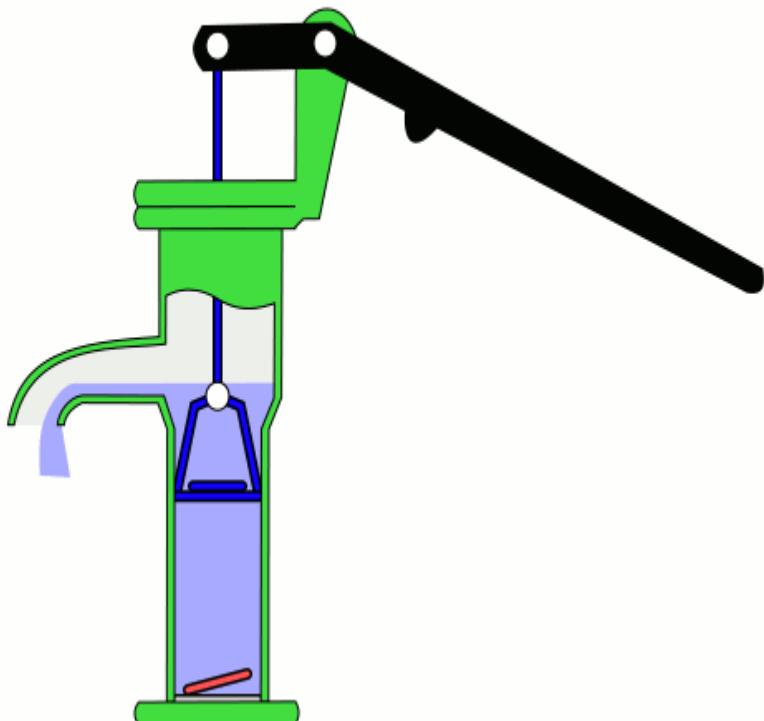


# ME338 Project : Hand Pump

- 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)

**Swapnoneel Kayal - 200100154**  
**Amshuman Sashi - 200100023**  
**Rohit Sankhala - 200100136**

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>

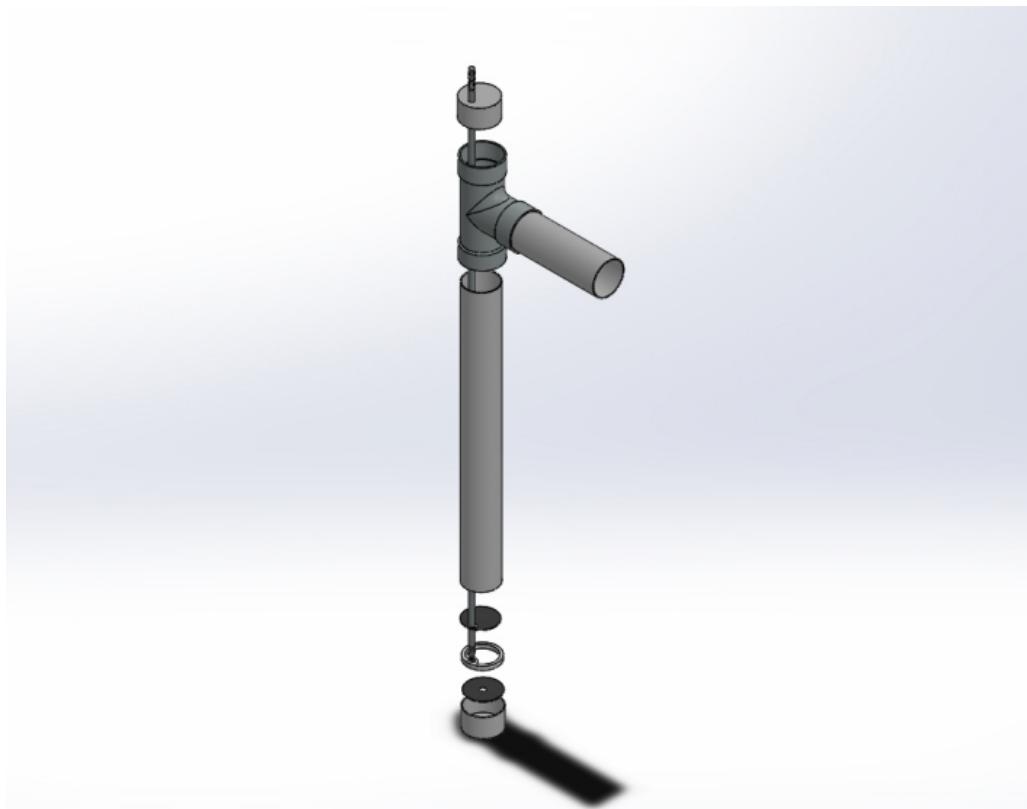
### **Role of Team Members :**

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.

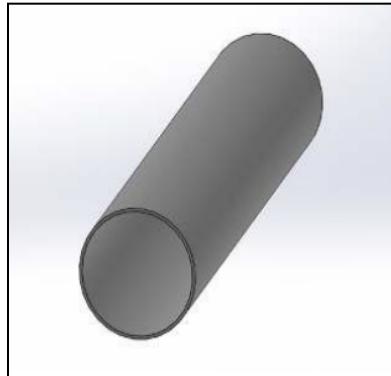
The accuracy of this particular component is not that important in comparison to other parts as adhesives like glue can be used to help seal any holes that exist between joints and rubber seals are used for the piston. Regardless, a more accurate component will always be more efficient than an inaccurate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



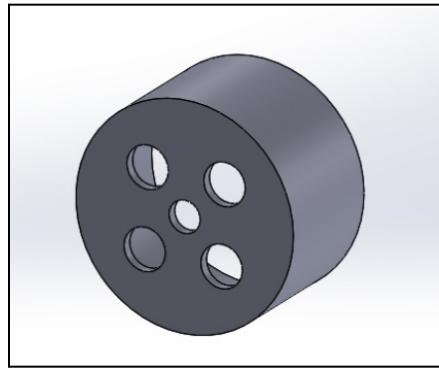
#### Foot Valve :

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.

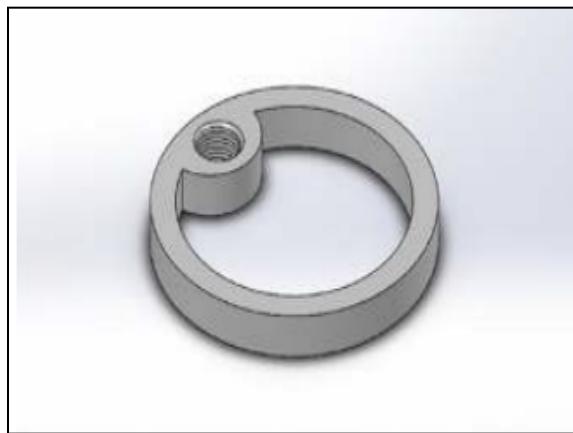


**Piston :**

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.

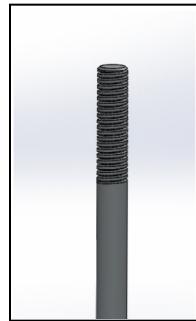
The piston doesn't require any supplementary lubrication as the water does this as well as cools the pump from the heat caused by the minor friction between the piston and main body.

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



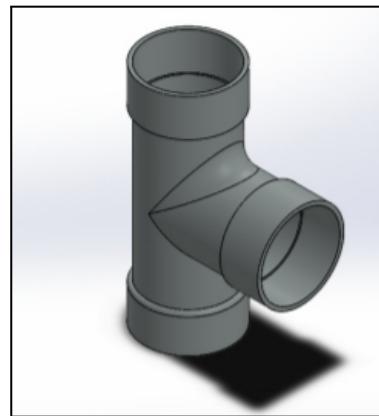
**Shaft :**

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 :

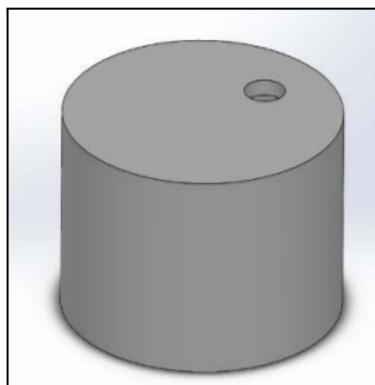
The PVC junction is a stationary part of the pump and role of the junction it to allow the water to exit the pump from the side, this allows for much easier transfer from the pump to the water storage device in comparison to allowing the water to just flow out the top, as this would cause a large amount 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 :

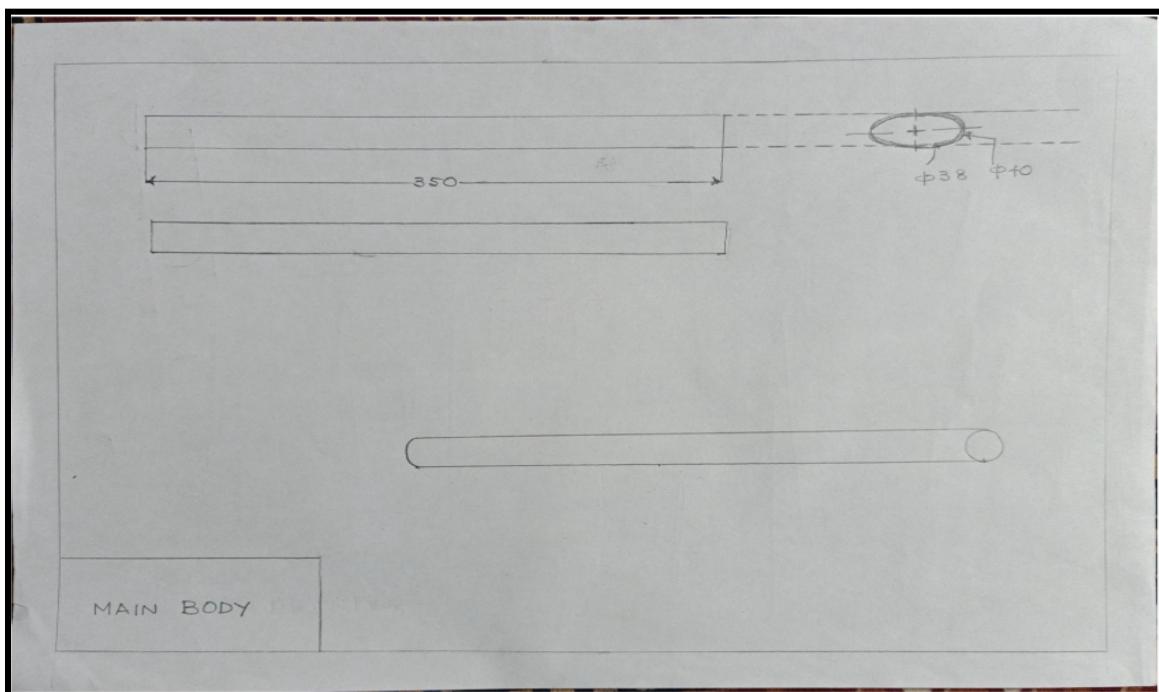
The role of the cap is to seal the top of the pump to ensure no time, water or energy is wasted while pumping. The small hole in the cap is offset like the piston to maintain a straight line of movement for the piston thus reducing the possibility of the piston running on an angle resulting in damage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

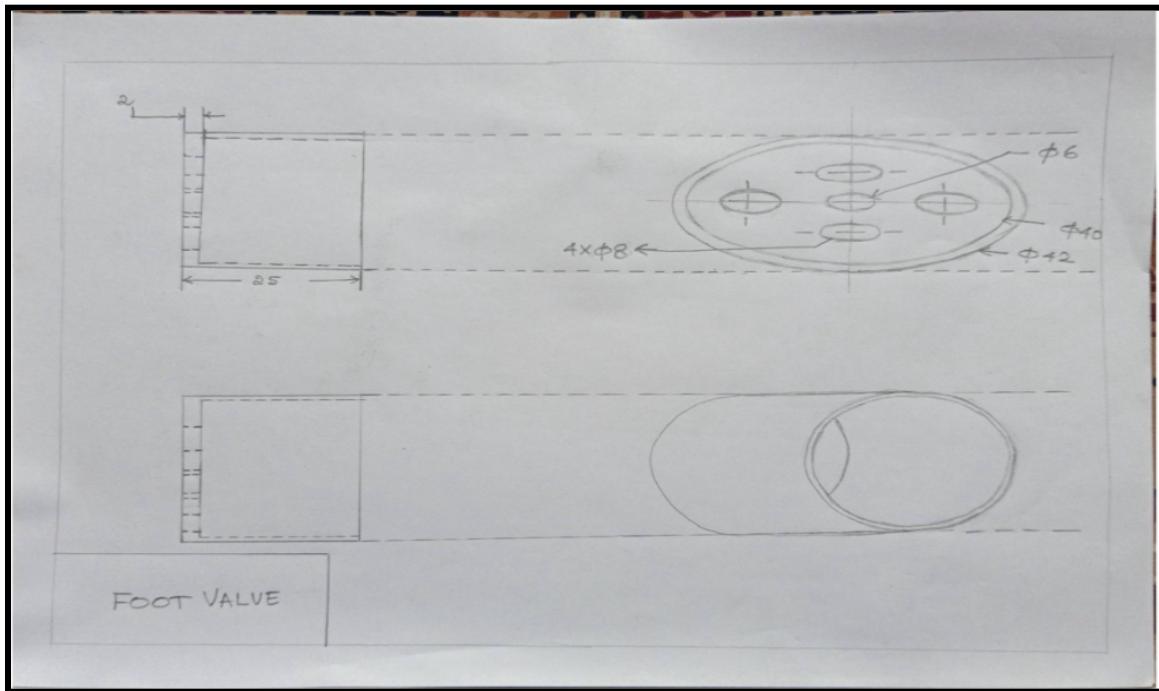


## Engineering Drawings :

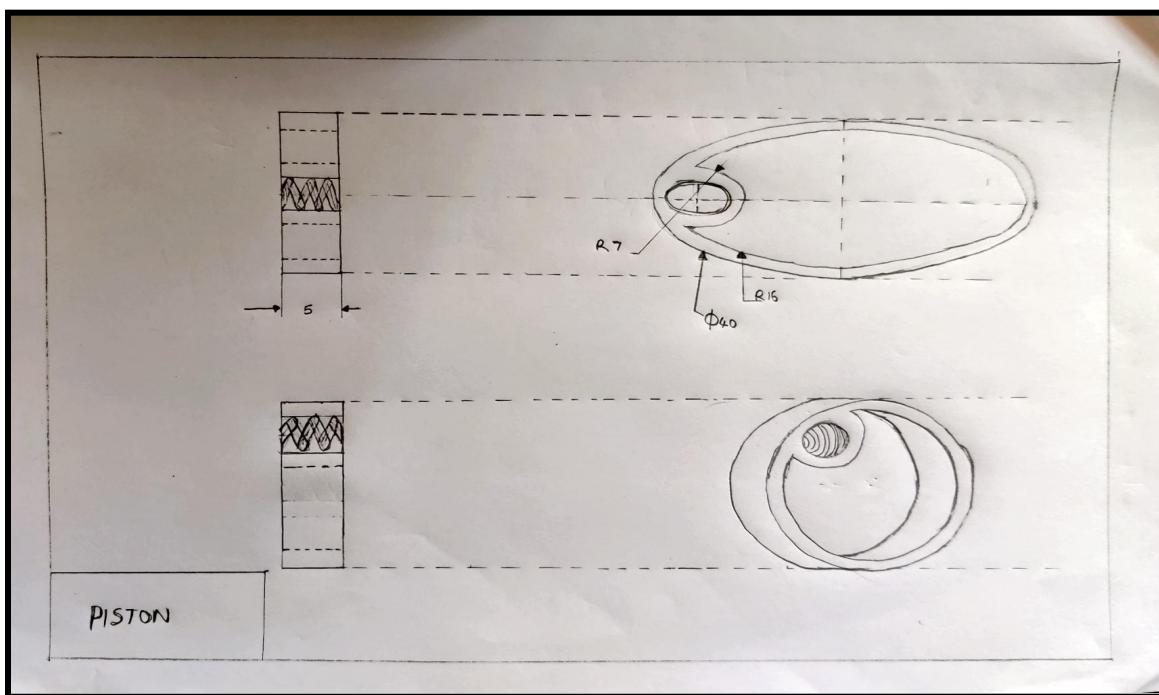
Main Body



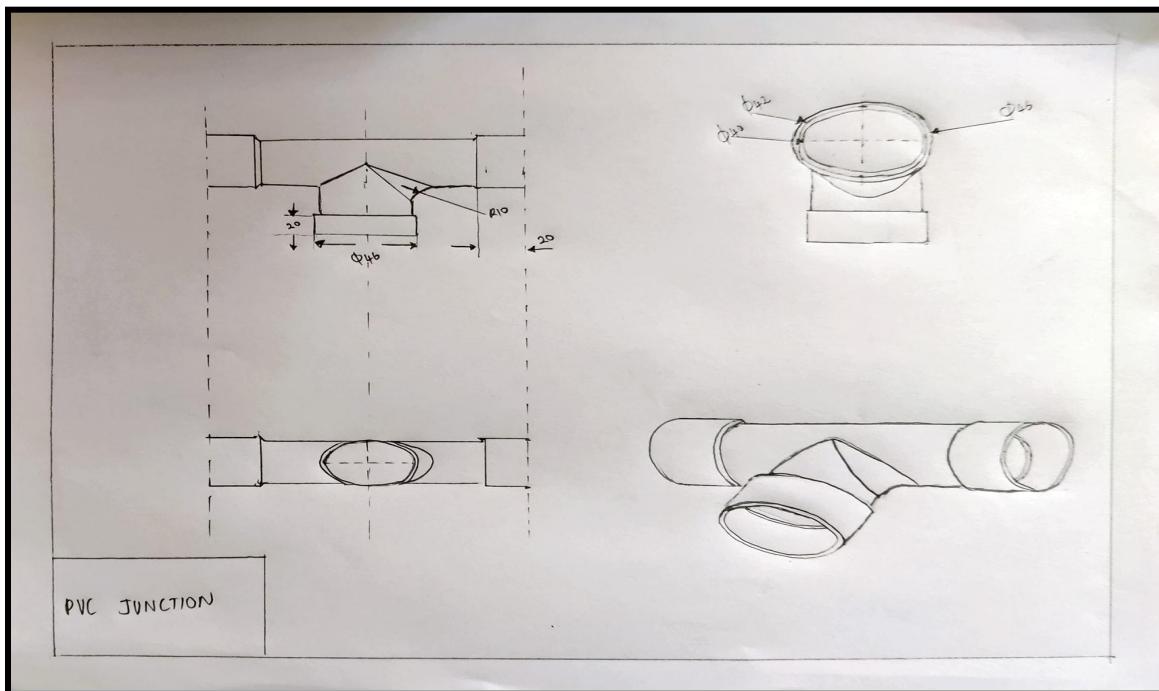
Foot Valve



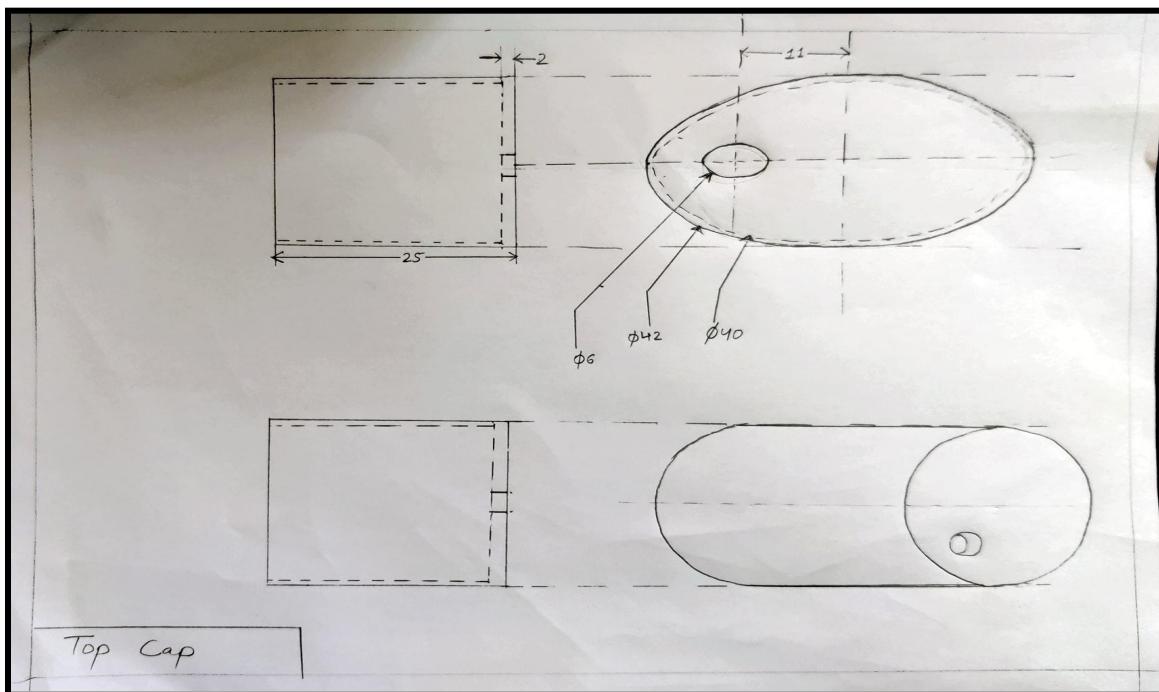
Piston



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 junction

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.



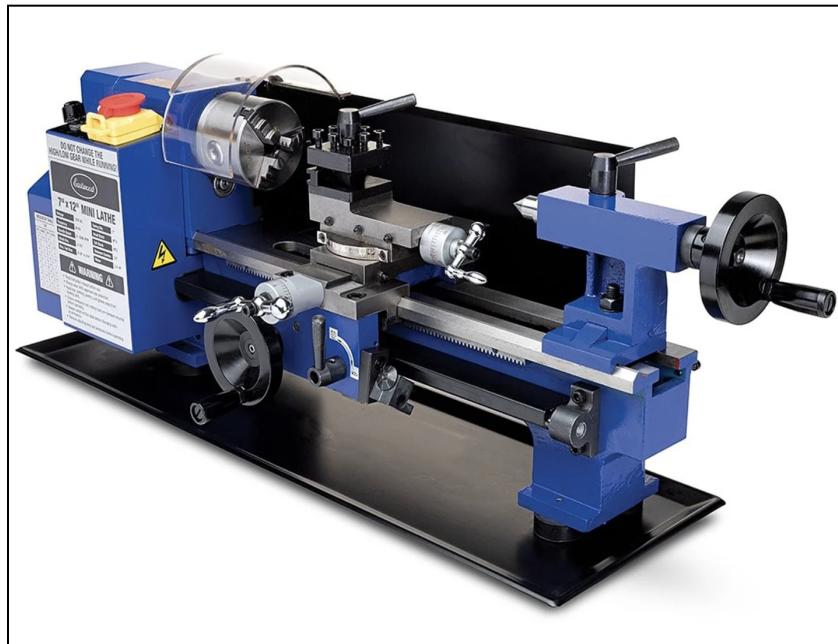
Battery drill

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

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