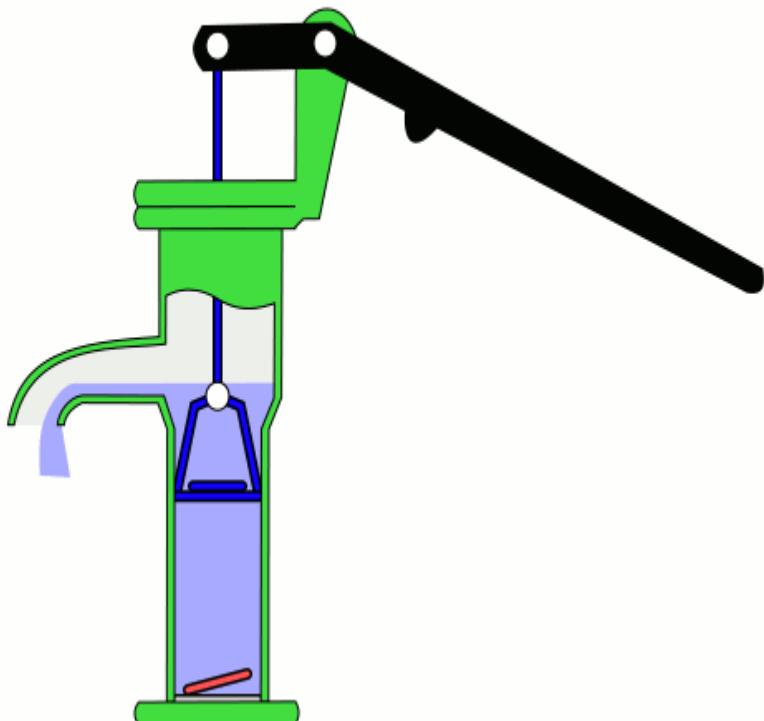


# ME338 Project : Hand Pump

- Deepak Marla -

- Department of Mechanical Engineering -

- Indian Institute of Technology, Bombay -



Reference: [https://commons.wikimedia.org/wiki/File:Hand\\_pump\\_-\\_Animation\\_with\\_soil.gif](https://commons.wikimedia.org/wiki/File:Hand_pump_-_Animation_with_soil.gif)

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10.09.2022

## Stage 1

### Title :

Manufacturing of Hand Pump

### Team Members :

- Swapnoneel Kayal
- Amshuman Sashi
- Rohit Sankhala

### Role of Team Members -

- Swapnoneel Kayal - Materials and Process Selection, Cost Analysis, Documentation
- Amshuman Sashi - Design, Components, Assembly, Final Inspection
- Rohit Sankhala - Product Description & Applications, Equipment Requirements for Manufacturing & Finishing

## Stage - 2

### Description :

Hand pumps are manually operated pumps. They use human power and mechanical advantage to allow the easy transfer of fluids from one location to another effectively. The specific application of our pump would be to transfer water from a well, which is below ground, to a bucket or some other means of storage, above the ground.

The **piston** is connected to a **shaft**, located inside the main body of the pump, providing enough suction to overcome the effects of gravity, effectively drawing water into the main body. Once the water has made its way into the pump and is trapped by the **foot valve**, the piston on its downward stroke allows the water to travel through its large inner hole and past a one-way valve located on top of the piston, the **one-way valve** then seals the water above the piston and the upwards stroke begins, lifting the water up until it escapes out of the **PVC junction's** side exit.

### Applications :

- They are commonly used in rural areas to withdraw groundwater for daily needs due to shortages and difficulties in delivering the river water to every village.

- The hand-operated water pump is also widely used for agricultural purposes.
- It is one of the most economical and simple solutions for providing a collective drinking water supply in rural areas.

### **Approximate Cost :**

Market Cost - INR 1800/-

Link : <https://www.indiamart.com/proddetail/plastic-hand-pump-11836523612.html>

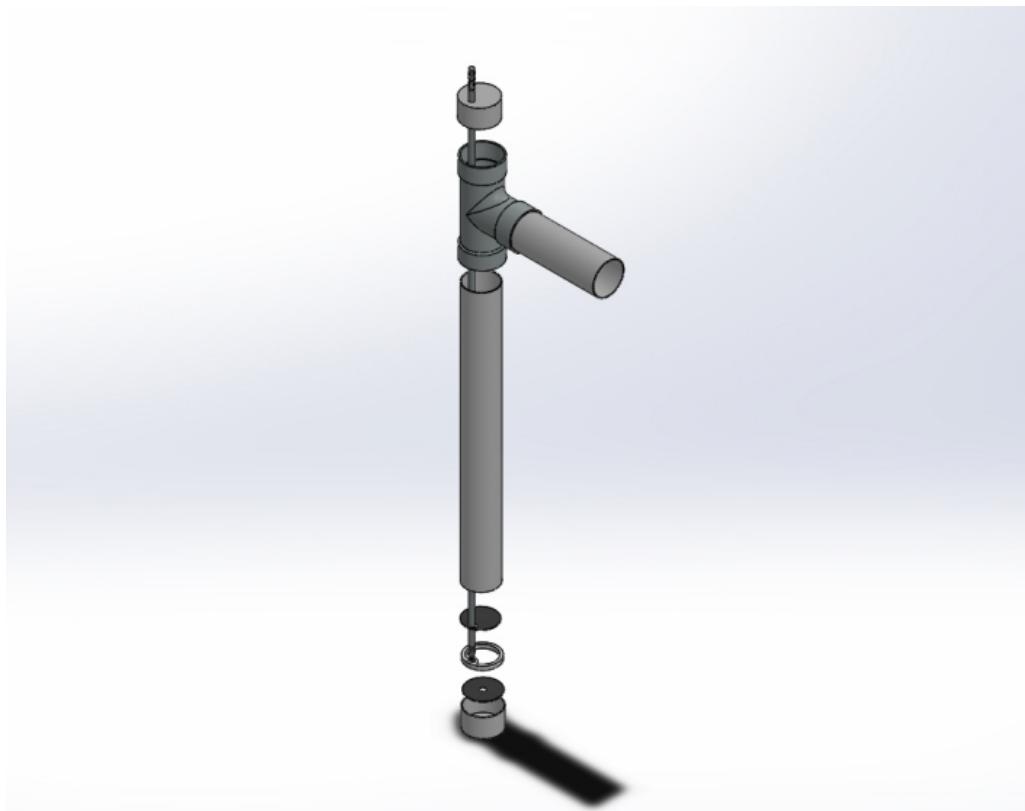
### **Role of Team Members :**

1. Swapnoneel Kayal - Materials and Process Selection, Cost Analysis, Documentation
2. Amshuman Sashi - Design, Components, Assembly, Final Inspection
3. Rohit Sankhala - Equipment Required for Manufacturing & Finishing

## Stage - 3

### Design Consideration :

The **piston** is connected to a **shaft**, located inside the main body of the pump. A one-way valve is located on top of the piston. A **PVC junction** is located on top of the main body serving as a side exit for the water. The **Foot Valve** is attached to the bottom of the pump. The **cap** seals the top of the pump.



The hand pump can be broken down into six main components required for an efficient transfer of water.

These components are as follows :

- Main Body :
  - A cylindrical barrel is used since round pipes are the most efficient shape (largest volume to surface area ratio).
  - Any other pipe would require more energy to pump water due to more surface area to drag on. Also, standard fittings would not work in case of

- any arbitrarily shaped pipe.
- For example, a square pipe would need to have thicker walls in comparison to a round pipe to hold the same pressure hence making it more expensive and heavier.
- Foot Valve :
  - This needs to be cylindrical since it is connected at the bottom of the main body which is also cylindrical
- Piston :
  - The piston located inside the main body of the pump is required to be cylindrical as the main body is also cylindrical.
- Shaft :
  - Shaft is a long rod of any arbitrary shape which is connected to the piston. We prefer cylindrical for ease of work.
- PVC Junction :
  - PVC junction is a rod of 'T' shape for the ease of exit of water. It is connected to the upper part of the main body.
- Cap :
  - Cap seals the top of the pump which has a small hole, for the shaft to pass through.

## **Components :**

### **Main Body :**

The main body is a simple but critical component of the pump. Its main function is to provide water a smooth path to travel up. Additionally, it joins most of the components together. The foot valve is connected at the bottom, the piston traverses up and down within the main body and the PVC junction is fixed at the top.

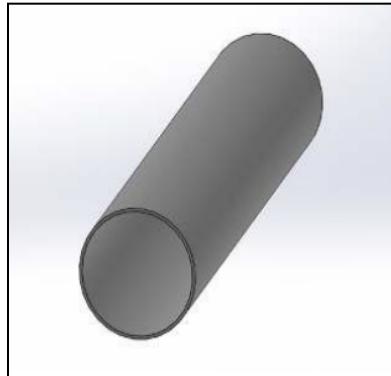
The accuracy of this particular component is not that important in comparison to other parts as adhesives like glue can be used to help seal any holes that exist between joints and rubber seals are used for the piston. Regardless, a more accurate component will always be more efficient than an inaccurate component.

We also would like to have a smooth internal surface. This ensures that the seal will be with the piston nicely and guarantees less water turbulence, hence further improving efficiency.

The main body will be the one that will have to bear with almost all of the frictional forces that will be exerted on the hand pump hence it needs to be strong enough to be

able to resist these forces for the short time it will be used.

Material selection of the main body would need to be done in such a way that a very minor amount of wear is experienced.



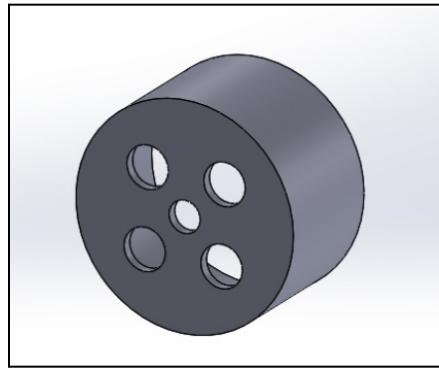
#### Foot Valve :

The main functionality of the foot valve would be to provide a single way valve for water to enter the main body of the pump. This is an extremely important component of the hand pump since an improper seal at the bottom of the pump will significantly reduce the efficiency of the pump. The resulting loss of water increases exponentially as the distance the water has to travel increases. This is because there is more pressure being applied to the foot valve as a result of gravity, but this added pressure on the foot valve will also help to maintain a proper seal.

The foot valve would also use a flexible piece of rubber placed inside the PVC cap, the PVC cap has five holes drilled into it, the four outer holes allow the water to flow into the main body of the pump when the suction is sufficient enough to overcome the effects of gravity. The inner hole in the cap will be used to hold the rubber seal in place. When the suction is sufficient (upward stroke) water would push the rubber seal out of the way and enter the main body of the pump, and when the suction is released (downward stroke) the pressure of water along with the elasticity of the rubber material would push the rubber downward with enough force in order to seal the four inlet holes.

The accuracy of this particular component is not that important in comparison to other parts as adhesives like glue can be used to help seal any holes that exist between joints.

The smoother the internal surface and accurate the cylindricity of the hole is, the lesser the water turbulence hence further improving efficiency.

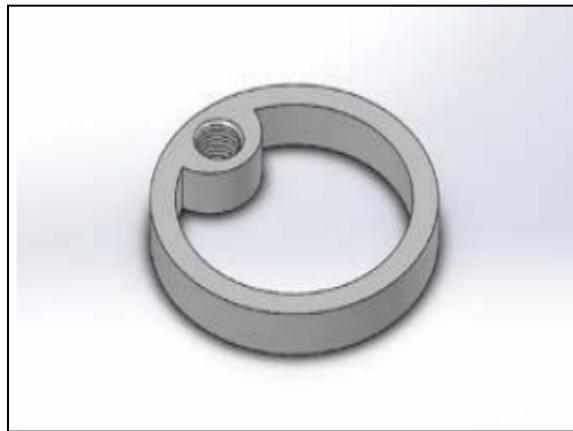


**Piston :**

The piston's role in the pump is to provide enough suction to overcome the effects of gravity while effectively drawing water into the main body of the pump. This water is trapped by the foot valve. The piston on its downward stroke allows the water to travel through its large inner hole and past a one-way valve located on top of the piston, the one-way valve then seals the water above the piston and the upwards stroke begins, lifting the water up.

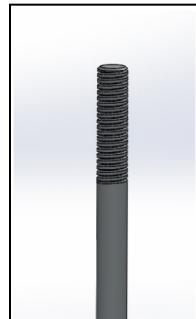
The piston doesn't require any supplementary lubrication as the water does this as well as cools the pump from the heat caused by the minor friction between the piston and main body.

The accuracy of this component is crucial, too large of a gap between the piston and main body will result in no water being pumped. Too small of a gap and the piston will get jammed resulting in pump failure



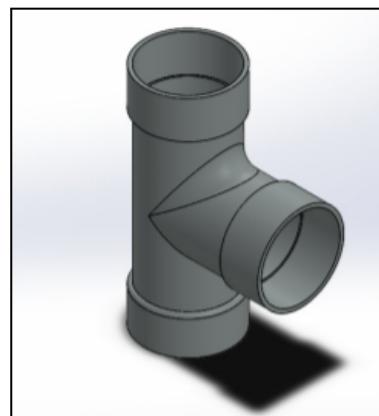
**Shaft :**

The shaft is the component that transfers the input movement to the piston. The shaft undergoes very little stress as it is only being moved up and down by the test apparatus at a slow rate.



#### PVC Junction :

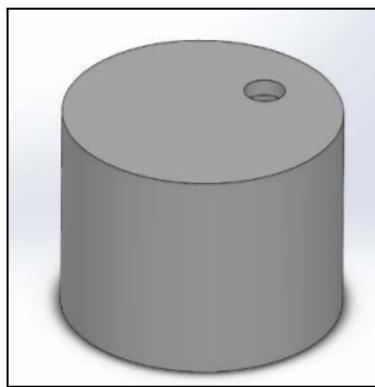
The PVC junction is a stationary part of the pump and role of the junction it to allow the water to exit the pump from the side, this allows for much easier transfer from the pump to the water storage device in comparison to allowing the water to just flow out the top, as this would cause a large amount of spillage and therefore wasted water, time and energy. It undergoes little to no stress, the only minor amount of stress would come from flexing in the pump.



#### Cap :

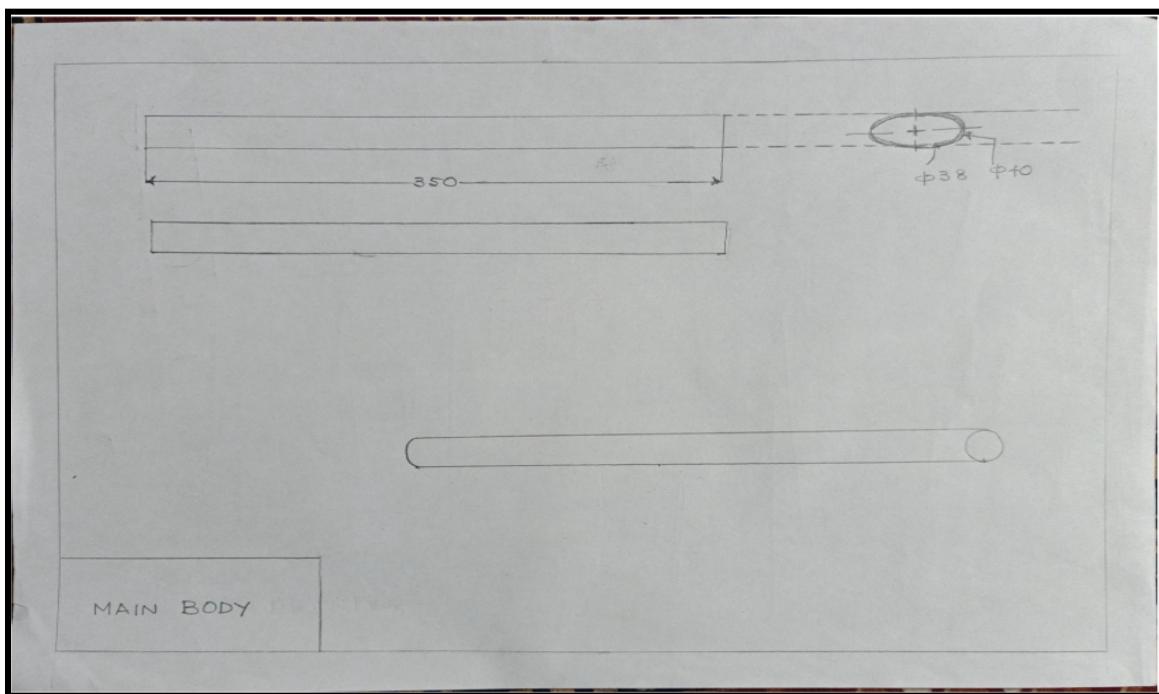
The role of the cap is to seal the top of the pump to ensure no time, water or energy is wasted while pumping. The small hole in the cap is offset for the piston to maintain a straight line of movement for the piston thus reducing the possibility of the piston running on an angle resulting in damage to the pump. The hole in the cap undergoes the

most friction in the pump as it isn't in constant contact with water like other components, however the water keeps the rod lubricated enough to ensure minimal wear. The rod has a smooth finish, this also helps to keep wear to a minimum on the cap. Plus given the short life of this component it would never wear down enough to result in failure of the pump.

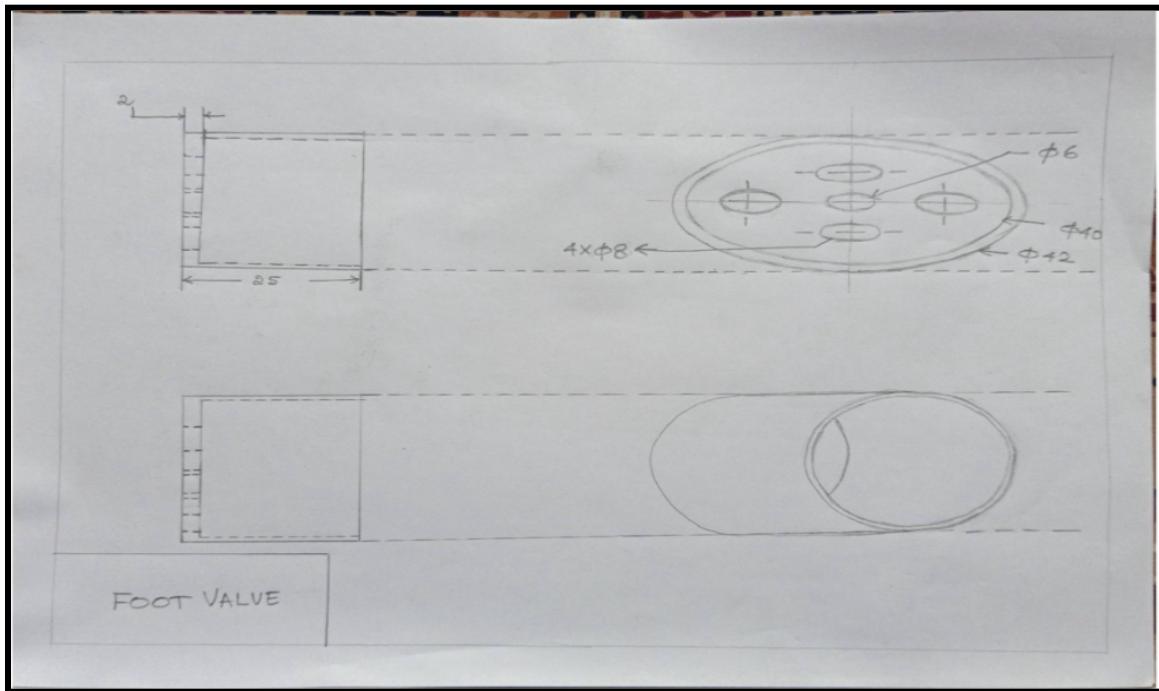


## Engineering Drawings :

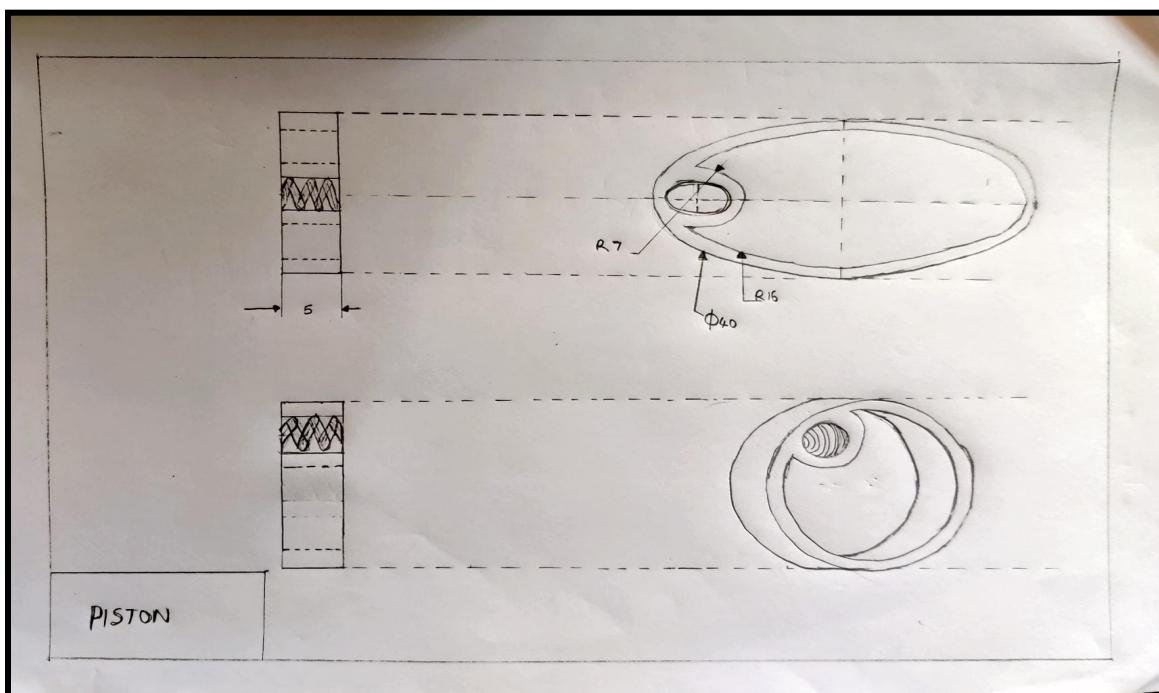
Main Body



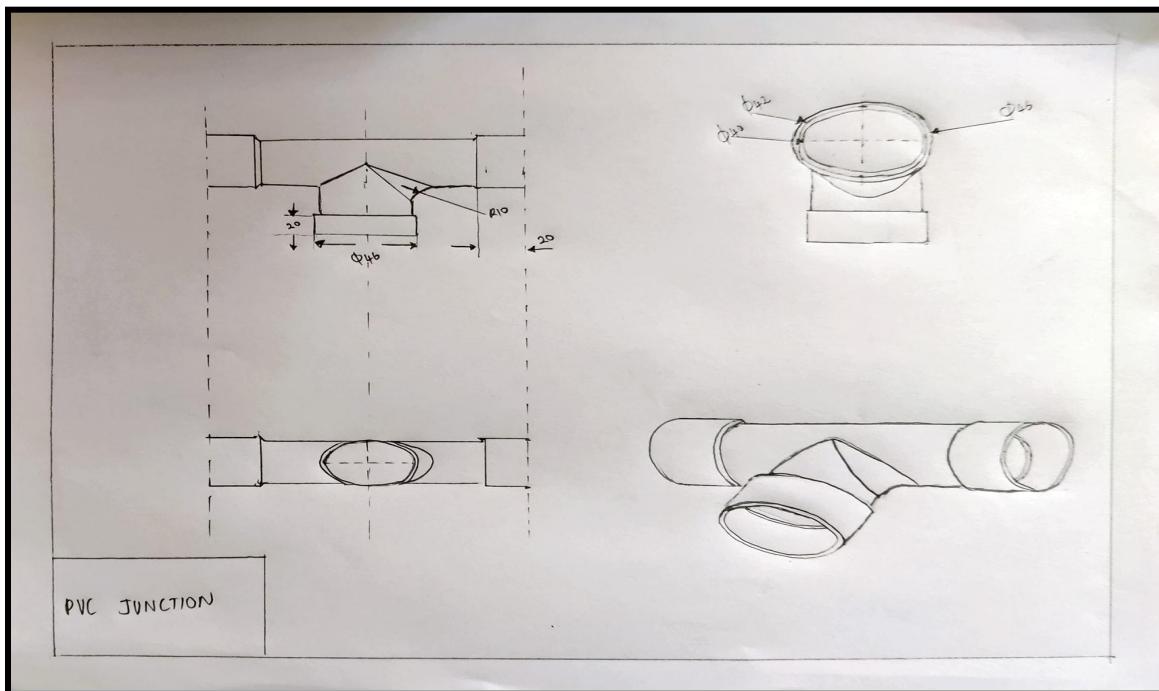
Foot Valve



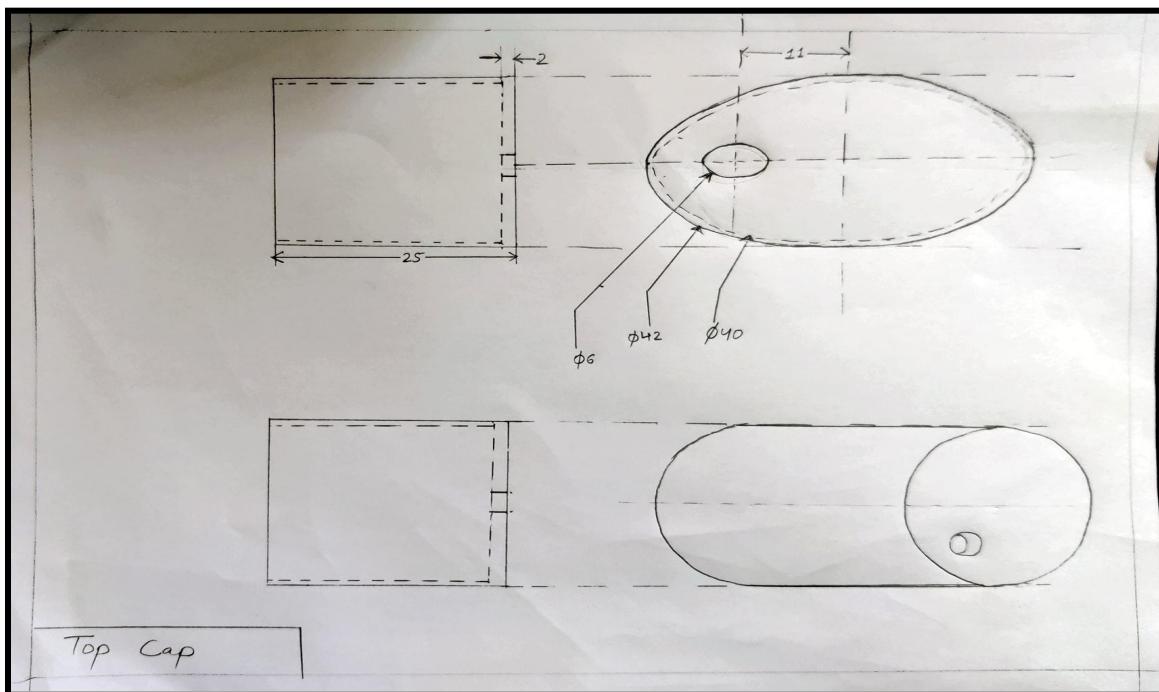
Piston



PVC Junction



Top Cap



## Stage - 4

### Materials:

Different materials were chosen for different components since the mechanical and physical requirements of each and every component varied in accordance to their functionality.

#### Main Body :

##### Material Used : PVC Pipe

The selection for PVC pipe was majorly governed by the fact that it is extremely cheap, something that is easily available, easy to work with and strong enough for the application. One major disadvantage of using PVC is that it tends to have poor cylindricity, meaning that the piston can be tight in some locations and loose in others thus, making it difficult to produce a highly efficient pump.

##### Alternate Material : Aluminum Tube

Aluminum tube turns out to be a good candidate for an alternate material because it is a much stronger material and has better cylindricity. In comparison to the PVC pipe, it also has increased hardness thus providing a higher resistance to scratching. Some disadvantages of using aluminum tubes include the cost, and this cost not only includes the cost of the material but also the cost of the tools required to machine the material which is much greater in the case of an aluminum tube.

##### Comparison : PVC Pipe v/s Aluminum Tube

#### Key :

	Better for application	Worse for application
Cost		
Strength		
Hardness		
Cylindricity		

Workability		
Accessibility		

#### Final Verdict :

Pumps generally have a short life, hence the lack of strength and hardness in the PVC pipes in comparison to aluminum tubes is not really a huge issue because the PVC pipe would not be used for that long to have adverse effects on the efficiency. Hence, using an aluminum tube for its superior physical and mechanical properties does not justify the increased cost especially when both the PVC pipe and aluminum tube can do the job expected from them equally well.

#### Foot valve :

##### Material Used :

- PVC end cap: The selection of PVC end cap was majorly governed by the fact that it was a cheap component, easily accessible, easy to work with and strong enough for application and something that could easily fit on the PVC pipe.
- Rubber seal: Rubber was selected as a component of the foot valve due to its elasticity.
- Plastic nut & bolt: Plastic nut & bolt were chosen as the joining components for the foot valve due to their low price.
- Rubber O-ring: The rubber O-ring was chosen to seal the small gap left between the hole and the bolt that attaches the rubber seal to the foot valve because it was a cheap, quick and an effective way of preventing the escape of water.

##### Alternate Material :

- Aluminum: Aluminum being a much stronger material than PVC naturally comes out to be a good candidate for an alternative material for the PVC end cap. However, the cost which does not only include the cost of the material but also the cost of the tools required to work on the material is much greater in the case of an aluminum tube.
- Leather seal: Leather has similar mechanical and physical properties that are required for a good seal. It can be used as an alternative material to the rubber seal as it is also waterproof, elastic and easy to work with. However, it is not as cheap as rubber and does not spring back to its normal state as efficiently as the rubber does.

- Rivet: A good substitute for the plastic nut & bolt would be rivet as they are quick and easy to install. However, they are very hard to uninstall.
- Glue sealant: A good alternative to the rubber O-ring would be to use a glue sealant because it has a higher strength and sealing ability. However, it is more expensive, difficult to use and hard to acquire in comparison to the rubber O-ring.

**Comparison : PVC Cap v/s Aluminum Cap**

	PVC Cap	Aluminum Cap
Cost	Green	Red
Strength	Red	Green
Hardness	Red	Green
Cylindricity	Red	Green
Workability	Green	Red

**Comparison : Rubber seal v/s Leather seal**

	Rubber seal	Leather seal
Cost	Green	Red
Strength	Red	Green
Elasticity	Green	Red
Workability	Green	Red

**Comparison : Plastic nut & bolt v/s Rivet**

	Plastic nut & bolt	Rivet
Cost	Red	Green
Strength	Green	Red
Ease of use	Green	Red
Suitability	Green	Red

**Comparison : Rubber O-ring v/s Glue sealant**

	Rubber O-ring	Glue sealant
Cost	Green	Red

Strength		
Ease of use		
Accessibility		
Sealing ability		

#### Final Verdict :

- The extra strength and hardness of aluminum does not outweigh the comparative lesser cost of the PVC end cap, and it is also faster and easier to produce a PVC cap strong enough for the required application.
- As only a small amount of force is applied to the seal, hence the added strength is not as important when compared to the elastic property which is way better in the rubber seal. So, the rubber seal was deemed more suitable.
- Due to the amount of pressure the river applies on the rubber seal, it is not that useful for this application. The plastic nut in comparison is a quicker and easier option that provides better results.
- The rubber O-ring was chosen over the glue sealant due to its ease in removal and lesser cost.

#### Piston :

##### Material Used : Plastic

Plastic was opted to be the primary choice of material for the piston. Plastic has a high strength to size ratio, which is highly favorable for the design of the piston. As the thickness of the piston decreases, the lesser will be the distance the water has to travel to make it on top of the piston which is where it is needed to be in order to make it out of the pump. This piston also has a very large opening to allow the water to flow through the piston, also resulting in less support. The main advantage of using plastic would be its ease of use to lessen the time consumption.

##### Alternate Material : Aluminum

Aluminum would also be a great alternative for this component. When it comes to strength, aluminum has the upperhand over plastic but then it would take a longer time to create the piston and because of plastic's strength we deemed it to be more suitable for the application than aluminum.

### Comparison : Plastic v/s Aluminum

	Plastic	Aluminium
Cost	Green	Red
Strength	Red	Green
Workability	Green	Red
Suitability	Green	Red

### Final Verdict :

As plastic takes a lesser amount of time to create the piston and due to the cost advantage it has over aluminum, it was chosen to be more suitable for the application.

### Shaft :

#### Material Used : Aluminum

Aluminum was our first preference as it is sufficiently strong for the application of a shaft and is also easy to work with.

#### Alternate Material : Plastic

Plastic rod would also serve to be a good alternative as it would make a good sacrificial component and allow us to make the pump with a much tighter tolerance. It is also lot easier to work with than aluminum.

### Comparison : Plastic v/s Aluminum

	Plastic	Aluminum
Cost	Green	Red
Strength	Red	Green
Workability	Green	Red
Suitability	Red	Green

**Final Verdict :** As aluminum rod is stronger than plastic and is also easy to work with, aluminum was chosen to be the material for the shaft.

#### **PVC Junction :**

##### **Material Used :** PVC

The selection for PVC junction was majorly governed by the fact that it was the quickest and the simplest solution as there is almost no stress or strain on this component and therefore, the PVC junction is more than capable of doing the job. This component can be easily attached and removed and this makes it the perfect option.

##### **Alternate Material :** Hose

A piece of hose would be a good alternative to the PVC junction due to the fact that one can angle it downward towards the measuring scale, therefore shortening the start time of the pump, however it would be a very complex task to try and attach it to a piece of pipe. Another disadvantage would be the cost as one would have to buy the hose in large lengths and then cut it down.

##### **Comparison :** PVC junction v/s Hose

	PVC junction	Hose
Cost		
Strength		
Elasticity		
Workability		

#### **Final Verdict :**

The PVC junction is something that can be easily attached and removed when compared to a hose where the process of attaching becomes a complex task and also due to PVC's cost advantage, using PVC junction for the application makes more sense than the hose.

**Cap :**

**Material Used :** PVC

The selection of a PVC end cap for the top cap of the pump was governed by the fact that it is easy to work with, elastic and cost-friendly.

**Alternate Material :** Aluminum

An aluminum cap can also do the job that a PVC cap can but it would not be easy to work with and it is also very expensive.

**Comparison : PVC v/s Aluminum**

	PVC	Aluminum
Cost		
Strength		
Elasticity		
Workability		

**Final Verdict :**

Since aluminum is a stronger material in comparison to PVC, it would not be easy to work with and PVC is also relatively cheaper so, using PVC felt like a more natural fit for the application than aluminum.

## **Process Selection:**

**Cutting**

- **Cutting PVC and plastic :**
  - A cold saw would be suitable to cut PVC into the correct size for each component.
  - The cold saw was chosen for cutting the PVC pipe due to the low tolerance requirement in the areas it was cutting.
  - Another alternative would be to cut it by hand. This process would be a lot harder to maintain a square cut though, as well as requiring a lot more effort.



Industrial Cold Saw

References : <https://www.ubuy.co.in/product/1HADGVS20-baileigh-cs-350sa-heavy-duty-semi-automatic-cut-off-cold-saw-3-phase-220v-4-3hp-motor-14-blade-diameter>

- **Cutting of metal :**

- The metal shaft used for connecting the piston to the testing apparatus would be cut using a pipe cutter.
- An alternative would be to use a saw, but the finish wouldn't have been as good and would have required more processing to clean up.



Pipe Cutter

References : <https://www.amazon.com/QWORK-Heavy-Cutter-1-inch-3-inch/dp/B07ZYLWDPL>

## Drilling

- **Battery Drill :**
  - A battery drill would be used to cut the holes in the PVC for the top cap and in the foot valve.
  - The correct drill bit size was then chosen based on the size of the hole being cut, as we were only cutting small holes, drill bits were used, if we needed to cut larger holes than what we did we may have needed to use a hole saw instead.
  - An alternative tool to the battery drill would be a drill press. The drill press would be a better alternative to the battery drill as it ensures a square hole, which would further help to reduce turbulence within the pump.



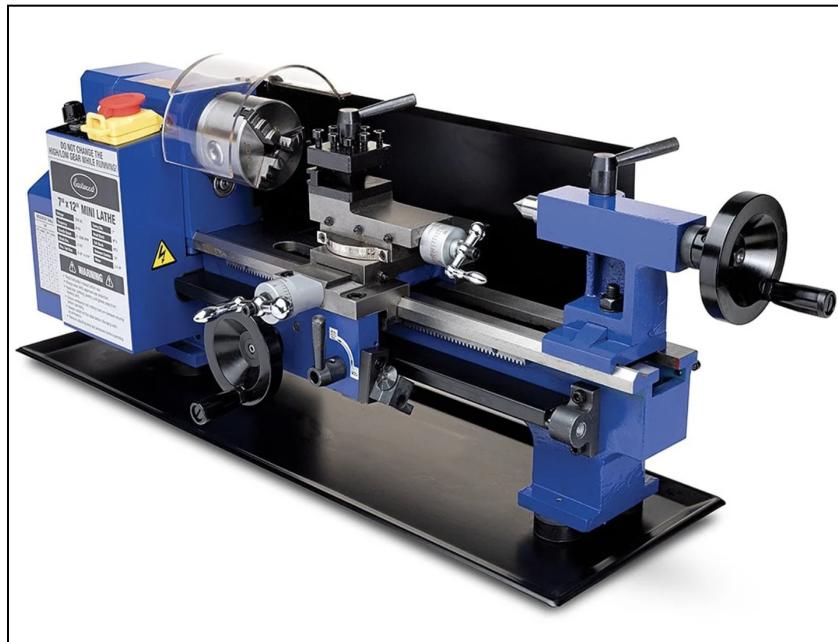
Battery drill

References : <https://www.indiamart.com/proddetail/cordless-drill-14664403691.html>

## Turning

- **Lathe :**
  - A lathe would be used to turn the piece of plastic which would later be used for our piston.
  - The reason we chose to use a lathe was because in most of the practical cases, we have to buy an oversized piece of plastic which then needs to be

- cut appropriately so that it fits inside the main body.
- The lathe was thought as a good option for this as it would cut the component into the perfect circle at the perfect size, even given the tight tolerances of the component.
  - The next best option I believe would've been to 3D print our piston. 3D printing would've been very accurate also but would've taken longer to design in Solidworks and then print given how much infill we would've had to use to make the component solid enough to withstand the task it was designed to do.



**Metal Lathe**

References : <https://www.frost.co.uk/eastwood-benchtop-mini-metal-lathe-7-x-12/#&gid=1&pid=1>

### Cutting thread

- Tapping:
- This process would involve pre-drilling the holes out to correct size, then a tap would be used to cut the thread into the hole by slowly twisting it down to the desired depth. Tapping would be used to attach the piston to the rod holes so the two components could be screwed together.
- An alternative would be to use a gluing process accompanied with a snug fit to the drilled hole, but it couldn't be removed to swap out parts so the

piston, seal and rod would all have to be replaced if anything went wrong.



Tap Bit

References : <https://www.kmstools.com/blog/hand-taps-proper-tapping-techniques/>

- Die cutting:
  - Die cutting would be used to provide the thread required to attach the piston to the rod and the rod to the testing apparatus. The reason thread would be cut is because it provides sufficient strength and makes parts easily removable, which is really helpful in the occurrence that something broke.
  - An alternative would be to use a CNC machine to remove the undesired material, however, these machines are extremely expensive to buy, run and maintain.



Die cutter

References : <https://www.exportersindia.com/product-detail/tool-masters-india-thread-cutting-dies-1749815.htm>

## Stage - 5 :

### Manufacturing:

#### 1. Production process for PVC pipe and PVC junction

PVC pipes are first and foremost produced through an **extrusion process**.

Extrusion is a low-cost process. It results in reduced wastage and a high production rate.

- The raw material is fed into the **extruder** via a hopper and a gravimetric or volumetric control system.
- Inside the extruder barrel the material is heated up to the melting point of around 200°C by electricity and the friction in the screw system.
- The melted material is pushed through a cavity, called a die-head and the molten pitches are set to create desired shapes and sizes.

#### 2. Production process for rubber seal

For the production of synthetic rubber seals, there is a wide variety of production methods of which the most widely used is **mould technology**. The most elementary form and also an example of a mould is the toasting iron. The product that takes the shape of the cavity of the toaster goes in between the bottom plate of metal and the top plate of metal.

#### 3. Production process for Plastic nuts & bolts

Most efficient way to produce plastic nuts and bolts would be the **plastic injection molding** process. Plastic injection molding is the process of melting plastic pellets (thermosetting/ thermoplastic polymers) that once malleable enough, are injected at pressure into a mould cavity, which fills and solidifies to produce the final product.

#### 4. Production process for Rubber O-ring

**Injection molding** is a manufacturing process that's used to create Rubber O-rings. It involves injecting raw material into a mold cavity. The raw material typically comes in the form of pellets. The pellets are heated, after which the newly liquified material is injected into a mold cavity.

## 5. Production process for Plastic Pistons

- To produce the pistons from plastic, **injection molding** process is used. The injection molding machine can be used to make pistons from waste plastic, such as broken plastic garden chairs.
- In injection molding process, the mold is loaded into a plastic injection molding machine where the process is performed. A hopper holds thermoplastic pellets, which are fed into the barrel of the machine.
- Friction between the rotating screw and barrel melts the pellets. After the mold is closed, the rotating screw then advances a preset distance injecting a prescribed volume of the molten plastic into the mold cavity under high pressure . Once the material enters the mold, it begins to cool and solidify to conform to the shape of the piston.
- Holes were then tapped into the piston using a battery drill so that it serves as a connection with the shaft.

## 6. Production process for Aluminium Shaft

One of the common ways that aluminum rods are manufactured is through the process of **extrusion**. In extrusion,

- An aluminum bar is made by pushing the material through a die that is under pressure. As the aluminum is pushed through under pressure, the desired shape of the rod is obtained.
- The extruded aluminum shapes are cooled and after cutting we obtain the final product.
- Die cutting process was used to provide the thread required to attach the piston to the rod on the rod.

## 7. Production process for PVC end cap

- For producing PVC end caps, an extrusion process is used. In which the raw material is fed into the **extruder** via a hopper and a gravimetric or volumetric control system. Inside the extruder barrel, the material is heated up to the melting point of around 200°C by electricity and the friction in the screw system. The melted material is pushed through a cavity, called a die-head, and thereby formed into a pipe.
- Then holes are drilled into it by the use of a battery drill.

## **Finishing/Coating:**

### **1. Filing**

Filing is a material removal process in manufacturing. It is used for finishing operations, namely in deburring operations. Filing operations can be used on a wide range of materials as a finishing operation.

In filing operation, the circular file would be used to shape the region in the piston in which water flows through the piston. The reason a circular file would be used is because it helps to provide a circular profile on the edge, whereas a flat file would potentially have small indents in the piston if one area is overworked. The file makes use of shear force to remove mass from the object, we use a file with only small teeth to ensure not too much mass is being removed with each stroke, making it easier to achieve the desired shape.

### **2. Deburring Tool**

Deburring is the process of removing the small imperfections known as burrs from machined metal products. It would be used to clean edges after procedures like drilling and filing would be done using a deburring tool. The tool works by slicing off a small amount of unwanted material on edges and it would be used all throughout the production of our hand pump. The tool is a small hand tool that you simply run along the edge with burrs applying a minor amount of force, if too much force is used the tool will cut into the edge at a greater depth than desired.

### **3. Coating in PVC Components**

Coating in the PVC material would be used to protect the components of the hand pump from water and environmental damages. There are two coating techniques to coat the PVC parts without destroying them.

- Two Coat Finish- It consists of a waterborne primer topcoated with a compatible epoxy or polyurethane enamel in the color of your choice.
- One Coat Finish- It consists of a water-reducible epoxy or water-reducible polyurethane enamel.

### **4. Aluminum Anodizing Process**

Aluminum anodizing is an electrochemical process that converts the metal

surface into a decorative, durable, corrosion resistant, anodic oxide finish. It would be used to protect the shaft from damages since it is made up of aluminum material, it provides corrosion resistant in aluminum material.

**Cleaning**- The surface of the aluminium product needs cleaning prior to anodising. Exposing the surface uses acidic or alkaline cleaning agents to clean grease/dirt from the surface.

**Pre-treatment**- This step eliminates any surface imperfections. The goal is to provide a visible finish with a clean and smooth surface. This is done by using two main processes – brightening and etching.

**Brightening**- Brightening or bright finishing cleans any heavy metal residues left over from the cleaning process. Using a concentrated mixture of nitric and phosphoric acids to chemically smoothen the surface provides a metallic finish ready for anodising.

**Etching**- Etching removes a layer of aluminium from the product surface to provide a matte finish. A hot solution of sodium hydroxide is used to remove surface imperfections.

**Anodising**- After pretreatment, the product is ready for anodising. As mentioned above, sulfuric acid is the go-to electrolyte for aluminium anodising. Alternatives that are sometimes used are organic acid, borate, tartrate, phosphoric acid, and chromic acid.

**Colouring**- There are several methods to add colour to anodised aluminium. Different colours need different methods. Let's look at two of the most popular methods of colouring anodised aluminium.

**Electrocolouring**- One of these methods is the electrocolouring method. This method is used for darker shades. In electrocolouring, the anodised aluminium product is introduced to inorganic metallic salts through an electrolyte. The anodised aluminium product becomes one electrolyte, and graphite (or aluminium) becomes the other. The oxide or hydroxide precipitates in the pores adding colours such as black, brown, blue, yellowish grey, and bronze to the film.

**Dyeing**- Dyeing is the other popular method of adding colour to an anodised aluminium product. The pores that are formed during the electrochemical process readily absorb dyes or pigments. They fill the pores through the entire thickness of the aluminium oxide layer. Since the thickness of this layer can be up to 50

microns in some cases, this method is quite durable. Scratching or rough usage of the part doesn't affect the colour due to the layer's thickness. Also, the range of available colours is wide.

**Sealing**- Sealing is the final step in the aluminium anodising process. This prevents water leakage and improves corrosion resistance of the anodised aluminium product. There are three methods of doing this – hot method, cold or a combination of the two. Sealing reduces the chances of staining, scratching, colour degradation and crazing of the surface.

## Machines/Equipment:

### 1. PVC Pipe Extrusion Machine

The extrusion machines are used to manufacture solid products such as films, profiles, tubes, and monofilaments and in obtaining new materials or granular recycled devices. It will be used to manufacture the PVC pipe, shaft, and PVC cap. The extrusion machines have a hopper through which the shredded material and granules are fed. The materials fall by gravity through a cylinder heated by electrical resistances. At this stage of the process, the material goes through three zones: feeding, compression, and measurement. In the feeding zone, the tube has very deep grooves, since the intention is only to heat the material to a melting point and transfer it to the next zone. In the compression zone, there is a progressive decrease in the grooves, by compressing material against the cylinder walls, which promotes its plasticization. Finally, in the measurement or dosing area as it is called, the material is pushed against steel screens that retain impurities such as metals and rubber residues, and then passes to a matrix where the final product will be formed. Extrusion is a low-cost process due to reduced wastage and a high production rate.

### 2. Cold Saw Machine

A cold saw is a machine designed to cut metals and other materials by using a circular toothed blade to remove material. It will be used to cut the PVC pipe into the correct size for each component. In cold saw process action transfers the heat generated by friction into the chip thereby allowing both the blade and material being cut to remain cool, thus the term "Cold Saw". These saws use either solid high-speed steel (HSS), tool steel (M2, M35, etc.), or carbide-tipped, resharpenable circular blades. They are equipped with an electric motor and quality industrial-grade saws offer a gear reduction unit to reduce the saw blade's

rotational speed for steady and precise cuts. This allows the saw blade to feed at a constant rate with a very high chip load per tooth.

### **3. Pipe Cutter**

A pipe cutter or tube cutter is a plumbing tool designed to cut pipes and tubing. Pipe cutters come in different shapes and sizes, and are often used by plumbers. It will be used to cut the metal shaft which will be used for connecting the piston to the testing apparatus. The pipe cutter made cutting the aluminum rod down to size accurately quick and easy. It squeezes the cutting blade up against the circular object and slowly rotates the pipe cutter around the object being cut, gradually tightening the cutting blade to make steady slow progress. A pipe cutter provides a cleaner cut and a good finish to a pipe.

### **4. Battery Drill Machine**

A battery drill machine is primarily used for drilling circular holes in the material, or for inserting screws and other threaded fasteners into the material. It will be used to cut the holes in the PVC for the top cap and in the foot valve. The process involves using a center punch to create a small dent in the PVC caps so that the drill bit wouldn't slip once it started to turn, it also helps to accurately mark the center of the hole. The correct drill bit size would be chosen based on the size of the hole being cut, as we would be only cutting small holes, drill bits would be used, if we need to cut larger holes then we would be using a hole saw. Once the holes have been drilled and they would be cleaned up using a deburring tool, this helps to reduce turbulence within the pump and increase efficiency.

### **5. Lathe Machine**

A lathe machine is a stationary cutting tool used primarily for shaping metal, which is referred to as workpieces. The lathe machine removes unwanted parts of the workpiece to produce the desired product. It will be used to turn the piece of plastic which would later be used for our piston. The piece of plastic we would be using for our piston will be placed in the lathe and a small cut would be made, the reason for the small cut is so we can measure the diameter of the plastic after the cut and work out how much more material needs to be taken off. The lathes dial indicator is zero at this point so we would be able to use it to move the lathe in and accurately make our next cut which would ultimately be the final size of our piston. The lathe is a good option for this process as it would make the component into the perfect circle at the perfect size, even given the tight tolerances of the

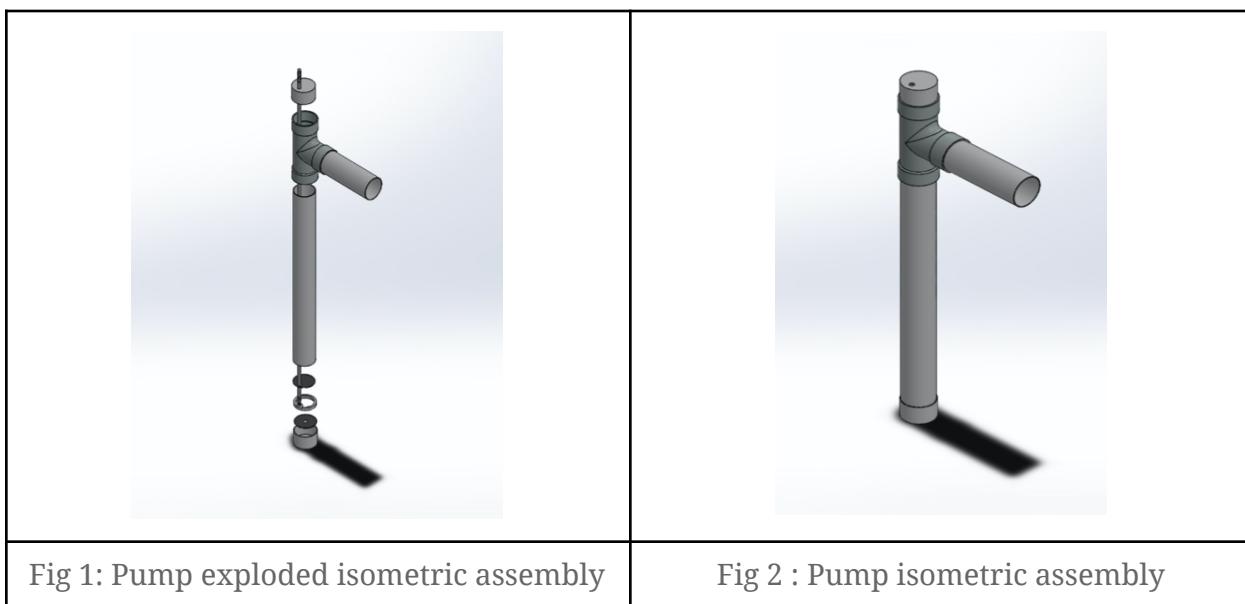
component.

## 6. Bench Vice

A bench vice is used to hold a workpiece stationary. It allows you to perform various operations like sawing and drilling when it is attached to the bench vice to hold a workpiece. It will be used to hold the hand pump components to perform cutting, sawing and drilling operations.

### Assembly:

- The piston rubber seal is placed on top of the piston. Then, one end of the shaft is placed on the piston and through the other end, the PVC pipe, the PVC junction, and the Cap are connected in the way shown in Fig 1.
- The flexible piece of rubber is then placed inside the foot valve i.e. PVC cap. The PVC end cap is directly connected at the bottom of the main body i.e. PVC pipe using plastic nuts and bolts. Finally, the rubber O-ring is used to seal the small gap left between the hole and the bolt that attaches the rubber seal to the foot valve.



### Inspection:

In order to make sure we end up with a high-quality product, we perform a large number of testing and measuring at every stage of production. Some of the main testing involved ensuring the thin size of our piston was up to the mark. This was done by

simulating the “jamming” by applying a reasonable amount of pressure on different regions of the piston. Proper inspection was performed and critical details were noted down during and after each and every process.

We also felt that there was a need to test the integrity of the materials that we had selected for making the pump. For example, we rubbed the plastic piston material against PVC with quite some force. This test was performed to simulate the dry start that is generally experienced by the pump in the testing apparatus. Since very minor scratches of less depth are generally observed hence to be on the safer side, we decided to apply vaseline between consecutive tests.

Other Inspections that are carried out:

- Weight checks - These are done at the end, where they are capable of precision weighting at required speeds. If a product is overweight, the checkweigher will instantly remove it from the line (reject the product) and alert the issue immediately, so one can address the problem before the line produces thousands of out-of-specification products.
- Dimensional checks - These are done for every part before assembly
- Visual Dent Inspections - These are done for preventing early failure and maintaining visual aesthetics.
- High Pressure Test - This is done in order to check if the main body can tolerate high pressures at even high temperatures. By high temperature, we consider the higher extreme of the operating temperature range.
- Cyclic Corrosion Testing (CCT) - This test consists of keeping the sample under different climatic conditions that are cycled automatically so that they undergo the same sort of changing environment that would be encountered in the natural world. The intention behind this test is to bring about the type of failure that might occur naturally, but more quickly i.e. accelerated.

## Stage - 6 :

### Cost Analysis :

Manufacturing time and labour cost for each manufacturing process

Process	Estimated Time (in minutes)*	Cost (in ₹)**
Cutting PVC and plastic	20	6.673

Process	Estimated Time (in minutes)*	Cost (in ₹)**
Cutting rubber	15	5.00475
Cutting metal	10	3.3365
Drilling	20	6.673
Turning	30	10.0095
Filing	15	5.00475
Tapping	10	3.3365
Die cutting	15	5.00475
Deburring	15	5.00475
Assembly of components	25	8.34125
<b>Total</b>	<b>175</b>	<b>58.38875</b>

\*Including setup and cleaning

\*\*At unskilled labour rate of ₹480/day or ₹0.33365/min

The total cost of labour for the manufacturing processes = ₹58.38875. However, this does not include the time spent designing the product (~8 hours). The total value for designing and manufacturing would be ~ ₹58.38875 + ₹160 = ₹218.38875

#### Equipment Cost

Tools/Equipment	Cost (in ₹)
Cold saw	77445
Scissors	154.89
Pipe cutter	2065.2
Battery drill	7744.5
Lathe	77445
Round file	774.45
6mm Tap	413.04
6mm Die	619.56

Tools/Equipment	Cost (in ₹)
Deburring tool	1032.6
Bench vice	6195.6
Safety glasses	103.26
<b>Total</b>	<b>173889.84</b>

Equipment for the most part is a one-time purchase cost. However, things break, machines need maintenance etc. Also, the cost of each component was taken from online and by no means we claim it to be 100% accurate.

#### Material Cost

Component	Cost (in ₹)
Main Body	206.52
Foot valve	309.78
Piston	361.41
Shaft	77.445
PVC Junction	361.41
Cap	72.282
<b>Total</b>	<b>1182.327</b>

Total cost per pump (materials + labour) ~ ₹1240.71575. However, labour would decrease drastically if pumps were mass produced due to people getting better at their task. Materials would also become cheaper as they would be bought in bulk.

#### Materials List

Component	Amount
PVC Pipe	Ø40mm x 400mm
6mm rubber O-ring	X1
Plastic M6 bolt	X1
Plastic M6 nut	X1

<b>Component</b>	<b>Amount</b>
Reinforced rubber	10cm <sup>2</sup>
PVC cap	X2
Plastic	Ø50mm x 100mm
Aluminium rod	Ø6mm x 300mm
PVC junction	X1

### **Contribution :**

- Stage 1
  - Product Proposal - All
- Stage 2
  - Product Description - Rohit
  - Product Applications - Swapnoneel
  - Approximate Cost - Amshuman
- Stage 3
  - Design Consideration - All
  - Components
    - Main Body, Foot valve - Swapnoneel
    - Piston, Shaft - Amshuman
    - PVC Junction, Cap - Rohit
  - Engineering Drawings
    - Main body, Foot valve - Swapnoneel
    - Piston, PVC Junction - Amshuman
    - Top Cap - Rohit
- Stage 4
  - Materials
    - Main Body, Foot valve - Swapnoneel
    - Piston, Shaft - Amshuman
    - PVC Junction, Cap - Rohit
  - Process Selection
    - Cutting - Amshuman
    - Drilling, Turning - Swapnoneel
    - Cutting thread - Rohit
- Stage 5

- Manufacturing - Amshuman
  - Finishing/Cutting, Machines/Equipments - Rohit
  - Assembly, Inspection - Swapnoneel
- Stage 6
  - Cost Analysis - Swapnoneel
- Slides - Swapnoneel, Amshuman

## References :

Video reference:

- Mechanical Basics, Working of Hand Water Pump or Hand Operated Water Pump  
Link: <https://www.youtube.com/watch?v=gp4Ywytgpkk>  
Accessed on 9/8/2022

Web articles:-

- What is a Hand Pump? | How does a Hand Water Pump work? | Engineer Waqar  
Link : <https://mechanicalboost.com/hand-pump/>  
Accessed on 8/8/2022
- Hand pump  
Link:[https://en.wikipedia.org/wiki/Hand\\_pump](https://en.wikipedia.org/wiki/Hand_pump)  
Accessed on 8/8/2022
- What is a Hand Pump? | Ken Black  
Link:<https://www.aboutmechanics.com/what-is-a-hand-pump.htm>  
Accessed on 10/8/2022
- Advantages and Disadvantages of Hand Pumps | Fanny Foudja  
Link:<https://wikiwater.fr/e36-advantages-and-disadvantages#:~:text=The%20main%20advantage%20of%20hand.particular%C2%0falling%20into%20open%20wells>  
Accessed on 12/8/2022
- When to Use a Foot Valve  
<https://www.pvcfittingsonline.com/resource-center/when-to-use-foot-valves>  
Accessed on 09/09/2022
- What is a Hand Pump? Definition, Parts, Working, Applications  
<https://www.mechstudies.com/what-hand-pump-definition-parts-working-applications/>  
Accessed on 09/09/2022
- Are square pipes better than circular pipes for groundwater pumping?  
<https://www.quora.com/Are-square-pipes-better-than-circular-pipes-for-groundwater-pumping>  
Accessed on 10/09/2022
- Hand Pump: Types, Components, Mechanism & Working Principle  
<https://engineeringlearn.com/hand-pump-types-components-mechanism-working-principle/>

Accessed on 08/09/2022

- How do hand-pumped tube wells work?

<https://www.quora.com/How-do-hand-pumped-tube-wells-work>

Accessed on 08/09/2022

- Hand pump

Link:[https://en.wikipedia.org/wiki/Hand\\_pump](https://en.wikipedia.org/wiki/Hand_pump)

Accessed on 10/9/2022

- 3 Way Fitting

Link: <http://www.polyvinpipe.com/3-way-fitting-5657447.html>

Accessed on 10/9/2022

- Best Pipe for Air Compressor Lines: Aluminum Pipe Vs. PVC Pipe

Link: <https://aluminumairpipe.com/pipes/aluminum-pipe-vs-pvc-pipe/#:~:text=The%20biggest%20advantages%20of%20using,a%20wide%20range%20of%20environments>

Accessed on 17/09/2022

- what thickness between PVC panel and aluminum composite panel

Link:<https://www.der-acp.com/what-thickness-between-PVC-panel-and-aluminum-composite-panel-.html>

Accessed on 17/09/2022

- Why Leather

Link:<http://cwmarsch.com/why-leather/>

Accessed on 18/09/2022

- When to Use a Foot Valve

Link:<https://www.pvcfittingsonline.com/resource-center/when-to-use-foot-valves/>

Accessed on 18/09/2022

- Leather seals and bushings

Link:<https://www.continentaltrade.com.pl/leather-seals-and-bushings>

Accessed on 18/09/2022

- FASTENERS 101™ Types of Fasteners

Link:<https://www.albanycountyfasteners.com/Fastener-Varieties-s/1130.html>

Accessed on 18/09/2022

- Types of Rivets: A Guide to Rivet Types and Their Common Uses

Link:<https://www.rapiddirect.com/blog/types-of-rivets/>

Accessed on 18/09/2022

- Plastic Bolts

Link:<https://www.electronicfasteners.com/plastic-bolts/>

Accessed on 18/09/2022

- O-ring

Link:<https://en.wikipedia.org/wiki/O-ring>

Accessed on 18/09/2022

- O-Rings  
Link: <https://www.iqsdirectory.com/articles/o-ring.html>  
Accessed on 18/09/2022
- Everything You Need To Know About Seals  
Link : <https://uk.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/o-rings-and-seals-guide>  
Accessed on 18/09/2022
- Bonded Rubber Piston  
Link : <https://www.saigagroup.com/product/bonded-rubber-piston.html#:~:text=The%20piston%20rubber%20and%20valve.working%20temperature%20range%20of%20rubber>.  
Accessed on 18/09/2022
- Why PVC junction is better than Hose  
Link : <https://www.gz-supplies.com/news/difference-between-hoses-and-pipes/>  
Accessed on 24/09/2022
- The Difference Between Plumbing PVC and Electrical Conduit PVC  
Link : <https://www.commercial-industrial-supply.com/resource-center/difference-between-plumbing-pvc-and-electrical-pvc/>  
Accessed on 24/09/2022
- Circular Cold Saw - Revolution Of Engineering  
Link : <https://www.kaltenbach.com/en/media/talking-steel/circular-cold-saw-revolution-of-engineering/#:~:text=Circular%20cold%20saws%20offer%20high.production%20runs%20and%20repetitive%20projects>.  
Accessed on 24/09/2022
- A Complete Guide to Pipe Cutters  
Link : <https://ph.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/pipe-cutters-guide>  
Accessed on 24/09/2022
- Top 5 Uses for Cordless Drills  
Link : <https://www.overstock.com/guides/top-5-uses-for-cordless-drills>  
Accessed on 25/09/2022
- Why is die cutting better for PVC?  
Link : <https://tombrowninc.com/blog/understanding-material-selection-die-cutting-methods/>  
Accessed on 25/09/2022
- Learn How To Use A Tap and Die Set for Thread Cutting  
Link : <https://tameson.com/tap-die-set.html>  
Accessed on 25/09/2022
- Aluminum Pipe Compared to PVC Pipe  
Link : <https://airpipeusa.com/compressed-air-news/aluminum-pipe-compared-pvc-pipe>  
Accessed on 25/09/2022
- What Can You Use a CNC Lathe For?  
Link : <https://hwacheonasia.com/cnc-lathes/#:~:text=A%20CNC%20lathe%20machine%20is,their%20needs%20in%20different%20industries>.  
Accessed on 25/09/2022
- A Beginner's Guide on How to Use a Cordless Drill

Link : <https://ronixtools.com/en/blog/guide-on-how-to-use-a-cordless-drill/>

Accessed on 26/09/2022

- What is Turning?

Link : <https://www.mmsonline.com/articles/machining-101-what-is-turning>

Accessed on 26/09/2022

- Production Processes

Link : <https://www.teppfa.eu/benefits-of-plastic-pipes-and-fittings/production-processes/>

Accessed on 08/10/2022

- Injection moulding

Link : [https://en.wikipedia.org/wiki/Injection\\_moulding](https://en.wikipedia.org/wiki/Injection_moulding)

Accessed on 08/10/2022

- Production processes

Link : <https://www.ndsseals.com/production-process/>

Accessed on 08/10/2022

- The Top 4 Manufacturing Processes for O-Rings

Link : <https://monroeengineering.com/blog/the-top-4-manufacturing-processes-for-o-rings/>

Accessed on 09/10/2022

- Production of pistons

Link : <https://www.wot.utwente.nl/en/demonstration-site/water/hand-pumps/rope-pump/production-of-pistons>

Accessed on 09/10/2022

- Aluminum

Link : <http://www.madehow.com/Volume-5/Aluminum.html>

Accessed on 09/10/2022

- Manufacturing Process of Plastic Caps & Closures

Link : <https://www.maauliassociates.com/manufacturing-process-of-plastic-caps-closures/>

Accessed on 09/10/2022

- Aluminum Bar - Flat, Hex, Round, Square

Link : [https://www.alro.com/divsteel/metals\\_comp\\_type.aspx?Mat=ALUMINUM&Type=Bars&mc=AL](https://www.alro.com/divsteel/metals_comp_type.aspx?Mat=ALUMINUM&Type=Bars&mc=AL)

Accessed on 09/10/2022

- what is pvc end cap?

Link: <https://www.pvcpipefitting.com/what-is-pvc-end-cap/#~:text=Pvc%20pipe%20end%20caps%20are.to%20be%20developed%20and%20applied.g>

Accessed on 09/10/2022

- Bench Vice - how to use it and its applications

Link : <https://www.ajaxtools.com/bench-vise-how-to-use-it-and-its-applications/>

Accessed on 09/10/2022

- The Cold Hard Facts of Cold Saws

Link : <https://www.southernfabsales.com/blog/the-cold-hard-facts-of-cold-saws>

Accessed on 15/10/2022

- The PVC pipe Extrusion machines. How do they work?

Link : <https://www.acceXtrusion.com/news/the-pvc-pipe-extrusion-machines-how-do-they-work.html>

Accessed on 15/10/2022

- Plastic Injection Molding Process

Link : <https://www.xcentricmold.com/injection-molding-process/>

Accessed on 15/10/2022

- Coating PVC Products

Link : <https://www.pfonline.com/articles/coating-pvc-products>

Accessed on 15/10/2022

- Aluminium Anodising

Link : <https://fractory.com/aluminium-anodising/>

Accessed on 15/10/2022