VI. SEPARATORS AND PURIFIERS

This section on separators and purifiers has been divided into four subsections:

A. MECHANICAL SEPARATORS

These are devices for separating solid/solid, liquid/solid, or solid/liquid mixtures. Included are magnets, sieves, filtration apparatus, and separatory funnels.

B. DISTILLATION APPARATUS

These devices are used for separating liquid solutions and include several types of distillation apparatus.

C. ELECTRICAL SEPARATOR

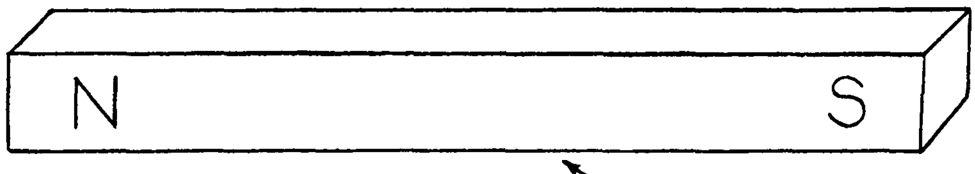
This device is used in the electrolytic separation of substances and to demonstrate Faraday's quantitative laws of electrolysis.

D. CENTRIFUGAL SEPARATORS

Centrifugal separators are used to cause the rapid precipitation of materials in suspension.

A. MECHANICAL SEPARATORS

Al. Magnets



(1) Bar Magnet

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bar Magnet	1	Bar Magnet	PHYS/IX/Al, Notes

b. Construction

(1) Bar Magnet

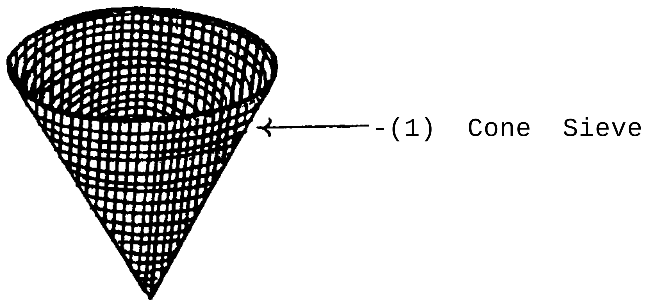
Purchase a magnet, or magnetize a steel bar according to the instructions described in PHYS/IX/Al, Notes.

c. Notes

(i) Magnets are used to separate ferromagnetic materials from other materials, such as dirt or sand.

(ii) Magnets in a variety of shapes, materials, and field strength may be purchased from commercial sources and may be used in place of the bar magnet above.

A2. Cone Sieve

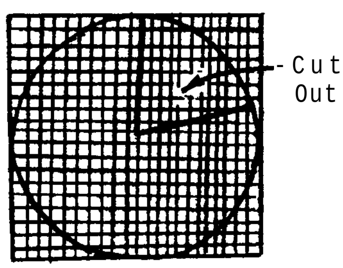


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cone Sieve	1	Wire Mesh (A)	Approximately 7 cm x 7cm
	1	Thin Wire (B)	Approximately 10 cm

b. Construction

(1) Cone Sieve



Cut a circle from the wire mesh (A). Then cut out and remove a segment of the circle as shown.

Roll the wire mesh into the shape of a cone, overlapping the edges slightly. Thread the thin wire (B) in and out of the wire mesh, at the overlapped edges, to hold them together.

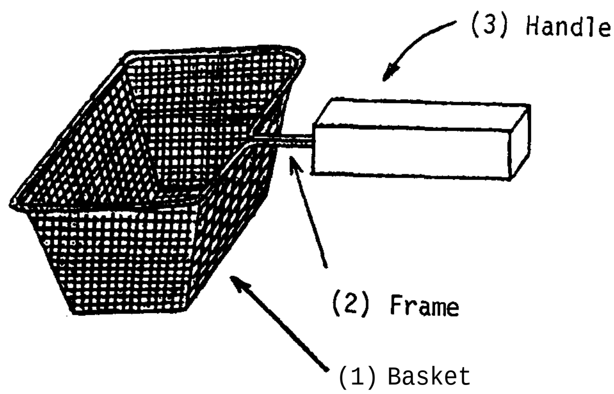
c. Notes

(i) This cone may be made larger or smaller by varying the dimensions of the wire mesh used.

(ii) Material suitable for replacing the wire mesh may be made by dipping a cloth having a very coarse weave into melted wax, varnish, or starch.

(iii) Sieves are suitable for grading small particles or washing small amounts of materials under a stream of water.

A3. Basket Sieve

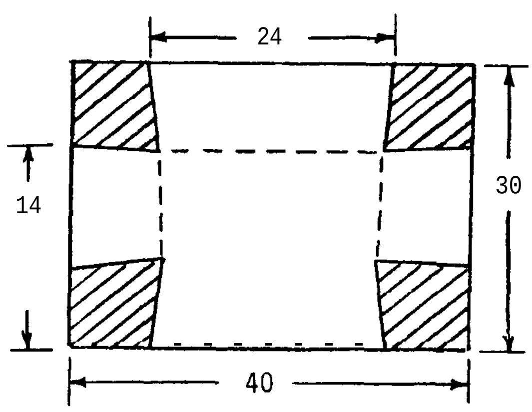


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basket	1	Wire Mesh (A)	Approximately 30 cm x 40 cm
	4	Thin Wire (B)	Approximately 20 cm
(2) Frame	1	Stiff, Heavy Wire (C)	Approximately 4 cm diameter, 80 cm long
	1	Thin Wire (D)	Approximately 80 cm long
(3) Handle	1	Wood (E)	2 cm x 2 cm x 15 cm

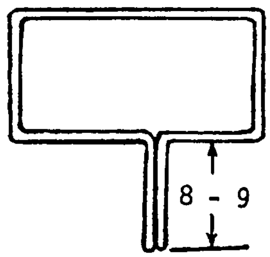
b. Construction

(1) Basket



Cut the wire mesh (A) according to the pattern shown, and discard the shaded portions. Then fold all the flaps up along the dashed lines. Overlap the cut edges slightly, and thread the thin wires (B) in and out of the wire mesh at the overlapped edges to hold them together.

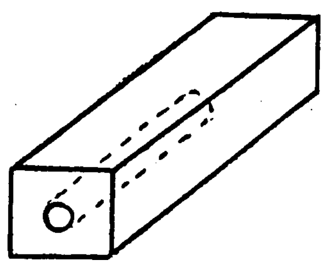
(2) Frame



Bend the heavy wire (C) as shown, to fit the dimensions of the top of the basket. Allow an extension of 8 - 9 cm to fit into the handle (E).

Fold the top 1 cm of the basket around the frame to the inside, and lace the thin wire (D) in and out of the basket mesh to secure the frame in place.

(3) Handle



Drill a hole approximately 0.8 cm in diameter and approximately halfway through the length of the wooden handle (E).

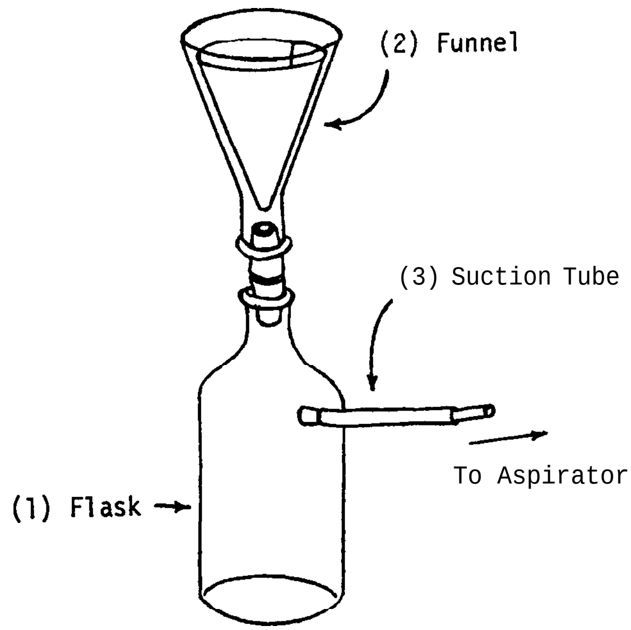
Insert the straight section of the frame into this hole in the handle, and cement it in place.

C.Notes

(i) This basket sieve may be made larger or smaller by varying the dimensions of the wire mesh, frame, and handle used.

(ii) This sieve is used just as the funnel sieve in the preceding section, but for larger amounts of material.

A4. Suction-Filter Flask

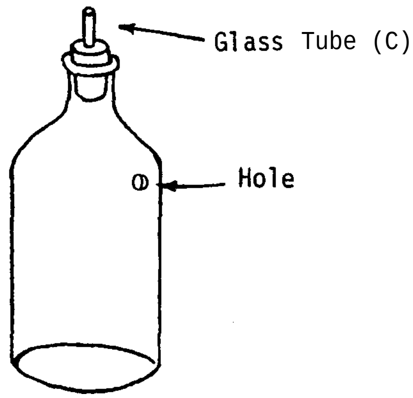


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask	1	Glass Bottle (A)	Capacity 250-500 ml
	1	l-Hole Rubber Stopper (B)	To fit bottle (A)
	1	Glass Tube (C)	0.5 cm diameter, 6 cm long
(2) Funnel	1	Funnel (D)	V/A3
	1	l-Hole Rubber Stopper (E)	To fit neck of funnel (D)
	1	Filter Paper (F)	Approximately 15 cm diameter
(3) Suction Tube	1	Rubber Tube (G)	1.0 cm diameter, 15 cm long
	1	Glass Tube (H)	0.7 cm diameter, 10 cm long

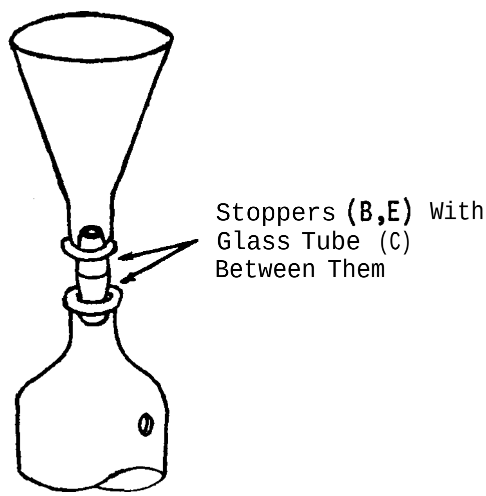
b. Construction

(1) Flask



Bore a hole (I/E2) just slightly smaller than 1.0 cm in diameter in the side of the bottle (A) near the top. Insert the glass tube (C) into the rubber stopper (B) so that approximately half the tube protrudes from the top of the stopper. Fit the stopper into the mouth of the bottle.

(2) Funnel



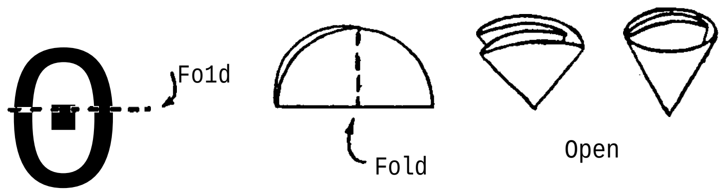
Insert the protruding end of the glass tube into the stopper (E) for the funnel (D). Push the two stoppers together, and fit the funnel stopper into the neck of the funnel (D).

(3) Suction Tube

Insert the rubber tubing (G) into the hole in the side of the bottle so that about 1 cm of tubing is inside the bottle. Seal the tubing in place with eqoxy resin. Insert a short piece of glass tubing (H) into the open end of the rubber tubing.

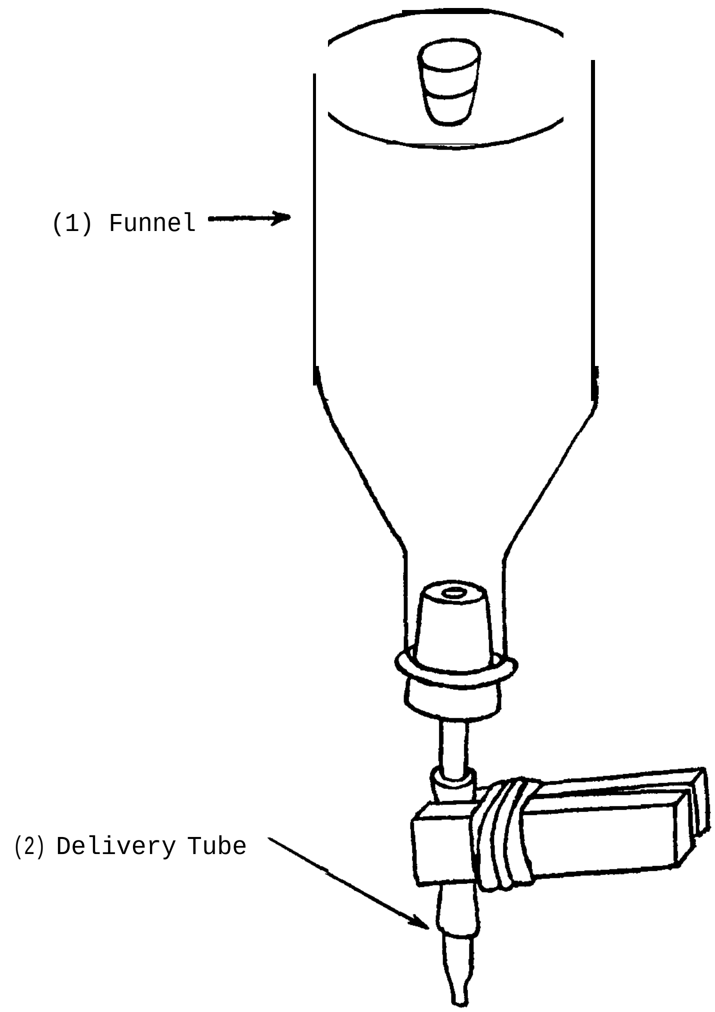
c. Notes

(i) A circle of filter paper is folded as illustrated and placed in the funnel. The suction tube is then connected to the water-filled aspirator (V/A8). The material to be filtered is placed in the filter paper in the funnel. Water is then allowed to drain from the aspirator. The partial vacuum thus formed will draw air from the flask, and air on the outside will be drawn through the funnel, causing more rapid filtration to occur.



(ii) Filter paper is available from commercial suppliers, but substitutes include paper towels, blotting paper, or cotton.

A5. Separatory Funnel

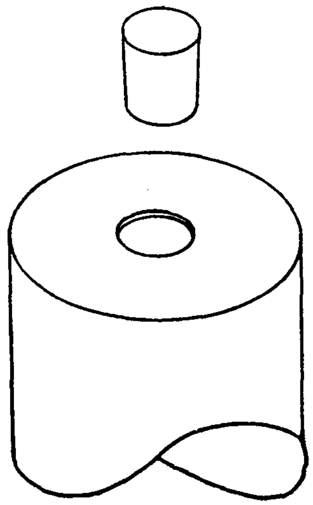


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	Capacity 250-500 ml
	1	Rubber Stopper (B)	Approximately 2 cm diameter (large end)
(2) Delivery Tube	1	l-Hole Rubber Stopper (C)	To fit bottle (A)
	1	Glass Tubing (D)	0.7 cm diameter, 15 cm long
	1	Rubber Tubing (E)	1 cm diameter, 8 cm long
	1	Wooden Pinch Clamp (F)	IV/A4

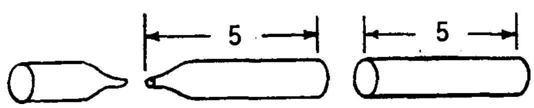
b. Construction

(1) Funnel



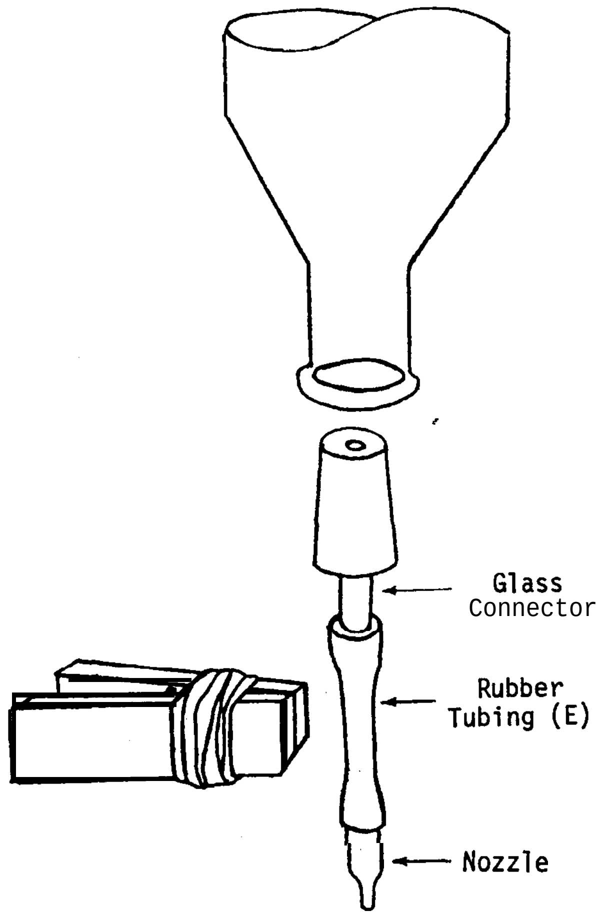
Select a clear glass bottle (A) with a tapered, narrow neck. Drill a hole in the bottom of the bottle and enlarge it sufficiently to receive the rubber stopper (B). Smooth the rough edge with emery paper before sealing.

(2) Delivery Tube



t Discard | t Nozzle | t Connector

Heat the glass tubing (D) with a burner and draw it out near one end and cut as shown to leave a 5 cm long nozzle and a 5 cm long connector. Carefully fire polish all cut edges.'

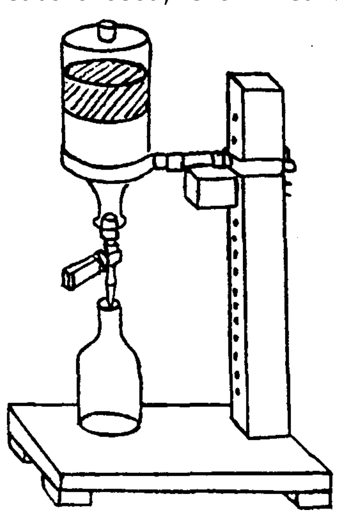


Fit the glass connector into, but not through, the one-hole rubber stopper (C). Insert the other end into the rubber tubing (E), and connect the rubber tubing to the nozzle. Fit the stopper into the neck of the bottle.

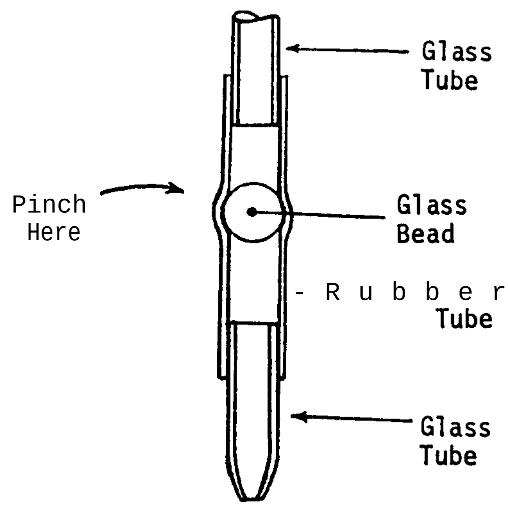
Construct a wooden pinch clamp (IV/A4) and use it to close the rubber tubing.

C. Notes

(i) The separatory funnel is used to separate two liquids that do not mix. With the delivery tube closed, the mixture of liquids is poured into the funnel through the hole at the top, (bottom of bottle). The funnel is then sealed and shaken vigorously for several seconds. Then the funnel is secured in a ring stand (IV/B4) or other appropriate support and allowed to rest undisturbed until the liquids separate into layers. The lower liquid is then drained through the delivery tube by opening the pinch clamp. In order to allow the funnel to drain properly, the stopper must be removed from the top.



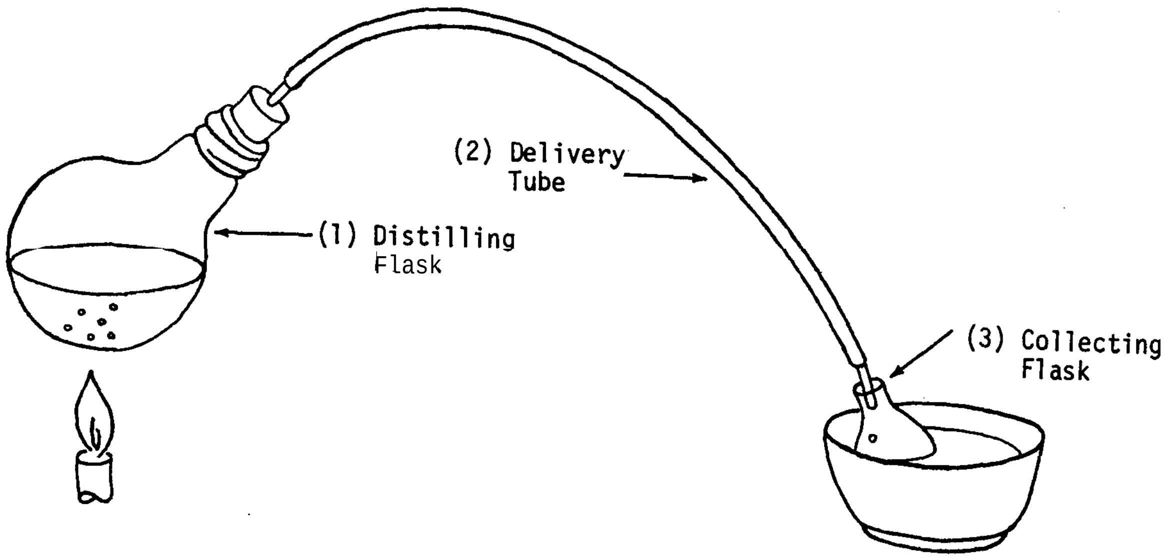
(ii) A glass bead just slightly larger than the internal diameter of the rubber tubing may be used in place of the pinch clamp. Push the bead into the rubber tubing before inserting the glass nozzle. The bead will seal the rubber tube. To dispense liquid from the funnel, squeeze the tube between thumb and forefinger at the location of the bead.



Cross Section

B. DISTILLATION APPARATUS

Bl. Simple Distillation Apparatus



a. Materials Required

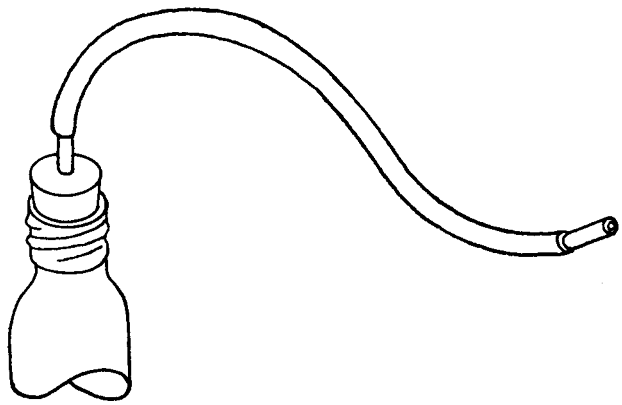
Components	Qu	Items Required	Dimensions
(1) Distilling Flask	1	Flask (A)	Capacity approximately 200 ml
	1	l-Hole Rubber Stopper (B)	To fit flask (A)
(2) Delivery Tube	2	Glass Tubing (C)	0.7 cm diameter, 5 cm long
	1	Rubber or Plastic Tubing (D)	1 cm diameter, approximately 60 cm long
(3) Collecting Flask	1	Flask or Bottle (E)	Capacity approximately 200 ml

b. Construction

(1) Distilling Flask

Fit the light bulb flask (A) or other flask with the one-hole rubber stopper (B).

(2) Delivery Tube



Support the flask in a stand, (IV/B4, B5, or B6).

Insert a short piece of glass tubing (C) into the stopper in the flask. Attach the other end of the glass tube to a long piece of rubber or plastic tubing (D). Insert another short piece of glass tubing (C) into the other end of the rubber or plastic tubing.

(3) Collecting Flask

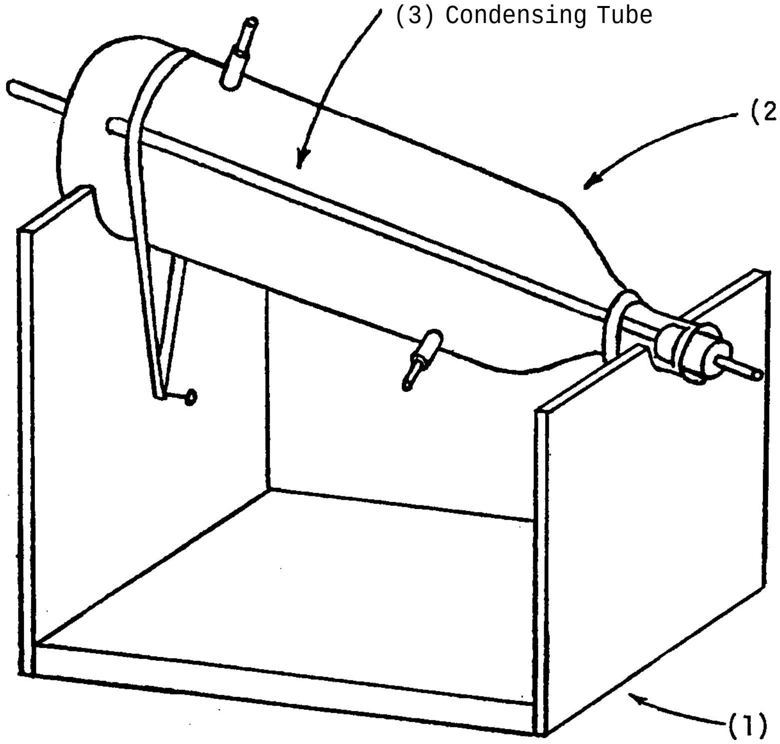
Place a flask (E) or jar in a bowl or pan of cool water and lead the free end of the delivery tube into the flask.

c. Notes

(i) A sample of a liquid--impure water, for example--to be distilled is placed in the distilling flask, and the stopper is inserted into the flask. The liquid is heated until it boils. As the liquid boils, its vapor travels through the delivery tube and is cooled enough by air surrounding the tube to condense and drip into the collecting flask. The water in the bowl helps cool the condensed liquid still more, as it is quite hot when first collected.

(ii) This simple apparatus is ideal for student participation in simple distillation operations involving small volumes of liquids.

B2. Condenser

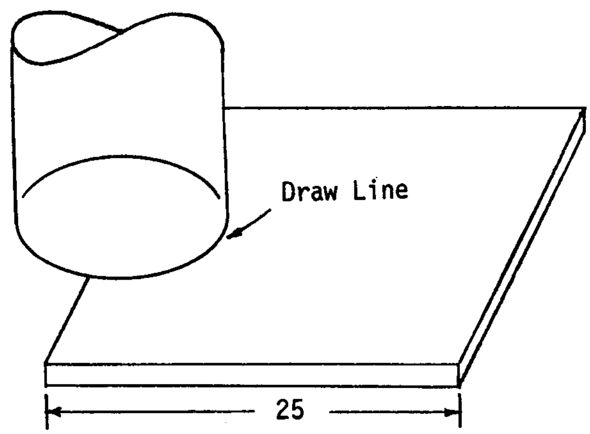


a. Materials Required

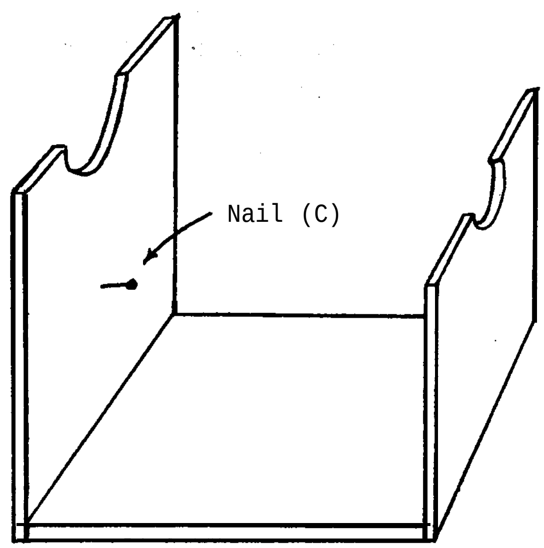
Components	Qu	Items Required	Dimensions
(1) Stand	2	Wood (A)	18 cm x 15 cm x 1 cm
	1	Wood (B)	25 cm x 15 cm x 1 cm
	2	Nails (C)	3 cm long
	2	Rubber Bands (D)	5 cm x 9 cm
(2) Water Jacket	1	Plastic or Glass Bottle (E)	Capacity approximately 1-2 liters
	1	1-Hole Rubber Stopper (F)	To fit bottle (E)
	2	Rubber Tubing (G)	1 cm diameter, 3 cm long
	2	Glass Tubing (H)	0.7 cm diameter 10 cm long
(3) Condensing Tube	1	Glass Tubing (I)	0.7 cm diameter, 10 cm longer than bottle

c. Construction

(1) Stand



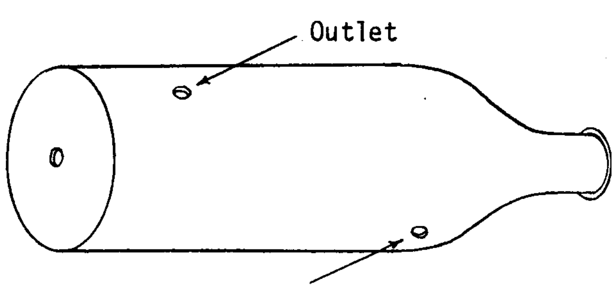
Trace around the base of the bottle (E) on the larger piece of wood (B) as shown. Cut along the traced line.



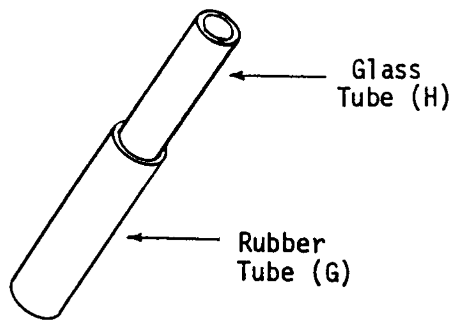
In a similar fashion, make a small semicircular cutout to accommodate the neck of the bottle (E) in one of the smaller pieces of wood (A).

Nail the two sections with cutouts to the third (A) to form the stand. Drive a nail (C) into each upright to anchor the rubber bands (D) that hold the water jacket in place.

(2) Water Jacket



Take a plastic bottle (E) if possible, a glass bottle if necessary. Drill three holes approximately 1 cm in diameter in the bottle as illustrated.



(3) Condensing Tube

Fit each short piece of glass tubing (H) into a piece of rubber tubing (G). Insert each piece of rubber tubing into one of the holes in the side of the bottle. Seal with epoxy resin if necessary to make sure that the seal is watertight.

Fit the mouth of the bottle with a one-hole rubber stopper (F).

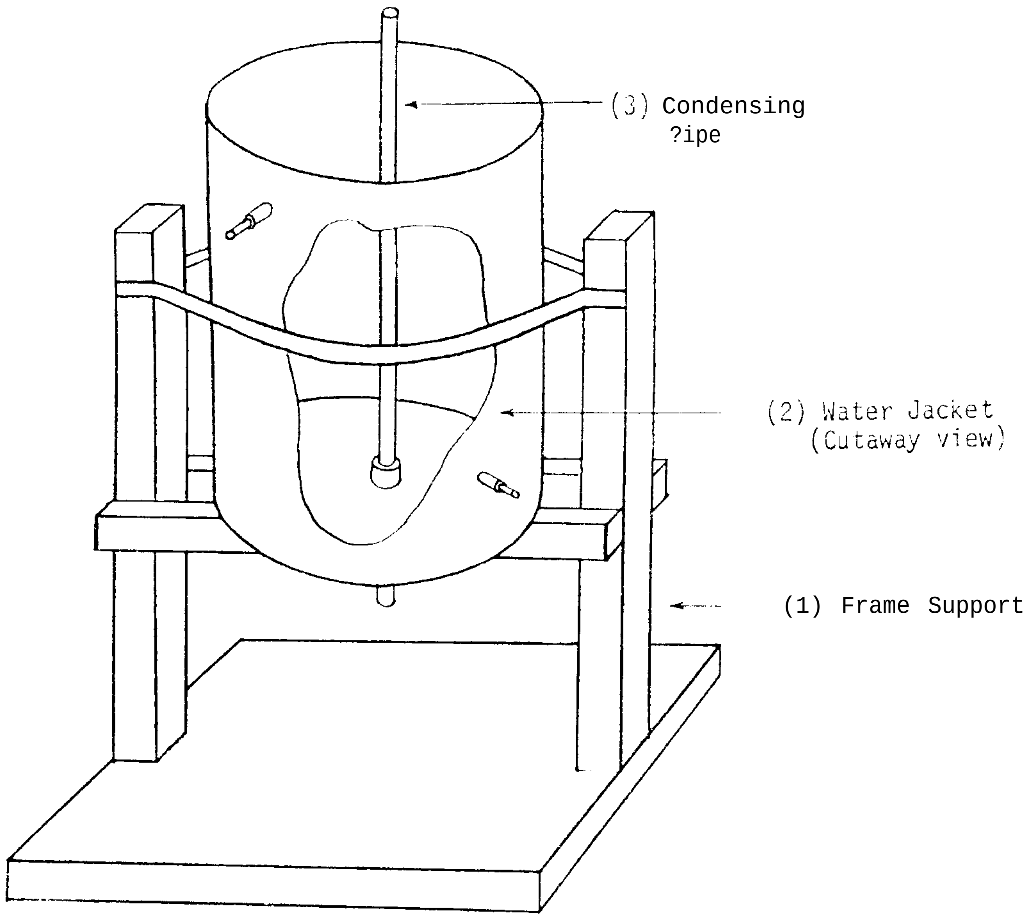
Insert a long glass tube (I) through the hole in the base of the bottle, all the way through the bottle, and through the rubber stopper to the outside again.

Rest the bottle in the stand with the base higher than the neck and the inlet tube below the outlet tube. Loop the rubber bands (D) around the base and neck of the bottle to secure it in position.

C.Notes

(i) To use this condenser, fasten a rubber or plastic tube from the flask in which a liquid is being boiled to the upper end of the condensing tube (that end protruding from the bottom of the bottle). Another tube, from a cold water source, is connected to the inlet (lower) tube, and a third rubber or plastic tube is attached to the outlet and led to a drain. As hot gas flows through the condensing tube, it is cooled by the water jacket and condenses, to drip as a liquid from the lower end of the condensing tube where it can be collected in a beaker.

B3. Water Still



a. Materials Required

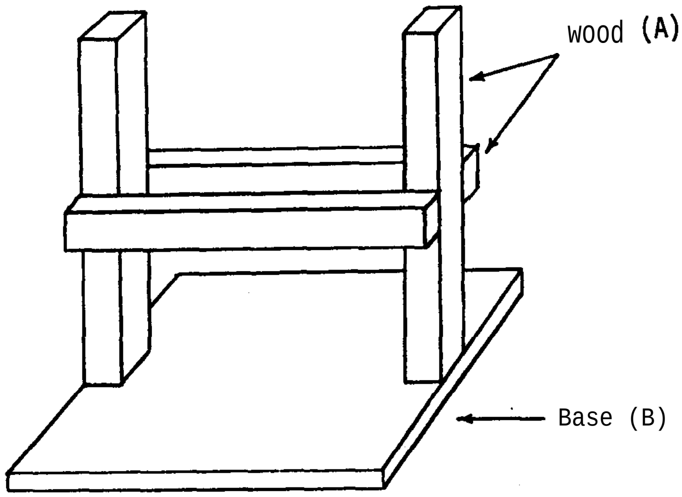
Components	Qu	Items Required	Dimensions
(1) Frame Support	4	Wood (A)	4 cm x 5 cm x 25 cm
	1	Wood (B)	2 cm x 16 cm x 25 cm
(2) Water Jacket	2	Metal Strapping (C)	1.5 cm x 23 cm
	1	Large Tin Can (D)	Capacity approximately l-l.5 kg
	2	Rubber Tubing (Ej	? cm diameter, 5 cm long
	2	Glass Tubing (F)	0.7 cm diameter 5 cm long
(3) Condensing	1	Copper pipe (G)	1 cm outside diameter, 5 cm longer than can height
	1	1-Hole Rubber Stopper (H)	Approximately 2.5 cm diameter (large end)

1 Glass Tubing (I) 0.7 cm diameter, 5 cm long

b. Construction

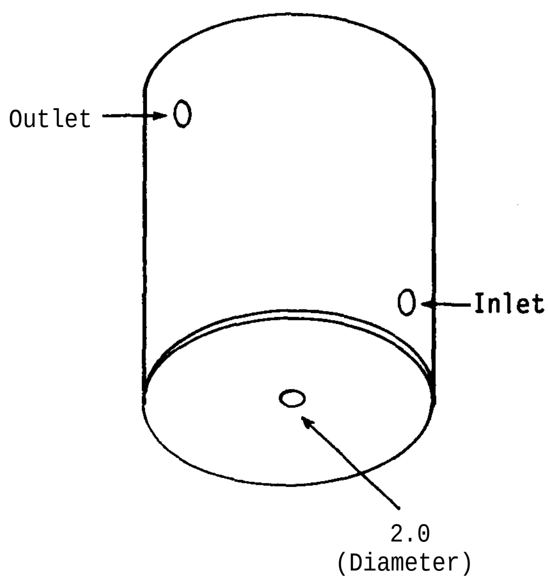
(1) Frame Support

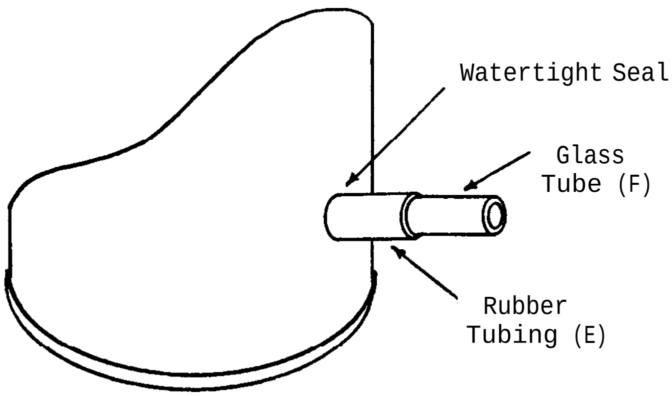
Nail two pieces of wood (A) to a flat piece (B) to form a base and uprights. Then nail two more pieces of wood (A) to the outsides of the uprights, as shown, to form supports for the can.



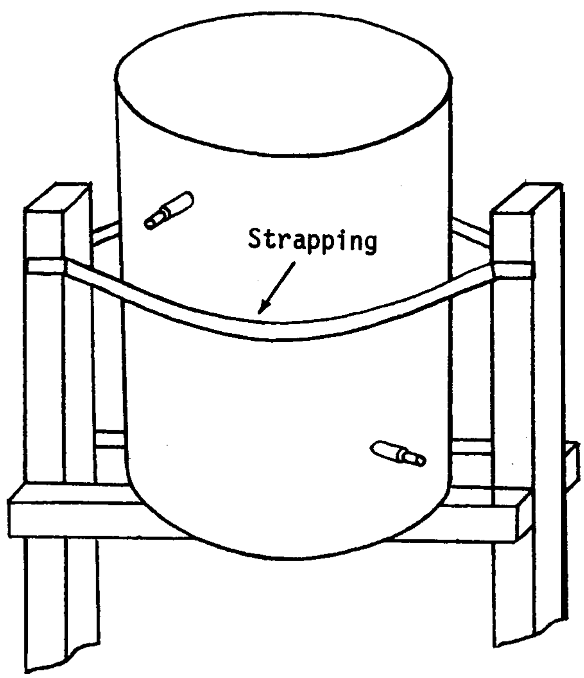
(2) Water Jacket

Cut a hole approximately 2 cm in diameter in the center of the bottom of the can (D). Crimp the cut edges inward. Cut a smaller hole, not quite 1 cm in diameter, in the side of the can near the bottom, to accommodate the inlet tube. Cut another small hole, not quite 1 cm in diameter, in the side of the can near the top, for the outlet tube.





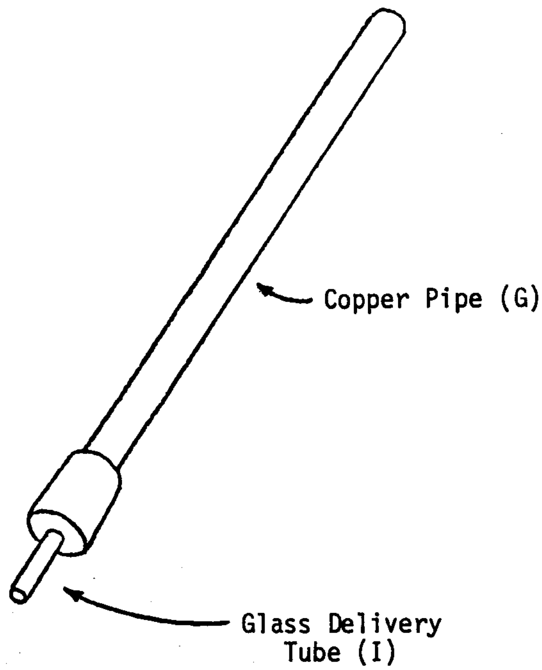
Insert each short piece of glass tubing (F) into a short piece of rubber tubing (E). Insert each rubber tube into one of the two small holes in the can. If the rubber tubes do not fit snugly by themselves, make a water-tight seal with candle wax or epoxy resin.



Set the can in place in the frame support. To secure it in position, nail two pieces of strapping (C) to the frame support, one on each side of the can.

(3) Condensing Pipe

Choose a one-hole rubber stopper (H) that tightly seals the hole in the bottom of the water jacket can. Insert a short piece of glass tubing (I) part way through the stopper, from the large end. Insert the copper pipe (G) into the stopper from the other end.



Insert the condensing pipe into the water jacket can through the hole in the bottom of the can. Push the stopper tightly into the hole from the outside. Seal with candle wax or epoxy resin, if necessary, to produce a watertight seam.

c. Notes

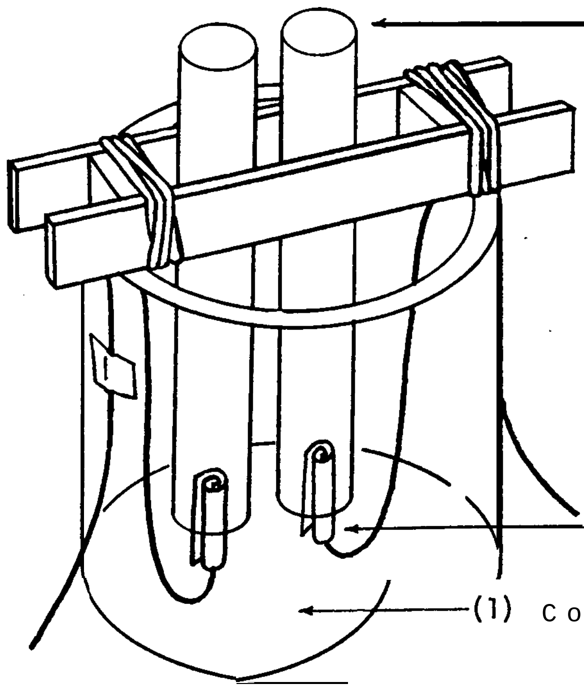
(i) A plastic or rubber tube from a water source is attached to the inlet tube, and another tube is attached to the outlet tube and led to a drain. A plastic or rubber tube from the container in which water is boiled is connected to the free end of the copper condensing pipe. Water vapor flowing through this tube will condense and drip from the glass delivery tube at the bottom of the still, where it can be collected.

(ii) This still is suitable for continuous operation, in order to produce distilled water for class use. In such a case, a large kettle should be used for boiling the water, and a plastic or rubber tube can be attached to the delivery tube and led to a storage container.

(iii) The size of the frame support for this still is determined by the size of the can used for the water jacket. Its dimensions will vary, according to the size of the can used.

C. ELECTRIC SEPARATOR

Cl. Electrolysis Apparatus



a. Materials Required

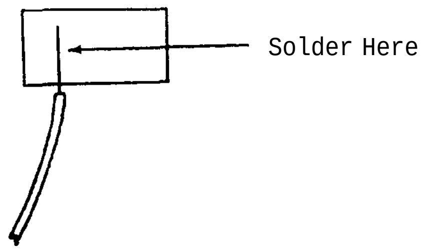
Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Jar (A)	Approximately 100-200 ml capacity
(2) Electrodes	2	Stiff Wire, Insulated (B)	Approximately 0.1 cm diameter, 25 cm long
	2	Thin Copper Sheet (C)	1.5 cm x 3.0 cm
	2	Masking or Adhesive Tape (D)	2 cm x 4 cm
(3) Collecting Tube	2	Test Tubes or Vials (E)	Approximately 1.5 cm diameter, 10 cm long
(4) Frame Support	2	Wood Strips (F)	0.2 cm x 2 cm x 15 cm
	2	Wood Blocks (G)	Approximately 2 cm x 2 cm x 1.3 cm
	2	Rubber Bands (H)	Approximately 0.2 cm x 4 cm

b. Construction

(1) Container

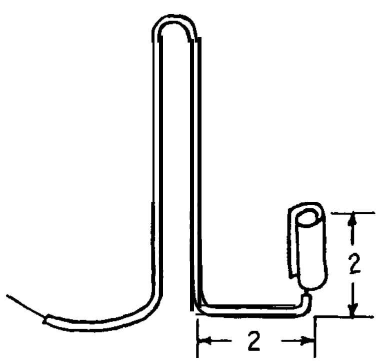
Choose a small glass jar (A) with a capacity of 100 - 200 ml, or cut off the top of a jar to make a container of appropriate size.

(2) Electrodes

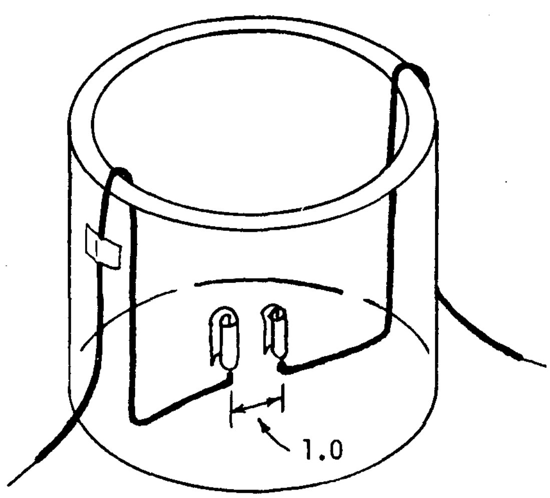


Strip about 1.5 cm of the insulation off each end of the stiff, insulated wire (B). Solder one end of each wire to a piece of the copper sheet (C), as shown.

When the solder has cooled, roll the copper sheet (C) into a spiral plate.



Bend each of the stiff wires (B) as illustrated. Make the large loop long enough to fit over the lip of the container (A) when the flat 2 cm portion of the wire is resting on the bottom of the container.



Place the electrodes at opposite sides of the container. Adjust the bends, if necessary, so that the plates of the electrodes are about 1 cm apart. Secure the wires to the outside of the container with tape.

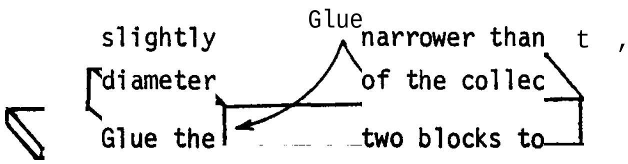
(3) Collecting Tubes

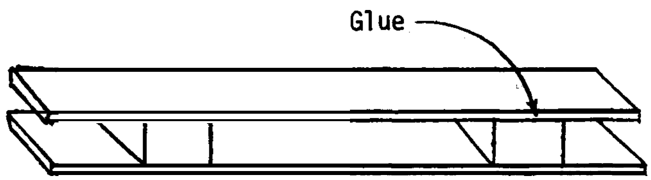
For the collecting tubes (E), use small glass or plastic test tubes or vials that are slightly taller than the height of the container (A).

(4) Frame Support

For the frame support, use two thin, flexible wooden strips (F) about twice as long as the diameter of the container. Cut two small wooden blocks (G) just h e diameter of the collecting tubes.

to one of the strips, about 5 cm apart.





Glue the other strip to only one of the blocks, as shown.

Hold the rubber bands (H) aside until the apparatus has been set up [see Note (i)].

C. Notes

(i) This apparatus is used to separate water into oxygen and hydrogen, which are collected in the tubes. The container is filled with water sufficient to cover the terminals by less than 1 cm. A little vinegar or washing soda ($Na_2CO_3 \cdot 10H_2O$) is added to the water to increase its conductivity. The collecting tubes are filled with the same acidic (vinegar) or basic (Na_2CO_3) solution. Then, with the open end sealed with a thumb or forefinger, each tube is inverted and placed into the container. The open end of the tube must be placed below the surface of the solution before it is uncovered. Then, without being lifted out of the solution, each tube is placed over one of the electrodes.

The frame support may be placed around the two collecting tubes. It is secured tightly around the tubes with rubber bands at each end. With the tubes thus supported, the frame is rested on the top of the container and the tubes are carefully adjusted so that the open ends do not rest on the bottom of the container, but are about 1 cm above the bottom and below the surface of the solution in the container.

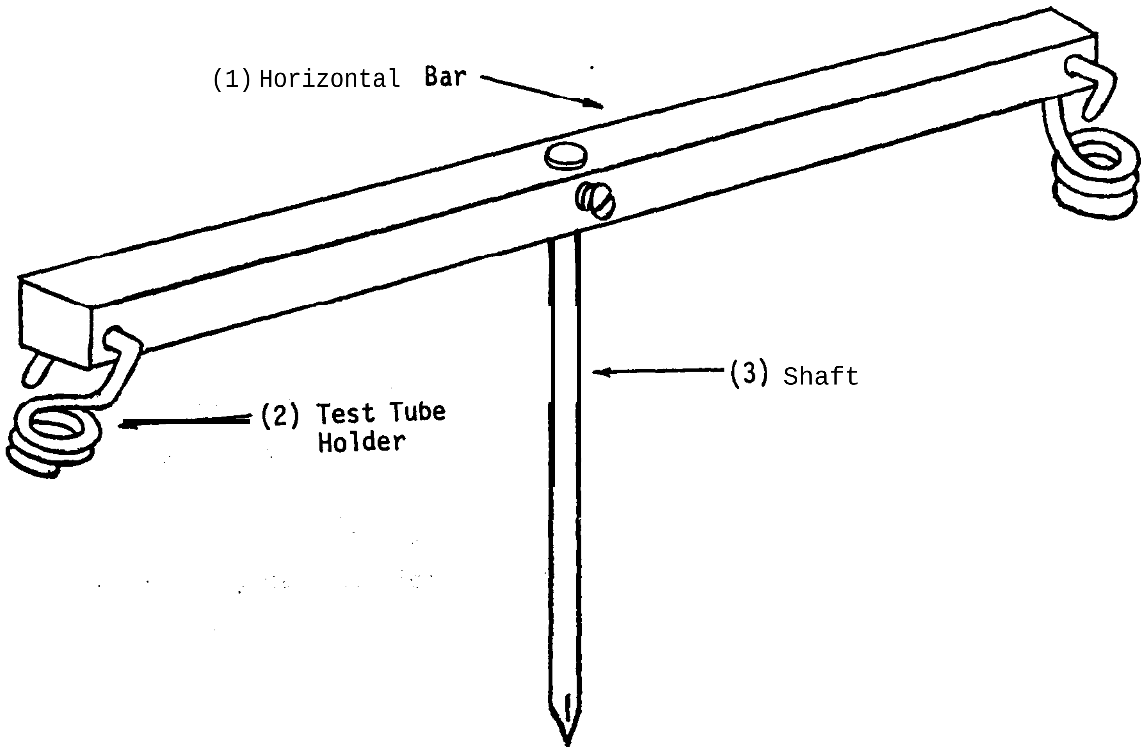
When the free ends of the electrodes are connected to three or more 1.5 volt cells connected in series, sufficient current passes through the solution to break down the water. Hydrogen is the gas generated at the negative plate (cathode) and collected in the tube placed over that plate. Oxygen is generated at the positive plate (anode) and is collected approximately one half as rapidly as hydrogen.

(ii) This apparatus is quite suitable for student use in the laboratory, as it is simple to set up and requires little current. With three or more 1.5 volt cells, the gases are evolved rapidly and the tubes can be filled in about 20 - 30 minutes.

(iii) Several factors enhance the efficient operation of this apparatus. The small volume of solution used and the proximity of the plates reduce the amount of resistance in the system and allow it to function on low current. If the plates are cleaned after each use, the apparatus will also function more efficiently.

D. CENTRIFUGAL SEPARATORS

Dl. Hand Drill Centrifuge

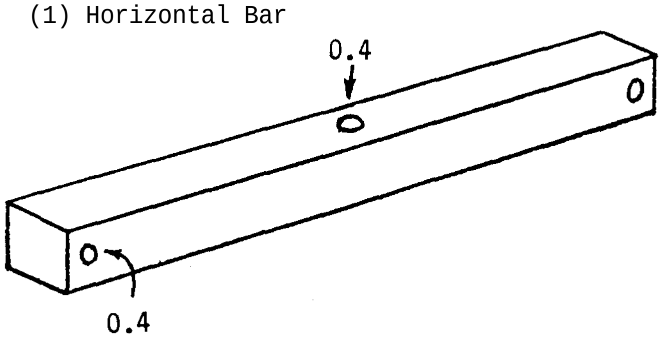


a. Materials Required

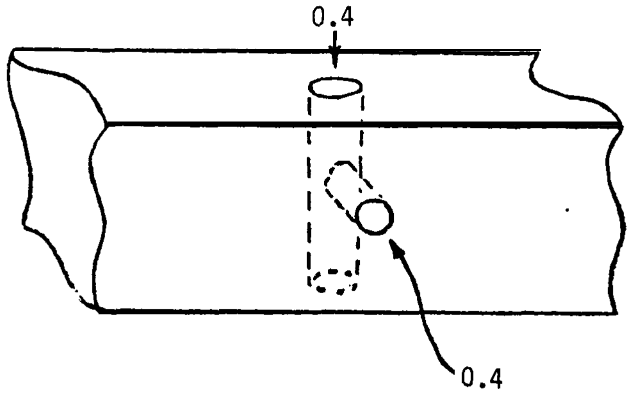
Components	Qu	Items Required	Dimensions
(1) Horizontal Bar	1	Wood (A)	2 cm x 2 cm x 32 cm
(2) Test Tube Holder	2	Stiff Wire (B)	Approximately 0.2 cm diameter, 30 cm long
(3) Shaft	1	Nail (C)	0.5 cm diameter, 18 cm long
	1	Bolt (D)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Horizontal Bar

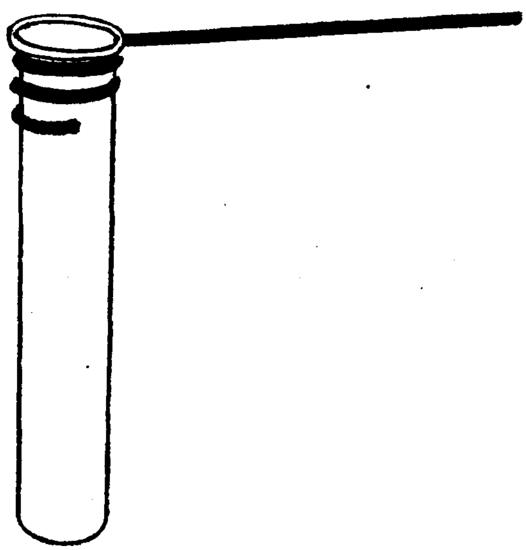


Drill holes, approximately 0.4 cm in diameter, at each end of the wooden bar (A). Drill a hole through the center of the bar, as shown. Make the diameter of this hole slightly smaller than the diameter of the nail (C) used for the shaft.

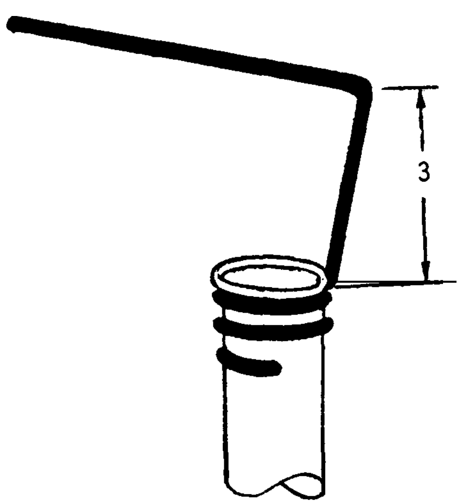


Then, drill a hole perpendicular to and intersecting the hole in the center of the bar. Make the diameter of this hole slightly **smaller than the diameter of the bolt (D) used to hold the shaft in place.**

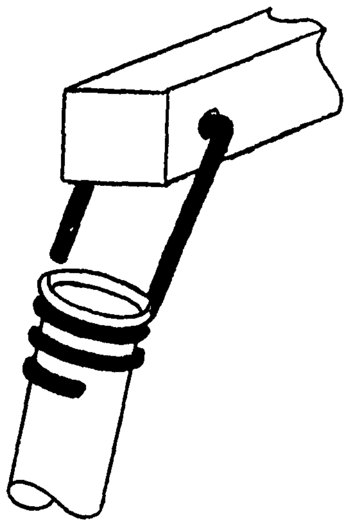
(2) Test Tube Holder



Take a test tube of the size that will be used in the centrifuge. Wind one piece of heavy, stiff wire (B) (coat hanger wire, for example) around the test tube two or three times. Make the coil very snug around the test tube so that the test tube lip will not slip through it. Leave a straight portion of about 8 - 9 cm at the top of the coil.



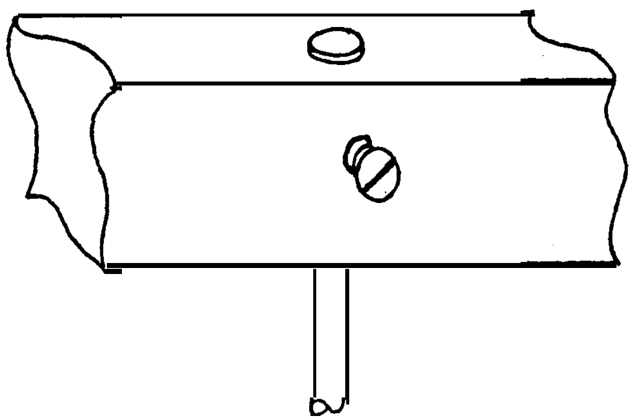
Bend the straight portion of the wire at an angle to the rest of the coil as shown. About 3 cm from the coil, bend the wire again, at right angles to the upright portion.



Fit the free end of the wire into one of the end holes in the horizontal bar. Check to see that the fit is loose enough for the holder to swing easily. Then bend the excess wire down, as shown, to secure the holder in the horizontal bar.

Repeat this procedure for the construction of the second test tube holder.

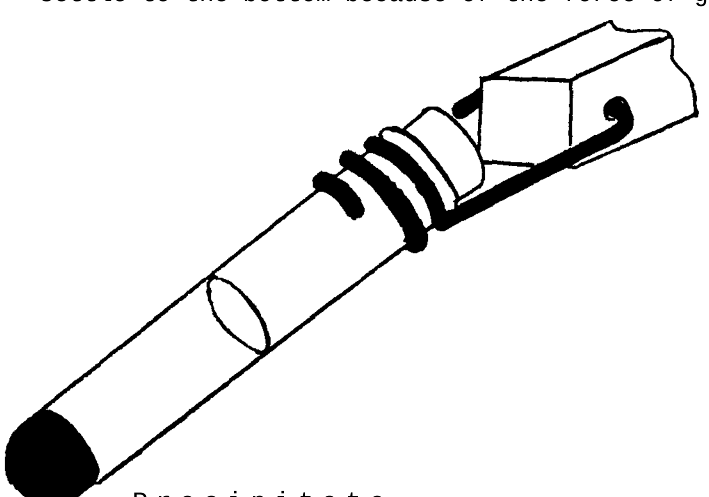
(3) Shaft



Carefully thread the short bolt (D) into the center, horizontal hole in the horizontal bar. Then unscrew it halfway. Fill the nail hole (vertical hole) with epoxy glue and tap the nail (C) into the hole. Tighten the bolt against the nail and coat the threads of the bolt with epoxy glue.

C. Notes

(i) A precipitate formed by a chemical reaction in a test tube will eventually settle to the bottom because of the force of gravity acting upon it. The time required for a given precipitate to settle is dependent on several factors; among these are the volume, density, and particle size of the precipitate. Spinning such material in a test tube in a centrifuge reduces this duration by creating a strong centrifugal force, which causes the heavier precipitate to settle to the



outside of the centrifuge. When the test tube holders are free to pivot outward, as in this centrifuge, the test tubes will assume a nearly horizontal position when the centrifuge is in rapid motion. Thus, the bottom of the test tube becomes the "outside" of the centrifuge, and precipitate is pulled to the bottom of the tube.

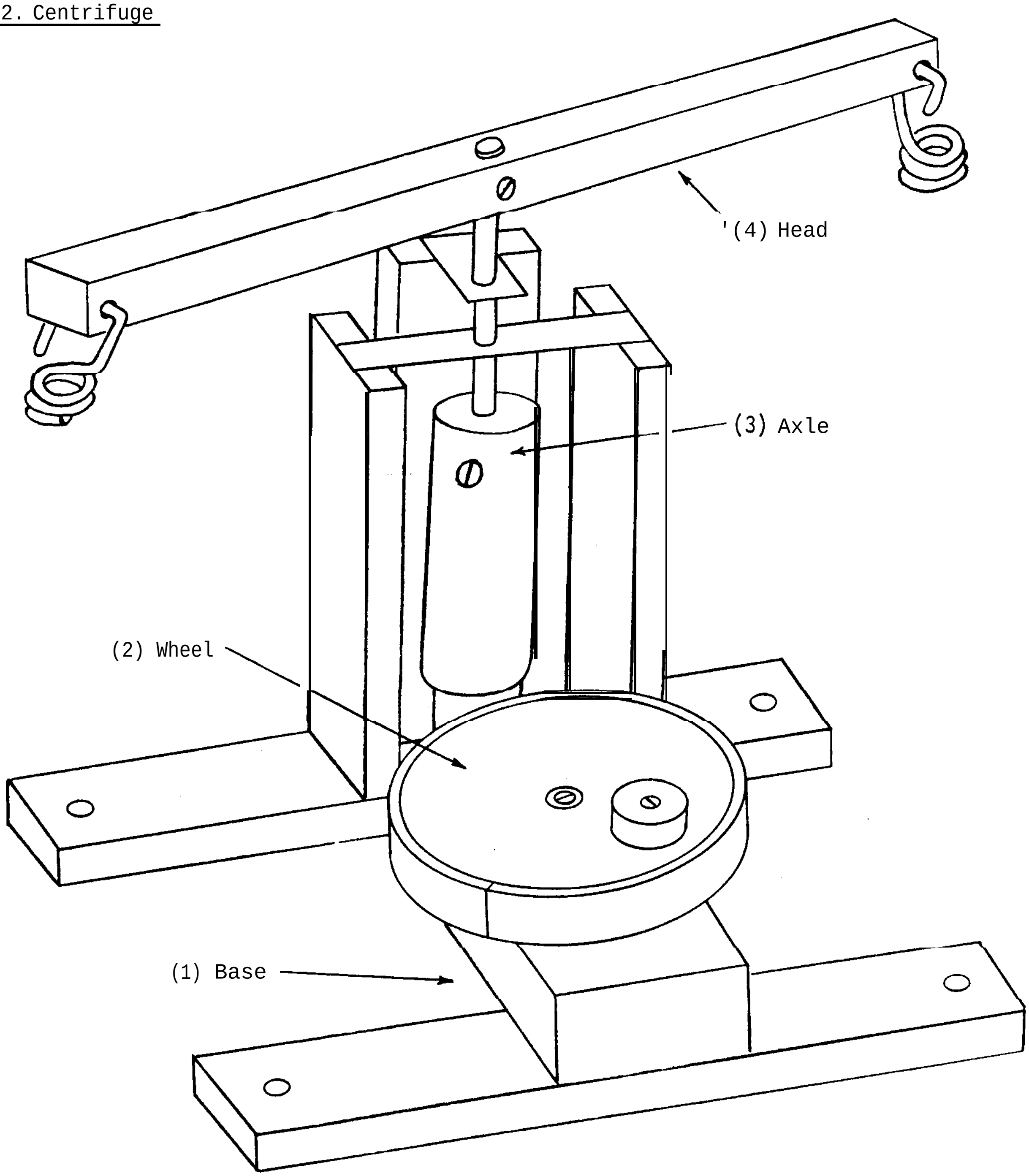
(ii) To use this centrifuge, place an appropriately sized test tube containing material to be centrifuged through one of the wire holders. To balance the centrifuge, place a test tube with an equal volume of water in the other holder. Take care to insure that the test tubes are securely held in place by the holders. Seal both test tubes with corks or stoppers to prevent spillage. Fix the end of the shaft firmly in a hand drill. Clamp the drill handle tightly in a heavy vise, stand at arm's length from the drill, and turn the handle of the drill. The centrifuge will spin, causing the precipitate to collect at the bottom of the test tube. To stop the centrifuge, let go of the drill handle and allow the centrifuge to continue to spin until it comes to a gentle stop. Another way to stop the centrifuge is to turn the drill handle more and more slowly until it is brought to a gentle stop. Sudden stops, which will shake up the precipitate, are to be avoided.

(iii) If a vise is not available, the drill may be held at arm's length from the body while the centrifuge is spun.

(iv) This centrifuge is capable of being spun at 300 - 500 revolutions per minute. It was tested with several precipitates, such as $CaCO_3$ and $AgNO_3$, and was found to reduce settling time from several hours (gravity) to less than one minute.

(v) This centrifuge, whether clamped in a drill or held at arm's length, must be used with extreme care since the test tubes swing close to the user. A safer, more permanent centrifuge, which incorporates this centrifuge as its rotating assembly, is described in the following section.

D2. Centrifuge



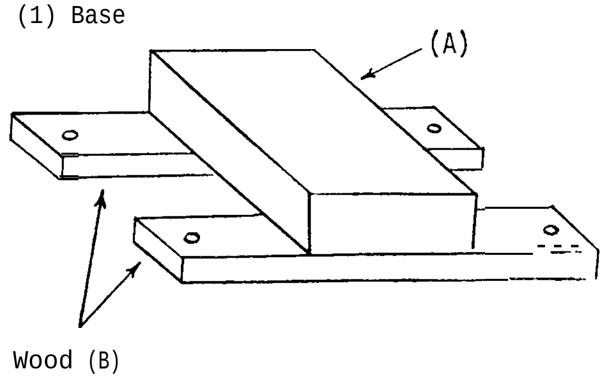
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	4 cm x 9 cm x 30 cm
	3	Wood (B)	2 cm x 5 cm x 30 cm
	2	Wood (C)	2 cm x 5 cm x 25 cm

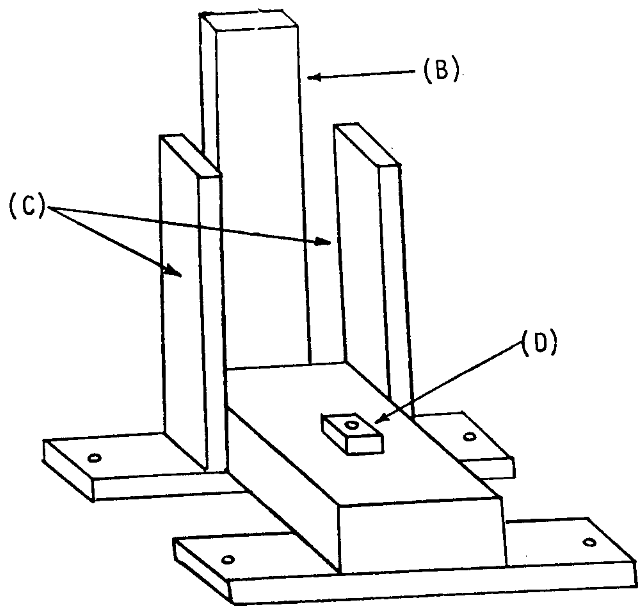
	1	Wood (D)	Approximately 3 cm x 3 cm x 1 cm
(2) Wheel	1	Wood (E)	1 cm x 15 cm x 15 cm
	1	Wooden Spool (F)	Approximately 3 cm x 3 cm x 3 cm
	2	Washers (G)	Approximately D.8 cm inside diameter, 2.0 cm outside diameter
	1	Screw (H)	Approximately 0.6 cm diameter, 6.0 cm long
	1	Screw (I)	Approximately 3 cm long
	1	Rubber Strip (J)	1 cm x 50 cm
(3) Axle	1	Wood (K)	4 cm x 4 cm x 16 cm
	1	Wooden Spool or Dowel (L)	3 cm diameter, 3.5 cm long
	3	Finishing Nails (M)	Approximately 5 cm long
	1	Screw (N)	Approximately 0.6 cm diameter, 6.0 cm long
	2	Washers (0)	Approximately 0.8 cm inside diameter, 1.5 cm outside diameter
	1	Nail (P)	0.5 cm diameter, 18 cm long
	1	Bolt (Q)	Approximately 0.5 cm diameter, 2 cm long
	1	Rubber Strip (R)	3.5 cm x 10 cm
	2	Metal Strapping (S)	11 cm x 1 cm
(4) Head	1	Wood (T)	2 cm x 2 cm x 32 cm
	2	Stiff Wire (U)	Approximately 0.2 cm diameter, 30 cm long
	1	Bolt (V)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Base

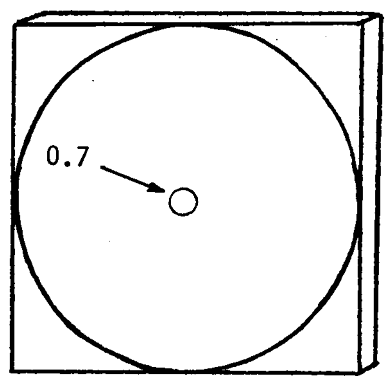


With nails or glue and screws, secure the thick piece of wood (A) to two pieces of wood (B) as shown to form the feet and bottom of the base. Drill a hole approximately 0.5 cm in diameter at each end of the feet (B).



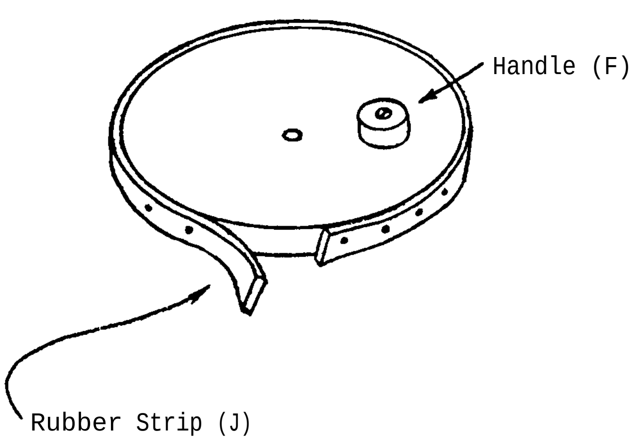
Next, nail or glue and screw the third piece (B) to the bottom of the base, in an upright position as shown. Secure the two shorter uprights (C) in position as shown. Glue the small piece of wood (D) to the center of the horizontal board. When the glue has dried, drill a hole about 0.5 cm in diameter through the small piece of wood (D) and a centimeter or so into the base (A).

(2)Wheel



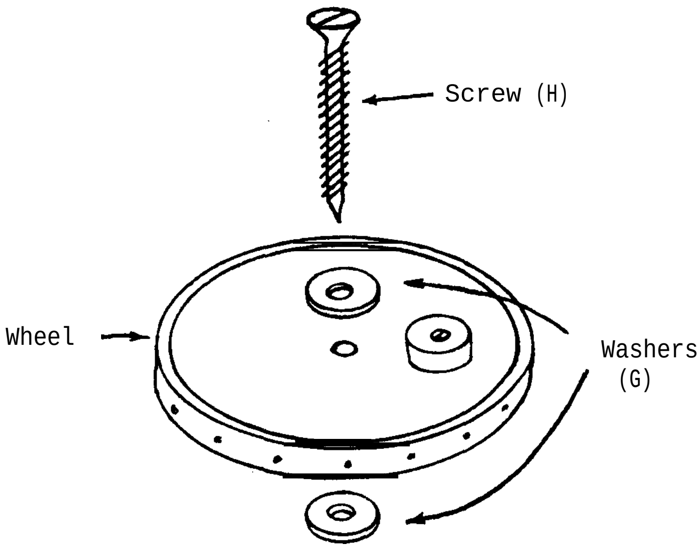
Wood (E)

Inscribe a circle in the thin wooden square (E). Carefully cut out the circle. Drill a hole, 0.7 cm diameter, through the center of the circle.



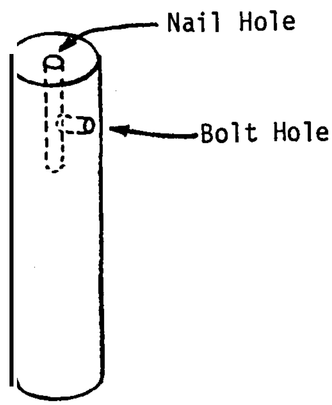
Fasten the strip of rubber sheeting (J) (e.g., from a tire inner tube) to the circumference of the wheel with glue and small nails with heads.

With the shorter screw (I), fasten the wooden spool (F) loosely to the wheel about halfway between the center and edge of the wheel. The handle must be free to rotate around the screw.

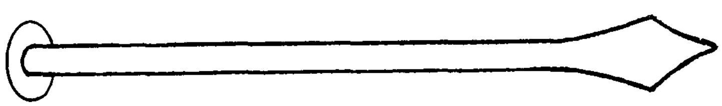


Mount the wheel to the base by inserting the long screw (H) through a washer (G), through the wheel, then through the second washer (G). The holes in the wheel and washers should be slightly larger in diameter than the screw (H). Finally, turn the screw firmly into the small piece of wood (D) on the horizontal board of the base. Make certain that the wheel will rotate freely around the screw without wobbling.

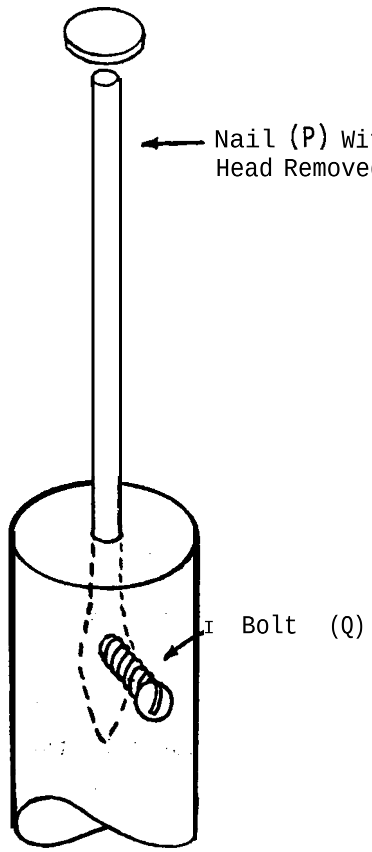
(3) Axle



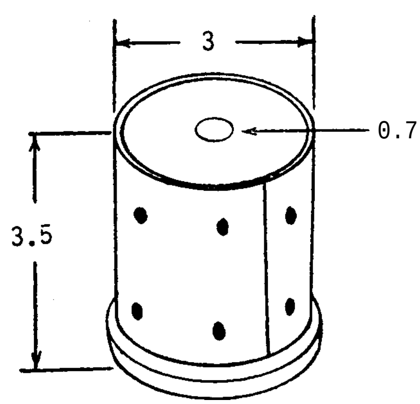
For the upper section of the axle, use the wooden block (K) or dowel. Drill a hole approximately 0.4 cm in diameter and approximately 5 cm deep into the center of one end of the block. Then drill a second hole, about 2.5 cm from the end, at a right angle to and intersecting the first hole. Make the hole about 0.4 cm in diameter, or just a little smaller than the bolt (Q) which is to be threaded into it.



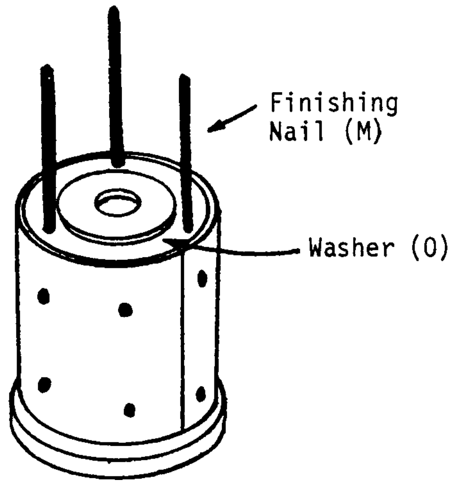
Flatten the end of a large nail (P) by hammering it on a metal block or anvil.



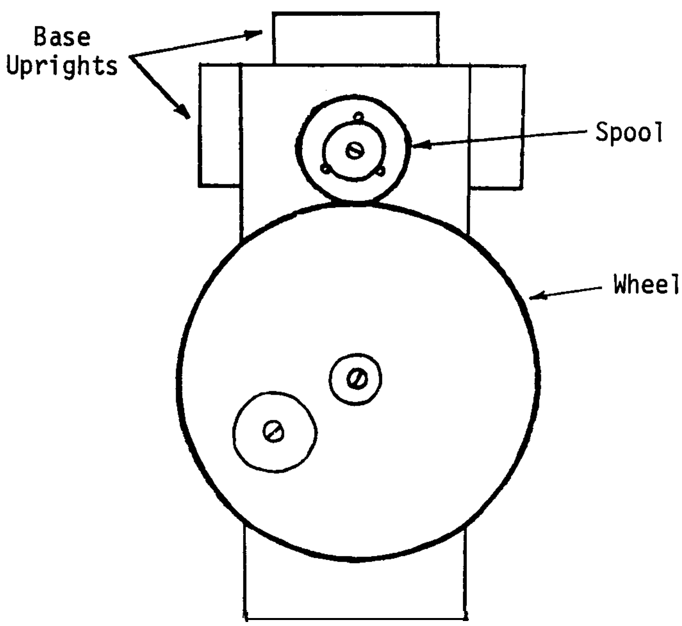
Carefully thread the bolt (Q) as far as possible into the bolt hole in the axle, then unscrew it halfway. Fill the nail hole with epoxy glue, and tap the nail (P) into the hole. Tighten the bolt against the nail, then coat its threads with epoxy glue. Finally, cut the head off the nail.



For the lower section of the axle, use a wooden spool (L) from which the thread has been removed, or a 3 cm diameter dowel. Cut the spool or dowel to a height of about 3.5 cm. Fasten a strip of rubber sheet (R) around the outside, just as for the wheel. Enlarge the hole in the spool to about 0.7 cm diameter.

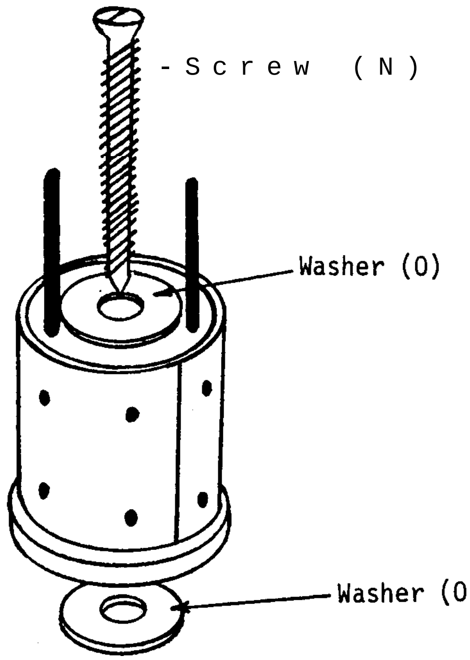


Fit one washer (0) on the top of the spool, aligning the holes of spool and washer. Drive three small finishing nails (M) into the top of the spool, outside the washer. Let approximately 3 cm of nails protrude from the top of the spool, and cut off their heads.

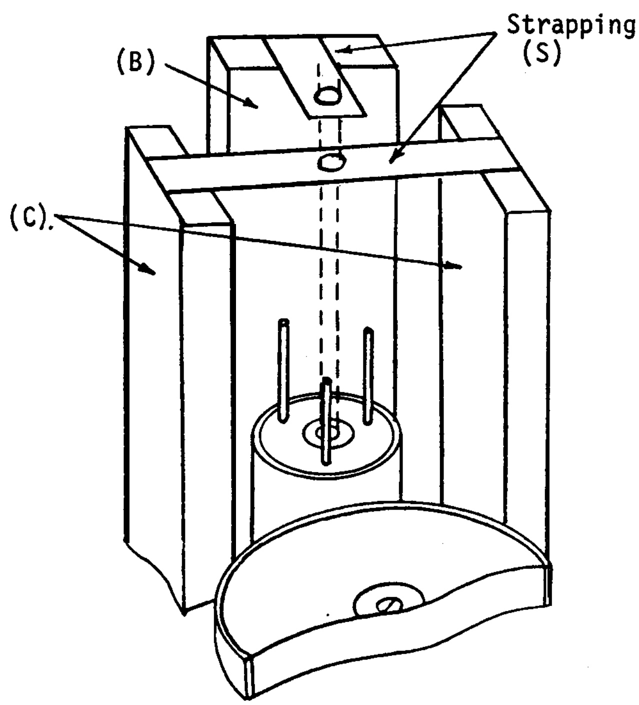


Overhead View of Base, Wheel and Axle Location

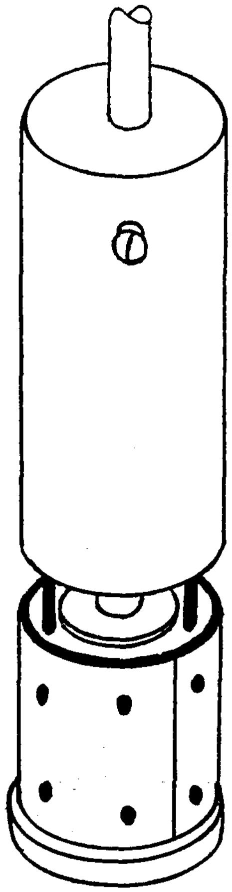
Locate the position of the axle by setting the spool on the horizontal board (A) of the base such that the rubber strip on the spool presses firmly against the rubber strip on the wheel. Mark the position of the center of the spool, and drill a small hole at that position.



Mount the spool (L) on the horizontal board (A) of the frame by passing a long screw (N) through the washer (O) and spool (L); then through a second washer (O), and into the hole in the base. Turn the screw firmly into the horizontal board, so that the spool is free to rotate. In addition, the edge of the wheel must rub the edge of the spool firmly enough so that when the wheel turns, the spool also rotates.



Construct strapping braces for the axle as follows: Drill a hole 0.8 cm in diameter in the center of one of the pieces of metal strapping (S). Nail this piece to the two shorter uprights (C) of the base such that the hole in the strapping is directly over the center of the spool on the base below. Drill a similar hole near one end of the other piece of strapping (S), and nail it, as shown, to the taller upright of the base (B) such that its hole is directly over the hole in the strapping below it. Trim off any excess.



Slip the nail end of the upper section of the axle through the holes in the strapping braces. Rest the other end of the upper section evenly on the tops of the three nails in the spool, and then drive the upper section into the nails with a hammer so that the spool and upper section will form a continuous solid piece. However, do not drive the upper section so far down that its end will hit the top of the screw and prevent the entire axle from turning. If this operation has been done correctly, the axle will turn when the wheel is rotated.

(4) Head

Prepare the horizontal bar and test tube holders according to directions given for the Hand Drill Centrifuge, VI/Dl, using the wood (T) and stiff wire (U). Secure the nail of the axle to the centrifuge head according to directions given in VI/D1 with the bolt (V).

c. Notes

(i) The centrifuge should be bolted or clamped to the table top before using.

(ii) To use this piece of apparatus% the substance to be centrifuged is placed in an appropriately sized test tube. A second test tube is filled with an equal amount of material to be centrifuged or an equal volume of water. Each test tube is placed in one of the holders and checked to see that they will not slip out through the holder. Both test tubes are sealed with stoppers. Stand at arm's length from the centrifuge and turn the wheel, first slowly, then more and more rapidly. The tubes will be spun about in a nearly horizontal position. Do not try to stop the centrifuge suddenly by holding the wheel stationary; either let go of the wheel and allow the centrifuge to come to a gentle stop, or turn the wheel more and more slowly until the centrifuge is brought to a gentle stop.

(iii) Matched pairs of test tube holders of various sizes may be constructed and used interchangeably in the same centrifuge head, if desired.

(iv) When the wheel of this centrifuge is turned rapidly, about 150 turns per minute, for example, the centrifuge head spins at nearly 500 revolutions per minute.