A Manual Vacuum Pump Made From a 60 ml Syringe
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Objective: The objective of this project is to produce a cheap and effective vacuum pump for use in vacuum science demonstrations.

Method: A readily available 60 ml plastic syringe (cost ~$1) is modified by the addition of two simple "flap" type valves made from electrical tape. These valves allow air to be drawn into the syringe through its normal port and expelled from a side vent.

Materials:

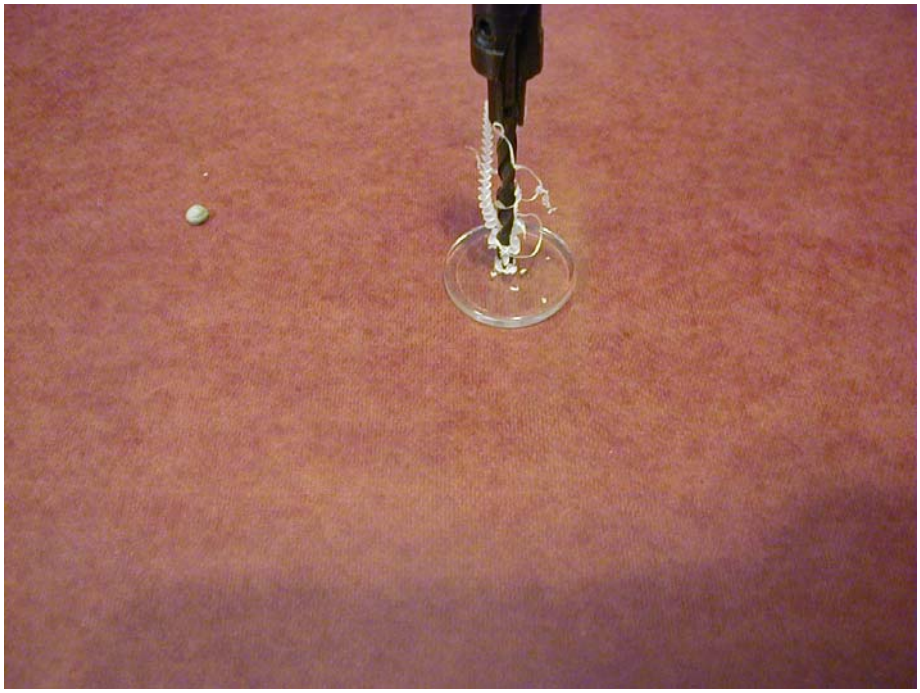
1. a 60 ml plastic syringe (for example Terumo, Kendall, Becton Dickinson)
2. Vinyl electrical tape ~6", typically ¾" wide
3. plastic disk, 1/8" to ¼" thick, diameter to match the syringe (typically 1")
4. Caulking cord (for example Mortite) or nondrying modeling clay (~3" x 1/8")

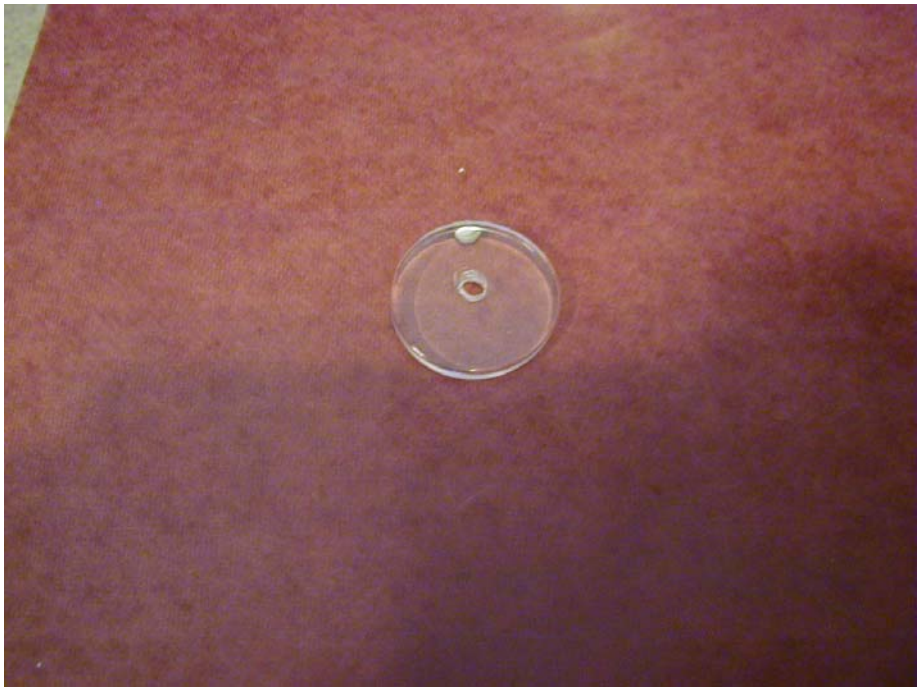
Tools needed :

1. Scissors to cut and trim electrical tape
2. Drill and 1/8" drill bit

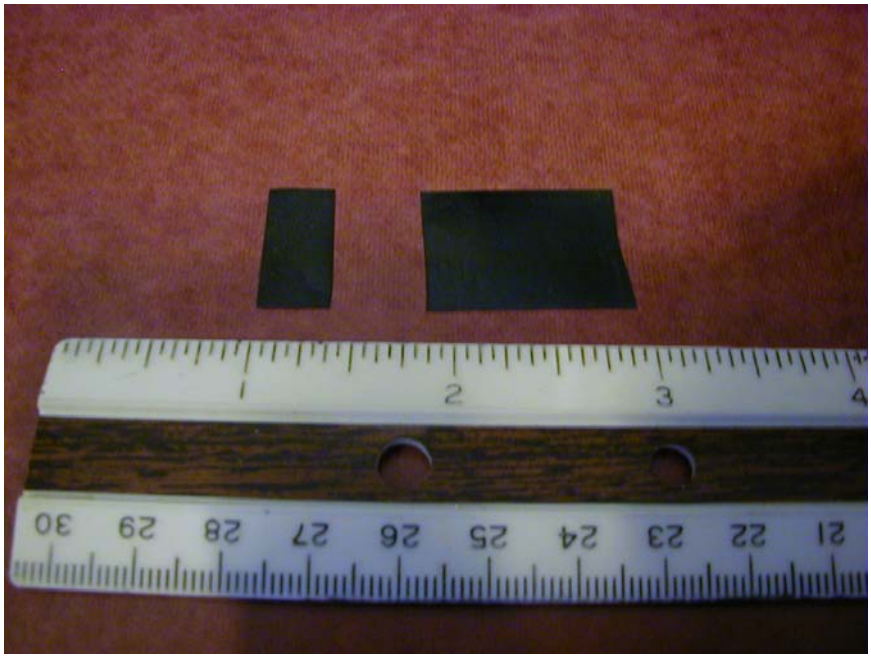
Fabrication procedure:

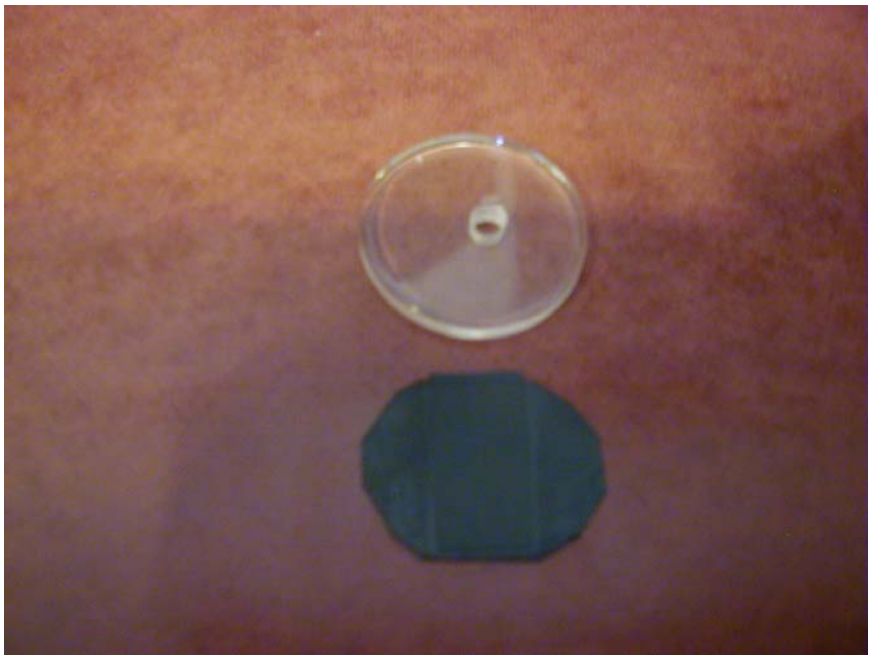
1. Drill a 1/8” hole through the center of the plastic disk. The plastic disk must have at least one smooth side. Carefully examine the 1/8” hole and remove any burrs or protrusions at the edge of the hole.



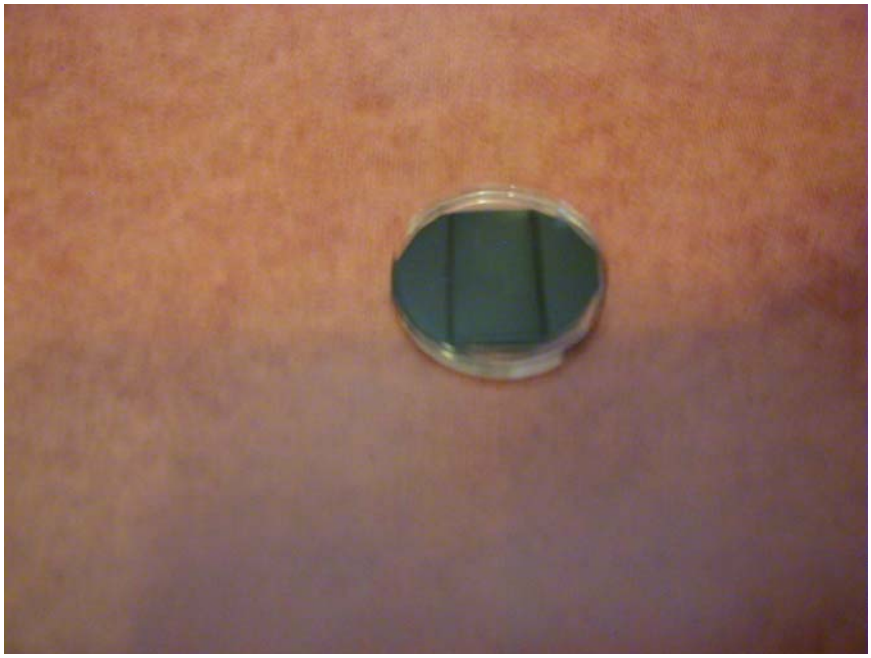


2. Cut two pieces of the electrical tape, one 3/8” long the other 1” long. Stick the two pieces together with the adhesive sides together so that the 3/8” piece is in the center of the 1” piece and extends from side to side. Snip off the corners of the 1” long piece so that it will fit within the plastic disk.





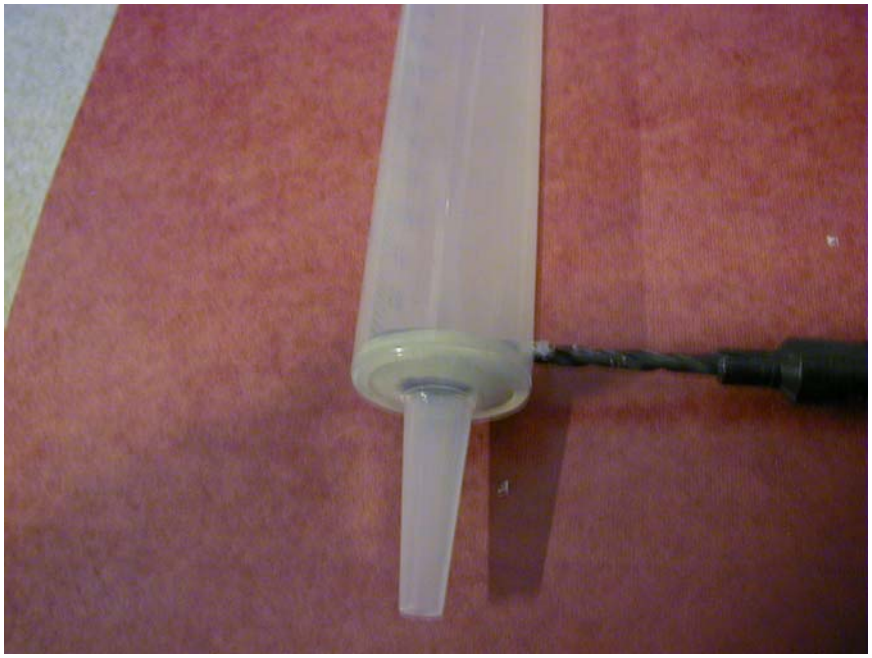
3. Attach the tape assembly to the plastic disk so that the 3/8” strip covers the 1/8” hole in the disk. Firmly press the 1” tape piece so that it firmly adheres to the disk.



4. Form the calking cord (or non-drying clay) into a ring (~1” diameter) to match the interior diameter of the syringe. The caulk should be approximately 1/16” thick. Remove the syringe plunger and insert the calk ring into the syringe, positioning it at the corner at the bottom of the syringe barrel. The eraser end of a standard pencil works well for this. Press the caulk lightly into this corner.

5. Insert the plastic disk (with hole and tape). **Make sure the tape side is up** – into the syringe. Lightly press the plastic disk into the caulk ring. You can insert the plunger and press firmly to seat the plastic disk well. No air should flow out of the syringe when you press. The caulk should "squish" out to form a good seal at the bottom of the syringe barrel.

6. Remove the syringe plunger and drill a 1/8” hole approximately 1/8” above the plastic disk. Be sure to remove any burrs or protrusions around this hole. Careful trimming with an Exacto knife may be useful. Try to remove any debris that falls within the syringe. Ideally, a piece of vinyl tape pressed over this hole will show a clean, round dimple. Do not leave the tape in place.



7. Cut two more pieces of the vinyl tape, one ~3/4” long, the other ~3 ½” long. As before, stick the ¾” piece to the center of the 3 ½” piece with the adhesive sides together.

8. Position the ¾” piece of tape over the 1/8” hole in the syringe barrel and wrap the 3 ½” piece around the barrel – stretching it slightly to hold the tape firmly over the 1/8” hole. Ideally you should see the hole as a dimple in the tape surface.

9. The plunger can now be reinserted into the syringe. When the plunger is pressed down, air should flow out from under the tape on the outside of the syringe. When the plunger is pulled back, air should flow into the tip of the syringe. If the tip of the syringe is temporarily plugged (for example using a piece of the caulk or clay), there should be a lot of resistance and when the plunger is released it should spring back into the syringe. With no plug on the tip, the plunger should move in and out freely with only the friction of the rubber against the barrel.

Operation and Performance:

Each stroke of the syringe plunger will pump approximately 60 sccm of volume (displacement). When the pressure within the syringe is less than the pressure at the inlet, air is drawn in through the inlet flap valve (the plastic disk and tape pieces). The higher pressure in the syringe tip will lift the tape slightly and allow air to flow into the barrel of the syringe. When the syringe plunger is pressed back into the barrel, the pressure in the barrel rises above that in the tip. This presses the tape of the inlet flap valve against the smooth surface of the plastic disk (seat) and seals the path back into the tip. As the plunger continues into the barrel, the gas within the barrel is compressed. As the pressure of the trapped gas rises above atmospheric pressure, the outlet flap valve (the tape on the exterior of the syringe) is lifted and the gas is allowed to escape to the outside. Pulling the plunger back for the next stroke reduces the pressure within the syringe barrel and causes the outlet flap valve to be pressed against the smooth side of the barrel, sealing the hole and preventing exterior air from entering the syringe.

Each stroke of the syringe plunger thus moves a certain volume from the tip to the exterior. This pumped volume is at the pressure of the air at the inlet of the syringe and thus as the pressure at the inlet falls, the absolute amount of air being pumped falls. Each stroke requires the plunger to be pulled back against atmospheric pressure. With a barrel diameter of 1” this requires a force of ~11.5 lbs.

The ultimate pressure (the lowest pressure this pump is capable of producing) is determined by the ratio between the volume of the syringe with the plunger fully inserted and the volume when it is fully withdrawn. The ultimate pressure is also influenced by any leakage at the inlet and outlet valves and by the force required to lift the flap valves. Measurements indicate that this pump is capable of producing a vacuum of less than 5% of atmospheric pressure (~.8 psi, ~40 torr). This displacement (~ 60 sccm) and ultimate pressure (.05 atmosphere) is adequate for many of the standard vacuum demonstrations (for example, crushing cans and bottles, expanding a marshmallow, etc.). It takes ~12 strokes to collapse a 500 ml water bottle.