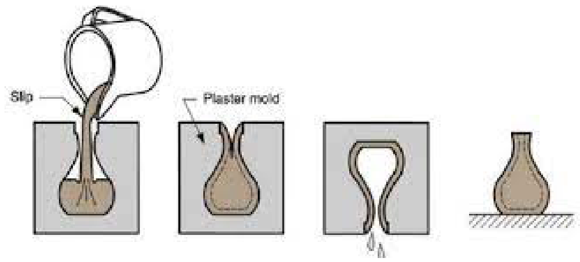
# Basics to Molds- Overview 1a

Before the age of mold-making artisans and craftsman would have to painstakingly master their crafts and create every piece, but that all changed with the introduction of molds and casting in the Bronze Age. This changed the course of manufacturing and allowed for efficiency that saved time, effort, and often materials. In this assignment, you will review some basic knowledge of molds and casting with them in various ways. Typically, in manufacturing mold-making and casting are efficient ways to mass produce products but one can take those same principles and apply them to your workflow and practices here at CAP and across many disciplines. The wide variety of ways one can generate a mold can be done with the array of fabrication methods that are available at CAP's FAB LAB that you will have been introduced to during the previous modules.

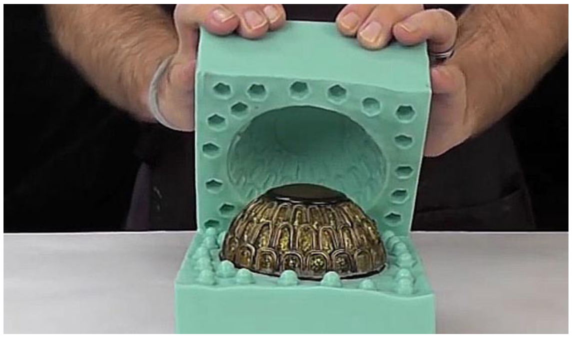
**What are molds and what are they used for?**

A **mold** is a designed, fixed tool, structure, or frame made from metals, plastics, ceramics, wood, foam, and more. They are used to in a process that requires a malleable raw material to shape into a reproduction of a uniform copy of an original design.

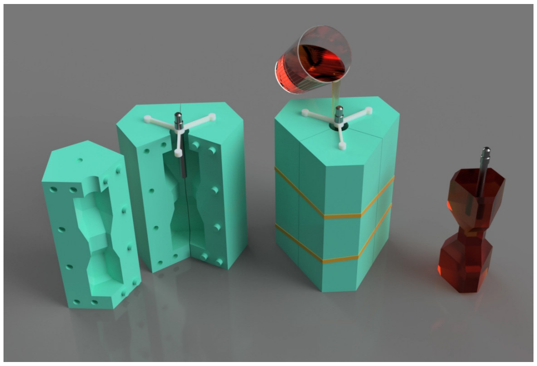



**What are the different types of molds?**

**One-part** molds refer to the simplest types of mold with uniform surfaces across all parts of the object to be molded. Mold designs or objects with one flat surface can also be reproduced using one-part or one-piece molds. Although one-part molds can be made from CAD models, these molds are generally developed from a physical master model.

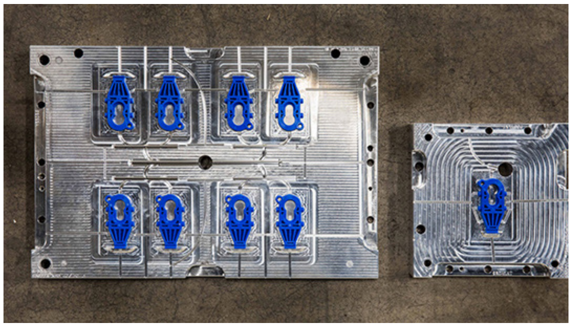


**Two-part** molds provide a capable approach to producing molds for more complex designs. A two-part mold is defined as a mold with two separate parts joined together at a parting line, to produce the end product. Each produced part mirrors the different features of both parts of the model design or the master model. Making a two-part mold also usually involves developing both parts of the mold from a master model or CAD model.



**Multi-part** molds are ideal for mold designs with more complex geometries requiring a different approach compared to the process of developing one or two-part molds. Multi-part molds account for the different aspects or features of the model. Hence the completed mold will consist of multiple parts to recreate the different features of the model.

**Multi-cavity** molds have more than one cavity that's shaped like the same part, making it possible to manufacture multiple parts per production cycle, thus increasing productivity.



**One-time-use or sacrificial molds:** These molds reproduce a single object and once used, the mold is destroyed during the demolding process. One-time-use molds are generally made from sand, clay, silicone, wax, or plastics.

**Reusable or permanent molds:** As the name suggests, these molds can be reused for multiple cycles, from low to large production runs. For lower volumes (sometimes referred to as soft molds), reusable molds can be made out of silicone, foam, wood, plastics, or softer metals like aluminum. Larger volumes that require more durable molds without wearing out (often referred to as hard molds) are mostly made out of hard metals, such as steel.

# Basics to Molds- Overview



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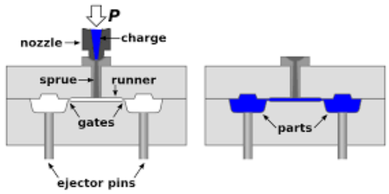
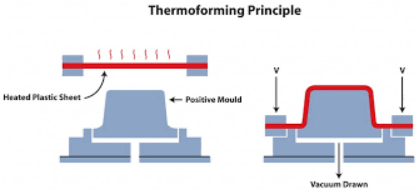
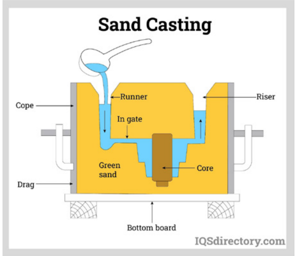
**What different manufacturing processes that use molds?**



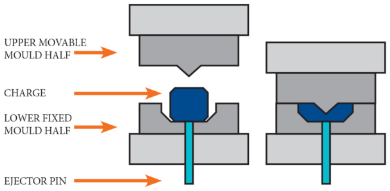

**Injection Molding** is popular manufacturing processes among polymers industry. It is a cost-effective and extremely repeatable technology that yields high-quality parts for large series production. With this process, the developed mold is inserted into the injection molding machine, then heated thermoplastics or the liquefied raw material are poured into the mold. Once the material solidifies, the final part is ejected from the machine and the process is repeated in quick succession.



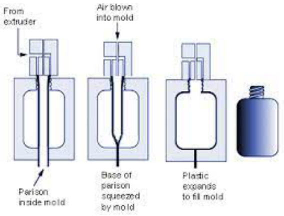

**Thermoforming** involves heating a plastic sheet and forming it to specific shapes using a mold. Molds provide the patterns thermoforming equipment utilize to develop a finished part. Depending on the thermoforming process, the heated, malleable material is pulled or pressed over the mold or forced onto it by vacuum. Thermoforming is the most common method for producing packaging, but it is also used in manufacturing durable end-use parts.



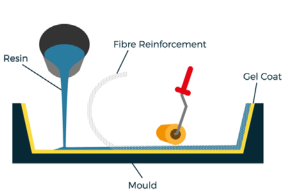

**Casting** involves filling a mold with molten metal or other liquefied material. The molten material cools and hardens within the mold to form the desired product. Casting is commonly used for manufacturing metallic products, as well as silicone and plastic parts.




**Compression Molding** is a manufacturing process where a measured amount of molding material that's generally preheated is compressed into the desired form using two heated molds. Compression molding is generally considered an alternative to injection molding for relatively simple designs for low and medium series of part production.




**Blow Molding** is a technique that's similar to glass-blowing. A blow-molding machine blows air into a heated tube-like piece, generally made out of plastic or glass, that is clamped into a mold. As the air is blown into it, the pressure pushes the plastic out to match the shape of the mold. Blow molding is commonly used for manufacturing hollowed products, such as bottles.




**Composite Lamination** involves the assembly of composite materials onto a mold and applying methods such as the wet lay-up, prepreg lamination, or resin transfer molding to form the finished composite parts out of high-performance materials, including carbon fiber, fiberglass, and kevlar.

# Basics to Molds- Technique Choice 1b

In this section we will go over the process of selecting the what mold type of mold and mold-making technique is best for what you are looking to design. Since there is a wide variety of mold types and mold-making techniques it is important to choose the right type and technique for the best outcome of your project. With such an array of options it can become an overwhelming process especially when it is something new to you. The main things to take into consideration are the desired end-part material, the intended manufacturing process, the model geometry, and production volume required. We will cover how the process of making design decisions can be broken down into manageable steps to help make the decisions best for each of your projects. We will continue to delve into the process and break things down as you progress through this module.

## Design Decision Process Outline

### 1. Outline the Development Criteria for Your Project

Before you can make a master plan to help iron out the details of your mold-making process you need to clarify the best option for your design. Once you have decided what your design will be it will be a much easier process to decide what mold-making technique will be the right choice and provide the most successful outcome. Narrowing down which technique might be best you will have to make a list of development criteria to help make a decision. These development criteria are not limited to but can include: your timeline or due date, the available budget, the limitations that come with your design geometry, the size of the part, material of your desired end product, the quality of your desired end product, the required tolerances, required production volume, sustainability, available fabrication technology, and more.

### 2. Select the Manufacturing Process

Selection of the proper manufacturing process is highly dependent on the development criteria and often the material choice and manufacturing volume. The decision can be made using a standard of practice rule of thumb by selecting the manufacturing process that can produce the designed parts required quality, at the lowest costs, while achieving all of the development criteria.

Arriving at a decisions you will be confronted with a thoughtful and thorough planning of your process criteria you will be able to determine the mold-making technique. The list to the right should help you understand the differences that can come from some of the criteria to assist in narrowing down the selection of a mold-making technique.

### 3. Select the Mold-Making Technique

**Design of the part:** Try to simplify the design as much as possible and align it with the design rules of the given manufacturing process to be able to choose the technique that can achieve the lowest costs. Simple designs might only require molds that can be created with manual techniques, while complex designs often require multi-part molds and digital manufacturing tools like 3D printers or CNC machining to create.

**Production volume:** Large-volume production runs require durable molds that can accurately replicate models without wearing out after a few uses. However, fabricating such tools comes with high costs and lead times. For one-off parts and lower volume batches, it might be more efficient to choose cheaper molds that can be created faster, such as sacrificial molds or soft molds that can be discarded when they begin to show signs of irreparable wear.

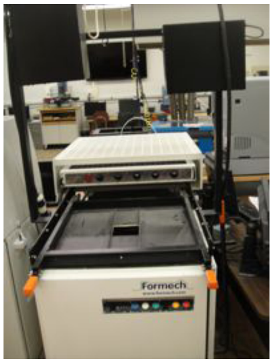
**Quality:** Tighter tolerances require more precise molds and tools to create, such as digital manufacturing tools, and need to be more durable to ensure consistent part quality over multiple cycles.

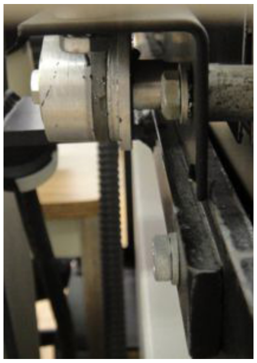
**Timeline:** Producing complex metal molds often takes months through a service provider. If you're working on a shorter timeline, try to look for alternatives that can shorten the lead time, such as 3D printed rapid tooling.

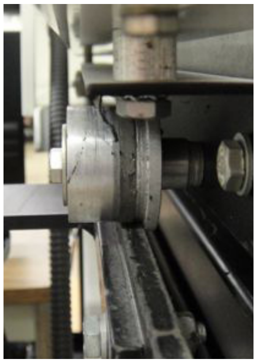
**Material:** Materials that have a higher melting point or are more abrasive will require molds that are more durable and can create the required volume of parts without degradation.

# Basics to Molds- Thermoforming Molds Overview 3c

In this assignment for sake of simplicity and accessibility of fabrication technology we have narrowed down the mold-making technique that is the most approachable for the mold you will create. You will be asked to use a common material and fabrication methods for this of module on mold-making techniques. This allows you some freedom in design but some challenges in terms of understanding each of the positive and negatives of the different stages in the process of mold-making and planning. You will learn how different design can add or subtract from these various challenges. The two techniques you will be need to demonstrate are Thermoforming and Casting. The materials that you are going to explore are plaster, plastic, and or wood. The fabrication methods for this assignment are: laser cutting, 3D printing, CNC milling, and thermoforming.





**Process Overview:**

**1.** Sheet is heated to thermoforming temperature.

**2.** A male or female mold and the hot sheet are moved into contact and a vacuum is then used to evacuate the air trapped between the sheet and the mold.

**3.** Part cools below its Heat Distortion Temperature (HDT) and is removed from tooling.

**4.** Part is trimmed and finished as required.

**Objectives:**

**1.** Identify and practice safe procedures when using a Formech 660 vacuum forming machine.

**2.** Create or obtain a model suitable for vacuum forming.

**3.** Select materials suitable for vacuum forming.

**3.** Vacuum form using a Formech 660.

**4.** Post-process a vacuum-formed part.

**Safety Instructions:**

**1.** Make sure you have received instructions on the use of the vacuum former before beginning. If you have any questions, consult the references and ask an instructor.

**2.** Treat the heating surfaces as if they are hot. Avoid burns.

**3.** Clean dust and foreign matter from the vacuum former before turning it on.

**4.** Be sure to wear safety glasses and proper lab attire (no loose clothing or hair, only closed-toed shoes.)

**5.** Do not place anything on the top of vacuum former (shown in the second photo above).

**6.** When moving the heating unit forward and back, it is possible for it to jump off its tracks as shown below on the left. Avoid doing this by moving it only forward or back with no lateral pressure. Move it carefully. It is best to use two hands. If it jumps the track, ask the lab supervisor for assistance in getting it back on track (as shown above on the right. Do not get burned.)

**7.** Do not touch hot plastic with your skin.

**8.** Do not place anything under the heating elements that can catch fire from them during normal use.

**9.** In the event of an emergency or accident, identify the lab supervisor or instructor immediately and follow their directions.

# Basics to Molds- Thermoforming Molds Design / Materials 3c

Thermoforming or vacuum forming is a process that typically involves heating or plasticizing a sheet of material, and then putting it contact with a model, evacuating much of the air from between the two. Atmospheric pressure then presses the material to the model, where it is cooled and hardens, retaining the shape. The varied materials that are often used in vacuum forming are: polystyrene, ABS, polycarbonate, PVC, and a PVC/Acrylic blend. The cardinal rule for the design of all formed plastic parts is to try and maintain uniform material distribution. Like any other technology this has its limitations and a lot of them are dependent on the geometry of the desired model to be reproduced. We will outline some design guidelines and rule of thumbs to assist in the success of your project below but thorough and well thought out plan is strongly suggested.

**Design Criteria:**

For this assignment portion you will need to create a tile design for a mold that will be cast in plaster. The tile will be a 6 inch by 6 inch by 1/4 to 1 inch thick.

How you design this tile is up to you whether you decide to laser cut, 3D print, or CNC mill the design as the positive of your mold.

**Design Geometry Rule of Thumbs:**

**1.** Read up on models for vacuum forming. Watch videos on this process, such as the one at https://www.youtube.com/watch?v=ficoGsmRK98

**2.** Consider that vacuum forming models generally should not have undercuts, and that the vertical sides should typically slope at an angle to provide the draft needed to remove the model from the sheet of formed material (about 5° draft is recommended, maybe more for some models and materials. Hard materials that are not impacted by the heat involved may provide better detail and wear.

**3.** After you find or make a model, check with the instructor to see if there are any problems with it. Make sure it is clean and dry, and that you will be able to remove it from the vacuum formed plastic. Delicate materials used as molds may break during vacuum forming, so don't use anything as a vacuum forming mold that is likely to break, or that is precious.

**4.** Consider that some models have additional bases though the vacuum-formed material around those bases is later excised. This additional height is referred to as standoff.

**5.** You might want to keep a camera handy so you can take pictures to document what you are about to do.

As thickness increases, the required heating time would increase. Note that no times are listed here, as these should be experimentally determined by you with your material.

**Material Preparation:**

**C**1. You need flat thermoplastic sheet stock of the sizes indicated in the Appendix, below. Try to obtain a few more than you need to allow for errors.

**Properties of the material:**

- It must be rigid when cool, soften when heated to allow forming, and then become rigid again in a new shape when it is cooled.
- It must not give off toxic vapors when heated.
- It must be of the right thickness, not exceeding the maximum listed in the Appendix, below
- It must be cut to the right length and width to match one of the material sizes listed in the Appendix, below.
- It should be free from scratches, coating, and foreign matter.

C2. Identify the material and read about it. Ideally you would locate a recommended thermoforming temperature. A manual from Formech provides the following recommended forming temperatures:

Recommended Forming Temperatures for Some Thermoplastics

| Material | Temperature |
|---|---|
| PS | 302 - 347 ° F |
| ABS* | 302 - 356 ° F |
| PP | 302 - 356 ° F |
| Acrylic | 284 - 374 ° F |
| PETE | 250 - 320 ° F |

* Indicates that the material is likely hygroscopic and may need to be dried for a specific time at a specific temperature prior to vacuum forming.

C3. Cut the material to size. If you have not received instruction on using our lab equipment for this, please see the instructor.

C4. Fill out a new line in the Material Log Sheet. If you make additional runs with different settings, models, or material, use a new line for each.

CAP FAB LAB

# Basics to Molds- Thermoforming Molds Process 3c

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**Position the model and material**

**1.** With all the dust removed from the working surfaces of the vacuum former, carefully install both halves of the reducing window that fits your model and material.

**2.** Raise the table using the drape table lever on the right.

**3.** Select the two-piece window of the appropriate size for your mold and place it into the vacuum former. After both halves are installed, you might need to move the bottom piece so the opening exactly aligns with the opening in the top half of the window.

**4.** Place your model on the platform so that it is well-positioned with regard to the window and lower the table.

**5.** Place the clean material between the two halves of the reducing window or material area so that it entirely covers the cushioning gaskets surrounding the opening.

**6.** Adjust the left and right clamps as necessary for your material thickness to lock them into place. The nuts should be adjusted finger-tight only to allow the clamp to securely lock the material, as shown to the right. Make sure the specialized washers are properly oriented. Please note that the clamps must squeeze the windows together tightly, and in the locked position the orange handles should be squeezed tighter-than-horizontal to lock. Below left shows a clamp that is loose. Adjust it so that it fits as pictured below right.

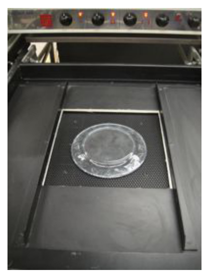
**Power and Pre-Heating the Heating Elements**

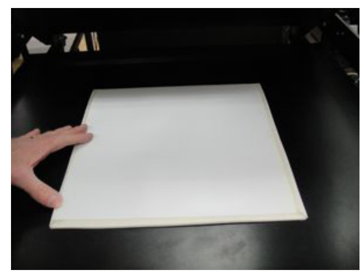
**7.** Check to make sure there is nothing on top of the heating area.

**8.** With safety glasses on, plug in the power cord for the vacuum former.

**9.** With the heater away from you, turn on the heating zones corresponding to your sheet size. You might want to have a slightly cooler setting on the center (Zone 1) since the heat will naturally tend to be greater in the center. Record what settings you use.

**10.** Be patient. The pre-heating period will likely last ten minutes. You will know it is over when all of the heating zones you have turned on begin to cycle off and on. During this time, you are not pre-heating your plastic, but just getting the heating elements up to temperature






**Note**

In production work, we would generally use a non-contact thermometer to determine the temperature of the material with different heater settings, aiming for a temperature that has been elsewhere determined ideal for this material and thickness. We could then experimentally determine which heating settings were optimal.

# Basics to Molds- Thermoforming Molds Process 3c

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**Heat and Form the Material**

**Note: Experimentally Determining Heating Times**

You will likely make more than one run. In order to determine what heating time will work, it is recommended that you start heating your plastic for a known number of seconds, then quickly push the heater away from you and use a non-contact thermometer to record the temperature in the center of the plastic. If this is not the recommended forming temperature, then you will have to heat it for some additional seconds before forming it using the steps outlined below. During the next run with another cold sheet of plastic, you would then increase the initial heating time and again measure the temperature. Measuring the temperature allows it to cool, so again it will likely require a bit more heating prior to forming. But you should soon be able to determine for how many seconds you must heat a cold sheet in order to reach the recommended forming temperature.

**11.** There is a timer on the front of the Vacuum Former, though you may want to use your own watch or smartphone so that you know the time between moving the heater over the material and when you move it away.

**12.** After preheating the heating elements for about fifteen minutes, move the heating unit toward the operator to the full extent of its travel. Do not allow it to jump off its rails or for electrical cords to impede its travel.

**13.** Begin timing how long the plastic sheet heats.

**14.** If you do not know a recommended forming temperature, then carefully watch the material through your safety glasses. Look for when it sags and then draws drum tight. For material that is relative thin (about 1 mm) you might want to try just a few additional seconds after the material draws drum tight. For thicker materials, it might take a little longer.

**15.** When you determine the heating stage should end, note the time.

**16.** Immediately move the heater away from you all the way without it running off its track.

**17.** Immediately pull the drape table lever toward you to raise the model.

**18.** Immediately press the green Mould / Vacuum button to engage the vacuum.

**19.** Look at your watch again so you can time how long you are drawing the vacuum. For thin materials, this might be a short as 5 seconds, but for thicker materials it might be 1 minute. You can turn on the overhead cooling fan by engaging the black Auxiliary switch and this should shorten the cooling period.

**20.** When you determine that the material has cooled long enough, disengage the vacuum switch by pressing the Stop button.

**21.** Press and hold the Release button for several seconds to send air up between your model and the plastic to aid in separation.

**22.** Press the Stop button and turn off the auxiliary fan.


**Note:**

If there is a partner, then it is recommended that the person on the left has the responsibility for moving the heater back and taking the temperature while the person on the right has the responsibility for raising the model and pressing the Mould button.

# Basics to Molds- Thermoforming Molds Process 3c

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**Post-Process**

**1.** Carefully remove your formed plastic sheet. If the model is stuck inside it, you might need to wiggle it out. In some cases a poorly chosen model with insufficient drafts or with undercuts will not be able to be removed without cutting the sheet away. Do not damage the model when you do that.

**2.** Turn off all heaters on the vacuum former.

**3.** Unplug the vacuum former.

**4.** Trim your vacuum formed product, as needed. Make sure to leave enough excess around the edges for casting.

**5.** Clean up any mess you’ve made, getting rid of waste and putting any materials, tools, and vacuum former accessories back where they belong.

**6.** Repeat the process so you have at least 3 of your molds for contingency that they break during casting.


**Note:**

If you were to repeat this process, you would not have to again pre-heat the heater if it is already at temperature.

If you were to repeat this process, you could use the built in timer to automatically indicate when the time you input in seconds had elapsed. This is handy for determining heating time. However, realize that the first few products of a production run are often not at the full temperatures of later products in that run.

**Specifications:**

**Forming Area and Reducing Windows**

26” x 26”
19 1/2” x 19 1/2”
13” x 13”
7 1/2” x 7 1/2”

**Maximum Depth of Draw**

12”

**Maximum Material Thickness**

.236”

# Basics to Molds- Casting Molds 3e

In this assignment for sake of simplicity and accessibility of fabrication technology we have narrowed down the mold-making techniques that you can choose to for your three molds you will create. You will be asked to use different mold materials and fabrication methods for each of the different mold-making techniques. This allows you some freedom in design but some challenges in terms of understanding each of the positive and negatives of the different processes and planning in which will is best for each design. The three techniques you will be need to demonstrate are Casting, Thermoforming, and Compression mold-making. The materials that you are going to be exploring are plaster, plastic, wood. These materials will be utilized through the fabrication methods: laser cutting, 3D printing, CNC milling.

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**Plaster of Paris:**

Plaster does not shrink as it sets, but instead sets by a chemical reaction. You will need to get it out of the cavity, possibly by breaking the mold. If you are using plaster as the mold, you can try to add a thick solution of soapy water to aid in removal.

Realize that rock gypsum ($CaSO_4 \cdot 2H_2O$) is mined and crushed, then it is heated (calcined) to drive out 3/4 of the water and produce plaster of Paris. When you add water to plaster, the plaster sets by hydrosetting, or chemically combining with water, in an exothermic reaction that can create quite a bit of heat. This heat could even soften thin thermoplastic containers.

Do not allow any plaster, plaster dust, or water with plaster in it to go down a drain. Again, plaster is hydrosetting, and it is common for it to clog a U-bend in a sink's or toilet's drain. It can set under water. Instead, place waste into a waste receptacle.

**Step by Step Process:**

**1.** Gather materials and prepare your vacuum formed molds.

**2.** Place a temporary surface (like a cardboard sheet) to preemptively avoid leaving a mess as plaster can quickly coat a work area. Once dry it is difficult to clean.

**3.** Measure out the plaster and water in this ratio: 2 parts plaster to every part water. Make enough for your 3 molds by filling your molds with water to get an accurate measurement. Allow the water to set to reach room temperature.

**3.** In a large bowl slowly sprinkle the plaster to the room temperature water while consistently and gently stirring until all the clumps are gone. Then allow to sit for a few minutes to let the bubbles rise to the surface and stir it again.

**4.** Once mixed, repeated tap on your work surface to agitate any leftover air out of the mix.

**5.** Take your mixture and pour it into your molds on your temporary surface. Then again allow it to rest for a few minutes.

**6.** Take your molds and make sure to repeatedly tap it gently to not spill as you agitate the remaining air out of your mold.

**7.** Leave your molds overnight to completely dry. Make sure to clean your workspace.

**8.** Return the next day and remove your plaster casts from their molds. If you have trouble removing it you can use dish soap and water as a removing agent.

**9.** Use a fine sandpaper and some water to smooth the surface if it is uneven or you are not satisfied with its texture. Wipe down and let dry.

**10.** Turn in one of your tiles to the CAP FAB LAB staff to finish this module.