing the "LED Torch" circuit.
- Students continue soldering techniques by completing the "Easy-Build Timer" & "Light Activated Switch" circuits.

Resources:

- Kitronik Circuit Board Kits (LED Torch, Easy Build Timer, Light Activated Switch)
- Soldering Iron(s)
- Rosin Core Solder
- Soldering Tip Cleaner
- Helping Hands Soldering Aid
- Safety Glasses

Assessment

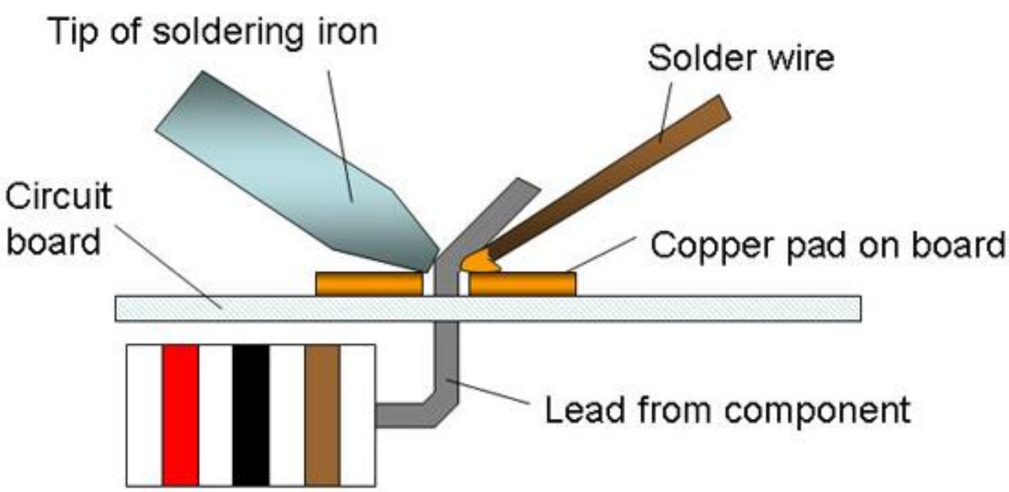
- Students will be evaluated on solder joints by instructor/student critiques, and making sure each completed circuit works properly.

Activity

Section 1.5

Soldering Electronics

Soldering is a joining process used to join different types of metals together by melting solder with a hot iron above 700°F which then cools to create a strong electrical bond.



Instructions: Properly place & solder all components shown below on the PCB provided. ***LED & battery connector have a polarity**

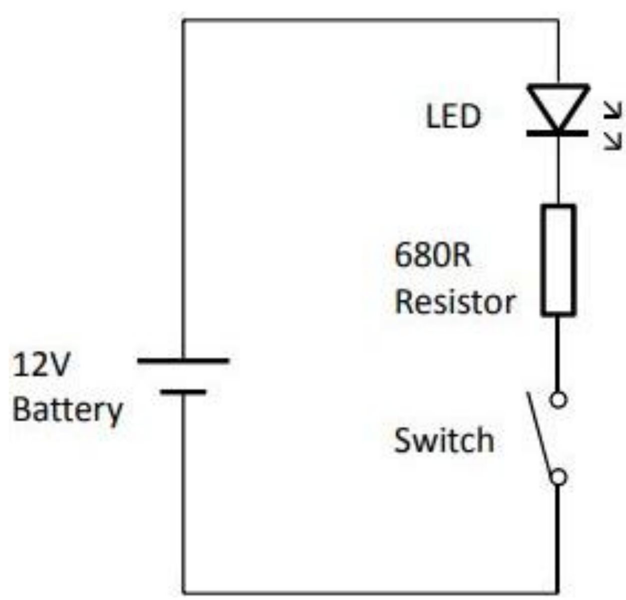
"LED TORCH"

R1

LED1

CONN1

SW1

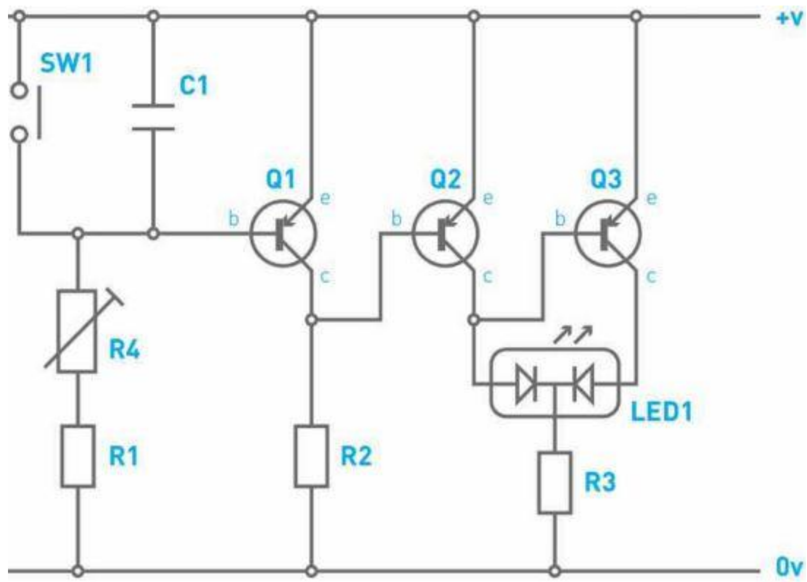


Activity

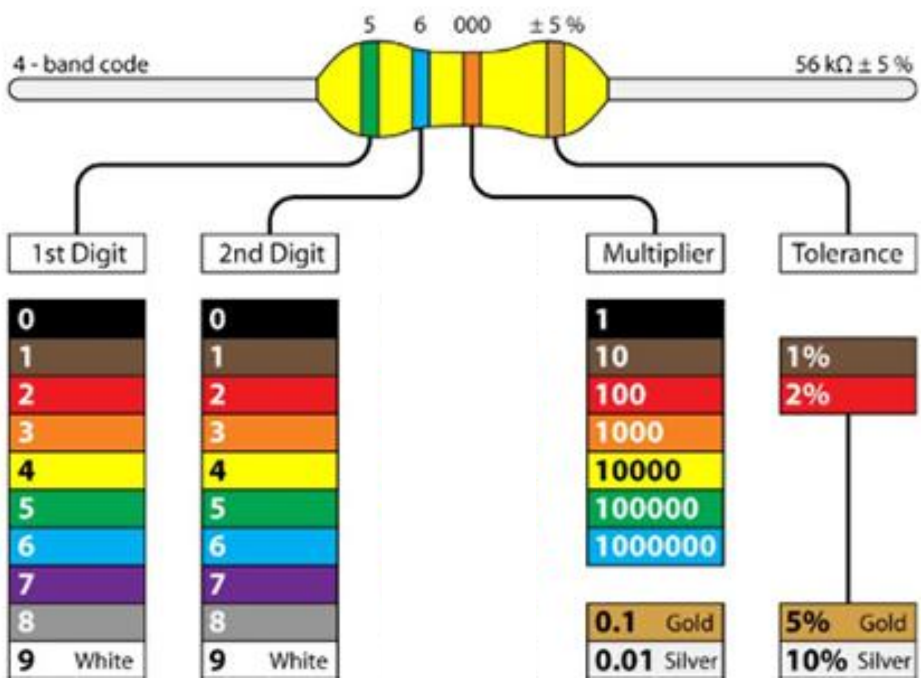
Section 1.5

Soldering Electronics (Continued)

"Easy Build Timer"



- **R1 & R2** - 10kΩ Resistors - Brown, Black, Orange
- **R3** - 47Ω Resistor - Yellow, Purple, Black
- **R4** - Potentiometer (Variable Resistor)
- **Q1, Q2, & Q3** - NPN Transistors
- **C1** - Electrolytic Capacitor
- **LED1** - Red & Green LEDs Built Into One
- **SW1** - Tactile Button Switch
- **Power** - Battery Holder (x2 AA)



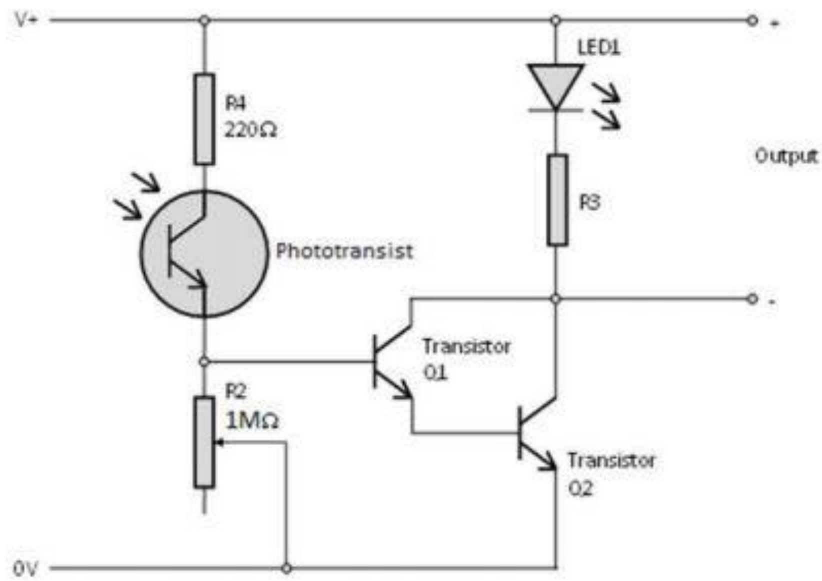
Activity

Section 1.5

Soldering Electronics (Continued)

"Light Activated Switch"

- **R1** - Potentiometer (Variable Resistor)
- **R2** - Phototransistor
- **R3** -220Ω Resistor - Red, Red, Brown
- **Q1 & Q2** - NPN Transistors
- **Power** - Battery Holder (x2 AA)
- **Output** - Motor, LED, Buzzer, or External Circuit

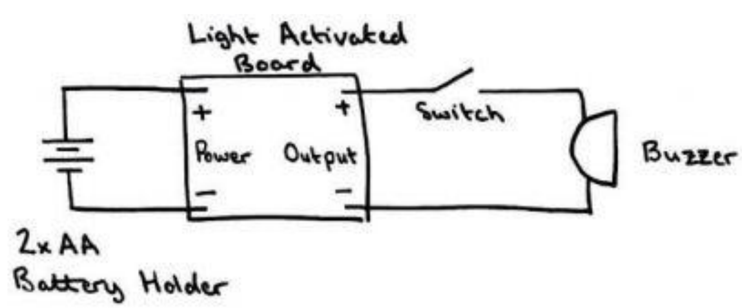


*Testing the PCB

- ➢ **If you want the circuit to trip at a lower light level, then adjust R1 forward in the clockwise direction.**
- ➢ **If you want the circuit to trip at a brighter light level, then adjust R1 back in the counter-clockwise direction.**

Drawer Alarm

As shown on the right, by simply adding a battery holder, switch, and buzzer to a PCB, you can create an alarm that sounds when a dark drawer is opened and the PCB is exposed to light. The switch will allow the alarm to be activated or deactivated.



SECTION 1.6

Project Development

Background Narrative

The maker movement, as we know, is a term for independent inventors and designers. Makers use open-source learning, contemporary design, and powerful personal technology to imagine, create, and mass-produce a wide range of products. It has the potential of giving anyone the tools they need to become makers and move them from passive users to active creators.

Trinity Fab Lab students will use what they've learned in technology and design related applications for individual innovation projects. These projects allow the students to further pursue their own goals with problem solving skills in engineering design. They will have the opportunity to choose from any of the multiple technologies provided in the lab to create these final projects.

To start this section, students will look back to the previous lessons learned in using their design skills to fabricate a circuit enclosure. By choosing one of the electronic kits soldered in the previous section, the students will use precise measurements to accurately accommodate any features on the circuit. The final lesson of this unit will have students going through the engineering design process to sketch, design, evaluate, and problem solve a unique project, to utilize multiple skills learned and to promote creativity.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

J. The nature and development of technological knowledge and processes are functions of the setting.

L. Inventions and innovations are the results of specific, goal-directed research.

STL 2. Core Concepts of Technology

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

L. The process of engineering design takes into account a number of factors.

STL 10. Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.
J. Technological problems must be researched before they can be solved.
L. Many technological problems require a multidisciplinary approach.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.
N. Identify criteria and constraints and determine how these will affect the design process.
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
Q. Develop and produce a product or system using a design process.
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.
N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
O. Operate systems so that they function in the way they were designed.
P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

STL 19. Develop an Understanding of and be able to Select and Use Manufacturing Technologies

M. Materials have different qualities and may be classified as natural, synthetic, or mixed.
N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.

PA State Standards:

3.4.C. Technology and Engineering Design

- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World

- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.

Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will demonstrate the ability to create and accurately model a project to produce a fitted design.
2. Students will apply all of the tools/skills learned in the Fab Lab.
3. Students will create and document an innovation project to develop their own creative skills.

Activities:

- Students create a small circuit enclosure to represent their understandings of accurately modeling a fabricated design.
- Students design and develop a unique prototype/model that synthesizes the knowledge gained and tools/machines used within the Fab Lab.

Resources:

- **Software:** CorelDRAW, Aspire, Fusion 360, CURA
- **Machines:** Vinyl Cutter(s), Laser Cutter(s), CNC Milling Machines(s), 3D Printer(s)
- **Consumables:** Vinyl, Plywood, Acrylic, 3D Printing Filament

Assessment

Students will be evaluated by instructor/student critiques and rubric.

Activity

Section 1.6

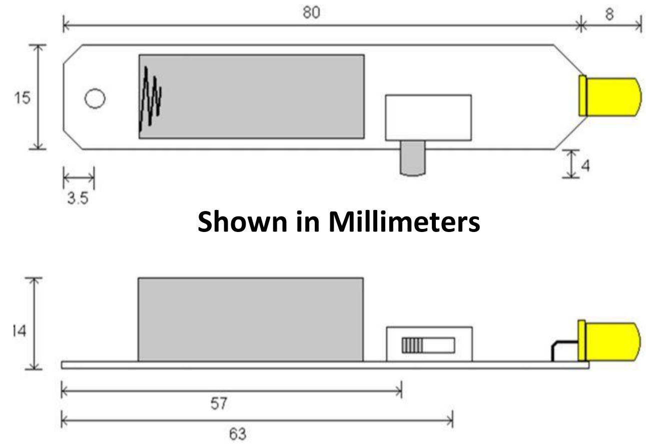
Enclosure Design Challenge

Instructions: Choose one of the following circuit schematics to accurately design and fabricate an enclosure that accommodates all of its features

"LED Torch"

Considerations:

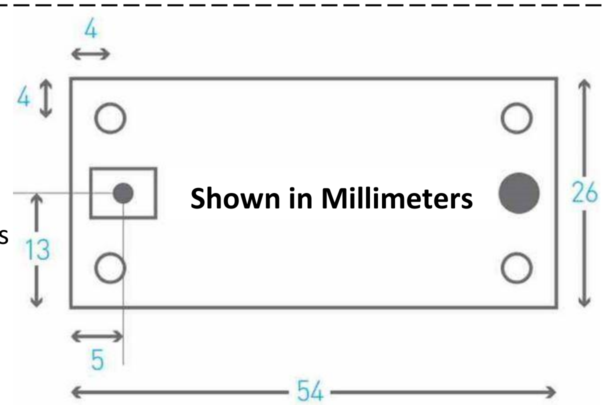
- The size of the PCB
- Where the LED is mounted
- Where the on/off switch is mounted
- Optional 3mm mounting hole on the back



"Easy Build Timer"

Considerations:

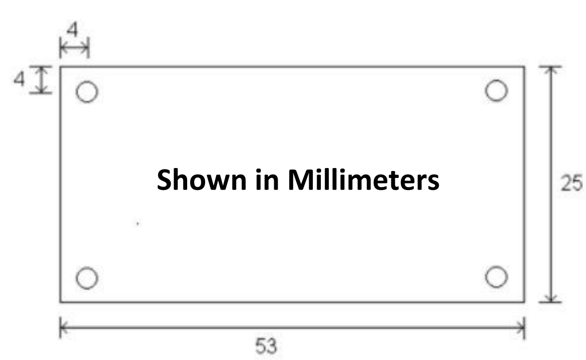
- The size of the PCB & 3mm mounting hole locations
- Where the switch & LED are located on the PCB
- Access to the potentiometer for adjustments
- Access to the batteries to allow them to be changed



"Light Activated Switch"

Considerations:

- The size of the PCB & 3mm mounting hole locations
- Where the phototransistor is mounted
- Access to the potentiometer for adjustments
- Access to the batteries to allow them to be changed
- Access to any output device used (buzzer, motor, etc)



Activity

Section 1.6

NAME ______________________________________ DATE_____________

Innovative Design Challenge

Instructions: Go through the engineering design process to define, create, prototype, & evaluate an innovative product that utilizes the most out of our Fab Lab.

Investigation/Research – Using a number of different search methods, find examples of artistic or innovative designs that empowers the way you or other people think about their day-to-day lives. Use additional pages if required.

Developing a Specification – Using your research for the product, identify the key requirements for the product & explain why each of these is important.

Requirement:	**Reason:**

Activity

Section 1.6

NAME ______________________________________ **DATE**_____________

Innovative Design Challenge (Continued)

Design – Develop your ideas to produce a design that meets the requirements listed in the specification.

Evaluation – Check that your design meets all of the points listed in your specification.

Good aspects of the design:	**Areas that can be improved:**

Improvements:

Unit 2 Overview

Advanced Digital Fabrication

Description

This course is a continuation of what the students learned in Digital Fabrication, teaching more advanced skills related to design and fabrication. Students will develop the ability to select and correctly use more complex processes to answer questions, understand explanations, and solve problems presented in real life situations. Classroom equipment includes a computer design lab with up-to-date 2D/3D software tools; a metals lab which utilizes a foundry, waterjet cutters, and CNC machines; and a complete fab lab that includes laser cutters, CNC milling machines, soldering workbenches, vacuum formers, plastic injection machines, and 3D printers.

Unit Goals:

Upon the completion of this unit, students will learn:

- Further usage of computer design and development techniques to create a product
- Superior material types by using different fabrication processes
- To safely select and use a wider variety of fabrication tools and machines
- More advanced drafting and design techniques
- The use of more complex manufacturing/CNC programming software
- Circuit designs and PCB fabrication
- To select and apply more resources to conduct a successful and innovative design

Weekly Planner:

Week 1	– Orientation of new groups – Students review & practice the engineering design process – Re-introduce vector design using CorelDRAW software

Week 2	– Demonstrate waterjet cutter operations – Students go through a waterjet cutter's workflow
Week 3	– Demonstrate fiber laser operations – Students go through a fiber laser's workflow
Week 4	– Activity: Metal Design Challenge – Finish work on waterjet & fiber laser applications – Quiz: Metal Fabrication
Week 5	– Re-introduce 3D modeling using Fusion 360 software – Activity: 3D Sculpting Challenge
Week 6	– Introduce 3D printing using Stereolithography (SLA) – Introduce 3D slicing using PreForm software – Activity: 3D Printing (SLA)
Week 7	– Re-introduce CNC tool-pathing using Aspire software – Introduce Aspire 3D modeling software features – Activity: 3D Milling
Week 8	– Demonstrate CNC machine (Shopbot) operations – Continue work on 3D milling applications
Week 9	– Demonstrate 3D scanner operations – Activity: 3D Scanning
Week 10	– Finish work on rotary design challenge – Quiz: 3D Modeling

Week 11	– Re-introduce 'Design' features on Fusion 360 – Activity: Computer-Aided Manufacturing
Week 12	– Demonstrate Tormach CNC milling machine – Activity: CNC Programming/Setup
Week 13	– Activity: Bottle Opener Design Challenge
Week 14	– Students continue work on CNC machining projects
Week 15	– Activity: Toothbrush Holder Design Challenge
Week 16	– Students finish all CNC machining projects – Quiz: CNC Machining
Week 17	– Introduce vacuum forming procedures – Demonstrate vacuum former operations
Week 18	– Students create 3D models to vacuum form – Students mix together molding material – Pouring/curing 3D model
Week 19	– Introduce sand casting procedures – Activity: Wooden Pattern Design
Week 20	– Finish work on fabricating 3D patterns – Activity: Aluminum Sand Casting
Week 21	– Introduce plastic injection molding procedures – Demonstrate plastic injection machine operations

Week 22	– Activity: Plastic Injection Molding
Week 23	– Continue designing/CNC milling aluminum mold
Week 24	– Finish work on plastic injection molding – Quiz: Molding & Casting
Week 25	– Introduce electronic design using Kicad software
Week 26	– Activity: PCB Design Challenge
Week 27	– Continue work on Kicad applications – Activity: Fab Modules
Week 28	– Demonstrate desktop CNC machine operations – Activity: Mp3 Speaker Soldering Guide
Week 29	– Students finish designing Mp3 amplifier circuit
Week 30	– Activity: Mp3 Speaker Design Challenge
Week 31	– Continue work on MP3 speaker enclosures
Week 32	– Students finalize & submit their MP3 speaker enclosures
Week 33	– Activity: Advanced Innovative Design Challenge

Week 34	– Students document, design, & prototype their advanced innovative design project
Week 35	– Students continue to tweak & improve their prototypes for their advanced innovative design project
Week 36	– Design & fabrication time needed to submit the advanced innovative design project

SECTION 2.1

Metal Fabrication

Background Narrative

After completing the previous course, students have a good understanding of how fabrication labs use 2D/3D digital files and design software to create objects. Its scope of different processes, workflows, and materials can further be explored as students create more kinds of projects. By using the engineering design process, students can now develop refined models by using advanced CNC machines.

This section serves as a review to the design processes learned in the previous course. This covers the general overview of digital fabrication, while also introducing metal as a new substrate to work with. By exercising these familiar workflows, designing projects from metal creates possibilities for new fabrication tools and machines to explore.

The first section of this course starts by re-introducing 2D design software to create a product. The sketching of a model is the essential starting point for manufacturing and analysis. Students will then study certain properties in metal materials, and how they can utilize the Fab Lab to cut, bend, or mark it for future projects. By the end of this section, students will review the prototyping workflows from the previous Digital Fabrication course, followed by trying new machine operations to manipulate metals.

ITEEA Standards:

STL 1. Characteristics and Scope of Technology

J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

L. The process of engineering design takes into account a number of factors.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

STL 19. Develop an Understanding of and be able to Select and Use Manufacturing Technologies

M. Materials have different qualities and may be classified as natural, synthetic, or mixed.
N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.

PA State Standards:

3.4.C. Technology and Engineering Design
- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World
- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.
- 3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World
- 3.4.10.E6. Illustrate how manufacturing systems may be classified into types such as customized production, batch production, and continuous production.
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will understand advanced CNC processes to fabricate metals.
2. Students will apply the engineering design process to create a mock product.
3. Students will create models and documentation that represent solutions to design problems.

Activities:

- Students create a simple tape dispenser and dog tag design to walk through the metal fabrication workflows.
- Students follow the engineering design process to plan, create, evaluate and improve a metal key organizer.

Resources:

- Vectoring Software (CorelDRAW)
- Waterjet Cutter (Wazer)
- Laser Cutter (Fiber Power Source)
- Materials (1/8" & 1/16" thick Aluminum, Wood, & Acrylic, 3/4" wide Tape Spools/Blades, 3mm (M3) Bolts/Nuts)

Assessment

- Students will be evaluated by instructor and rubric.
- Written quiz follows at the end of this section.

Activity

Section 2.1

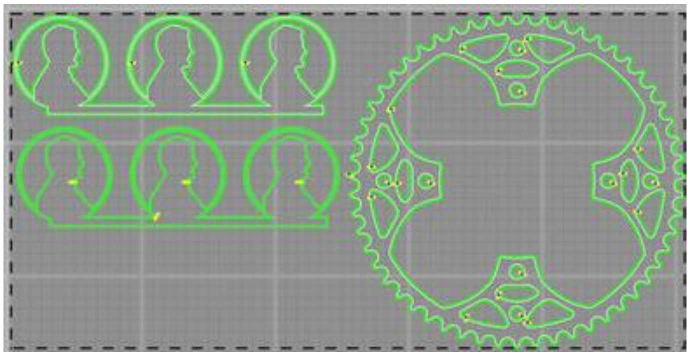
Waterjet Cutting

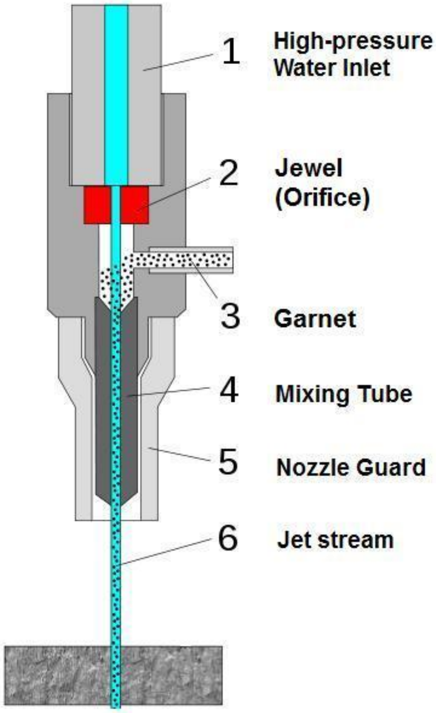
Waterjet cutting uses an ultra-high pressure stream of water to carry an abrasive grit. The abrasive does the cutting through a mechanical sawing action, leaving a smooth, precision cut surface. Waterjets are able to cut more dense materials including a variety of metals, stones, and glass materials.

Workflows

CAD Software (CorelDRAW) – Create the 2D vectors needed to be cut and export the finished design as a scalable vector graphic file (.SVG)

CAM Software (Wam) – Use the provided program by Wazer to import the .SVG file and send all waterjet cutting operations to the machine (Wazer). https://wam.wazer.com/





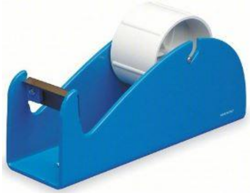
Create a Tape Dispenser

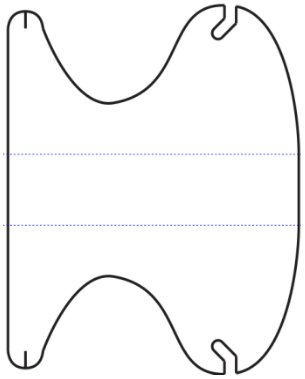
Use the features shown to you in CorelDRAW & Wam in order to cut a custom aluminum design. To create the tape dispenser, use a vice to fold the base to 90 degrees for both sides.

Aluminum Used: 4” x 4” x 1/16”

Base Size: 0.75” x 3.25”

Shaft on Spool: 0.125” Diameter





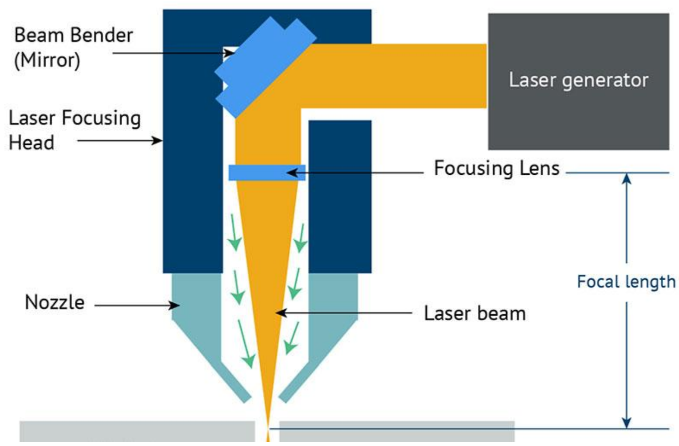
Activity

Section 2.1

Metal Marking

Fiber Laser

A fiber laser engraver produces a laser beam by silica glass mixed with a rare-earth element, which makes them considered as solid-state lasers. Compared to CO_2 lasers, fiber lasers produce an extremely small focal diameter that uses shorter wavelengths. This makes fiber lasers ideal for different metal processing applications.



Etched markings remove material from the metal. Essentially, it is a shallow engraving that produces a high contrast mark in the metal.

Polished markings are laser effects where the laser beam heats the surface of a material and as it cools, the material takes on a different finish. Most common on matte-finish metal, this technique creates marks that can look almost holographic.

Annealed markings are similar to the polishing process. The laser is used to heat metal to near melting points, which induces a color change to the top layer of material. Depending on the metal type, annealing often gives a dark look.

Engrave a Dog Tag

Design your own graphic/branding to mark onto a metal dog tag

Activity

Section 2.1

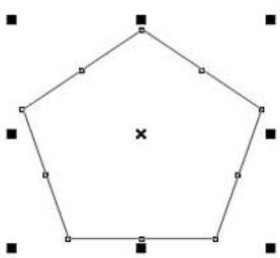
Metal Design Challenge

Design & Create a Custom Key Organizer

1. Sketch Ideas:

Material Info	
Metal Thickness	0.125”
Bolt/Nut Size	3mm (3M)

2. Design a Vector Layout:



3. Laser Cut Prototype (Acrylic or Wood):

4. Waterjet Cut Final Metal Design:

5. Fiber Mark Graphics:

Quiz

Section 2.1

NAME ____ SCORE_____________

1. What is the difference between "pure" and "abrasive" waterjets?

Fill in the Blanks

2. A ultra-high pressure system in a waterjet cutter consists of a cutting head, plumbing, and a ____________________________.

3-4. The ___________________ is used to convert high pressure water into velocity, creating a stream which is then introduced to _________________ , giving it even greater cutting power.

Circle the descriptors that apply to Fiber lasers when compared to CO2 lasers.

5. Power Source: Gas-State OR Solid-State

6. Wavelength: Shorter OR Longer

7. Materials Used: Metallic OR Organic

Name the following metal marking strategies below.

8. _________________ A smooth, darker finish made by heating metal to near melting points, which induces a color change to the top layer of material.

9. __________________ Shallow engraving that produces a high contrast mark in the metal.

10. __________________ A smooth, white finish used on matte-finish metal. Its effects are caused by heating the surface of a material and letting it cool.

SECTION 2.2

3D Modeling

Background Narrative

3D modeling is a technique in computer graphics for producing a 3D digital representation of any object or surface. An artist uses special software to manipulate points in virtual space (called vertices) to form a mesh: a collection of vertices that form an object. These kinds of 3D models can be applied to a wide variety of fabrication techniques involving both additive and subtractive manufacturing.

The variety of software used in past sections adds 3D design tools which enable students to create 3D relief models, and machine them with 3D fabrication strategies. The software's unique 3D modeling tools make it easy for students to create their own 3D parts from scratch, with the ability to import and edit external 3D data.

In this section, students are given the opportunity to use 3D modeling tools to create more complex designs in fabrication. The different rendering software includes a suite of 3D editing tools to use more drawing and modeling capabilities. This section will also introduce new fabrication tools including 4th axis rotary indexers and stereolithographic (SLA) 3D printers.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
- BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
- CC. New technologies create new processes.

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

- H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
- J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

- I. Design problems are seldom presented in a clearly defined form.
- J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
- K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

- I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.
- J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
- L. The process of engineering design takes into account a number of factors.

STL 11. Develop the Abilities to Apply the Design Process

- M. Identify the design problem to solve and decide whether or not to address it.
- N. Identify criteria and constraints and determine how these will affect the design process.
- O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
- P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems.

- N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
- O. Operate systems so that they function in the way they were designed.
- P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design
- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World
- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.
- 3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World
- 3.4.10.E6. Illustrate how manufacturing systems may be classified into types such as customized production, batch production, and continuous production.
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.

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Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
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Performance Objectives:

1. Students will understand the different features on 3D design/modeling software and how it can be easily used to their needs.
2. Students will apply 3D design for multiple fabrication methods.
3. Students will create 3D models with documentation that represent solutions to problems.

Activities:

- Students model and edit a 3D form to walk through the (SLA) 3D printing workflow.
- Students accurately model 3D bitmaps to use for CNC milling operations.
- Students generate a 3D scan and create a 3D model using a 4th axis rotary motor.

Resources:

- 3D Design CAD & CAM Software (Fusion 360 & Aspire)
- SLA Slicing Software (PreForm)
- SLA 3D Printer with Washing & Curing Stations (Form 3+)
- 3D Scanner(s) with Software (3D Sense)
- CNC Milling Machine with 6" Rotary Indexer (Shopbot)
- 0.25" - Square End Mill & Ball Nose End Mill Bits
- Materials (SLA Resin, 6"x 6" x 1" AND 6"x 4" x 4" Wood or Foam)

Assessment

- Students will be evaluated by instructor/student critiques and rubric.
- Written quiz follows at the end of this section.

Activity

Section 2.2

3D Sculpting Challenge

Create a Freeform Model

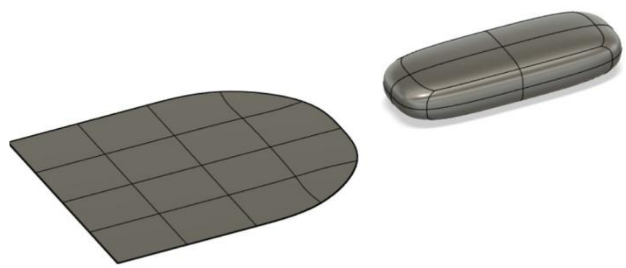
Freeform modeling empowers you to define and capture geometry without spending time worrying about features, constraints, and original design intent. Use the following steps below as a general workflow to design a freeform model.

Step 1

Select the freeform shape that best represents the desired geometry

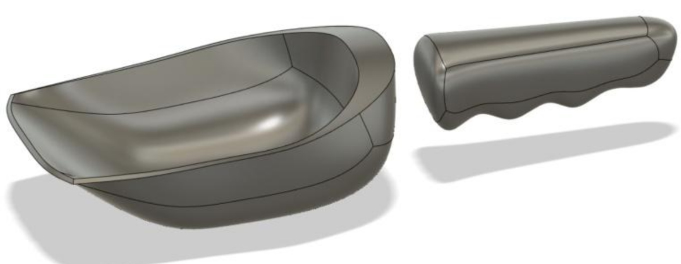
Features Learned:

☐Faces, Edges, & Vertices
☐T-Spline Bodies
☐Orientation Tools



Step 2

Use the freeform edit tools to change the shape



Features Learned:

☐Edit Form ☐Symmetry
☐Subdivide ☐Thicken

Step 3

If desired, create extra freeform shapes, edit them, and use different methods depending on their geometry to connect multiple freeform bodies

Features Learned:

☐Align ☐Merge Edge
☐Bridge ☐Weld Vertices

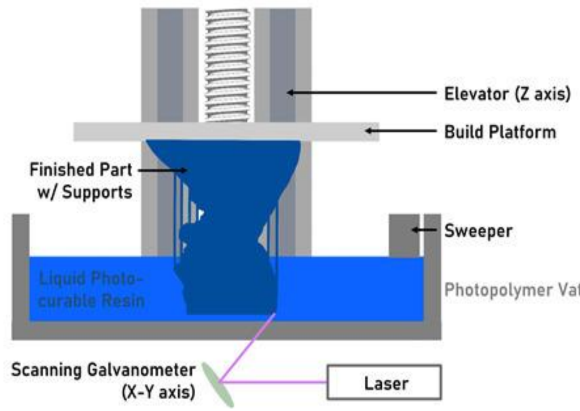
Activity

Section 2.2

3D Printing

Stereolithography (SLA)

SLA 3D printers use a laser to cure liquid resin into hardened plastic in a process called photo-polymerization. Once printed, the designed parts do not come out of the SLA printer 100% finished. The following post-processing steps are required:



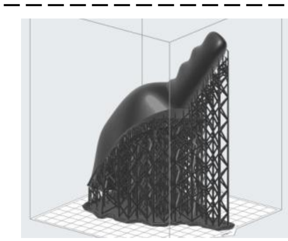
Washing - Removes sticky, excess resin from the surface by using isopropyl alcohol (IPA).

Post-Curing - Exposes the print to light and heat to help solidify its material properties in the photo-polymerization process.

formlabs **Stereolithography (SLA)**	VS. UltiMaker **Fused Deposition Modeling (FDM)**
Slicing Software: Formlabs PreForm **Materials:** Varieties of resin (thermosetting plastics). Standard, engineering (ABS-like, PP-like, flexible, heat-resistant), castable, dental, & medical (biocompatible) **Pros:** High accuracy, smooth surface finish, & range of functional applications **Applications:** Functional prototyping, patterns, molds, dental, model making, & jewelry casting	**Slicing Software:** UltiMaker CURA **Materials:** Standard thermoplastics, such as PLA, ABS, & their various blends **Pros:** Fast prints, low cost machines/materials, & less post-processing **Applications:** Low-cost rapid prototyping & basic proof-of-concept models

3D Print Your Freeform Model

Export the finished 3D model (.STL File) from the previous activity to set up in the PreForm software. Select to correct materials used & oriente the model appropriately for print.

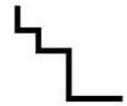


Activity

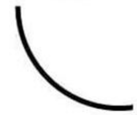
Section 2.2

3D Milling

Roughing & Finishing Tool-Paths

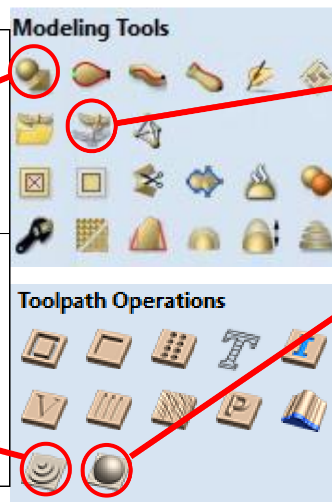


2.5D milling refers to the CNC's ability to move the cutter along X and Y in a synchronized manner with the Z axis moving only a predetermined amount during each pass.



3D milling refers to the CNC's ability to move X, Y and Z all at the same time in a synchronized fashion to create contoured bottoms, sides, and tops of objects.

Create Shape from Vector
- Sculpts a 3D component using a 2D outline



Create Component from Bitmap
- Uses the color contrasts in a bitmap to convert into different levels of elevation

Roughing Tool-Path
- Carving 3D parts to clear away excess material when the part is too deep for the finishing tool to cut in a single pass

Finishing Tool-Path
- Used to machine the final pass on the finished 3D part & typically used with a ball-nose end mill of various sizes for different levels of detail

3D Bitmap Challenge

Aspire

Create a 3D Model from a Bitmap

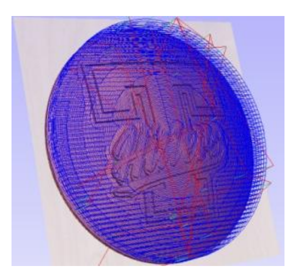
ShopBot

Use the modeling features shown to you in Aspire software in order to shape a 2D Bitmap into a 3D carving. The piece of wood material for the job setup will be 6" x 6" x 1".

1. **Import completed bitmap & outline on separate layers**

2. **Create 3D shapes from outline / 3D skin from bitmap**

3. **Generate "roughing & finishing" tool-paths**



Activity

Section 2.2

3D Scanning

3D scanners work on the principle of laser triangulation. A laser beam is projected at a known angle onto a target to be measured; a camera at a known offset from the laser views the projected image.

The "3D Sense" software is intuitive and allows gaps to be filled, along with outputting the completed mesh. It keeps most of the texture and once the mesh is exported, you are ready to render it further through the Fusion 360 software.

Rotary Design Challenge

Create a Wooden Bust

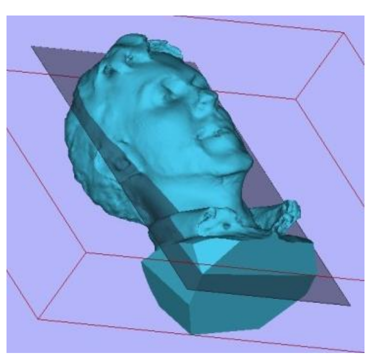
Use the 3D modeling features shown to you in 3D Sense & Aspire software in order to 3D scan/3D carve a model of you or another person's head. You will use the exported 3D file to program a CNC milling machine with a Rotary Indexer.

Create a "Rotary" job setup on Aspire

Cylinder Length: 6"
Cylinder Diameter: 4"
Z Origin On: Cylinder Axis
XY Drawing Origin: Bottom Left
Cylinder Orientation Along: Y Axis

1. **Import completed .STL file**

2. **Orientate the 3D model**



3. **Generate "roughing & finishing" tool-paths**

Quiz

Section 2.2

NAME ____ **SCORE**____________

Match the following 3D freeform terms

1. _____ **T-Spline**
2. _____ **Subdivide**
3. _____ **Symmetry**
4. _____ **Bridge**

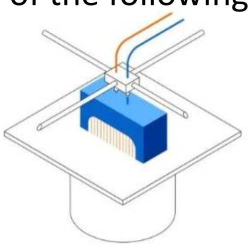
A. Enables you to constrain two sets of entities with respect to an axis line

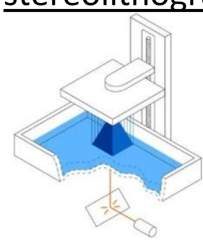
B. Allows you to connect two bodies by adding intermediate faces

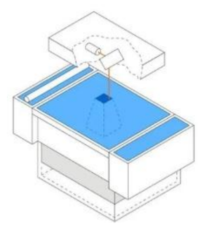
C. Mathematical model for allowing you to sculpt shapes for conceptual designs

D. Takes one selected face and turns it into multiple smaller faces

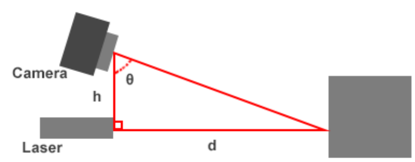
5. Which of the following describes a stereolithography 3D printer?

A. 

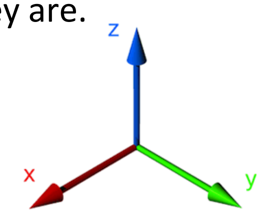
B. 

C. 

6. Describe the principle of laser triangulation from the diagram below.



7-8. Label the 4th and 5th axis on the right and describe what they are.



9-10. Describe in detail what the differences are between 2.5D and 3D milling.

SECTION 2.3

CNC Machining

Background Narrative

Computer numerical control (CNC) machining consists of highly detailed cuts out of metal pieces for industrial hardware products. These industrial components require precise engineering and timely turnaround. To adhere to these standards, many sectors use CNC machines to create the custom parts they need. These industries require reliable, well-made parts with a high level of precision. Common CNC industrial applications include parts for the aerospace, electronics, and medical industries.

In this section, the students will prepare multiple designs on a CNC milling machine. Students start by learning extensive features in computer-aided manufacturing (CAM software). Once the appropriate tool-paths/g-code are generated, it is up to the students to learn how to setup proper work offsets in order to fully operate a CNC milling machine used in the manufacturing industry.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

CC. New technologies create new processes

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

STL 11. Develop the Abilities to Apply the Design Process

M. Identify the design problem to solve and decide whether or not to address it.

N. Identify criteria and constraints and determine how these will affect the design process.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

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3.4.10.C1. Apply the components of the technological design process.

3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.

3.4.D. Abilities for a Technological World

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

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Performance Objectives:

1. Students will apply the ability to use professional CAM software to make parts.
2. Students will demonstrate the proper setups and offsets to operate a CNC milling machine.
3. Students will create accurate metal parts from a CNC milling machine.

Activities:

- Students accurately design, setup, and perform CNC operations to create a drink coaster, bottle opener, and toothbrush holder project.

Resources:

- CAD & CAM Software (Fusion 360)
- CNC Milling Machine (Tormach) With ATC, ETS & Passive Probe
- Cutting Tools: Carbide End Mills, Drills, Chamfer Mills, & Spot Drills
- Aluminum: Flats (1"x 4" & 0.75"x 1.75") & Rods (0.5", 2", & 3.5" Diameter)
- Taps & Dies: 1/2" - 20 NF

Assessment

- Students will be evaluated by instructor/student critiques and rubric.
- Written quiz follows at the end of this section

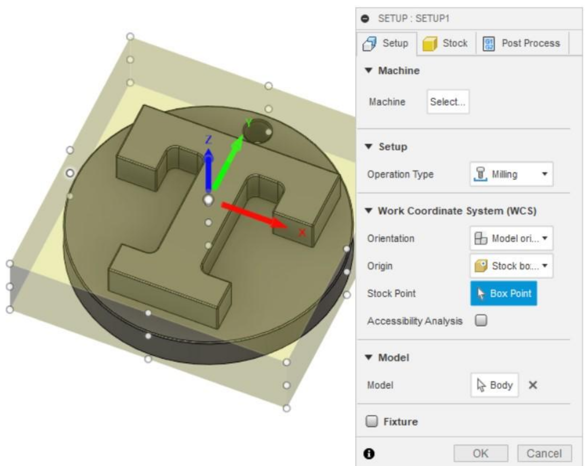
Activity
Section 2.3

Computer-Aided Manufacturing
Using Fusion 360

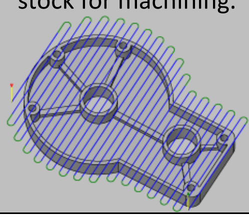
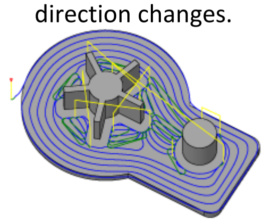
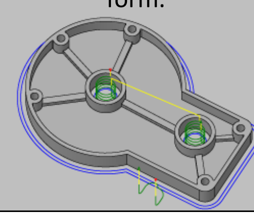
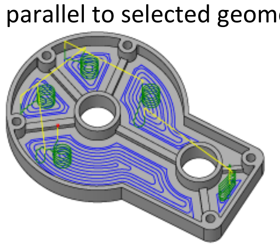
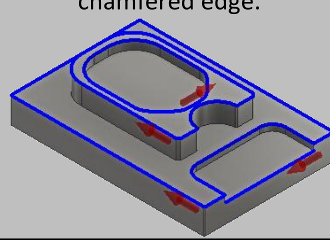
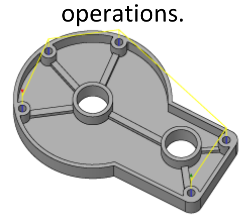
***Start by opening the provided 'T Medallion.step' CAD model & importing the 'Trinity HS' tool library.**

Creating a Setup: The setup feature is how you input where everything is located. This includes what you're machining, the x/y/z direction/location, and the defined stock dimensions.

- Setup Tab - Setting the job type and CAD model's work coordinate system (WSC)
- Stock Tab - Sizing and positioning of the stock in relation to the CAD model
- Post Process Tab - Programming inputs to note in final g-code file



Creating a Tool-Path: Most of the tool-paths for milling/drilling in Fusion 360 consist of five separate setup tabs: Tool, Geometry, Heights, Passes, & Linking. Below are some of the more common tool-path operations that we will be using throughout the course.

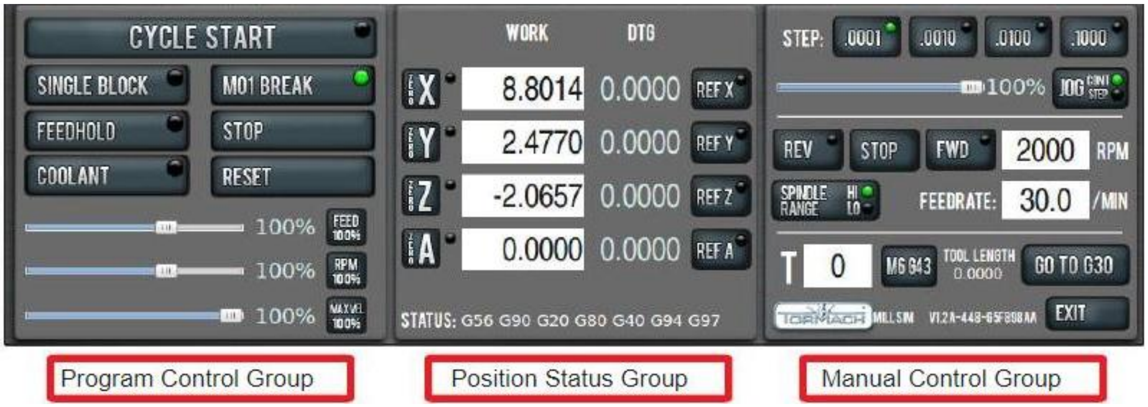
Face	Adaptive Clearing	Contour
Removes all material from top of stock to top of model to prepare raw stock for machining.	Roughing operation that uses a more optimized tool-path that avoids abrupt direction changes.	Creates a tool-path based on an outline that represents a shape or form.
		
Pocket	**Chamfer**	**Drill**
Roughing operation that uses tool-paths parallel to selected geometry.	Machines along contours creating a chamfered edge.	Provides access to a wide range of drilling, tapping, & hole making operations.
		

Activity

Section 2.3

<u>CNC Programming/Setup</u>

Using PathPilot



Referencing the Mill

The axes should be referenced before operating the mill to establish soft limits to protect the mill from over travel and to give meaning to work offset values.

Work Coordinate System (WCS)

Also known as the work offset, allows the operator to think in terms of X/Y/Z coordinates with respect to the part, instead of the mill position. Using Tormach's passive probe can touch off the location of your part (often the top face, center of your part or the top left-hand rear corner) and sets the digital readouts (DRO) to zero.

Passive Probe

Tool Length Offsets (TLO)

Also known as the tool offset, allows the operator to use tools of different lengths. Using Tormach's electronic tool setter (ETS) can touch off tools automatically to find their offset lengths.

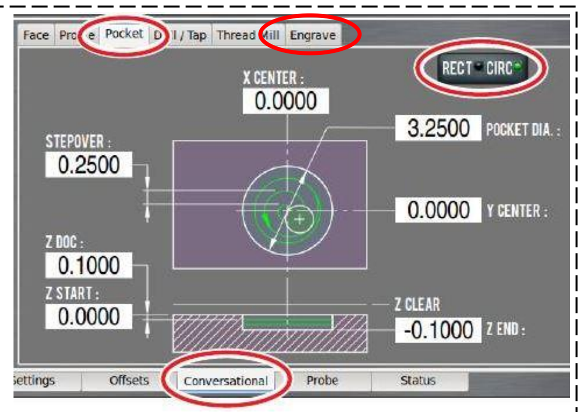
Electronic Tool Setter (ETS)

Create a Metal Coaster

Use conversational programming by creating both a pocket tool-path & engrave tool-path.

<u>Circular Pocket</u>
Tool: 0.375" End Mill
Size: 3" Diameter
Cut Depth: 0.05"

<u>Engraved "T"</u>
Tool: 0.125" End Mill
Size: 2.5" Tall
Cut Depth: 0.05"

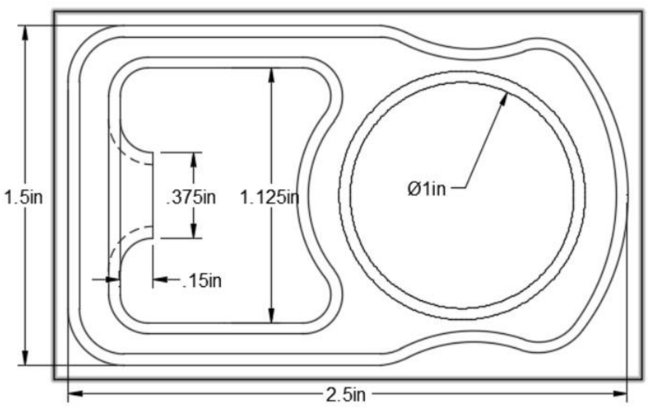


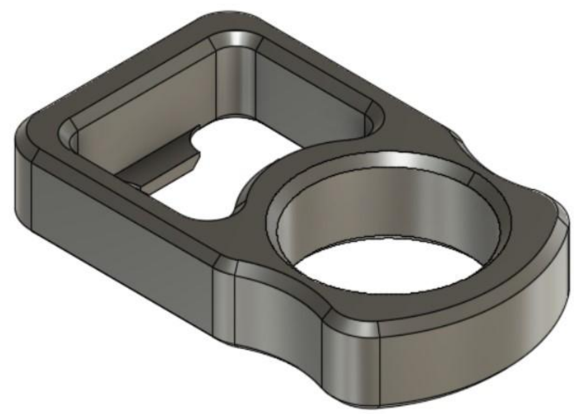
Activity

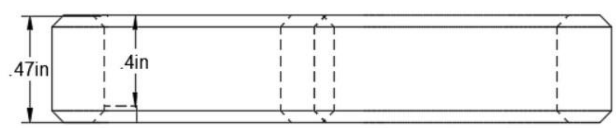
Section 2.3

Bottle Opener

Design Challenge







***Chamfer All Edges: 0.05”**

Rough Stock

0.75”x 1.75" Aluminum Flat

- 2.6” Length

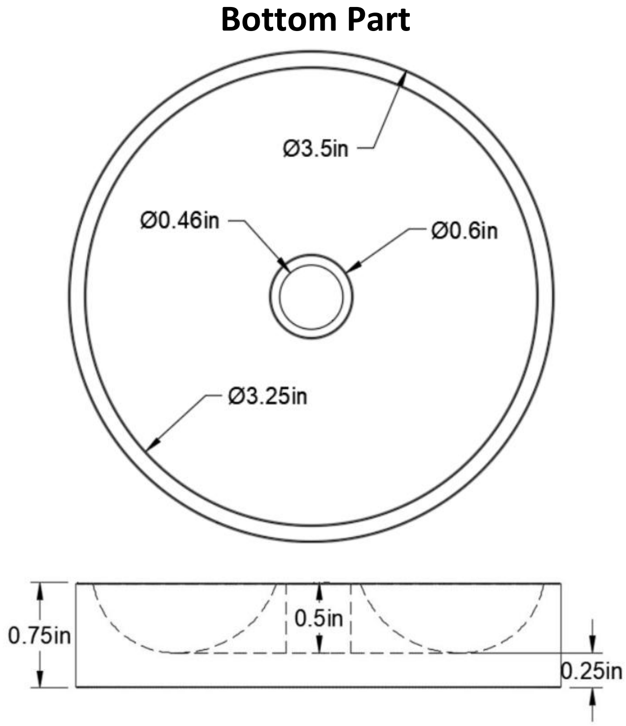
Tool-Paths Required	
(Setup 1)	**(Setup 2)**
• 2D Face • Adaptive or Pocket Clearing • 2D Contour • 2D Chamfer	• 2D Face • 2D Chamfer

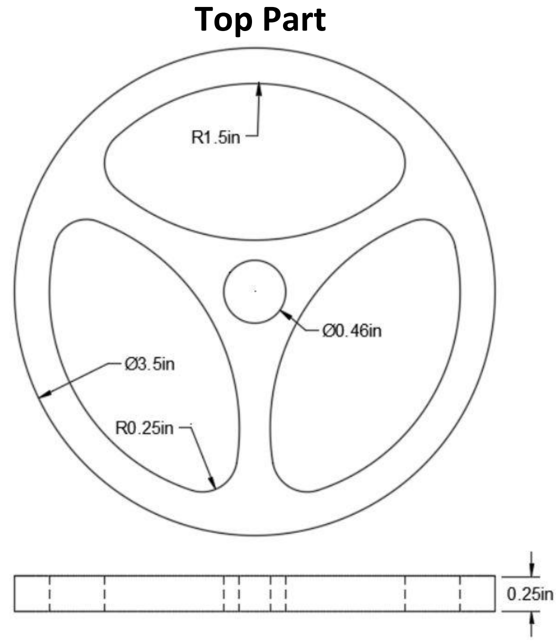
Activity

Section 2.3

Toothbrush Holder

Design Challenge





***Chamfer All Edges: 0.01"**
***Tap & Die Threads: 1/2" - 20 NF**

Rough Stock

3.5"Diameter Aluminum Rod
- 0.875" Length (Bottom Part)
- 0.35" Length (Top Part)

0.5" Diameter Aluminum Rod
- 4" Length (Connecting Shaft)

Tool-Paths Required	
Both Top & Bottom Parts (Setup 1)	**Both Top & Bottom Parts (Setup 2)**
• 2D Face • Spot Drill & Drill • Adaptive or Pocket Clearing • 2D Contour • 2D Chamfer	• 2D Face • 2D Chamfer

Quiz

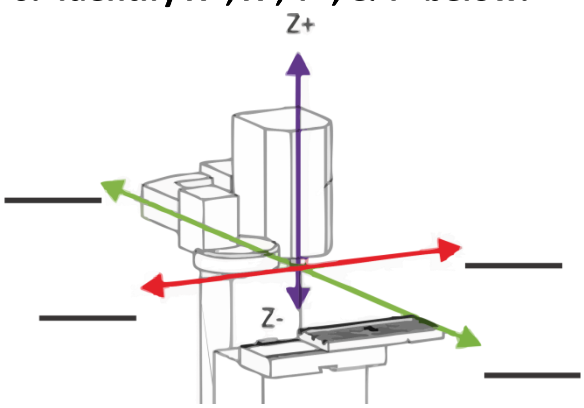
Section 2.3

NAME ____ **SCORE**____________

Match AND Label the following CNC machining abbreviations.

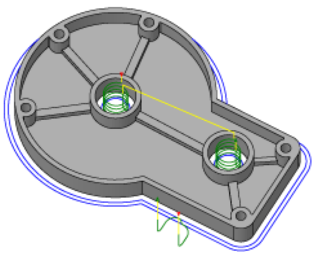
1. _____ **DRO** ______________________________	**A.** Offset that allows the operator to use tools of different lengths
2. _____ **ETS** ______________________________	**B.** X/Y/Z coordinates with respect to the part, instead of the mill position
3. _____ **ATC** ______________________________	**C.** Device for automatically touching off tools to find their offset lengths
4. _____ **WCS** ______________________________	**D.** Used to improve both the tool carrying capacity and production
5. _____ **TLO** ______________________________	**E.** Numeric display used to indicate the position of the cutting tool

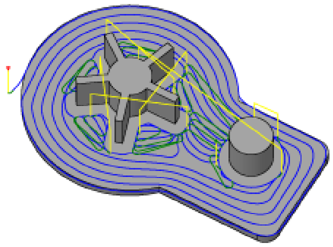
6. Identify X+, X-, Y+, & Y- below.

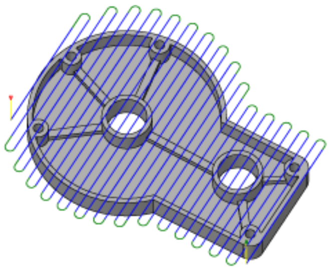


7. Draw arrows to illustrate the correct representation of a tool's offset.

Identify the following tool-path operations based on illustrations shown below.







8. ____________________ **9.** ____________________ **10.** ____________________

SECTION 2.4

Molding & Casting

Background Narrative

Molding is a manufacturing process that shapes pliable raw material using a rigid frame called a mold. This molded part may have been made using a pattern or model of the final object. The liquid hardens or sets inside the mold, adopting its shape. A mold is a hollowed-out block that is filled with a liquid or pliable material such as silicones, plastics, metals, or waxes. The counterpart of a mold is a cast.

Casting is a manufacturing process in which a liquid material is usually poured into hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. The basic difference between molding and casting is the method by which molten material is poured. Casting use a onetime mold but molding can use molds on repetition.

This course will be focusing on three specific molding and casting techniques; vacuum forming, sand casting, and plastic injection molding. These processes represent a broad range of capabilities that enable students to design 3D molds that normally wouldn't be made from a CNC machine. The student's job is to follow through the molding and casting workflow to create models out of pliable materials. By using previous skills in 3D modeling, the students will design original patterns using the engineering design process, and prepare them to for the molding or casting processes.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.

STL 2. Core Concepts of Technology

- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
- BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
- CC. New technologies create new processes.

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

- H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
- J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

- I. Design problems are seldom presented in a clearly defined form.
- J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
- K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

- I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.
- J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
- L. The process of engineering design takes into account a number of factors.

STL 11. Develop the Abilities to Apply the Design Process

- M. Identify the design problem to solve and decide whether or not to address it.
- N. Identify criteria and constraints and determine how these will affect the design process.
- O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
- P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems.

- N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
- O. Operate systems so that they function in the way they were designed.
- P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World

- 3.4.10.E6. Illustrate how manufacturing systems may be classified into types such as customized production, batch production, and continuous production.
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will demonstrate machine workflows in molding and casting part designs.
2. Students will apply the proper tools/material setups to melt and pour aluminum.
3. Students will create accurate molds and casts from their digital 3D designs.

Activities:

- ➢ Students create a vacuum mold casting of their 3D design that will become a model from an alternative material (soap, chocolate silicone, plastic, candy, etc.).
- ➢ Students create a sand casting of their 3D design that will become an aluminum part.
- ➢ Students create an aluminum mold of their 3D design that will become a plastic injected part.

Resources:

- Vacuum Forming Machine (Formech)
- Sand Casting Tools: Metal Melting Furnace, Large Crucible, Tongs for Handling Crucible, Casting Flask, Sand Sifter, Oil Bonded Foundry Casting Sand
- Plastic Injection Machine (APSX-PIM)
- Materials (Thermoplastic Sheets & Pellets, 3/4" Plywood, & Aluminum Ingots, Aluminum Blanks, Soap/Candy/Silicone/etc. for Casting)

Assessment

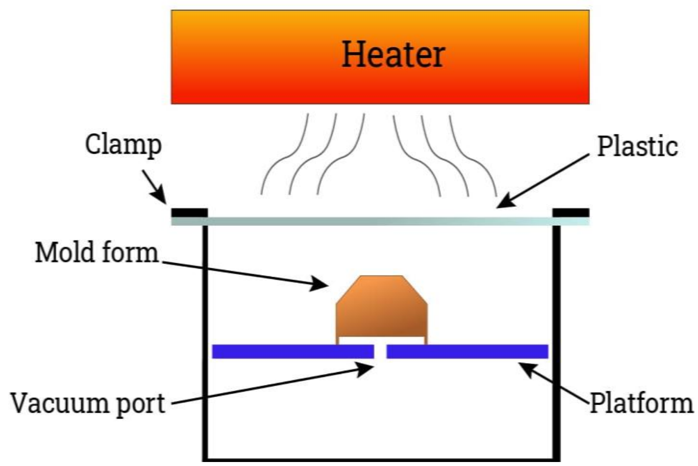
- ➢ Students will be evaluated by instructor/student critiques and rubric.
- ➢ Written quiz follows at the end of this section

Activity

Section 2.3

Vacuum Forming

Vacuum forming is also known as the simplest form of plastic **thermoforming** as only a mold is required, and the plastic is placed over it. It is the process of heating a thermoplastic material, and then a suction force is applied to shape the plastic according to the desired shape of the mold.



Thermoplastics - Polymers that can be softened through heating before being processed and then left to cool and harden.

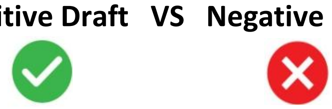
Positive VS Negative Molds:

Final Object | **Positive Mold (Convex Shape)** | **Negative Mold (Concave Shape)**

Draft Angles:

The angle of taper that exists on a vertical sidewall of the mold.

Positive Draft VS Negative Draft



Create a Custom Mold

Digitally fabricate a 3D model from plastic resin (SLA 3D printed) OR MDF (CNC milled) material.

The instructor & classroom resources will determine the type of mold you will create/pour (soap, chocolate, silicone, plastic, candy, etc.).

<u>**Approximate Model Size**</u>
3” x 2” x 0.75”
Draft Angle: 10 Degrees or More

Activity

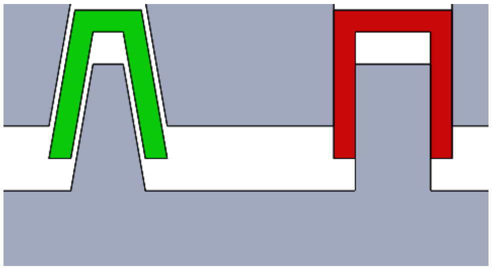
Section 2.4

Sand Casting

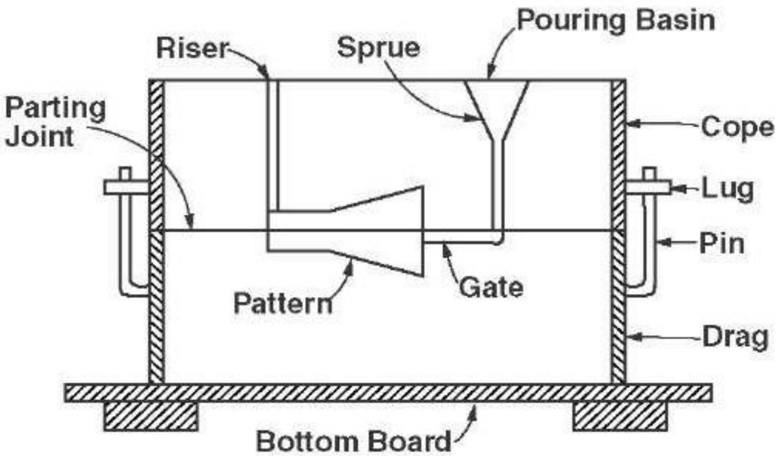
Creating the Mold:

Sand casting is a metal casting process that uses sand as the molding material. The sand will contain the cavity (negative mold) that will then be filled with molten metal. By designing the 3D pattern yourself, you will use the flask components in order to pack the sand onto the model and create the appropriate cavity form.

Draft Angles - An example of knowing draft angles is a stack of plastic cups, and how the air suction allows them to separate due to their shape. If the cups that were stacked were 100% vertical (0% draft), they would never release from each other. This principle applies with releasing a pattern design from the sand mold.



Assembling the Casting Flask:



Using a gas furnace, properly heat up the aluminum ingots past its' melting point (1.221°F).

Sand Caste an Aluminum Nameplate

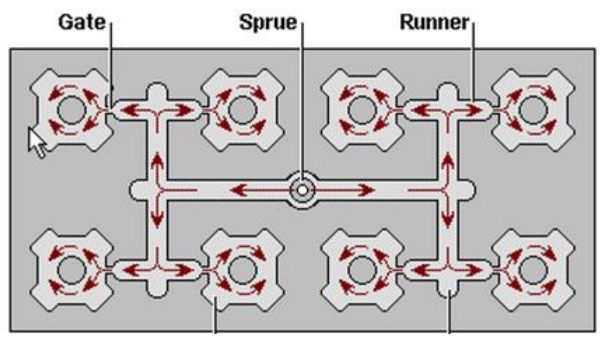
Design & model a wooden pattern that size is
6"x 3"x 0.5"
Include vector shapes, text, and/or image tracings
Draft Angle: 10 Degrees or More

Activity

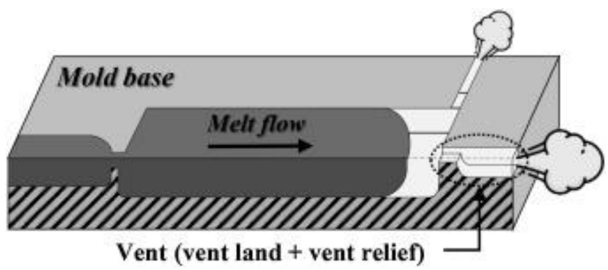
Section 2.3

Plastic Injection Molding

Plastic injection molding is a manufacturing process for producing parts in large volume by injecting molten thermoplastic material into a mold. Waste plastic from injection molding typically comes consistently from four areas:



Sprue: A round, tapered hole which leads the plastics material from the nozzle of the injection machine to the distributing runners in the mold.
Runner: a channel cut into the mold that allows plastic material to flow from the sprue to the cavity.
Gate: A narrow intersection between the main runner and the mold cavity.
Flash: Overflow material that leaks out of the part cavity itself.



*Venting Slots

- Air inside of the mold needs to escape so that the plastic can fill the entire space. Without vents, the trapped air will compress as the plastic tries to force the air out of the mold and will cause burning

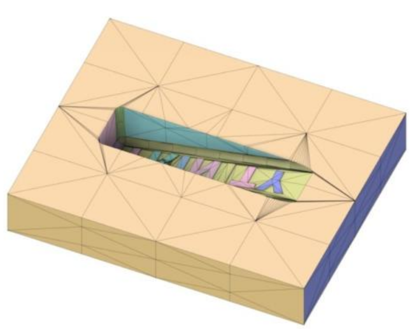
Plastic Injection Challenge

Design a Door Wedge Mold

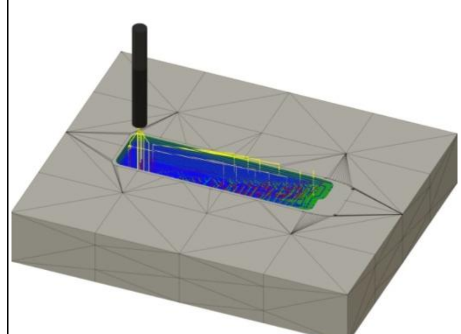
Use the 3D design/manufacturing features shown to you in Fusion 360 to CNC machine an aluminum blank. The part size will be **4" x 1" x 0.875"** with a draft angle of **10 degrees**.

1. **Design a completed door wedge**

2. **Use "Mesh" editing tools to create a negative mold**



3. **Generate CNC tool-paths**



Quiz

Section 2.4

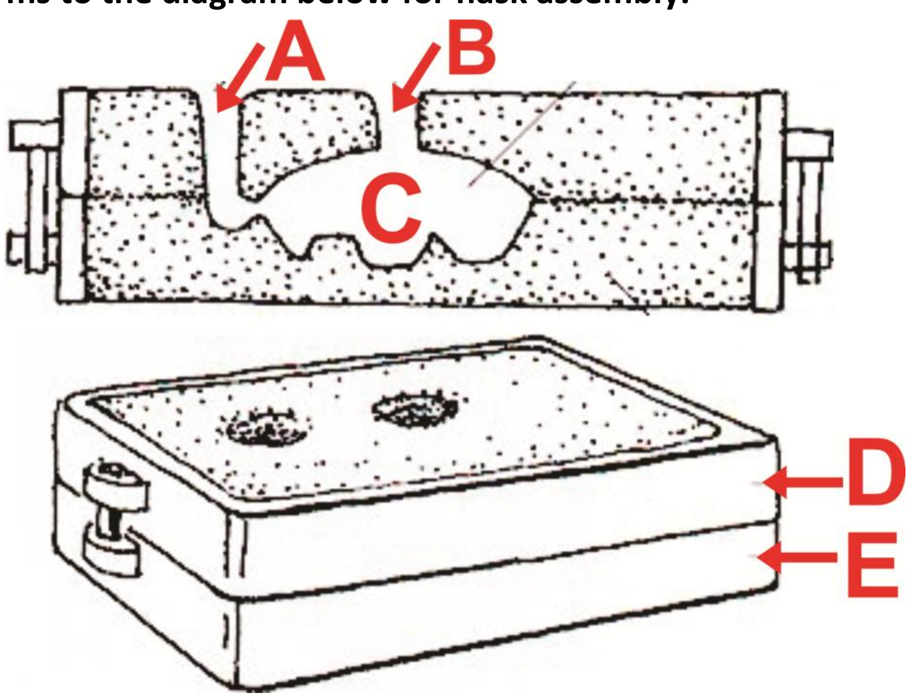
NAME ______________________________________ **SCORE**____________

Fill in the Blanks

1. ____________________ is a polymer that can be softened through heating before being processed and then left to cool and harden.
2. In order for a part to release from the mold, the part MUST have a ____________ ____________.
3. In injection molding, the overflow plastic material that leaks out of the part cavity is considered _____________.
4. The ___________ is a channel that feeds directly into the gate of each part.
5. Appropriately designed _______________ slots are able to reduce injection pressure from air and other gases.

Match the following terms to the diagram below for flask assembly.

6. _____ **Drag**
7. _____ **Riser**
8. _____ **Pattern**
9. _____ **Cope**
10. _____ **Sprue**



SECTION 2.5

Electronics Production

Background Narrative

Printed Circuit Boards (PCBs) form the backbone of all major electronics. These amazing inventions pop up in nearly all computational electronics, including simpler devices like digital clocks, calculators etc. For the uninitiated, a PCB routes electrical signals through electronics, which satisfies the device's electrical circuit requirements. In short, PCBs tell the electricity where to go, bringing your electronics to life. The complex system of copper routes determines the unique role of each piece of printed circuit board. These conductive pathways are etched or "printed" onto board, connecting different components on the PCB, such as capacitors, resistors, and integrated circuits.

There are many different ways that can be used to fabricate a PCB, such as CNC milling or using the Etching Method. However, the Etching method is not advised due to the toxic chemicals used in the process. Thus Trinity students are going to discover and test the CNC milling method for this course.

For this section, students will be introduced to electronic design software (KiCad) to create a schematic and board layout. Once the digital file is made, they will prepare the design to be cut from a copper clad material on a desktop CNC milling machine. The final step includes assembling all electronic components by using advanced soldering techniques while troubleshooting their finished project.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.
- L. Inventions and innovations are the results of specific, goal-directed research.

STL 2. Core Concepts of Technology

- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.

CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.

H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.

J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.

I. Design problems are seldom presented in a clearly defined form.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

O. Operate systems so that they function in the way they were designed.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

PA State Standards:

3.4.C. Technology and Engineering Design

3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World

3.4.10.D2. Diagnose a malfunctioning system and use tools, materials, and knowledge to repair it.

3.4.10.D3. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.

3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World

3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.

Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.

Electronics.1 - I can follow instructions to build a simple electrical circuit using conductive material basic components and power.

Electronics.2 - I can follow a schematic diagram and create a circuit including a microcontroller with electronic components.

Electronics.3 - I can create my own schematic diagrams and use them to build electronic circuits including microcontrollers.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.

Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.

Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.
Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Student will understand the essential properties and features with electronic design.
2. Students will analyze schematics/board layouts for printed circuit boards (PCB's).
3. Students will create and solder electronic components for a circuit design.

Activities:

- Students are introduced to electronic design by completing the "MP3 Amplifier" circuit.
- Students continue learning soldering techniques by completing the production of the "MP3 Amplifier" circuit.

Resources:

- Electronic Design Software (KiCad)
- CAM Software (Fab Modules)
- Desktop CNC Milling Machine (Roland SRM-20)
- 2"x3" copper clad material (PCBs)
- Soldering Iron(s)
- Rosin Core Solder
- Soldering Tip Cleaner
- Helping Hands Soldering Aid
- Safety Glasses

Assessment

- Students will be evaluated on solder joints by instructor/student critiques, and making sure each completed circuit design works properly.

Activity

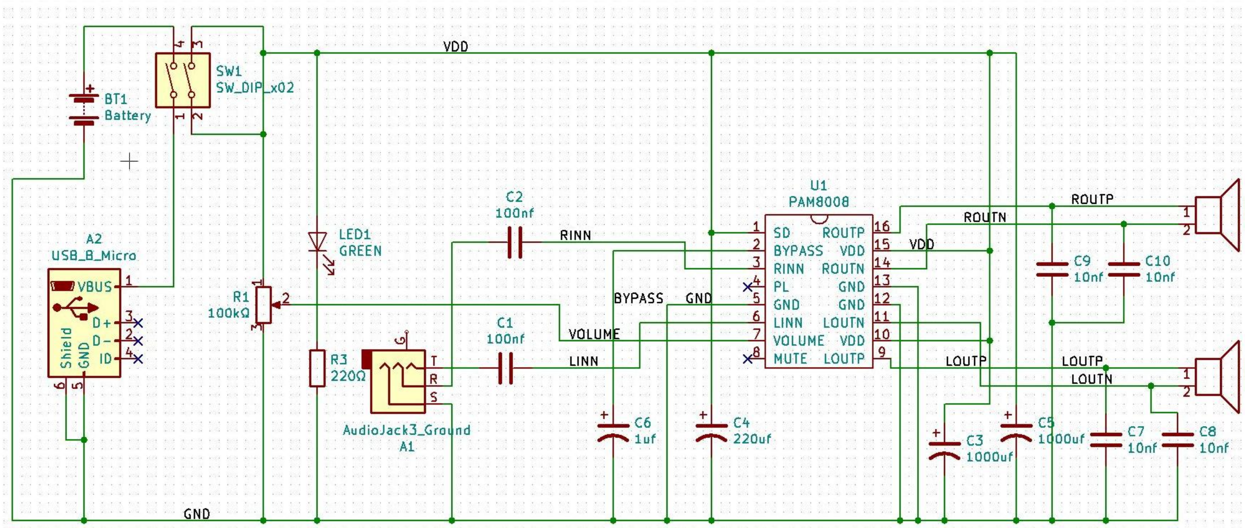
Section 2.5

PCB Design Challenge

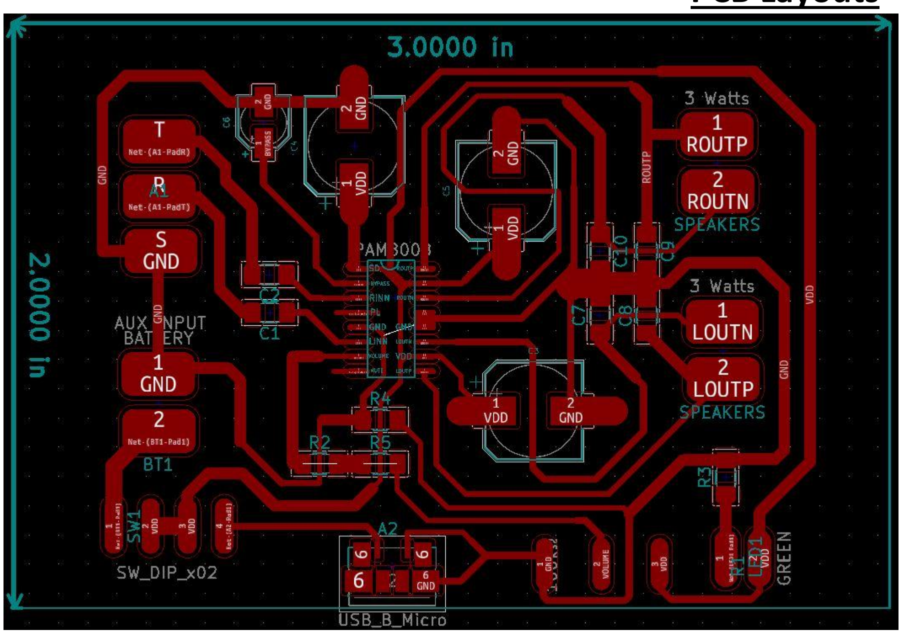
Create an Mp3 Speaker Circuit

KiCad software facilitates the design of schematics for electronic circuits and their conversion to PCB designs. The goal is to take an existing schematic/board layout and use software tools to design your own version that is 2″ x 3″ in size. Be sure to export your finished board layout into a **Black/White SVG File**.

Schematic Captures



PCB Layouts



Features Learned

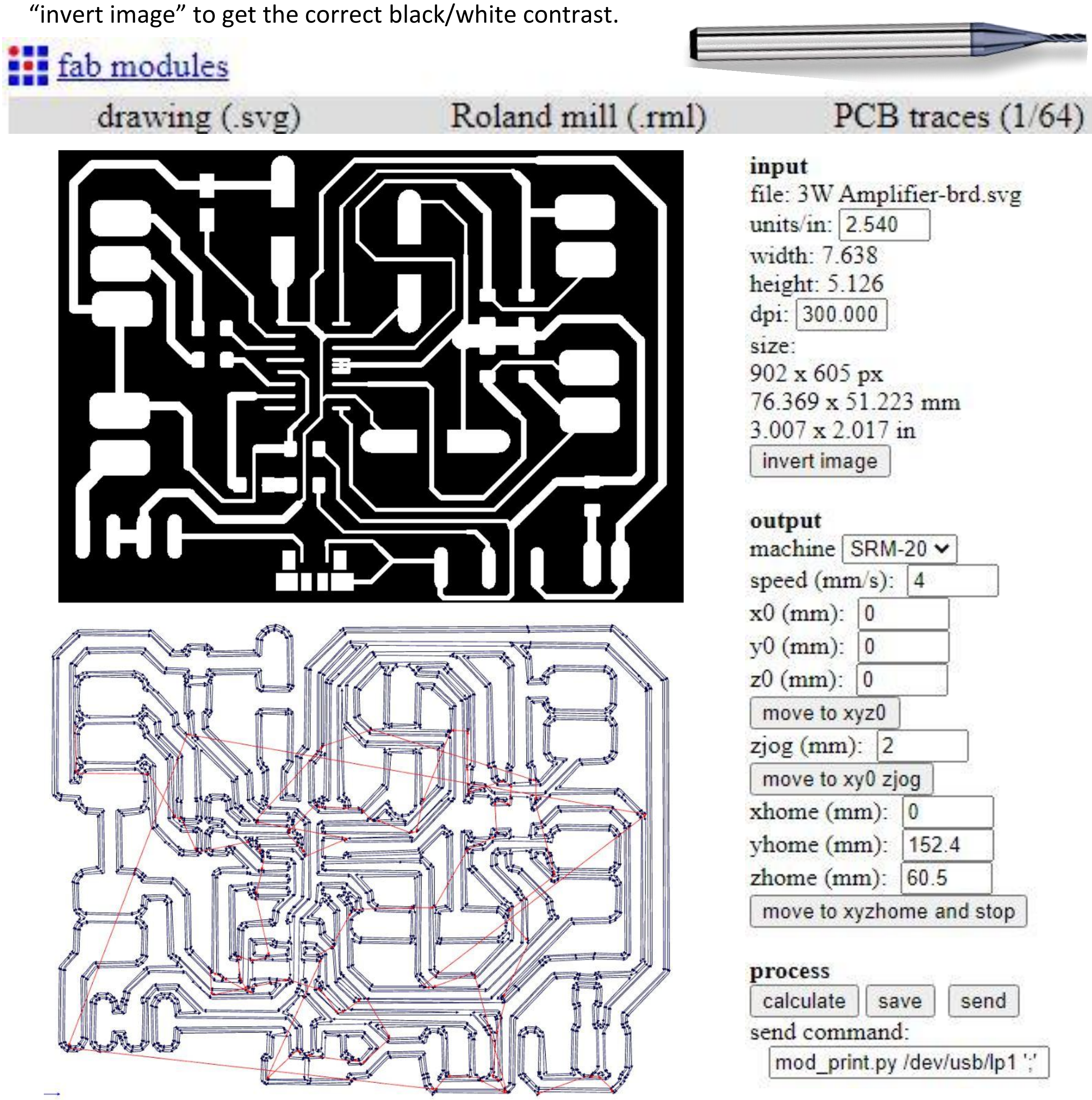
- ☐ Fabrication Design Rules
- ☐ Component Placement
- ☐ Routing
- ☐ References/Labeling
- ☐ Board Dimensions
- ☐ Netlists
- ☐ Ratsnest
- ☐ Layers Manager

Activity

Section 2.5

Fab Modules

The fab modules provide a set of software tools for personal fabrication, intended for use with machines common to fab labs. It Functions to generate 2D and 3D tool paths for our circuit production and runs off any web browser from www.fabmodules.org. Once you are on the website, input the correct .SVG file you created earlier in this section while also pressing "invert image" to get the correct black/white contrast.



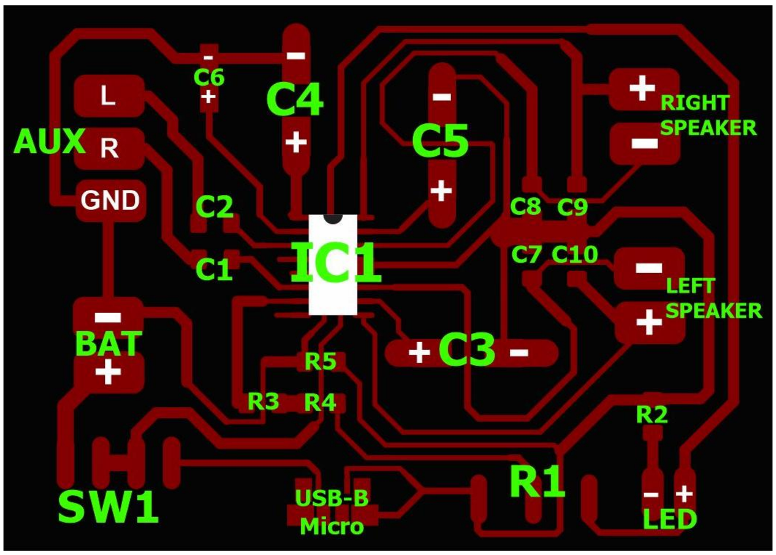
Activity

Section 2.5

Mp3 Speaker Soldering Guide

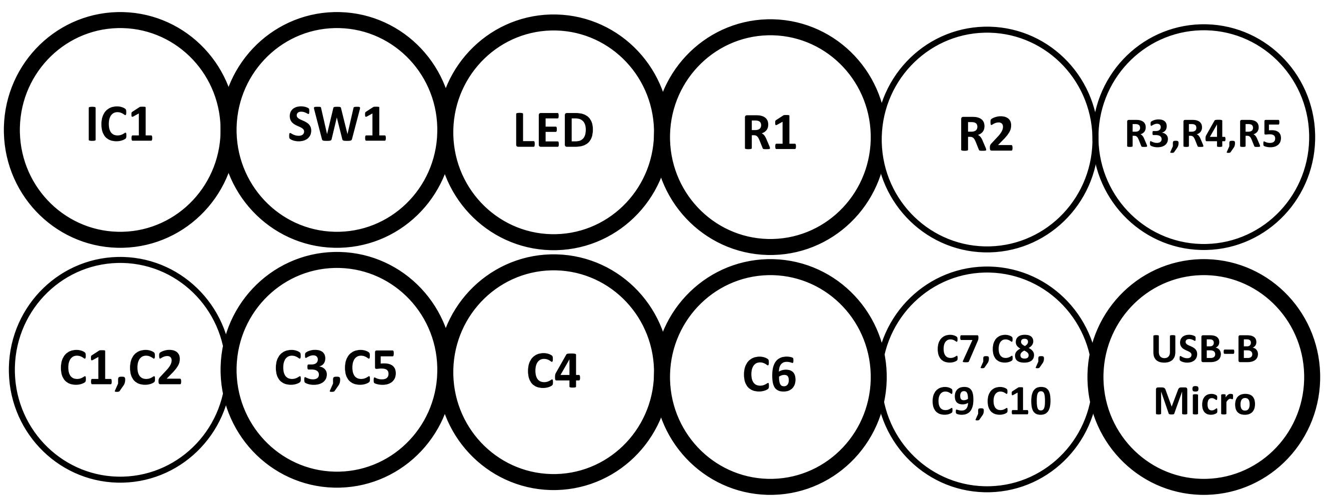
In the image below, you can see the various components of the 3W amplifier circuit, as well as their position and orientation (only those marked with an "**!**" have an orientation).

*Note that "AUX", "BAT", "LEFT SPEAKER", & "RIGHT SPEAKER" are all wire connections to other components that need to be soldered on the circuit board.



IC1 - PAM8008 Amplifier **(!)**
SW1 - DPST Switch **(!)**
LED - Green LED **(!)**
R1 - 10K ohm Potentiometer **(!)**
R2 - 220 ohm Resistor
R3,R4,R5 - 0 ohm Resistors
C1,C2 - 10nf Capacitors
C3,C5 - 1000uf Capacitors **(!)**
C4 - 220uf Capacitor **(!)**
C6 - 1uf Capacitor **(!)**
C7,C8,C9,C10 - 10nf Capacitors
USB-B - USB Micro **(!)**

Gather your Materials!
Tape your components onto their allotted spaces below to make the soldering process easier. Refer the image above to identify their locations. Bold circles replace the **(!)** explained above.



SECTION 2.6

Project Development

Background Narrative

Fabrication labs across the world have given access to advanced software and technology to support a student's personal or professional creative pursuits. The Trinity High School Fab Lab has provided a advanced suite of rapid prototyping machines used in the manufacturing industry. Students at this point in the course have developed the critical thinking, problem solving, and analytical skills needed to create their own innovations.

Trinity Fab Lab students will end this course by using what they've learned in technology and design related applications for individual innovation projects. These projects allow the students to further pursue their own goals in engineering design. They will have the opportunity to choose from any of the multiple technologies provided in the lab to create these final projects.

To start this section, students will look back to the previous lessons learned in using their design skills to fabricate a MP3 amplifier enclosure. By using the section 2.5 soldered circuit designs, students will use precise measurements to accurately accommodate any features on the circuit. The final lesson of this course will have students going through the engineering design process to sketch, design, evaluate, and problem solve a unique project, to utilize multiple skills learned and to promote creativity.

Technology Content Standards:

STL 1. Characteristics and Scope of Technology

- J. The nature and development of technological knowledge and processes are functions of the setting.
- L. Inventions and innovations are the results of specific, goal-directed research.

STL 2. Core Concepts of Technology

- W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.
- AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

- BB. Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
- CC. New technologies create new processes

STL 3. Relationships among Technologies and the Connections between Technology and Other Fields of Study

- G. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.
- H. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
- J. Technological progress promotes the advancement of science and mathematics.

STL 8. Attributes of Design

- H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.
- I. Design problems are seldom presented in a clearly defined form.
- J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
- K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

STL 9. Engineering Design

- I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.
- J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.
- L. The process of engineering design takes into account a number of factors.

STL 10. Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.
J. Technological problems must be researched before they can be solved.
L. Many technological problems require a multidisciplinary approach.

STL 11. Develop the Abilities to Apply the Design Process
M. Identify the design problem to solve and decide whether or not to address it.
N. Identify criteria and constraints and determine how these will affect the design process.
O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
Q. Develop and produce a product or system using a design process.
R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

STL 12. Develop the Abilities to Use and Maintain Technological Products and Systems
L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.
N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
O. Operate systems so that they function in the way they were designed.
P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

STL 19. Develop an Understanding of and be able to Select and Use Manufacturing Technologies
M. Materials have different qualities and may be classified as natural, synthetic, or mixed.
N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.

PA State Standards:

3.4.C. Technology and Engineering Design
- 3.4.10.C1. Apply the components of the technological design process.
- 3.4.10.C2. Analyze a prototype and/or create a working model to test a design concept by making actual observations and necessary adjustments.
- 3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
- 3.4.12.C3. Apply the concept that many technological problems require a multi-disciplinary approach.

3.4.D. Abilities for a Technological World
- 3.4.10.D1. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of a final product.
- 3.4.12.D2. Verify that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

3.4.E. The Designed World
- 3.4.12.E6. Compare and contrast the importance of science, technology, engineering and math (STEM) as it pertains to the manufactured world.

Fab I Can Statements:

Design.1 - I can be responsible for various activities throughout a design process within a group with instructor guidance.
Design.2 - I can participate in design reviews with prepared presentation materials as well as give and receive feedback from peers.
Design.3 - I can initiate design processes to generate multiple solutions to problems I have framed for multiple stakeholders.

Modeling.1 - I can arrange and manipulate simple geometric elements, 2D shapes, and 3D solids using a variety of technologies.
Modeling.2 - I can construct compound shapes and multi-part components ready for physical production using multiple representations.
Modeling.3 - I can define complex systems with parametric relational modeling using generative, algorithmic, or function representation.

Fabrication.1 - I can follow instructor guided steps that link a software to a machine to produce a simple physical artifact.
Fabrication.2 - I can develop workflows across four or more of the following: modeling software, programming environments, fabrication machines, electronic components, material choices, or assembly operations.

Fabrication.3 - I can make my own applications, machines, or electronic components to solve new problems and to grow my Fab Lab's capacity.

Safety.1 - I can safely conduct myself in a Fab Lab and observe operations under instructor guidance.
Safety.2 - I can operate equipment in a Fab Lab following safety protocols.
Safety.3 - I can supervise others in a Fab Lab and ensure safety protocols are being followed.

Performance Objectives:

1. Students will demonstrate the ability to create and accurately model a project to produce a fitted design.
2. Students will apply all of the tools/skills learned in the Fab Lab.
3. Students will create and document an innovation project to develop their own creative skills.

Activities:

- ➢ Students create a MP3 speaker enclosure to represent their understandings of accurately modeling a fabricated design.
- ➢ Students design and develop a unique prototype/model that synthesizes the knowledge gained and tools/machines used within the Fab Lab.

Resources:

- **Software:** CorelDRAW, Aspire, Fusion 360, CURA, PreForm
- **Machines/Tools:** Vinyl Cutter(s), Laser Cutter(s), CNC Milling Machines(s) with Rotary Motor, 3D Printer(s), Waterjet Cutter(s), 3D Scanner(s), Soldering Station(s)
- **Consumables:** Vinyl, Plywood, Acrylic, 3D Printing Filament &/or Resin

Assessment

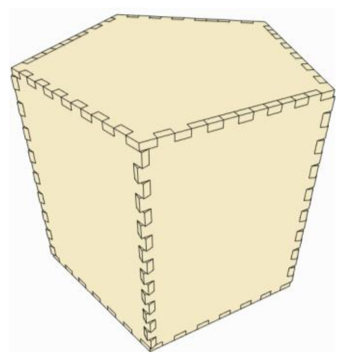
Students will be evaluated by instructor/student critiques and rubric.

Activity

Section 2.6

MP3 Speaker Design Challenge

Instructions: Accurately design and fabricate an enclosure for the MP3 amplifier circuit that accommodates all of its features created in section 2.5.



Circuit

Considerations:

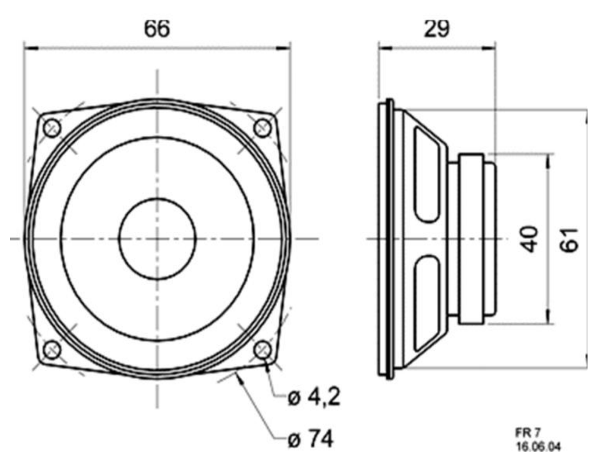
- The size of the PCB
- X4 3mm mounting hole locations
- Where the switch & LED are located on the PCB
- Access to the potentiometer for volume adjustments
- Access to the batteries to allow them to be changed

Left/Right Speakers

Considerations:

- The cutout size hole for each speaker
- X4 3mm mounting hole locations on each speaker
- How to make the wire connections to the circuit

Shown in Millimeters



Activity

Section 2.6

NAME ______________________________________ **DATE**_____________

Advanced Innovative Design Challenge

Instructions: Go through the engineering design process to define, create, prototype, & evaluate an innovative product that utilizes the most out of our Fab Lab.

Investigation/Research – Using a number of different search methods, find examples of artistic or innovative designs that empowers the way you or other people think about their day-to-day lives. Use additional pages if required.

Developing a Specification – Using your research for the product, identify the key requirements for the product & explain why each of these is important.

Requirement:	**Reason:**

Activity

Section 2.6

NAME ______________________________ **DATE**______________

Advanced Innovative Design Challenge (Continued)

Design – Develop your ideas to produce a design that meets the requirements listed in the specification.

Evaluation – Check that your design meets all of the points listed in your specification.	
Good aspects of the design:	**Areas that can be improved:**
Improvements:	