GUIDEBOOK TO CONSTRUCTING

INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume I: Biology

Inexpensive Science Teaching Equipment Project

Science Teaching Center

University of Maryland, College Park

U.S.A.

Inexpensive Science Teaching Equipment Project

Science Teaching Center

University of Maryland

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The Guidebook is presented in three volumes:

Volume I, Biology
Volume II, Chemistry
Volume III, Physics

The following table refers only to the contents of this volume, but the listing at the back of each volume provides an alphabetical index to all three volumes.

References within the text normally indicate the volume, chapter and number of the item referred to (e.g., PHYS/V/A3), but where a reference is to an item within the same volume, the reference indicates only the chapter and number of the item (e.g., V/A3).

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FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-Z Study), the Project was to (1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; (2) improvise, wherever possible, equivalent inexpensive science teaching equipment; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours' that are available for apparatus production.

However, in designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest of ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8") capacity
Glass Cutter
Knife
Razor Blades
Scissors: 200 mm (8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (8")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90^o
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i 1/32" 1/16" 3/32", 1/8" 5/32", 3.16", 7/32", 1/4") set
Wood Brace with Ratchet: 250 mm (10")
Wood Auger, Bits: 6, 12, 18, 24 nun
(i.e., 1/4", 1/2", 3/4", 1")

Files, Double Cut

Flat: 100 mm, 200 mm (4", 8")
Round: 100 mm, 200 mm (4", 8")
Triangular: 100 mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper, Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose - volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

Set Square
Square, Carpenter's: 300 mm (12") blade
Spoke Shave: 18 mm (3/4")
Wood Smoothing Plane

Pliers

Combination: 150 mm (6")
Needle Nose: 150 mm (6")
Side Cutting: 150 mm (6")
Vise Grips

Saws, Metal

300 mm (12") blades

Saws, Wood

Back Saw: 200, 300 mm (8", 12")
Coping Saw: 200 mm (8")
Cross Cut: 600 mm (24")
Hand Rip: 600 mm (24")
Key Hole Saw: 200 mm (8")

Screw Drivers

100 mm (4"), with 2 and 3 mm tips
150 mm (6"), with 5 mm tip
200 mm (8"), with 7 mm tip

Vise

Metal Bench Vise: 75 mm (3")
Wood Bench Vise: 150 mm (6")

Miscellaneous

Asbestos Pads
Goggles, Glass
Oil Can: 1/2 liter (1 pint)
Oil Stone, Double Faced
Punch, Center
Sandpaper and Carborundum Paper, Assorted grades
Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

All Purpose Cement (Elmers, Duco)
Epoxy Resin & Hardener (Araldite)
Rubber Cement (Rugy)
Wood Glue (Weldwood)
Cellophane Tape
Plastic Tape
Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2",1", 2") lengths
Nails: 12,24mm(1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4", 1", 1 1/2") lengths
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5.16") diameter
Wingnuts (Steel): 5 mm (3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

* U.S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be make in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (1/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm(1/16") diameter
*Copper: #20 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20, 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)
Grease
Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord, Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.

I. MAGNIFIERS AND MICROSCOPES

A. MAGNIFIERS

Magnifiers are used for low power magnification. The three included here can be employed wherever it is desirable to see a little more detail than is obtainable with the naked eye.

B. MICROSCOPES

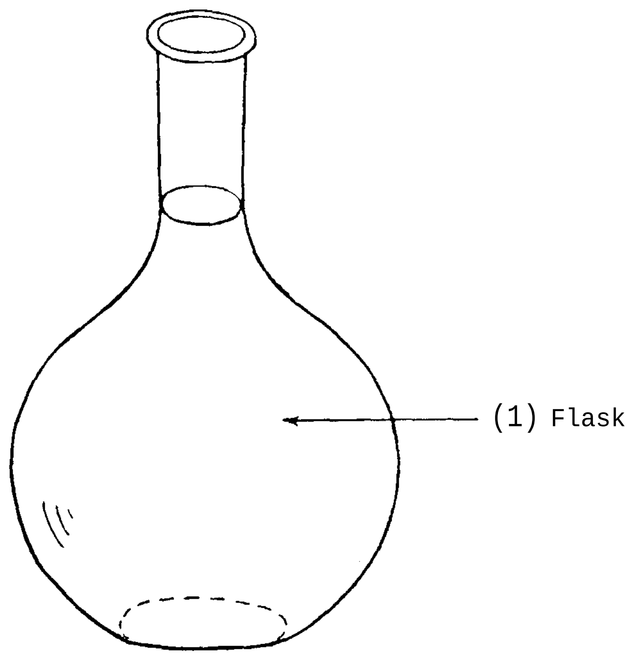
Where high power magnification is needed, microscopes can be used. The ones in this section can, for the most part, be adapted to use water drop, glass bead, or penlight bulb lenses. Magnifications up to around 60X - 80X may be gotten using these microscopes. All are designed for use with freshly and/or permanently mounted glass slides.

C. SUPPLEMENTARY APPARATUS

These items are essential for preparing the slides to be viewed with the microscopes.

A. MAGNIFIERS

Al. Water Filled Magnifier



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask	1	Spherical Body Flask (A)	50-500 ml

b. Construction

(1) Flask

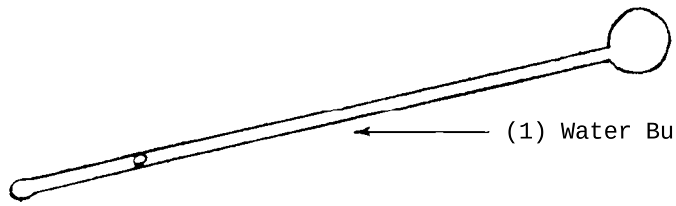
Simply fill the flask (A) with clear water up to the neck.

c. Notes

(i) A 250 ml flask (about 7.5 cm in diameter) will magnify approximately the same as a double convex magnifying glass 4 cm in diameter and 0.7 cm in thickness.

(ii) Smaller diameter flasks appear to magnify more than larger diameter ones.

A2. Water Bulb Magnifying Glass *

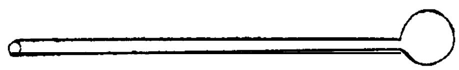


a. Materials Required

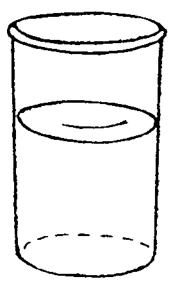
Components	Qu	Items Required	Dimensions
(1) Water Bulb Magnifying Glass	1	Glass Tubing (A)	0.3 cm diameter, 10-13 cm long

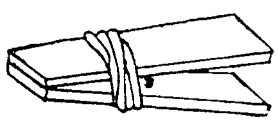
b. Construction

(1) Water Bulb Magnifying Glass

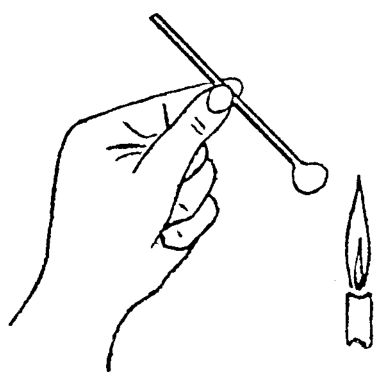


Use a Bunsen Burner or gas burner and fuel system (CHEM/II/Cl and 2) as a heat source. Follow the glass-blowing instructions (CHEM/I/D6) and blow at one end of the glass tube (A) a bulb of about 0.8 cm diameter.



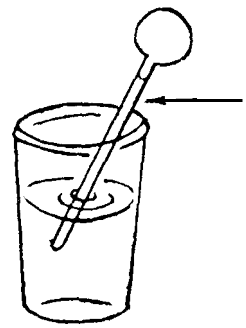


Provide a glass or cup of water and a wooden clothespin, pinch clamp (CHEM/IV/A4) or a few square centimeters of cloth to serve as a holder.

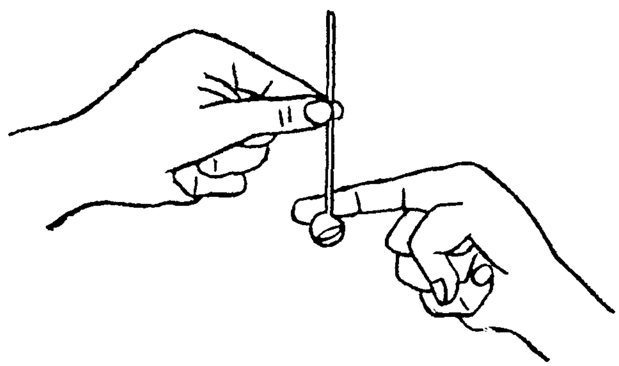


Rotate the bulb near, but not in, the flame to expand the air in the bulb.

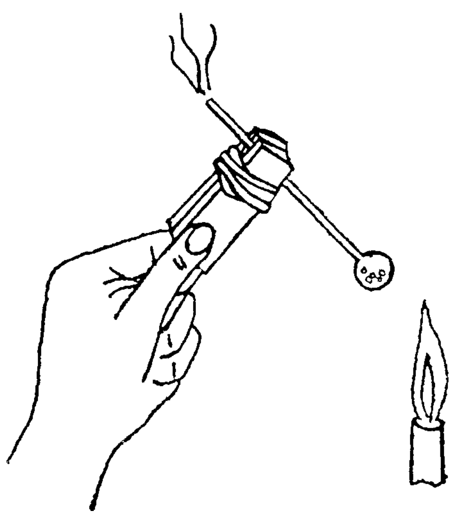
*Adapted from James E. Hammesfahr and Claire L. Strong, Creative Glassblowing, (San Francisco: W. H. Freeman and Company, 1964), pp 108-9.



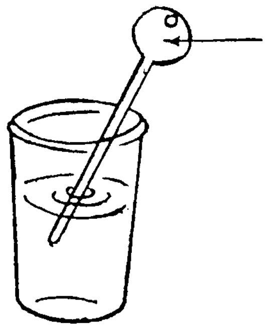
After a few seconds of heating, quickly invert the piece and put the open end into the water. Allow the piece to remain in the water a few seconds. The air in the bulb contracts and water is drawn up into the tube.



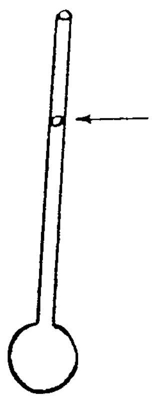
Remove the piece from the water and hold it, bulb down, in one hand near the open end of the tube. Lightly flick the bulb with the index finger of the other hand. Continue flicking until the water has gone from the tube into the bulb.



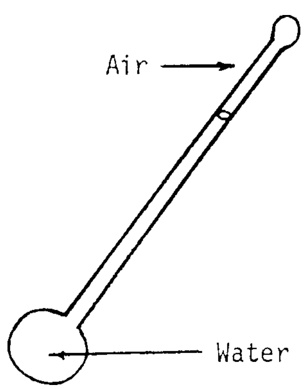
Next, grasp the tube with the clothespin, pinch clamp, or folded cloth, and again hold the bulb close to the flame until the water boils. Point the open end of the tube away from yourself and anyone else.



Heat the bulb while steam escapes from the tube for about 5 seconds. Then quickly invert the tip of the tube into the water. Allow the tube to remain in the water until the bulb is full, or nearly full, of water. If after a few minutes, the bulb has not filled with water, repeat the heating and filling process.



Remove the piece from the water and invert it so that any air remaining in the bulb can enter the tube. Flick the bulb, as before, and the bubble will rise to the open end of the tube.



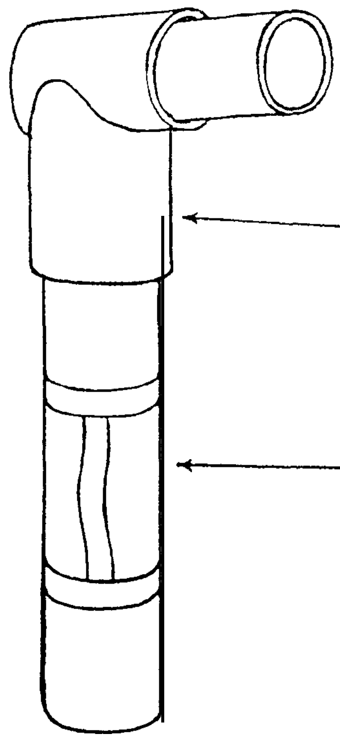
Holding the bulb with the tube upright, heat the end of the tube in the hottest part of the flame to seal the tip. As the tip seals, the expanding air of the trapped bubble blows a tiny bulb at the end of the tube.

c. Notes

(i) The first heating of the bulb expands the air, which, when it contracts, draws a small amount of water into the bulb. Converting this water into steam expels all the air and causes the bulb to fill completely with water as the steam condenses.

(ii) When this water-filled bulb is held about 0.5 cm from an object, the object will appear distorted around the edges, but clear and greatly enlarged at the center of the bulb.

A3. Illuminated Hand Magnifier



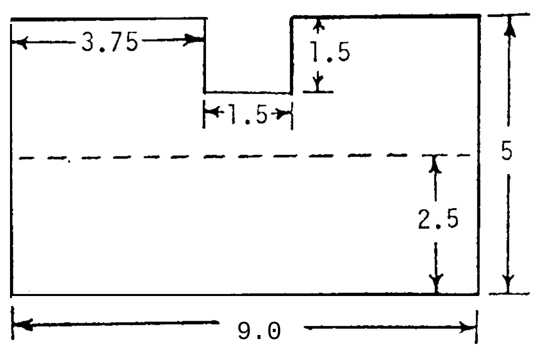
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Eyepiece	1	Double Convex Lens (A)	2.5 cm diameter
	1	Single Convex Lens (B)	2.5 cm diameter
	1	Cardboard Tube (C)	5 cm long, 2.5 cm inside diameter
	1	Cardboard Tube (D)	5 cm long, 2.8 cm inside diameter
(2) Adaptor	1	Cardboard Tube (E)	5 cm long, 3.5 cm inside diameter
(3) Barrel	1	1.5 Volt Penlight Bulb (F)	2.2 cm long, 1.0 cm diameter
	1	Tin Sheet (G)	3.7 diameter, 0.05 cm thick
	2	Electrical Wire (H)	10 cm long, #26 gauge (about 0.05 cm in diameter); strip insulation from 1 cm of each end

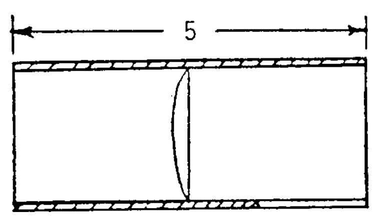
2	1.5 Volt Dry Cells (I)	3.2 cm diameter 5.7 cm long
1	Steel Bolt (J)	2 cm long, 0.5 cm diameter
1	Steel Nut (K)	0.5 cm inside diameter
1	Steel Strapping (L)	12.5 cm x 1.2 cm x 0.05 cm
1	Cardboard (M)	3.5 diameter
1	Cardboard Tube (N)	15 cm long, 3.2 cm inside diameter

b. Construction

(1) Eyepiece

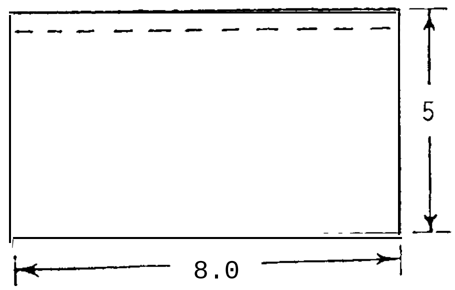


Tube (D)

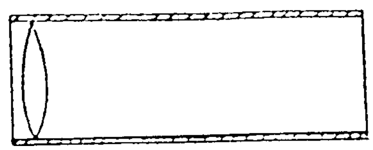


Cross Section of
Tube (D)

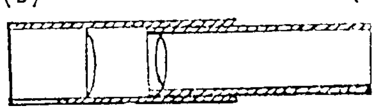
If a cardboard tube cannot be found of the required size, one can easily be made from a piece of cardboard cut as shown. Roll the cardboard into a tube (D) 5 cm long and position the single convex lens (B) in place with the edge on the dotted line. The lens can be held in place with rubber cement or similar flexible adhesive while the tube (D) is held together with masking tape. Be certain the flat side of the lens faces the front (notched) end of the tube.



Tube (C)



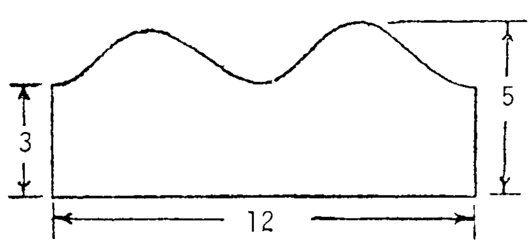
Cross Section of
Tube (C)



Cross Section

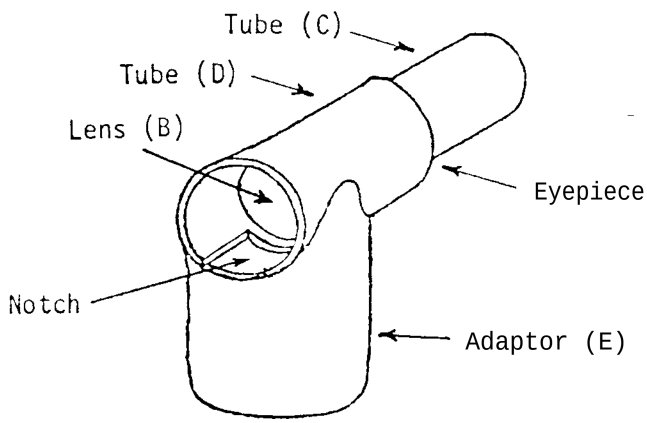
The second tube (C) may be made the same way as the first if a manufactured cardboard tube of the correct size cannot be found. Roll the cardboard into a tube and position the double convex lens (A) at one end with rubber cement. Fasten the tube securely with masking tape. This tube (C) should fit rather snugly inside tube (D), but still be able to slide easily back and forth.

(2) Adaptor



Adaptor Pattern

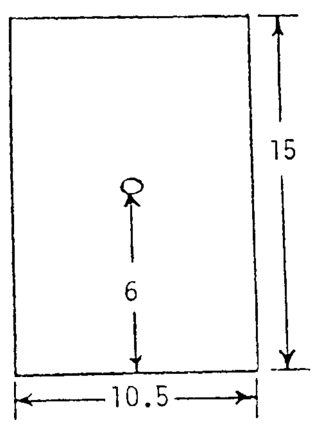
The adaptor can be made from a cardboard tube (E) by notching one end so that it will interlock with the eye-piece. The adaptor and eye-piece can then be taped with masking tape. Alternatively,



the pattern for the adaptor can be cut from cardboard, rolled into a cylinder, and taped. Even if the two tubes don't "mesh" exactly, they can be taped well enough to overcome inaccuracies.

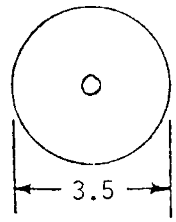
When binding the eyepiece and adaptor together with tape, be sure that the notch in the eyepiece tube (D) is directly over the adaptor tube opening.

(3) Barrel

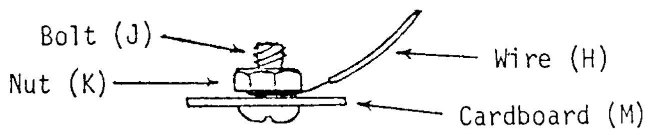


Tube (N)

If a tube (N) of the correct size is available, simply punch a small hole (0.2 cm) about 6 cm from one end of the tube. Otherwise, a tube can be fashioned from a piece of cardboard of the indicated dimensions. Roll and tape it so that it is 15 cm long and has a 3.2 cm inside diameter.

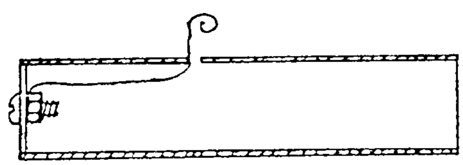


Cardboard (M)



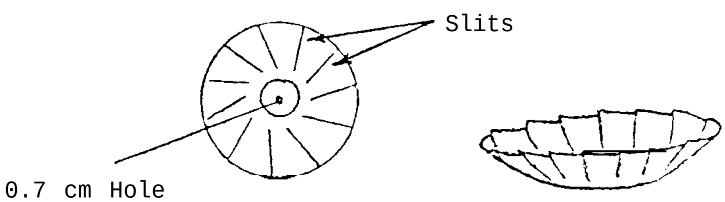
Side View

To seal off the end of tube (N), use the circular piece of cardboard (M). First, punch a hole in the center of the cardboard disc, and insert the short steel bolt (J). Fasten one of the pieces of electrical wire (H) in place with the nut (K). Pull the free end of the wire through the hole in the tube (N) and glue the disc (M) in place to seal off one end of the tube.



Cross Section of Tube (N)

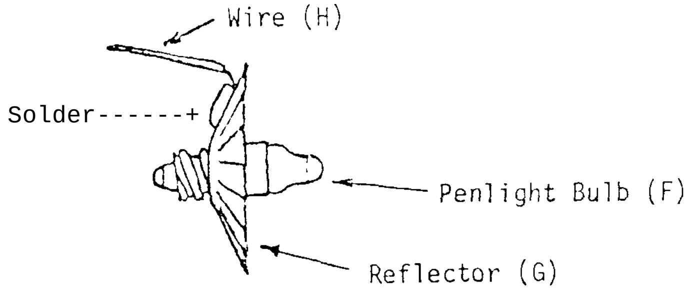
Use the disc of tin sheeting (G) to make a reflector. First, drill a hole in the center of the disc of a diameter such that the pen-light bulb (F) will screw into it securely (approximately 0.7 cm diameter). Next, cut slits in the disc (G) as shown. Fold the resulting flaps up slightly so that



Before Folding

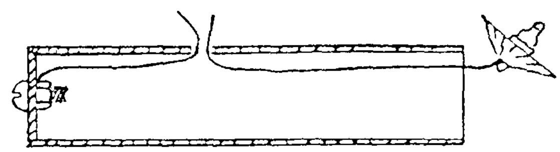
After Folding

Reflector (G)

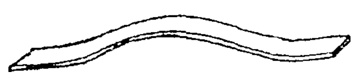


the reflector approximates a cone in appearance.

Next, screw the bulb (F) in place, and solder one end of the second piece of wire (H) to the back of the reflector. Pull the free end of the wire through the hole in the barrel tube (N) and leave the reflector assembly loose temporarily.

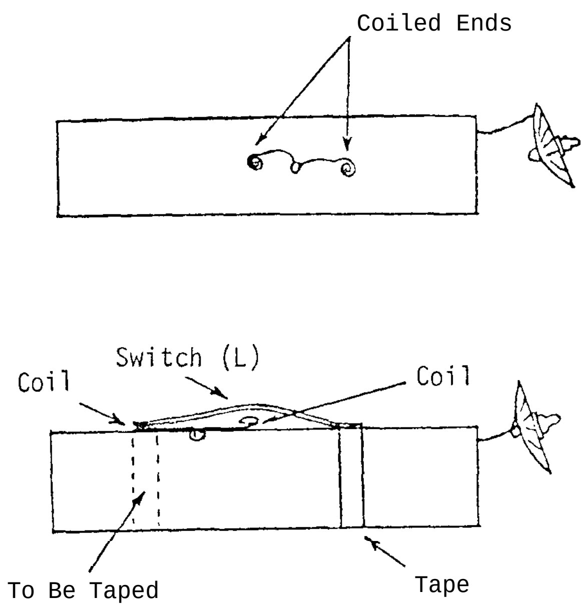


Cross Section



Switch (L)

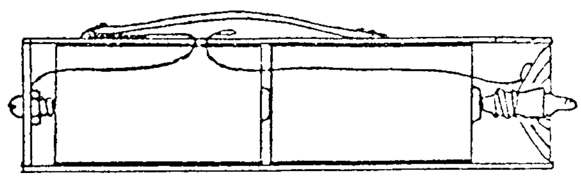
The switch is made from the piece of steel strapping (L). Give it a slight bend in the middle.



Side Views

Coil the free end of the wire which comes from the sealed end of the barrel. Do like-wise for the other wire.. Tape the switch to the barrel making certain that one end of the switch is taped directly over one of the wire coils and that the second coil is directly under the bent portion of the switch but not touching it. In other words, when the switch is depressed, contact will be made with the wire coil and the circuit from the bolt to the bulb will be completed.

Finally, insert two dry cells (I) into the barrel and push the reflector assembly into place.



Cross Section of Completed Barrel

The bulb must make contact with the battery. The reflector assembly should hold in place by tension, and require no further fastening. When the switch is pressed, the light should go on.

To complete the illuminated hand magnifier, insert the barrel into the adaptor.

c. Notes

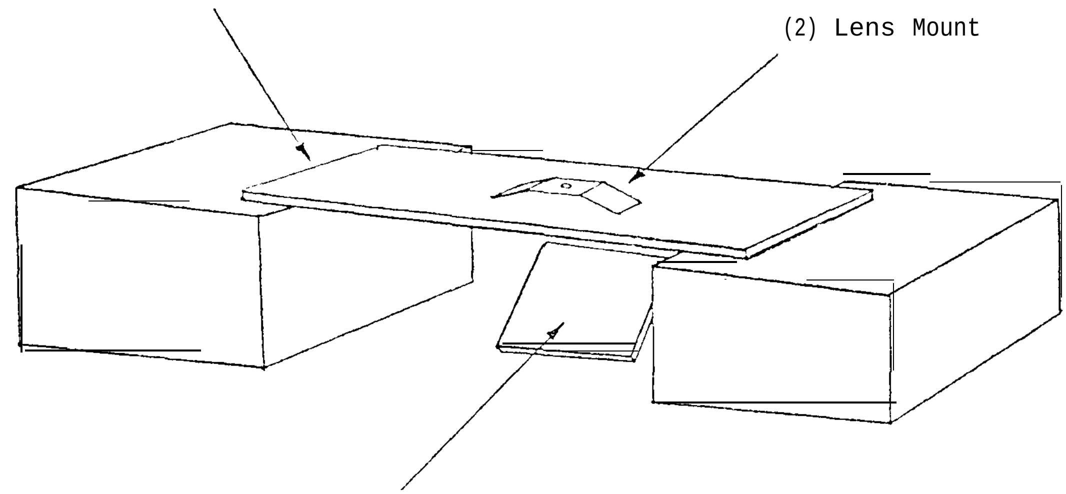
(i) The illuminated hand magnifier must be held directly over the object to be viewed. The light serves to concentrate the illumination of the object while focusing is accomplished by moving the eyepiece tube (C) up and down in relation to the second tube (D).

(ii) This magnifier is excellent for observing detail on such items as insect parts, plant surface features, crystals, etc.

(iii) Obviously, any variation in the lens diameter as given here will necessitate changes in the dimensions of the item. If a lens is slightly smaller than the cylinder into which it must be fit, it can be built up by wrapping thin pieces of tape around its edge until it will fit snugly.

B. MICROSCOPES

Bl. Glass Stage Microscope



a. Materials Required

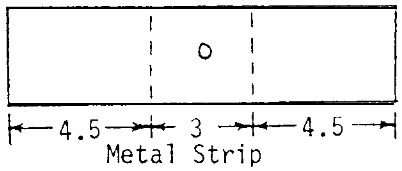
Components	Qu	Items Required	Dimensions
(1) Glass Plate	1	Window Glass (A)	20 cm x 10 cm (at least)
(2) Lens Mount	1	Metal Strip (B)	12 cm x 3 cm x 0.1 cm
(3) Mirror	1	Mirror Glass (C)	Approximately 5 cm x 5 cm

b. Construction

(1) Glass Plate

Rest the glass plate (A) on two books or other stable supports. The glass plate serves as the microscope stage.

(2) Lens Mount



Drill a hole through the center of the lens mount (B). The diameter of the hole will depend on the size and type of lens used [see Notes (ii), (iii), (iv)]. Bend the end of the lens mount down at a slight angle.

(3) Mirror

Use the mirror (C) to reflect enough light through the specimen to permit it to be seen well. If a mirror is not available, use polished metal or other reflective material.

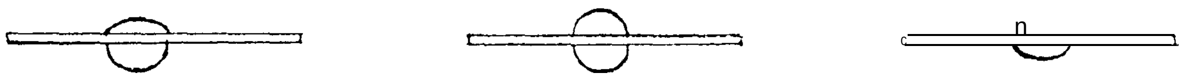
c. Notes

(i) Operating the glass stage microscope is exceptionally easy. Simply place the glass slide containing the specimen under the lens mount and reflect light through the specimen with the mirror. Focusing is accomplished by pushing on the lens mount so that the lens moves closer to or further from the specimen.

(ii) For maximum success in making water drop lenses, the hole in the lens mount must be properly prepared. First of all, this means that the hole should be as nearly circular as possible. A drill will yield best results although holes can be punched with nails, punches, or other sharp implements. Additionally, the edge of the hole should be made smooth and free from burrs. This can be done with a file or tool made especially for this purpose. The optimum size for the hole was found to be approximately 2.5 mm - 3.5 mm in diameter.

Once the hole has been made, the area around the hole should be heated and candle wax melted onto both sides of the lens mount around the hole. Be certain that no wax gets into the hole. This coating of wax prevents the water drop from spreading out and deforming.

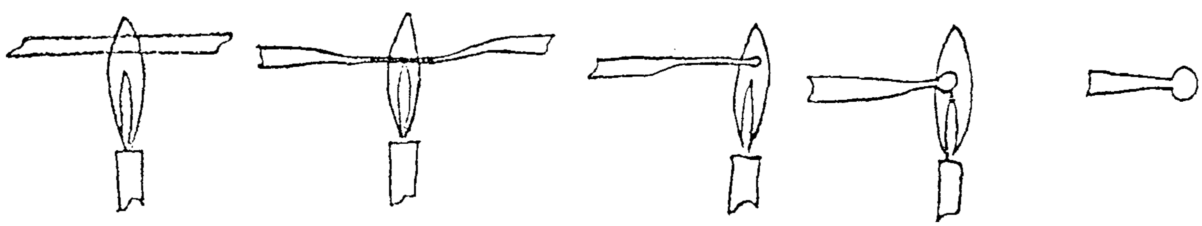
When the hole has been prepared, the water drop lens is made simply by carefully placing a drop of water in the middle of the hole so that it is suspended from the edge. The drop is most easily handled with a dropper. It was found that a water drop with a slightly flattened side provided the best image while a drop flattened on both sides was poor.



Excellent Good Poor

(iii) The object in making a glass bead lens is to form as nearly spherical and clear a bead as possible. This is most easily done if soft glass rods are available. If harder glass is used, extremely hot flames are needed to work it.

First, evenly heat a portion of the glass rod in a flame until it softens. When it is soft, pull the ends out until a long filament is formed and continue to pull until the filament breaks. Using the longer of the two filaments, heat the tip until a bead begins to form. Turning the filament so that the bead forms evenly, continue to heat the bead until it reaches the desired size. Allow the bead to cool and then break it off along with a portion of the stem.



Heating the Rod — Drawing Out the Filament — Beginning the Bead — Completing the Bead — Bead with Stem

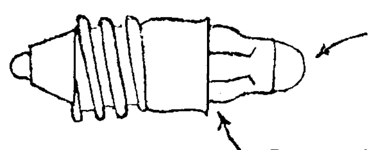
Beads can be made from approximately 2.0 mm to 5.0 mm in diameter, although those from 2.5 mm - 4.0 mm work best. Before mounting the bead on the lens mount, be certain that the hole in the mount is slightly smaller in diameter than the bead. This is extremely important. The bead can then be glued or held in place by a rubber band (see diagram).

Side Views

As the diagrams show, the bead stem should be kept on the underside of the lens mount.

Although glass beads can be made from glass tubing, it is almost impossible to prevent air bubbles from forming in the bead which cause great distortion of the image. Therefore, use solid glass rods, if possible.

(iv) Penlight bulb lenses are made from the penlight bulbs used in small, fountain-pen sized flashlights (battery operated torches). Those commercially available in the United States are approximately 2 cm long and 1 cm in diameter at the widest point. The portion used as a microscope lens is the thickened glass at the tip of the bulb (see diagram).



The lens can be removed from the bulb by scratching the glass portion of the bulb close to the metal part. This avoids scratching the tip of the bulb itself, and is best accomplished with a small, triangular file. Once the whole glass bulb has been separated from the metal part, the lens will break off quite readily; in fact, it may fly off and be damaged unless caution is observed.

The lens may be mounted to the lens mount merely by drilling a hole the same diameter (or slightly smaller) as the lens. Then, apply a flexible glue (e.g., rubber cement) around the edge of the hole and set the lens in place (see diagram). Allow the glue to set before using the microscope.

Cross Section

The penlight bulb lens appears to work best when mounted rounded side up as shown in the diagram.

(v) Because all the microscopes described here are single lens types with small diameter lenses, the focal length is extremely small, which means that the lens must be close to the object viewed and also, the eye must be kept very close to the lens. This tends to cause a strain on the eye if the microscope is to be used for an extended period of time. In addition, it means that the depth of field is extremely limited, requiring frequent adjustments to focus.

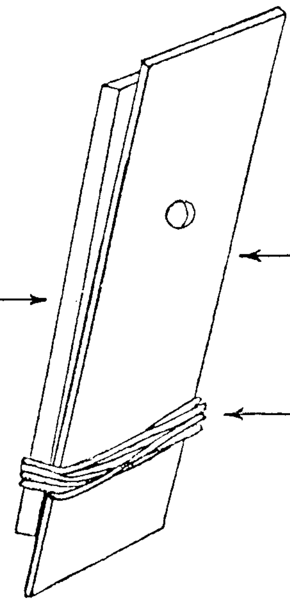
(vi) Magnification power for the different lenses is difficult to determine, but it appears that water drops and glass beads of the same diameter have the same power of magnification. Drops or beads with diameters of 2.0 mm to 4.0 mm give magnifications of approximately 40X - 60X to 20X - 30X with smaller diameter beads yielding larger magnifications. The penlight bulb lens is approximately 5 mm in diameter and 3 mm thick, and gives magnification of about 50X - 70X. With all lenses, the portion of the field in focus is rather small.

(vii) Care should be taken to keep the lenses (except water drop) clean with tissues. Also, slides, mirrors, etc., should be kept as dust free as possible.

(viii) The best material for the lens holder seems to be aluminum sheeting about 0.5 mm thick. Other types of stiff, flexible metal sheeting also work well. Cardboard or strong paper can be used, but yields poor results.

(ix) Light to illuminate the specimen should be reflected through the microscope with a mirror or other shiny surface. A strong light source is required with sunlight working as well as any.

B2. Hand-Held Microscope



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Lens Mount	1	Metal Strip (A)	8 cm x 2.5 cm x 0.1 cm
(2) Rubber Band	1	Rubber Band (B)	--

b. Construction

(1) Lens Mount

Drill a hole in the metal strip (A). The position of the hole will depend upon where on the slide the specimen has been mounted.

The dimensions given here are for a lens mount to be used with a standard 7.5 cm x 2.5 cm (3 inches x 1 inch) glass slide.

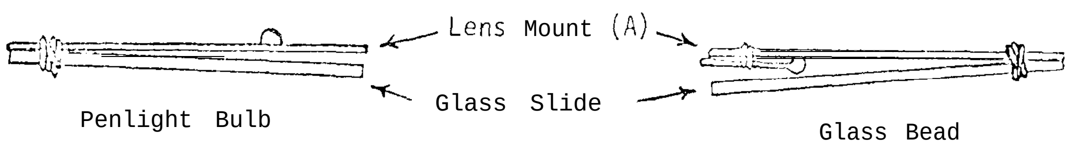
(2) Rubber Band

Wind the rubber band (8) around the slide and lens mount (A) to hold the two together so they don't slip. Be certain to position the lens directly over the specimen or portion of specimen to be viewed. Take care in moving the lens mount that the edge does not cut the rubber band.

c. Notes

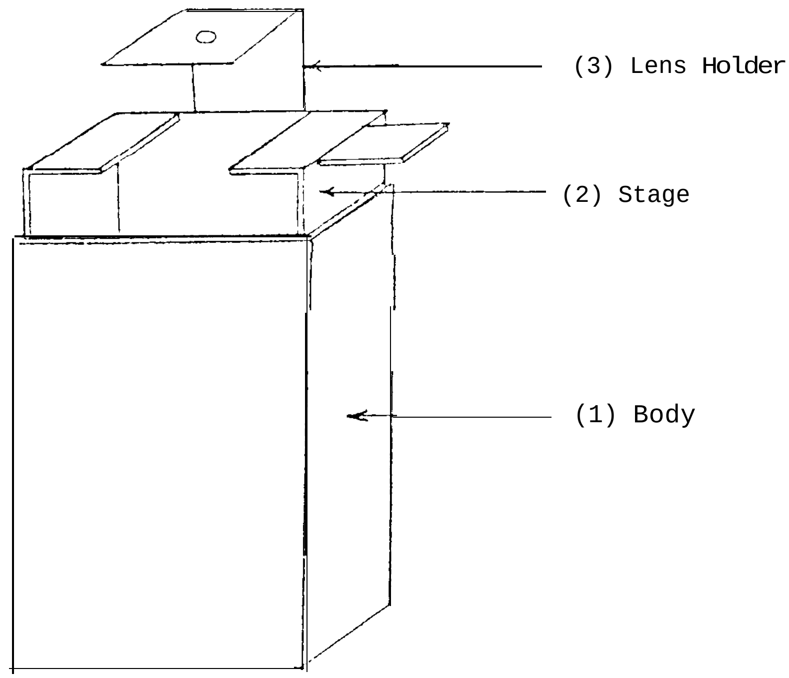
(i) This simple microscope works well with either glass bead or pen light bulb lenses [see I/B1, Notes (iii) and (iv)]. Using it with a water drop lens is quite difficult in that it is difficult to prevent the water from touching the slide. In addition, this microscope works best when held vertically rather than horizontally as is necessary with the water drop.

(ii) See the following diagrams for positioning the glass bead and penlight bulb lenses on the lens mount.



(iii) This microscope should be used primarily with permanently prepared slides as opposed to fresh mounts. Focusing is achieved simply by holding the slide with one hand and moving the lens mount back and forth with the other.

B3. Match Box Microscope *

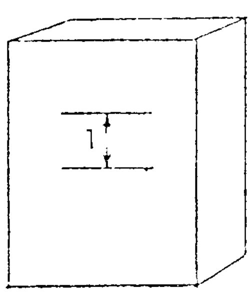


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	1	Match Box Cover (A)	5 cm x 3.5 cm x 1.5 cm
(2) Stage	1	Match Box Drawer (B)	5 cm x 3.5 cm x 1.5 cm
	1	Metal Strip (C)	3 cm x 1 cm x 0.1 cm
(3) Lens Holder	1	Aluminum Strip (D)	7.5 cm x 2.5 cm x 0.1 cm

b. Construction

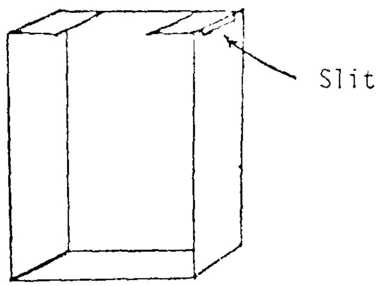
(1) Body

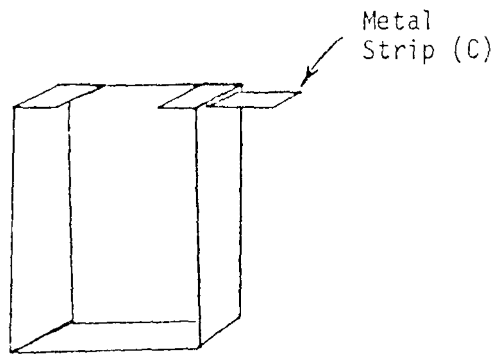


With a razor blade, make two slits in the back of the match box cover (A). These slits need to be slightly wider than the width of the lens holder (2.5 cm).

*Adapted from African Primary Science Program, Making Things Look Bigger, (Nairobi, Kenya: Curriculum Development and Research Center, 1967), pp 24-25.

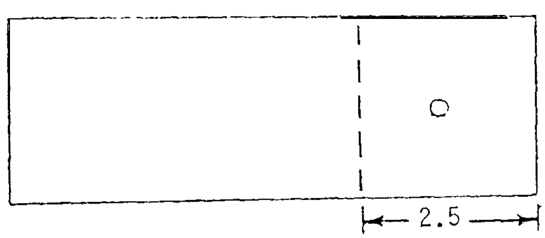
(2) Stage

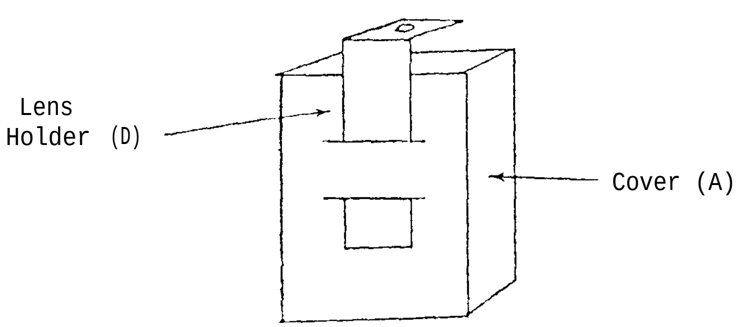




Cut out one end of the match box drawer (B) so that portions of the end 0.5 cm wide are left on either side. At the same end cf the drawer, make a slit about 1 cm wide with a razor blade. Insert the metal strip (C) into this slit and glue it in place. Use this strip to move the stage up and down when focusing.

(3) Lens Holder





Drill a hole in one end of the aluminum strip (D), and bend it at right angles. If a drill is not available, punch a hole in the metal with a nail. Insert the metal strip through the slits in the back of the match box cover (A) to insure that it will be held in place securely. Then, remove the lens holder, slide the stage into the body, and replace the lens holder. The microscope is now ready for use.

c. notes

(i) To use this microscope, place the slide or specimen on the stage directly under the lens. Focusing is accomplished by moving the stage up and down as the lens holder remains stationary. As with all single lens microscopes, the eye must be kept quite close to the lens in order to see the image.

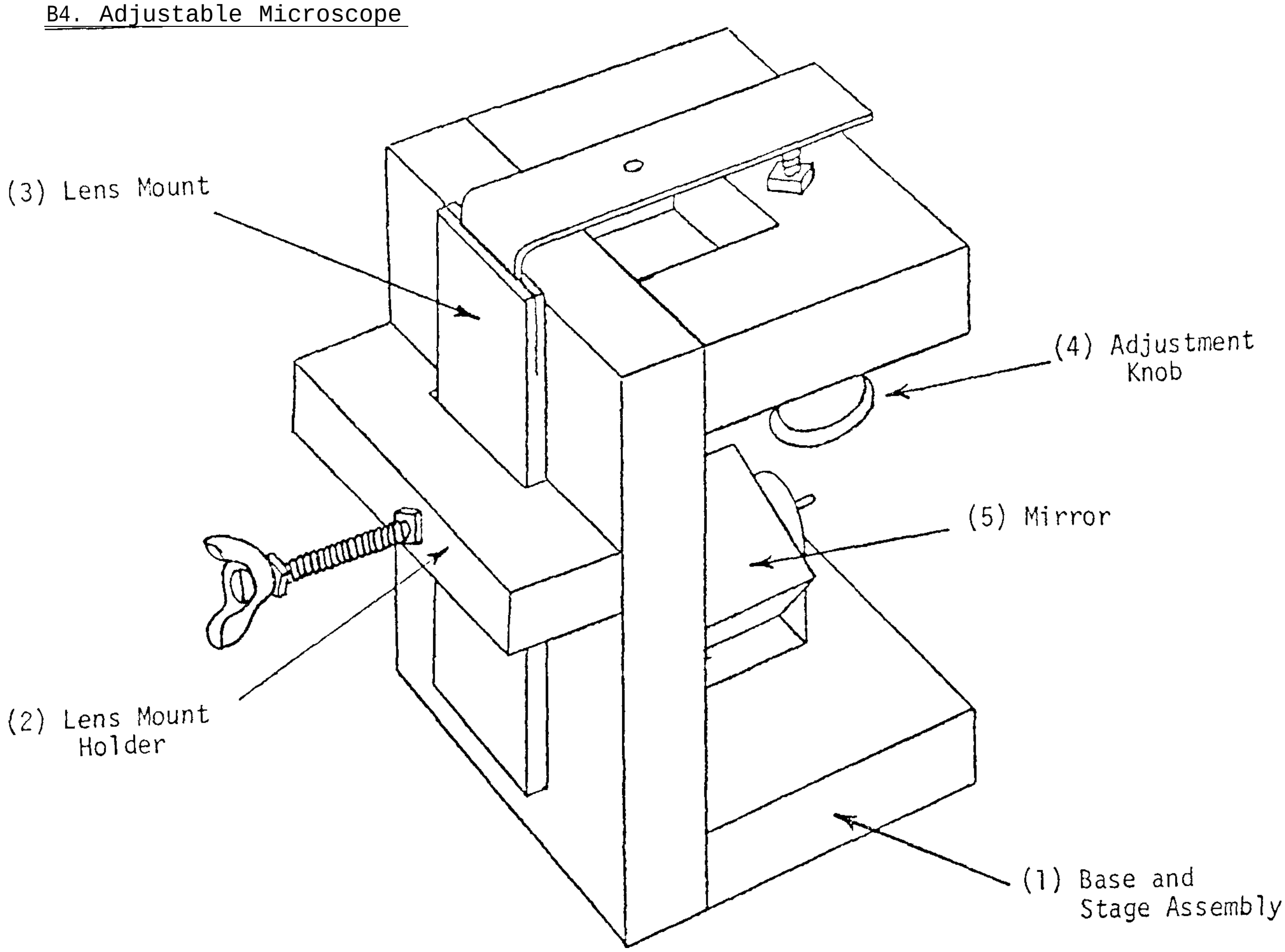
(ii) See I/B1, Notes (ii), (iii), and (iv) for complete instructions in adapting the lens holder to use either water drop, glass bead, or penlight bulb lenses.

(iii) With an item this small, it is found that there is some difficulty in keeping a glass slide on the stage, especially when the stage must be moved in focusing.

(iv) Since it is difficult to get sufficient light through the specimen, it is suggested that the inside of the match box drawer be lined with light colored paper or metal foil to increase reflected light.

(v) This microscope was found to be good for inspecting such items as coins, newsprint, insect wings, crystals, etc.

B4. Adjustable Microscope



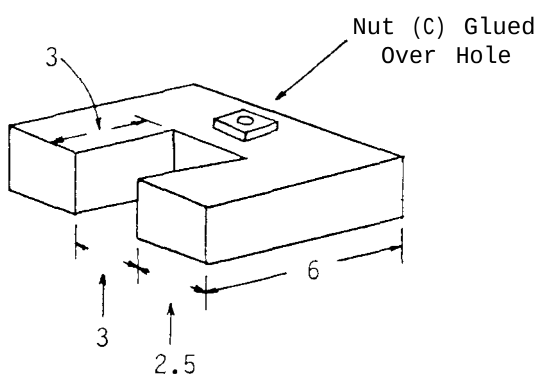
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base and Stage Assembly	1	Wood (A)	12 cm x 8 cm x 1.5 cm
	2	Wood (B)	6 cm x 8 cm x 1.5 cm
	1	Nut (C)	0.5 cm internal diameter
(2) Lens Mount Holder	1	Wood (D)	2.5 cm x 8 cm x 1 .5 cm
	1	Bolt (E)	0.5 cm diameter, 6 cm long

		Wing Nut (F)	0.5 cm internal diameter
	2	Nuts (G)	0.5 cm internal diameter
(3) Lens Mount	1	Wood (ii)	10 cm x 3.5 cm x 0.5 cm
		Aluminum Sheet (I)	9 cm x 2 cm x 0.1 cm
(4) Adjustment Knob	1	Wood Spool (J)	3 cm long, 2 cm diameter
	1	Bolt (K)	0.5 cm diameter, 6 cm long
	1	Nut (L)	0.5 cm internal diameter
(5) Mirror	1	Mirror Glass (M)	3 cm x 3 cm
	1	Wood (N)	3 cm x 3 cm x 0.5 cm
	1	Metal Sheet (0)	8 cm x 2 cm x 0.05 cm
	1	Nail (P)	5 cm long, 0.2 cm diameter
	1	Tack (Q)	1 cm long

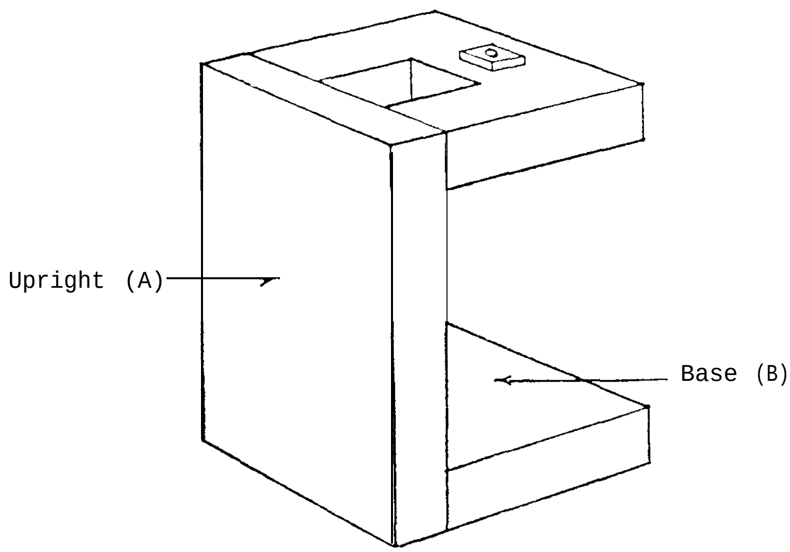
b. Construction

(1) Base and Stage Assembly



Stage (B)

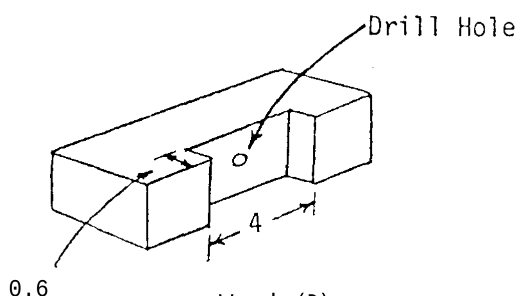
Cut a notch 3 cm square in one piece of wood (B) to make the stage. In this same piece, drill a hole through the wood. It should be centered between the edge of the notch and the edge of the stage. Make this hole slightly smaller in diameter than the bolt (K) used to make the adjustment knob. Place the nut (C) over the hole in the wood. Give it a sharp blow with a hammer so that it forms an indentation in the



Base and Stage
Assembly

wood. Remove the nut, then glue it back in place taking care not to get glue in the hole or in the threads of the nut. It is best to allow the nut to dry with the bolt threaded through both it and the hole to assure proper alignment. Nail or screw this piece, the stage (B), to the upright (A). Likewise, nail or screw the base (B) to the upright.

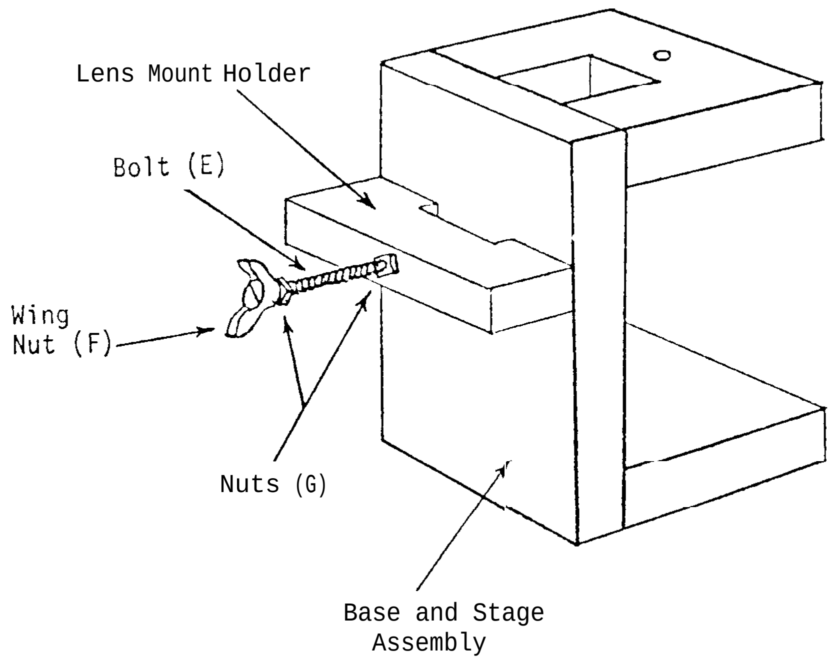
(2) Lens Mount Holder



Wood (D)

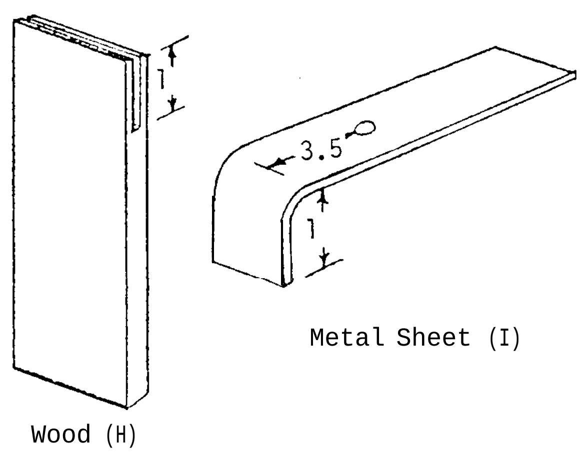
Cut a notch 0.6 cm deep and 4 cm wide in the piece of wood (D). Drill a hole in the center of the notch. This hole should be slightly smaller than the bolt (E) used to hold the lens mount in place.

Screw the wing nut (F) onto the bolt (E) and run it to the end of the bolt. Use one nut (G) to hold the wing nut tight to the end of the bolt. Place the other nut (G) over the hole in the piece of wood (D) and strike it hard with a hammer, taking care not to split the wood. Remove the

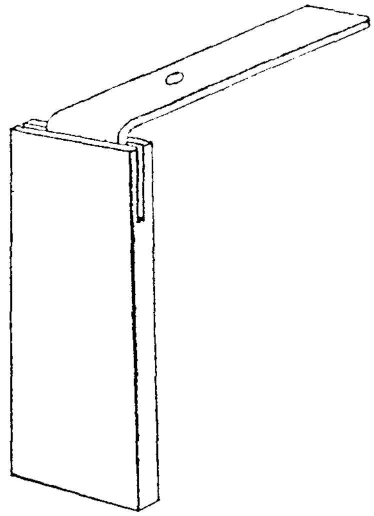


nut from the impression in the wood thus formed, and place a drop of strong glue in the impression and replace the nut. Be sure not to get glue in the threads of the nut or in the hole (this may be avoided by allowing the nut to dry with the bolt run all the way through the hole). Finally, glue, nail or screw the lens mount holder to the base and stage assembly.

(3) Lens Mount



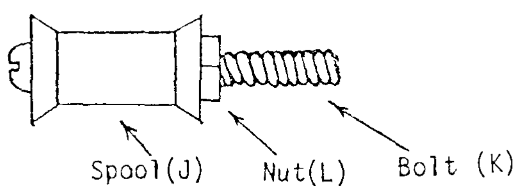
Make a slit in the end of the piece of wood (H), with a saw. This slit should be about 1 cm deep and slightly wider than the thickness of the metal sheet (I) used.



Lens Mount

Bend the aluminum sheet (I) to a right angle 1 cm from its end. Drill a hole 3.5 cm from the bend and centered. The diameter of this hole will depend upon the size of the water drop desired, the size of the glass bead used, or the size of the penlight bulb lens. [See I/B1, Notes (ii), (iii), and (iv) for instruction in making and using such lenses.] Glue the aluminum sheet (I) to the piece of wood (H).

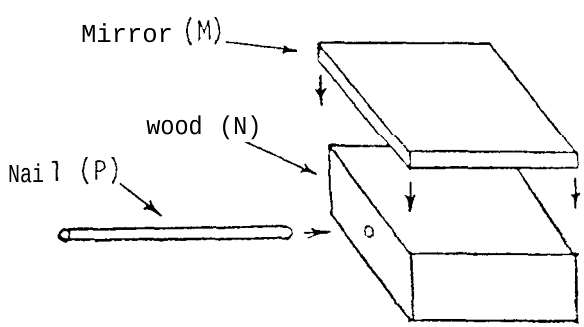
(4) Adjustment Knob



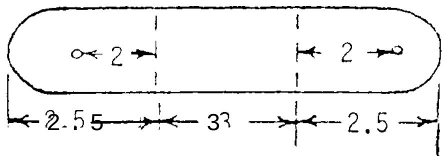
Side View

Run the bolt (K) through the hole in the wooden spool (J). Secure the spool tightly in place with the nut (L). Screw the end of the bolt through the hole and nut in the base and stage assembly.

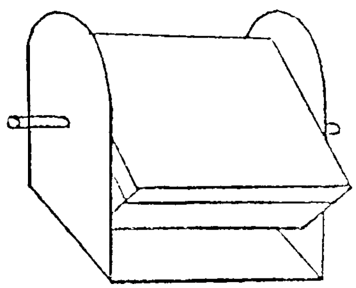
(5) Mirror



Cut the metal sheet (0) and drill two holes the same diameter as the nail (P) used. Bend the ends up at right angles along the dotted lines. Drill a hole through the wood (N) which is about the same diameter as the nail,



Metal Strip (0)



Completed Mirror

Insert the nail (P) through this hole and glue it in place. Glue the mirror (M) to the wood. Nail or screw the metal strip into position on the base directly under the notch in the stage. Insert both ends of the nail through the holes in the metal strip. There should be enough friction to keep the mirror at the desired angle.

c. Notes

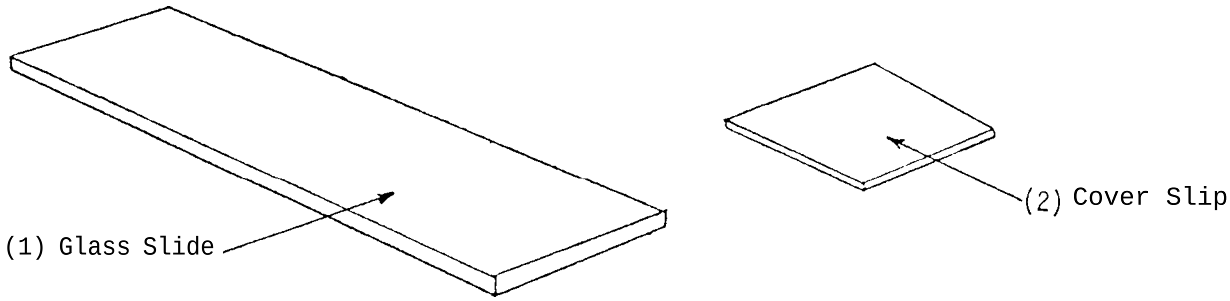
(i) The slide containing the specimen to be observed is placed over the hole in the stage. Light is reflected through the specimen and lens by means of the mirror. Coarse adjustment is obtained by varying the position of the lens mount with the lens mount holder bolt. Fine adjustment is attained by turning the adjustment knob so that it moves the metal portion of the lens mount up and down.

(ii) This microscope may be used with any of the three types of lenses : water drop, glass bead, or penlight bulb lens. See `I/B1, Notes (ii), (iii), and (iv) for details in mounting each type lens on the lens mount.

(iii) Light is reflected through the lens by use of the mirror. The mirror need not be a real glass mirror - any smooth, shiny surface (e.g., polished metal) is acceptable. The source of light may be a bulb, room light, or skylight, with skylight proving most satisfactory.

C. SUPPLEMENTARY APPARATUS

Cl. Glass Slide and Cover Slip



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Glass Slide	1	Glass Plate (A)	7.5 cm x 2.5 cm x 0.2 cm
(2) Cover Slip	1	Transparent Plastic (B)	2.5 cm x 2.5 cm x 0.05 cm

b. Construction

(1) Glass Slides — Glass slides may be hand cut from plate glass (A), but this is tedious and time consuming.

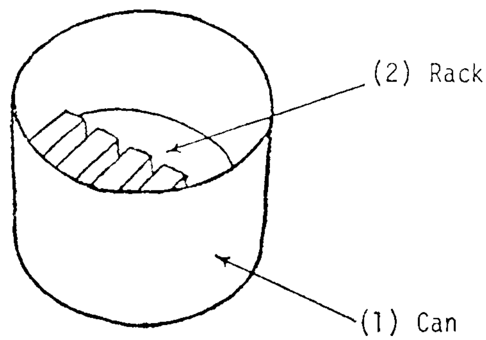
(2) Cover Slip — Cover slips can be cut from stiff transparent plastic sheets (B) with scissors.

c. notes

(i) Good quality slides may be purchased almost as inexpensively as they can be handmade, or they may be obtained for free from hospital blood laboratories as they are often discarded after use.

(ii) Consult a good general biology source book for information on preparing either fresh or permanently mounted slides.

C2. Staining Vessel



a. Materials Required

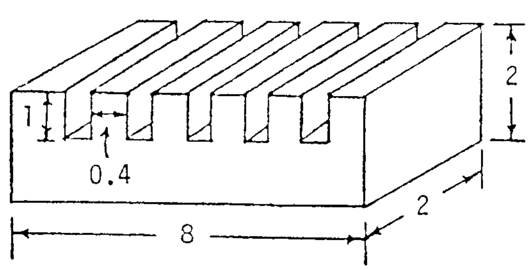
Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	8 cm high, 8 cm diameter
(2) Rack	1	Wood (B)	8 cm x 2 cm x 2 cm

b. Construction

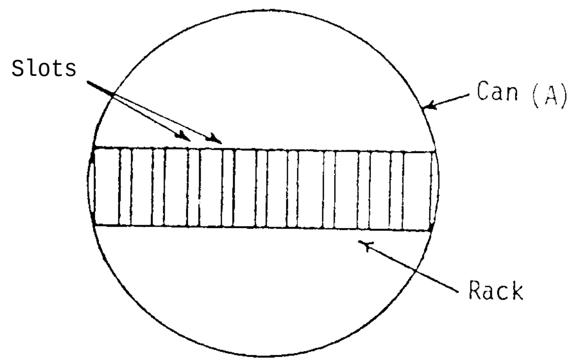
(1) Can

The diameter of the can (A) may be somewhat larger than 8 cm (it should not be much less), and the height of the can should be about the same as the length of the slides used.

(2) Rack



Cut notches in the wood (B) about 1 cm deep and just slightly wider than the slides used. Paint the wood with a sealant (e.g., varnish, shellac) to prevent the stain from soaking into it. Push the rack down into the



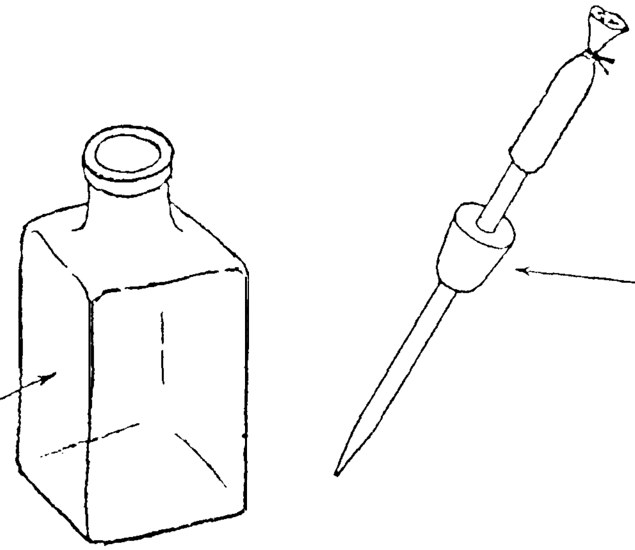
Top View

bottom of the can (A), notches up. The rack holds the slides upright and prevents them from touching each other. Always make the length of the rack equal to the diameter of the can to insure that it will fit tightly in the bottom of the can.

c. Notes

(i) Staining vessels are necessary when preparing slides for microscopic inspection. Consult a good standard biology source book for instruction in preparing slides and stains.

C3. Stain Bottle



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Pill Bottle (A)	25-50 ml capacity
(2) Dropper	1	Glass Tube (B)	12 cm long, 0.75 cm diameter
	1	Rubber Tube (C)	4 cm long, 1.0 cm diameter
	1	One-hole Cork Stopper (D)	To fit mouth of pill bottle
	1	Wire (E)	5 cm long

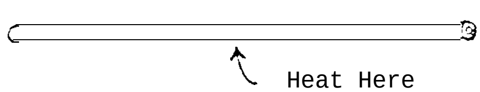
b. Construction

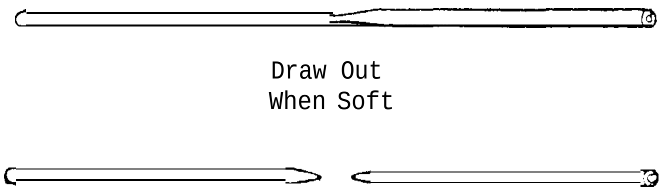
(1) Bottle

Use a clear glass pill or medicine bottle (A).

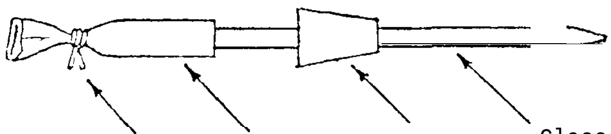
(2) Dropper

Make the tube portion of the dropper two at a time by heating a piece of glass tubing 20 cm long in the





middle and drawing it out to a narrow filament when soft. Break the tube at the most narrow part of the constriction to form two tubes (B).



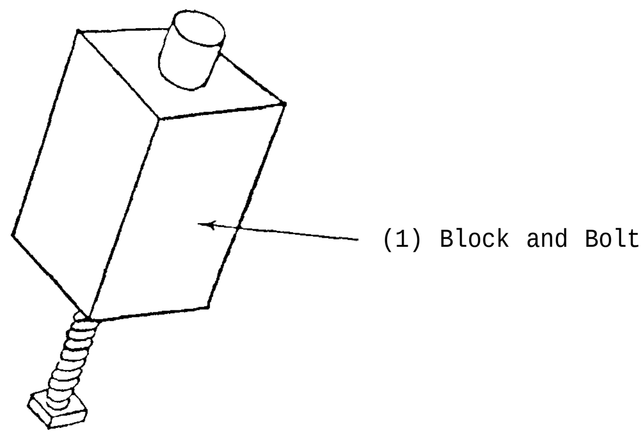
Force the glass tube through the one-hole cork stopper (D). Push the piece of rubber tubing (C) onto the wide end of the glass tubing and tie it off with the wire (E) to form the dropper's suction cap. Adjust the length of the glass tube so that when the cork is in place in the bottle, the tip of the glass tube almost touches the bottom of the bottle.

c. Notes

(i) If one-hole cork stoppers are not available, use a cork borer to make them from regular corks or use one-hole rubber stoppers.

(ii) Be sure to label the bottle with the name of the type of stain it contains.

C4. Hand Microtome

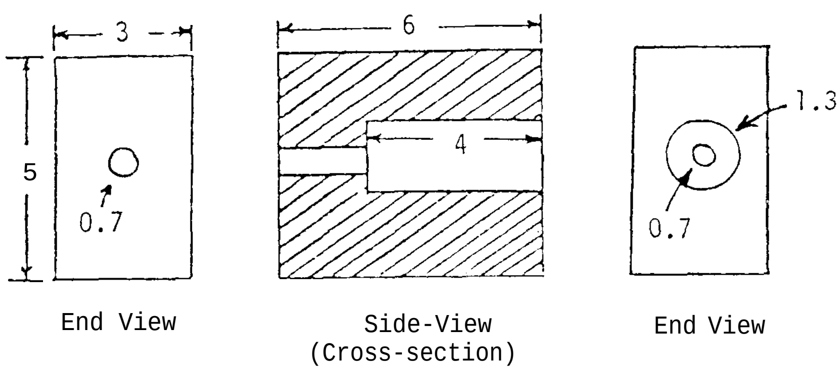


a. Materials Required

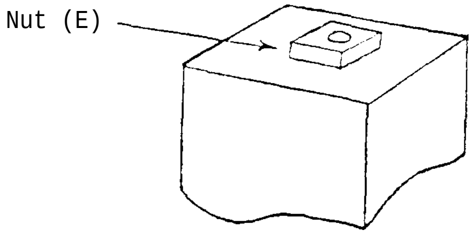
Components	Qu	Items Required	Dimensions
(1) Block and Bolt	1	Wood Block (A)	3 cm x 5 cm x 6 cm
	1	Glass Tubing (B)	5 cm long, 1 cm inside diameter
	1	Wood Dowel (C)	1 cm long, 1 cm diameter
	1	Steel Bolt (D)	9 cm long, approximately 0.7 cm diameter
	1	Nut (E)	To fit bolt

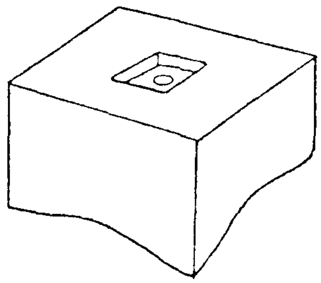
b. Construction

(1) Block and Bolt



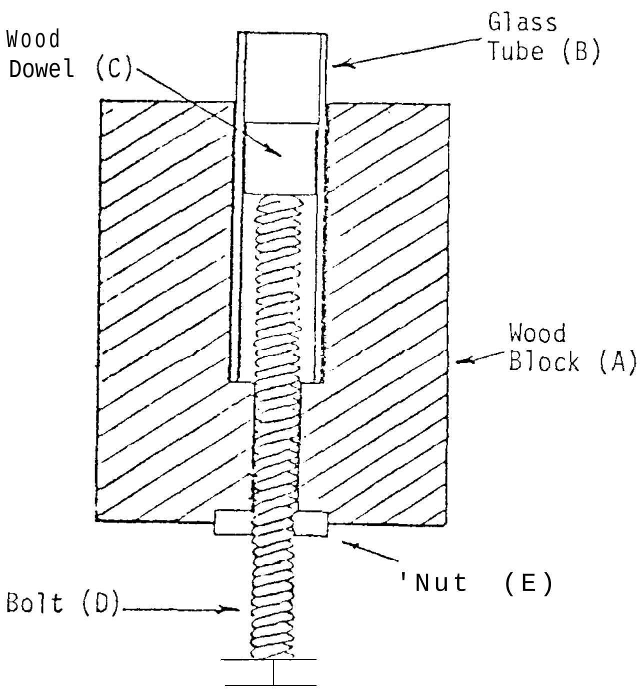
Prepare the wood block (A) by drilling or boring a hole slightly larger in diameter than the outside diameter of the glass tubing (B) 4 cm into one end of the block. Drill another hole (0.7 cm diameter) through the same end of the block. This second hole should be





Impression of Nut

centered in the bottom of the first, larger hole, and be drilled through the block. Next, lay the nut (E) on the end of the block which has the small hole in it. Strike the nut sharpiy with a hammer to make an impression of the nut in the wood. (Be careful not to split the wood, and also make sure the hole in the nut aligns with the hole in the wood.) After the impression has been made in the wood, glue the nut into place with epoxy resin cement.



Side View
(Cross-section)

Shove the piece of glass tubing (B) down into the large hole in the wood (A), and glue it in place. The end of the tube should stick out about 1 cm. See that this end is cut as evenly as possible and fire polish it just enough to remove any possible burrs. Insert the short wooden dowel (C) into the tube. Screw the bolt (D) through the nut until the end of the bolt touches the wooden dowel.

The microtome is now ready for use.

c. Notes

(i) To operate the hand microtome, screw out the bolt until the wood dowel drops to the bottom of the glass tube. Then, insert the section of plant stem (or whatever is to be cut for the microscope slide) into the glass tube. Fill the space which remains between the specimen and the glass tube with melted paraffin and allow it to cool. When the paraffin is hard, screw the bolt in until it begins to force the wood dowel to push the paraffin and specimen out of the glass tube. As the specimen comes out, use a single-edge razor blade to cut off sections. Practice with the microtome will eventually allow very thin sections to be sliced from specimens.

(ii) It may be desirable to substitute metal tubing for the glass as glass is easily broken. Also, painting the end of the wood dowel with shellac or varnish will prevent the paraffin from sticking to it.

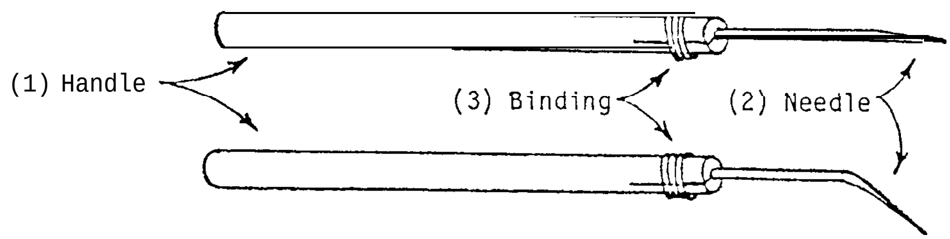
11. DISSECTING APPARATUS

A. DISSECTING APPARATUS

These items will permit the student to do many of the dissections normally done in elementary biology course work. If possible, each student should have each of the items in this section, but if cost and materials prohibit this, then enough items should be produced to permit students to work in groups of two or three.

A. DISSECTING APPARATUS

Al. Dissecting Needles

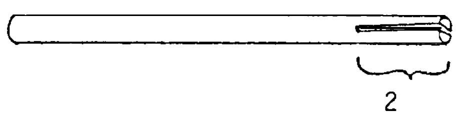


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	10 cm long, 0.6 cm - 0.8 cm diameter
(2) Needle	1	Steel Wire (B)	5 cm long, #20 gauge wire (approximately 0.05 cm diameter)
(3) Binding	1	Iron Wire (C)	About 10 cm of #24 gauge wire (about 0.025 cm diameter)

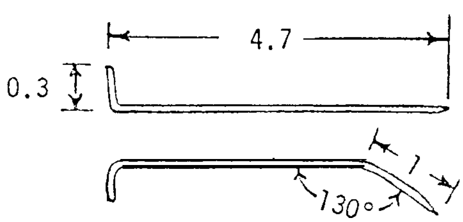
b. Construction

(1) Handle



The wood dowel (A) serves as the handle. Make a slit about 2 cm deep in one end to receive the needle. Sand the two ends to make them smooth.

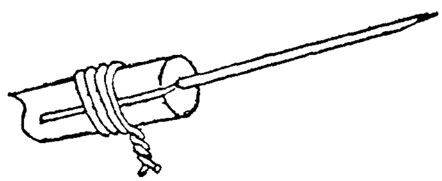
(2) Needle



Break the wire (B) by bending it back and forth instead of cutting it with wire cutters as hard steel can easily damage wire cutters. File one end to a point.

At a point 0.3 cm from the unpointed end, grasp the wire with two pliers and slowly bend until a 90° angle has been reached. If a "bent tip" dissecting needle is desired, bend the needle to an angle of 130° approximately 1 cm from the pointed end.

(3) Binding

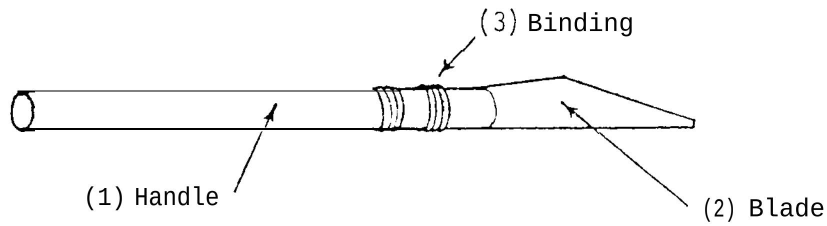


Insert the end of the needle into the handle about 1 cm deep. Wrap several turns of binding wire (C) tightly around the handle and twist the ends together.

c. Notes

(i) Iron, rather than steel, wire may be used for the needle by first making the bends where needed. Then heat the wire until it becomes dull red and immerse it in cold water'to temper it. The iron wire will become hard enough so that it does not bend easily; however, it may be broken if pressed with too much force.

A2. Strapping Scalpel

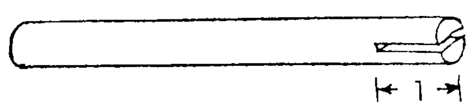


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	10 cm long, 1 cm diameter
(2) Blade	1	Steel Strapping (B)	6 cm long, 1 cm wide
(3) Binding	1	Iron Wire (C)	About 12 cm long, #24 gauge (approximately 0.025 cm diameter)

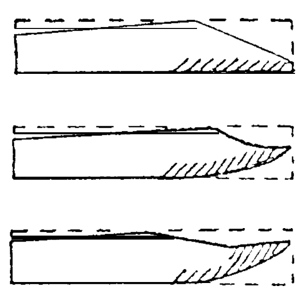
b. Construction

(1) Handle



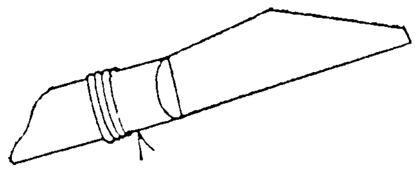
Make a slit in one end of the dowel (A) with a saw for the blade. Sand the ends to make them smooth.

(2) Blade



Cut the piece of strapping (B) into the shape of a scalpel blade (many shapes are useful for different purposes). Taper one end so it will fit the handle. File the edges (as shown by the shaded areas) to make the cutting edge.

(3) Binding

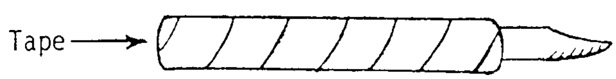


Insert the blade into the slit in the end of the handle. Wrap several turns of #24 gauge wire (C) tightly around the handle and twist the ends together. This should hold the blade firmly in place.

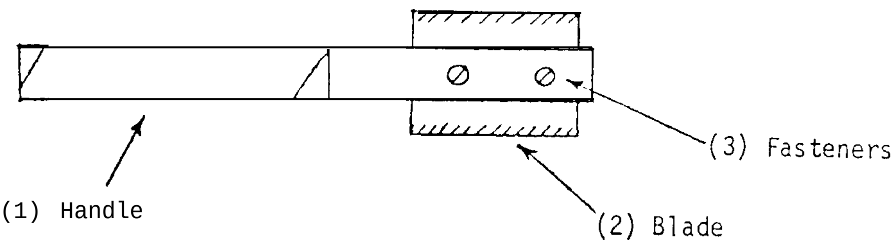
c. Notes

(i) The blade should be sharpened after the entire scalpel has been assembled in order to lessen the danger of being cut,

(ii) An equally good scalpel may be made from a piece of strapping about 15 cm long. Simply form a blade at one end as described above, and let the remainder act as the handle. This portion should be wrapped in tape to make it more comfortable to handle.



A3. Razor Scalpel

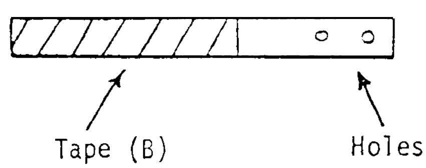


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	2	Steel Strapping (A)	15 cm long, about 1.25 cm wide
	1	Tape (B)	About 50 cm long
(2) Blade	1	Double-Edged Razor Blade (C)	2.5 cm x 3.5 cm
(3) Fasteners	2	Bolts (D)	1.0 cm long, 0.4 cm diameter
	2	Nuts (E)	0.4 cm inside diameter

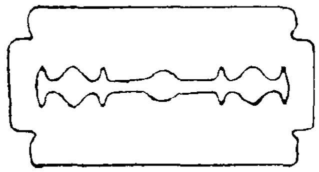
b. Construction

(1) Handle

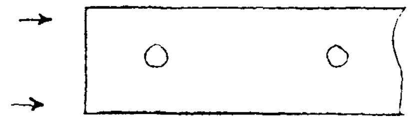


Fasten the two pieces of strapping (A) together with tape (B). Drill two holes (0.5 cm diameter) in the other end for the bolts (D) to fit through. Locate these holes so that the razor blade (C) will be held in the desired position.

(2) Blade



Razor Blade (C)



Strapping (A)

Insert the blade between the two halves of the scalpel handle so that the two holes align over the holes in the razor blade.

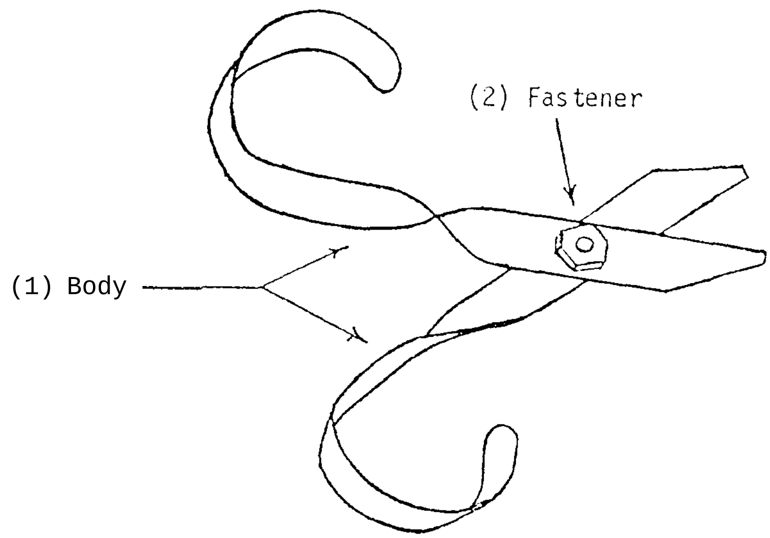
(3) Fasteners

Insert the short bolts (D) through the holes and screw on the nuts (E). This scalpel is now ready for use.

c. Notes

(i) The razor blade can easily be replaced as it becomes dull.

A4. Scissors

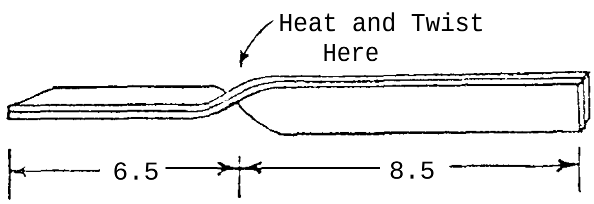


a. Materials Required

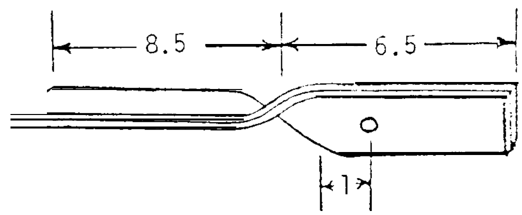
Components	Qu	Items Required	Dimensions
(1) Body	2	Steel Strapping (A)	15 cm x 1.25 cm, at least 0.05 cm thick
(2) Fastener	1	Bolt (B)	0.5 cm long, 0.5 cm diameter
	1	Nut (C)	0.5 cm inside diameter

b. Construction

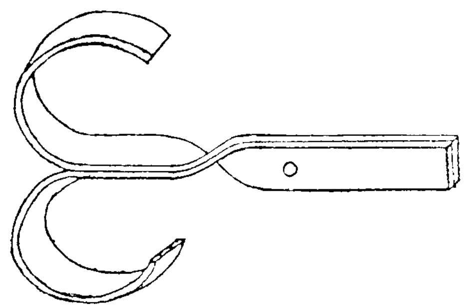
(1) Body



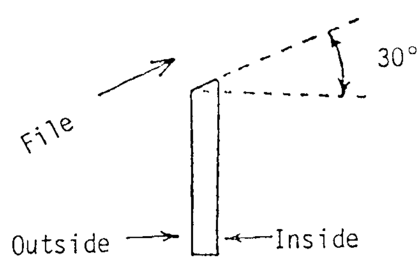
Hold the pieces of strapping (A) tightly together and heat them at a point approximately 6.5 cm from the end until they both glow dull red. Then, twist them a full quarter (90°) turn. Immediately plunge them into cold water to restore their temper.



Drill a hole 0.6 cm in diameter about 1 cm from the twist on the short (6.5 cm) end of both pieces.

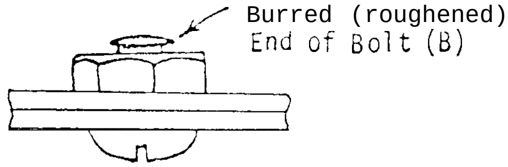


Bend the long (8.5 cm) ends up to form the handles.



Trim the tips of the strapping to the shape of blades. Sharpen the shaded area of the blade. File this area on the <u>outside</u> edge only, not the inside edge where the blades meet, In sharpening, file upward at an angle of 30°.

(2) Fastener

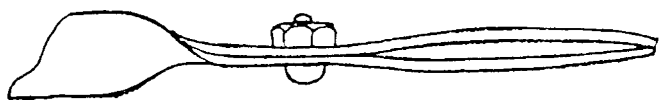


Fasten the two halves of the scissors together with the short bolt (B) (a long bolt may be cut to length) and nut (C). When the proper tightness is obtained, burr the end of the bolt to prevent the nut from loosening and falling off.

c. Notes

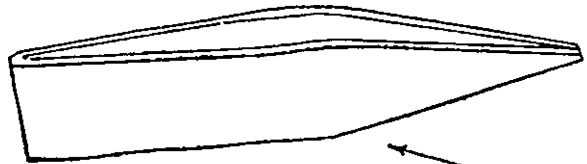
(i) Scissors constructed of strapping of 0.05 cm in thickness work fairly well in cutting tissues as long as short cuts are made, and the material being cut is kept well back between the blades.

(ii) Scissors work better if the blades are slightly curved as shown below.



Side View

A5. Forceps



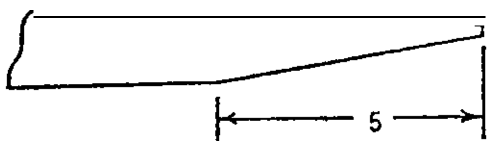
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Strapping	1	Steel Strapping (A)	20 cm long, about 1.25 cm wide

b. Construction

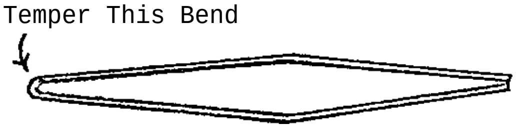
(1) Strapping

Cut each end of the steel strapping (A) to a taper.



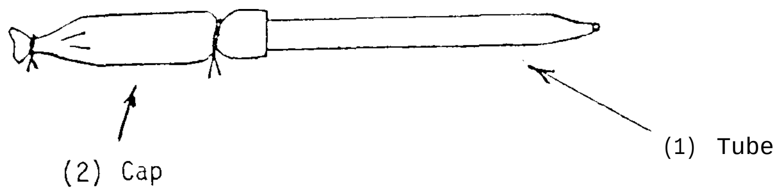
Bend the strapping a full 180° at the midpoint. Make certain the tops touch and are in good alignment. Heat the bent area to dull red and plunge immediately into cold water to temper the steel. Bow the blades of the forceps slightly

Temper This Bend



Side View

A6. Dropper

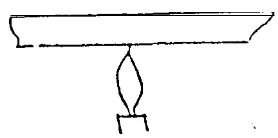


a. Materials Required

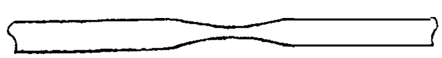
Components	Qu	Items Required	Dimensions
(1) Tube	1	Glass Tubing (A)	7 cm long, about 0.6 cm diameter
(2) Cap	1	Rubber Tubing (B)	4 cm long, 1 cm outside diameter
	2	Soft Wire (C)	4-5 cm long

b. Construction

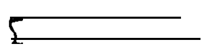
(1) Tube



Heat



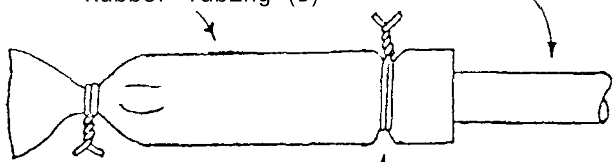
Draw out



cut

Hold the glass tubing (A) over a hot flame, turning it to heat it evenly. When it begins to soften, draw it out until the constriction is the desired diameter, and allow it to cool. When cool, cut the tubing at the constriction with a small triangular file.

(2) Cap

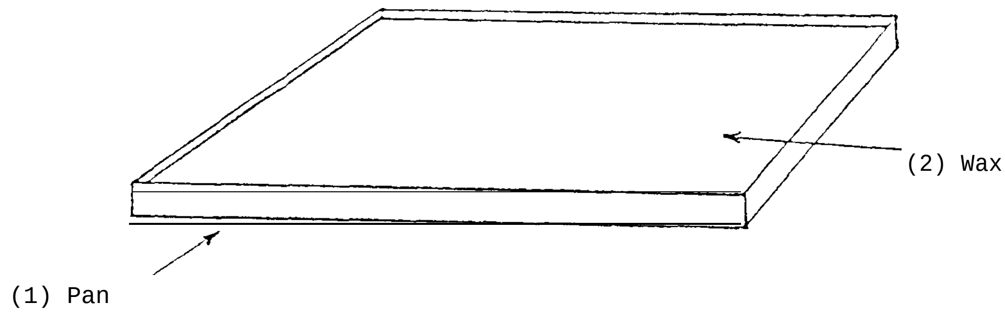


Slip the rubber tubing (B) over the end of the glass tube. Wrap a piece of wire (C) tightly around the tubing to hold it tight to the glass, and twist the end of the wire together. In a similar manner, close off the open end of the rubber tubing so that it is airtight.

c. Notes

(i) Droppers may be made in many shapes and sizes to fit the various uses for which they are needed.

A7. Dissecting Pan

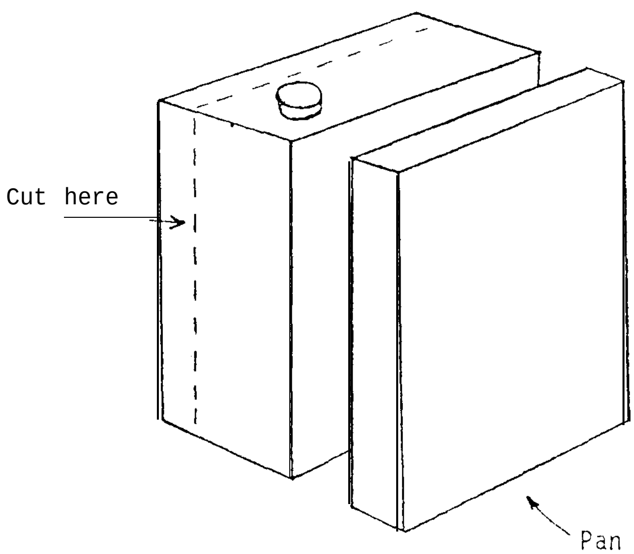


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pan	1	Oil Can (A)	Approximately 17 cm x 25 cm x 3 cm
(2) Wax	--	Paraffin Wax (B)	Enough to partially fill the pan (about 1 liter)

b. Construction

(1) Pan



Remove the handle from a 4 liter rectangular oil can (A). Cut off the sides about 3 cm from the edge. It is best to put tape on the sharp edges of the pan to prevent students from cutting themselves.

(2) Wax

Fill the pan about two thirds full of melted paraffin wax (B), and allow the wax to harden. Be careful in heating the wax not to get it too hot or it may ignite. It is best to place the paraffin block in a glass jar, and put the glass jar in hot water until the wax melts,

c, Notes

(i) Any container like an oil can (e.g., waxed cardboard milk containers) can be used as long as a suitable pan can be made from it. Alternatively, pans can be made from sheet metal if there is sufficient technical help available.

(ii) Cases for dissecting tools can be made from heavy cloth material if it is desirable to keep each student's kit separate from the others.

111. AQUATIC COLLECTING APPARATUS

These are a wide variety of items used in collecting plant and animal specimens from the aquatic environment. Remember to use waterproof and water resistant materials wherever possible in the construction of this apparatus.

A. NETS AND DREDGES

Nets and dredges are easily made items useful in collecting both plants and animals. They are all made with some sort of netting or mesh.

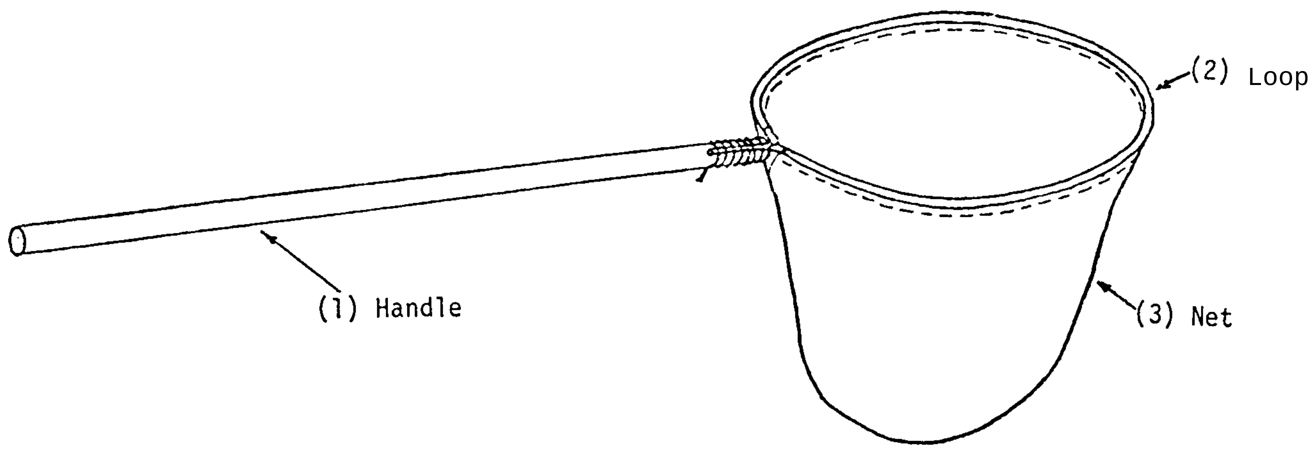
B. AQUATIC TRAPS

These two traps can be used to catch some types of aquatic animals.

C. SUPPLEMENTARY AQUATIC MATERIALS

Materials included here are less necessary, yet still useful, items in aquatic collection.

Al. Dip Net

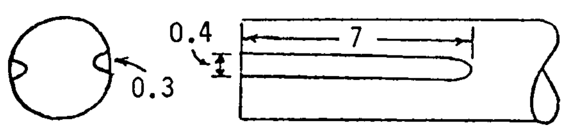


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	100 cm long, 2 cm diameter
(2) Loop	1	Heavy Wire (B)	115 cm long, 0.3 cm diameter
	1	Stiff Wire (C)	About BO-90 cm long, 0.1 cm diameter
(3) Net	1	Nylon Bag (D)	50 cm wide, 60 cm long

b. Construction

(1) Handle

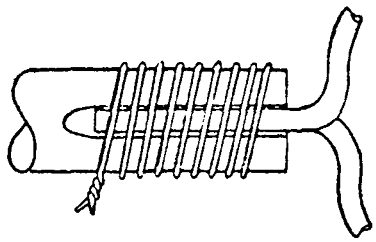


End View   Side View

The length of the handle may be varied according to personal preference. cut two grooves in one end of the wood dowel (A), one opposite the other. Make these grooves about 7 cm long, 0.3 cm deep, and about 0.4 cm wide.

(2) Loop

Form a loop 30 cm in diameter from the heavy wire (B). Leave about 7 cm of excess wire at each end which will fit into the grooves in the handle. Bend these 7 cm portions to 90° angles. Fit the wire ends into the grooves in the handle and bind them in place with the stiff wire (C).



Binding of Loop to Handle

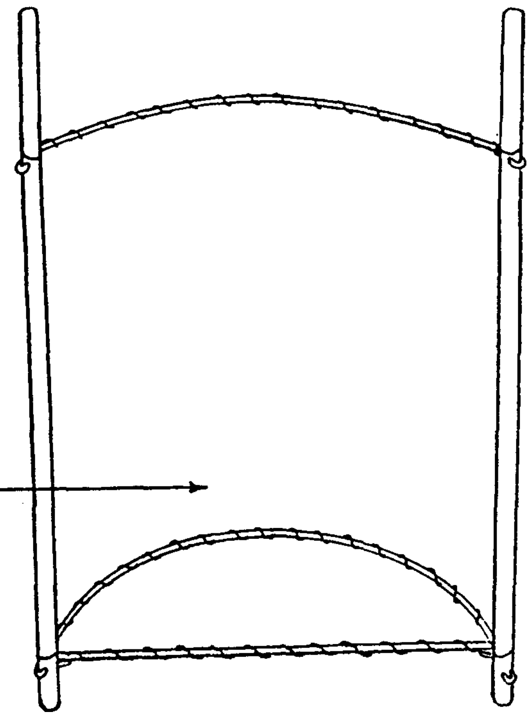
(3) Net

If a nylon laundry bag (D) of the given dimensions is used, cut it down so that it is only about 30 cm deep rather than 60. Other types of cloth or netting can also be used. Use cloth or netting through which water can easily pass, but remember that the size of the net weave determines the size of the smallest organisms which will be held by the net. Make sure the opening of the net is 5 - 10 cm greater in circumference than that of the loop. Simply sew the open portion of the net around the loop with strong thread.

c. Notes

(i) The dip net is used to collect aquatic organisms of all kinds from the shore or boat. Be sure to make its construction as sturdy as possible.

A2. Hand Screen



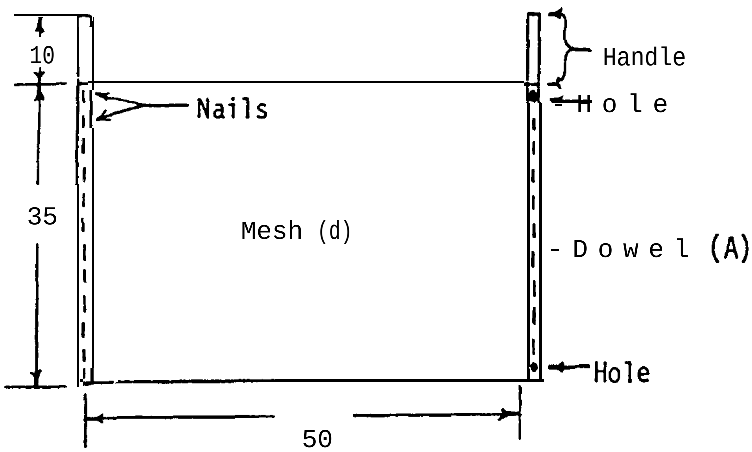
(1) Frame and Screen

a. Materials Required

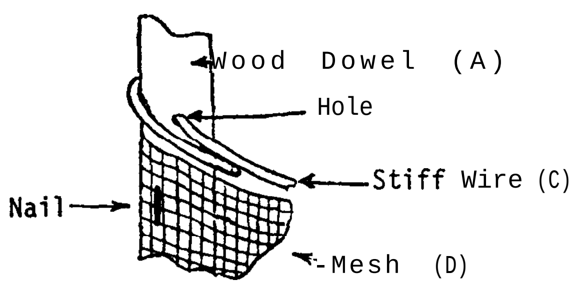
Components	Qu	Items Required	Dimensions
(1) **Frame and Screen**	2	Wood Dowels (A)	45 cm long, 1.5 cm diameter
	1	Stiff Wire (B)	35 cm long, 0.4 cm diameter
	2	Stiff Wire (C)	50 cm long, 0.4 cm diameter
	1	Fine Wire Mesh (D)	35 cm x 50 cm
	1	Fine Wire Mesh (E)	30 cm x 15 cm
	1	Fine Wire (F)	150 cm long, 0.05 cm diameter

b. Construction

(1) Frame and Screen



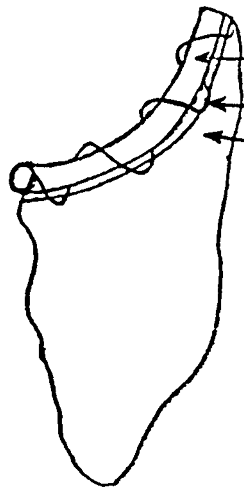
Front View



Detail

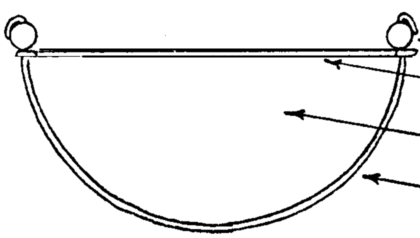
Set the two wood dowels (A) so that they are 50 cm apart. Take the wire mesh (D) and secure it to the dowels by wrapping it around each dowel once and then nailing it in place on the dowel. Be sure to leave 10 cm free at one end of each dowel to serve as handles. Drill two holes, 0.4 cm in diameter, in each dowel; drill the first 1 cm from the end with which the wire mesh is even, and the second, 12 cm from the end which is to be the handle.

Bend the two 50 cm sections of stiff wire (C) into semi-circles, each with a diameter of 30 cm. Place one end of one piece of wire into one hole of the wood dowel, so that about 5 cm of wire is protruding out of each hole. Bend these end pieces around the wood dowel until they reach the main body of wire. Follow this procedure for the other piece of wire. These two pieces of wire now form an outside frame to which the wire mesh (D) is attached.



Detail

Using the fine wire (F), in much the same way as one would use thread in sewing, wire the wire mesh (D) to the stiff wire frame, letting the edges of the wire mesh slightly overlap the wire frame.



Bottom View

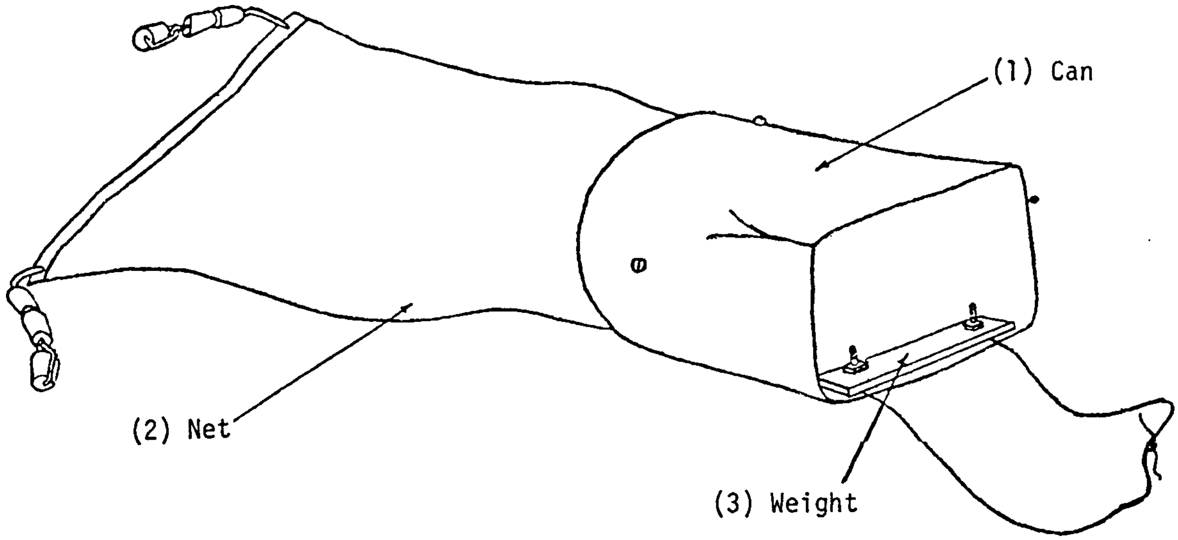
Take the last piece of stiff wire (B) and run it between the ends of the two wood dowels with which the wire mesh is flush. Secure it by bending about 3 cm of each end around the wire frame. Now, take the remaining piece of wire mesh (E) and cut it into the shape of a semicircle. Wire this semicircle onto the bottom of the hand screen with the "sewing" method described above.

c. Notes

(i) This simple device is an effective means of collecting small plants and animals in streams. To operate, simply hold it in the water and permit the stream water to flow through the wire mesh and remove organisms as they are collected.

(ii) As an extra measure, have someone stand upstream and disturb rocks, thus chasing out underlying organisms.

A3. Dredge

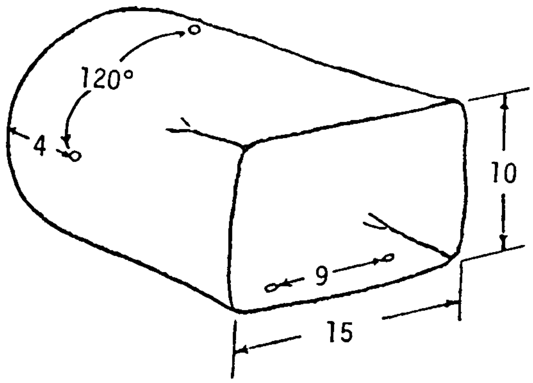


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	15 cm diameter, 18 cm long
(2) Net	1	Nylon Bag (B)	50 cm wide, 60 cm long
	1	Wire Strapping (C)	50 cm long, 1.5 cm wide, 0.05 cm thick
	3	Bolts (D)	1.5 cm long
	3	Nuts (E)	To fit bolts
	2	Cords (F)	20 cm long
	6	Corks (G)	3 cm x 3 cm
	1	Nail (H)	0.5 cm long
(3) Weight	2	Steel Bars (I)	12 cm x 3 cm x 0.3 cm
	2	Bolts (J)	1.5 cm long
	2	Nuts (K)	To fit bolts
	1	Cord (L)	100 cm long

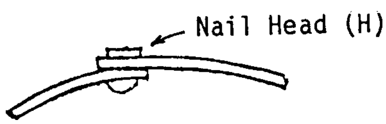
b. Construction

(1) Can



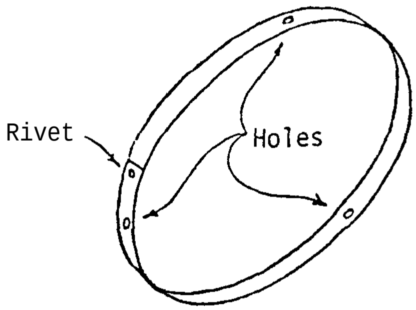
Cut both ends from the tin can (A). Flatten one end of the can to a rough rectangular shape about 15 cm x 10 cm. Drill three holes in the round end of the can, each about 4 cm from the ends. Space these holes every 120° and make them slightly larger in diameter than the bolts (D) used. Make two more holes the same diameter at the other end of the can. These holes should be about 2 cm from the edge and 9 cm apart.

(2) Net



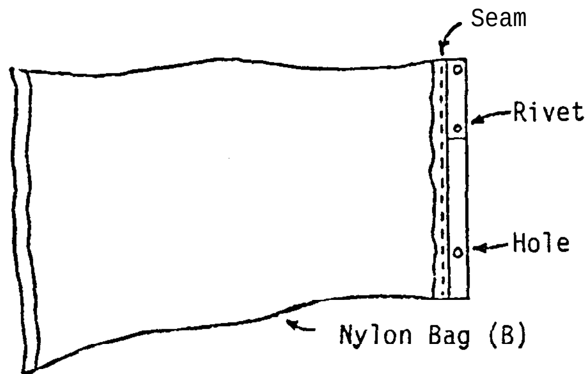
Side View of
Rivet

Make a loop from the strapping (C) that will fit inside the can (i.e., slightly smaller than 15 cm in diameter). To do this easily, drill a small hole near each end of the strapping. Cut the head off a flat-headed nail (H) and insert this nail through the holes in the strapping. Flatten the nail down like a rivet to hold the loop together.



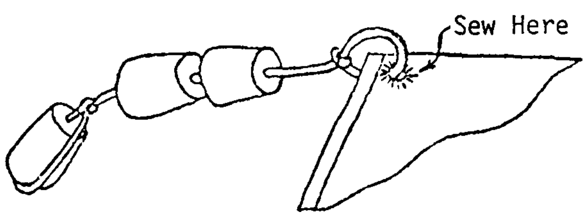
Strapping Loop (C)

Drill holes in the strapping which will align with the holes in the round end of the can. One might wish to drill these holes before riveting the loop together. These holes should be the same diameter as the holes in the can.



Side View

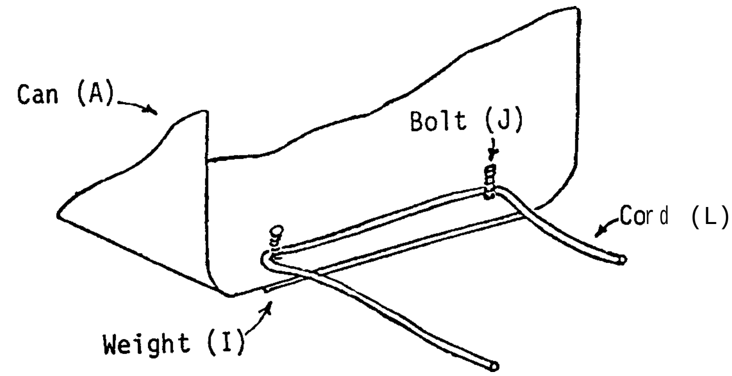
Sew the open end of the nylon bag(B) around the strapping loop with stout thread. The net may also be made from nylon netting if ready-made bags are unavailable. Punch holes through the nylon bag to correspond to the holes in the strapping loop. Fasten the net and loop to the can with the three nuts (E) and bolts (D).

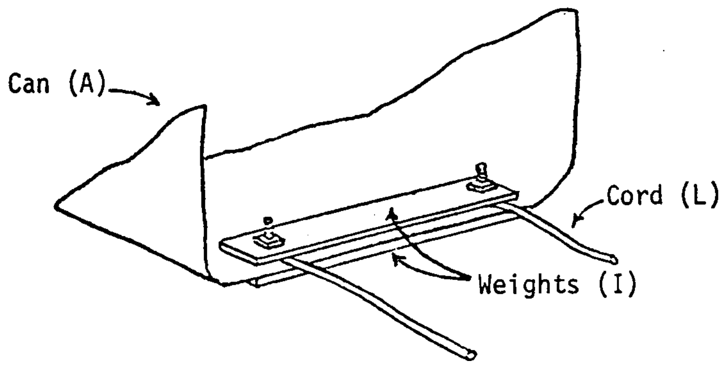


Detail of Cork (G) Attachment

Punch holes through the six corks (G) and tie one of them to each of the two cords (F). Run each of the cords through two of the remaining corks and tie one cord to each corner of the net (B). It may be necessary to sew around each connection to prevent the nylon from tearing.

(3) Weight





Detail

Drill two holes slightly larger than the bolts (J) used in each steel bar (I). Make these holes 9 cm apart so they will align with the holes already drilled in the can. Insert the two bolts (J) through the holes in one of the steel bars and then put the bolts through the holes in the can so that the steel bar weight is on the outside of the can. Stretch the cord (L) around the two bolts.

Place the second steel bar (I) over the two bolts and fasten with the nuts (K). The cord (L) should be firmly held between the can and bar. Tie the loose end of the cord together to form a loop.

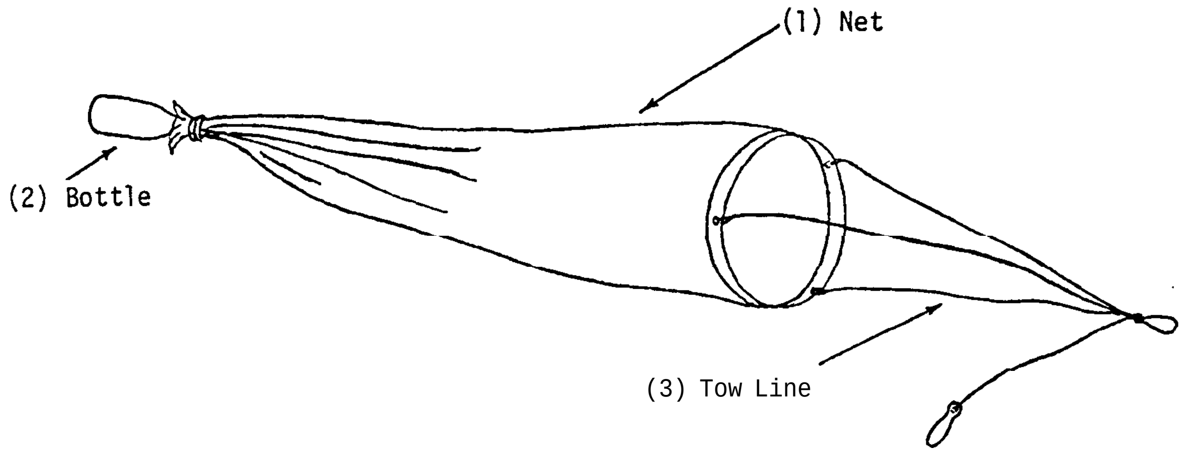
c. <u>Notes</u>

(i) In use, the dredge is tied to a long rope and dragged along the bottom of a body of water. Organisms living on or near the bottom are collected in the net.

(ii) The weights insure that the dredge will stay in the correct position on the bottom. The corks are to help keep the net off the bottom until it is filled with collected material. This prevents it from being torn.

(iii) Use water resistant materials wherever possible in construction of this and all aquatic apparatus.

A4. Plankton Net *

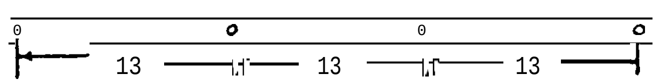


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Net	1	Nylon or Silk Stocking (A)	About 50 cm long
	1	Metal Strapping (B)	40 cm long, 1.5 cm wide, 0.05 cm thick, 2.5 cm diameter
(2) Bottle	1	Glass Bottle (C)	2.5 cm diameter, 6 cm long
	1	Rubber Band (D)	--
(3) Tow Line	2	Cords (E)	60 cm long
	1	Lead Weight (F)	Weight is variable

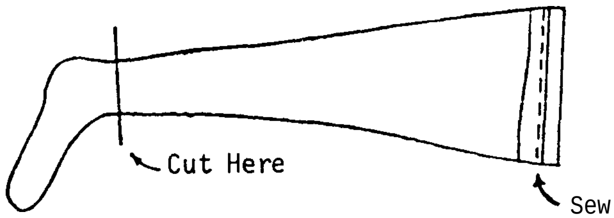
b. Construction

(1) Net



Drill four holes into the metal strapping (A) at 13 cm intervals. Make the holes about 0.3 cm in diameter.

*Adapted from Biological Sciences Curriculum Study, High School Biology: Student's Manual, (Chicago: Rand McNally and Company, 963), p 157.

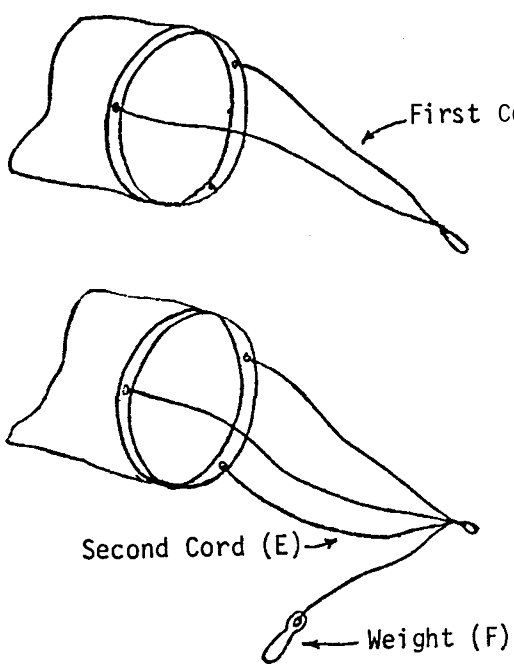


Hold the strapping in a ring shape and sew the open end of the stocking (A) to this ring. Cut off the foot of the stocking.

(2) Bottle

Attach the glass bottle (C) to the end of the net by. wrapping the rubber band (D) tightly around it. Be sure the opening to the bottle is not clogged by material from the net.

(3) Tow Line



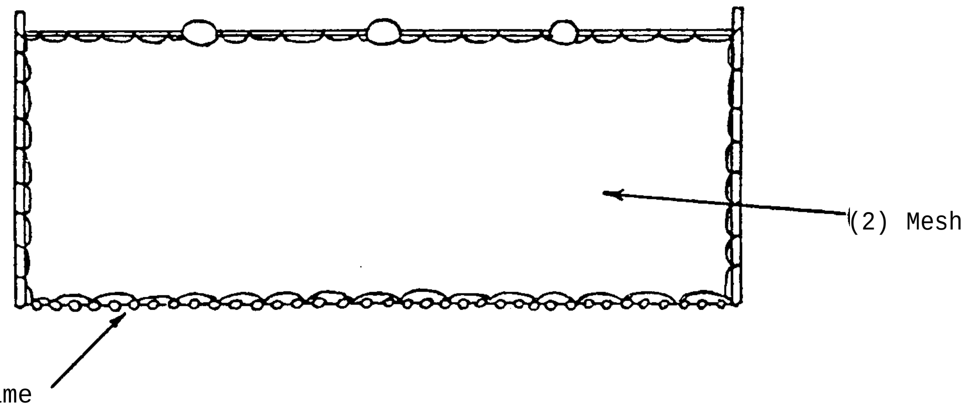
Punch small holes in the net to correspond to the three holes in the strapping ring. Tie one end of one cord (E) to one of these holes, make a loop in the middle of the cord, and tie the other end to the hole formed where the two ends of the strapping overlap. Next, tie the other cord (E) to the re-maining hole in the ring. Tie the middle of this cord to the knot in the other cord, and tie the free end to a lead fishing weight (F).

c. Notes

(i) The plankton net is best used by dragging it behind a boat near the surface of the water. Organisms are trapped in the bottle as the water washes through the net.

(ii) Use netting with as fine a mesh as possible. An old parachute is an excellent source of material for the net.

A5. Two-Man Seine*

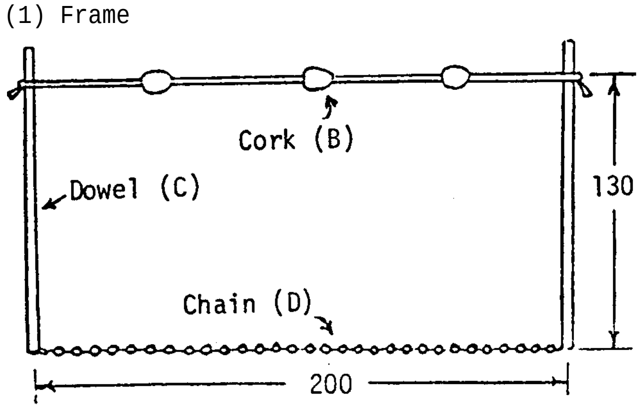


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Nylon Rope (A)	250 cm long, 0.5 cm diameter
	3	Cork Floats (B)	15 cm long, 10 cm diameter
	2	Wood Dowels (C)	150 cm long, 3 cm diameter
	1	Galvanized Chain (D)	200 cm long
(2) Mesh	1	Nylon Cord (E)	About 1000 cm long, 0.2 cm diameter
	1	Nylon Seine Net (F)	130 cm x 200 cm

b. Construction

(1) Frame



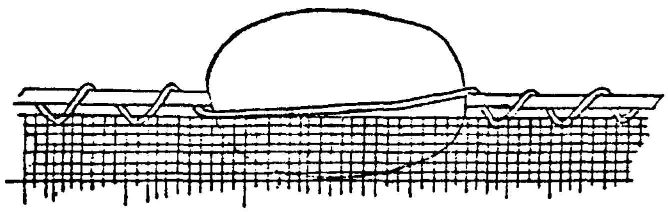
Fasten the ends of the chain (D) to the bottoms of the wooden dowels (C). Tie one end of the nylon rope (A) to the top of one dowel about 20 cm from the end. Run the free end of the rope through the holes in the cork floats (B) and tie it to the other

*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 326.

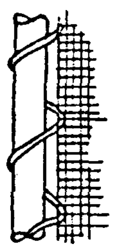
dowel so that the distance between the two dowels when the rope is stretched out is 200 cm.

(2) Mesh

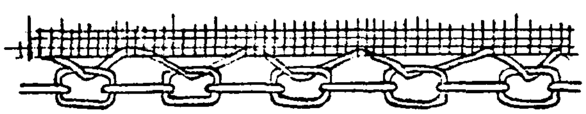
Use a mesh (F) from 0.25 to 0.50 cm square. Fasten it to the dowel (C), chain (D), and rope (A) as shown by using the small diameter nylon cord (E).



Attachment of Mesh (F) to Rope (A)



Attachment of Mesh (F) to Dowel (C)



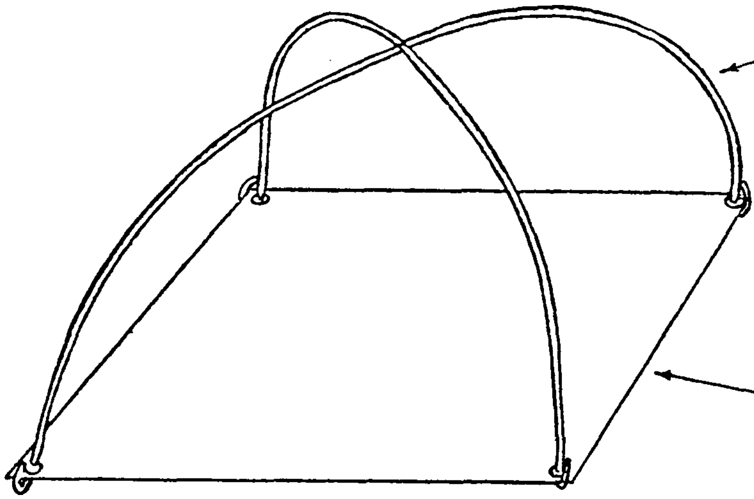
Attachment of Mesh (F) to Chain (D)

c. Notes

(i) Two persons are required to use the seine net. Each holds one of the poles upright in the water and they both walk slowly toward the shore. A great variety of organisms can be collected in this manner.

(ii) Wherever possible, use corrosion and rot resistant materials for the seine such as nylon rope, cord and mesh and galvanized chain.

A6. Lift Net *

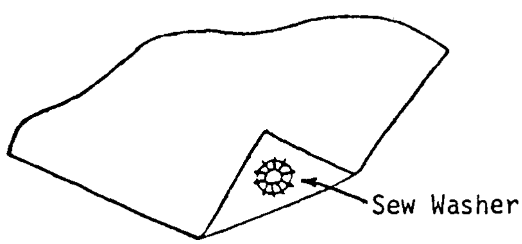


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Net	1	Nylon Mesh (A)	50 cm x 50 cm
	4	Metal Washers (B)	1.5 cm diameter
(2) Spreaders	2	Heavy Wires (C)	100 cm long, 0.3 cm diameter

b. Construction

(1) Net



Corner Detail

Construction of the lift net is quite simple. Simply fold over each corner of the nylon mesh (A) and sew a washer (B) to the double thickness of material. Punch a hole through the center of each washer and through the double layer of nylon.

*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 283.

(2) Spreaders

Roll each wire (C) to a roughly semicircular shape. Insert one end of each wire through adjacent corners of the net and bend up the ends. Insert the other end of each wire through the corner diagonally opposite the first corner and bend up the ends again. Use a small piece of wire to bind the spreaders together where they cross.

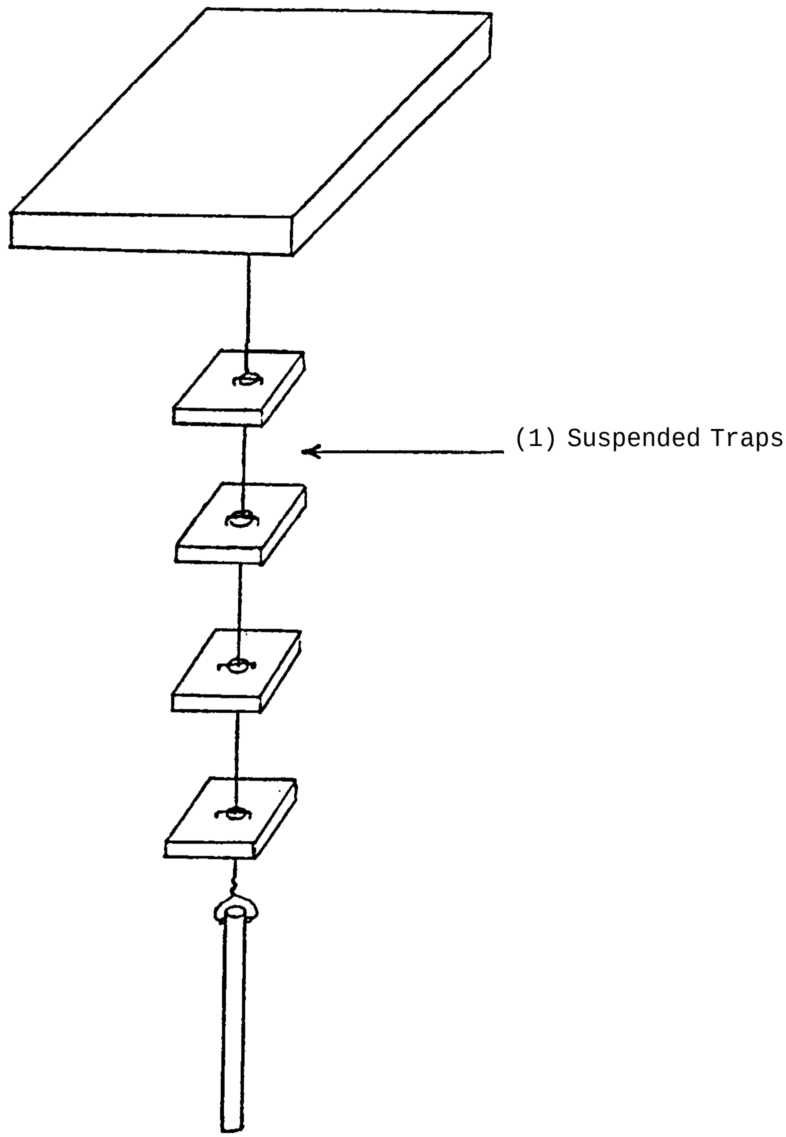
c. Notes

(i) Use the lift net to catch small fish and crustaceans. Place a suitable bait firmly tied to a weight in the center of the net. Tie a line to the lift net where the spreaders cross and lower the net into the water. If the water is clear, watch for fish or crustaceans to near the center of the net, and when they do, quickly lift the net to trap them. If the water is not clear, simply wait for one or two minute intervals before quickly raising the net.

(ii) Small fish may be collected by floating food on the surface of the water. As small fish come to the food, the net may be raised, and the fish collected.

B. AQUATIC TRAPS

B1. Piling Trap



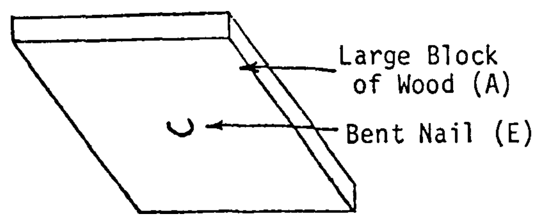
a. Materials Required

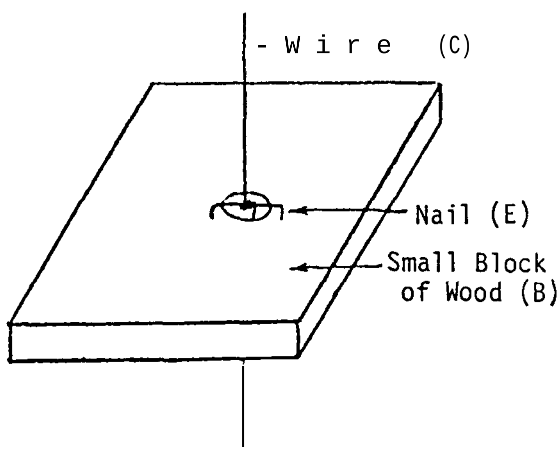
Components	Qu	Items Required	Dimensions
(1) Suspended Traps	1	Wood (A)	24 cm x 24 cm x 4 cm

4	Wood (B)	10 cm x 10 cm x 2 cm
1	Wire (C)	120 cm long, 0.1 cm diameter
1	Metal Rod (D)	26 cm long, 1.5 cm diameter
5	Nails (E)	2.5 cm long, 0.3 cm diameter

b. Construction

(1) Suspended Traps





Place a heavy staple or bent nail (E) in the center of the large block of wood (A). Drill a hole 0.4 cm in diameter through the center of each of the small blocks of wood (B). Place a nail (E) near each of the holes and wrap the wire (C) around these nails as it is passed through the holes. Bend the nails down across the holes. The small blocks should be spaced about 20 cm apart, with the first block about 30 cm from the large wood block (A), and the metal rod (D) about 30 cm from the last block. Drill a hole in the metal rod through which the wire is run, and connect the rod to the wire. Finally, attach the upper end of the wire to the staple or bent nail on the underside of the large block of wood.

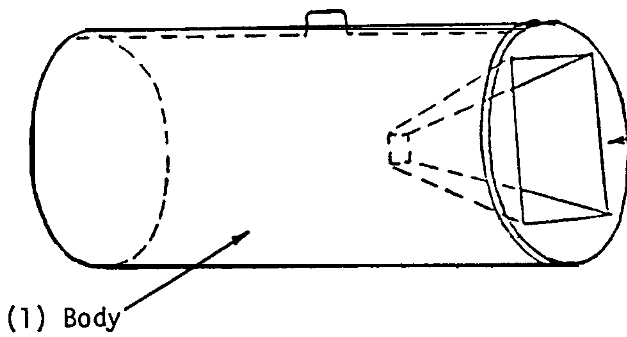
c. Notes

(i) Many aquatic animals attach themselves to the bottom of boats and piers. This trap utilizes this principle in capturing these organisms. To operate, simply place the apparatus in the water and remove approximately every 30 days and collect the organisms which have attached themselves to the blocks of wood.

(ii) The large wood block may be substituted for by some other type of float. A watertight plastic container (e.g., an empty plastic bottle of bleach) can be used. This float can be painted a bright color, thus making it easy to see.

(iii) Any type of weight may be used provided that it is not heavy enough to submerge the large block of wood while still keeping the small blocks of wood under water.

B2. Funnel Trap

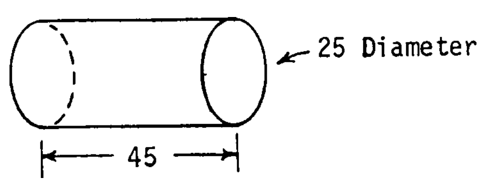


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	1	Wire Mesh (A)	45 cm x 80 cm
	1	Wire Mesh (B)	25 cm diameter
	1	Stiff Wire (C)	85 cm long, 0.2 cm diameter
	1	Stiff Wire (D)	50 cm long, 0.2 cm diameter
	1	Fine Wire (E)	0.05 cm diameter, about 300 cm long
(2) Funnel	1	Stiff Wire (F)	85 cm long, 0.2 cm diameter
	1	Spring (G)	2 cm long
	1	Wire Mesh (H)	30 cm diameter
	4	Wire Mesh (I)	17 cm x 17 cm
	1	Fine Wire (J)	0.05 cm diameter, about 300 cm long

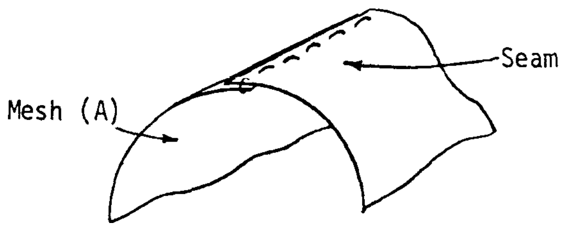
b. Construction

(1) Body



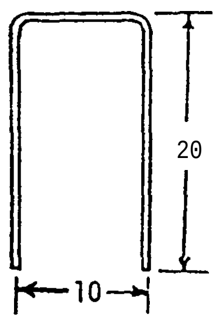
Cylinder

Make a cylinder 45 cm long and 25 cm in diameter from the rectangular piece of wire mesh (A). Wire the 45 cm sides together with the fine

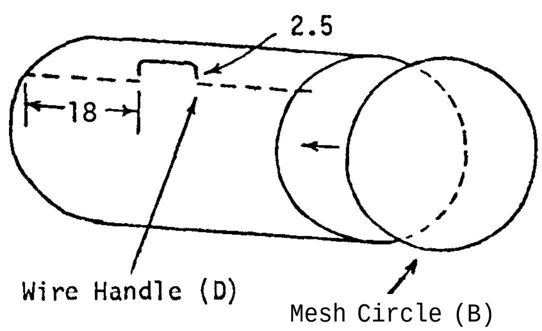


Detail

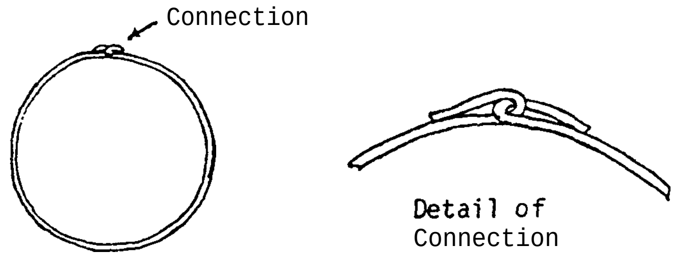
wire (E) in much the same way as one would sew a cloth seam. Let the edges of the mesh overlap about 1 cm to facilitate "sewing" them together with the wire.



Wire (D)

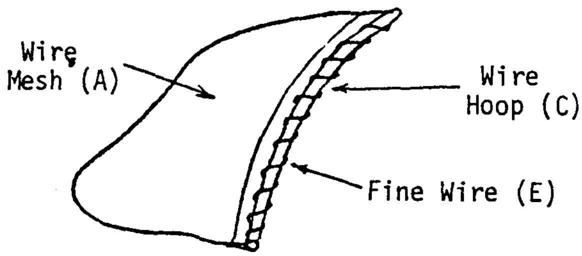


Next, bend the stiff wire (D) to the shape of a "U" Make two small holes 10 cm apart in the cylinder. Insert the U-shaped wire through these two holes, and bend up the ends leaving about 2.5 cm of the wire extending out of the cylinder as a handle. Take the 25 cm diameter piece of wire mesh (B) and "sew" it to one end of the cylinder with a piece of fine wire (E) to seal it off.



Hoop Made from Wire (C)

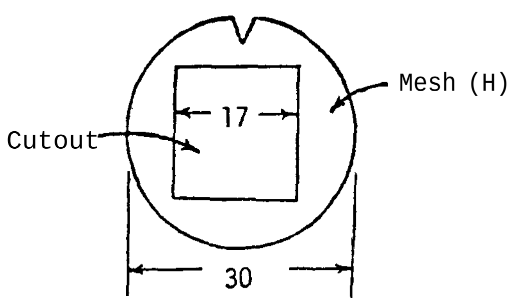
Detail of Connection



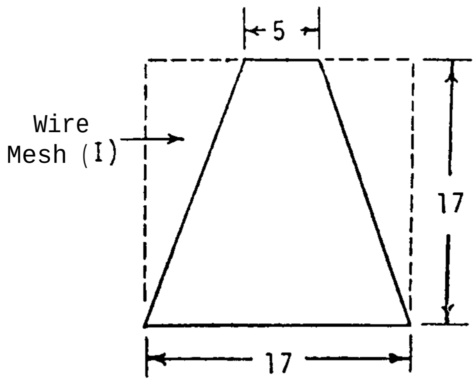
Detail

Finally, make a 25 cm diameter "hoop" from the stiff wire (C) by hooking the ends together. Connect the wire hoop to the open end of the cylinder with fine wire to stiffen the cylinder. This is best done by folding about 2 cm of the end of the cylinder back over the hoop and sewing the hoop inside this flap for the full circumference of the hoop.

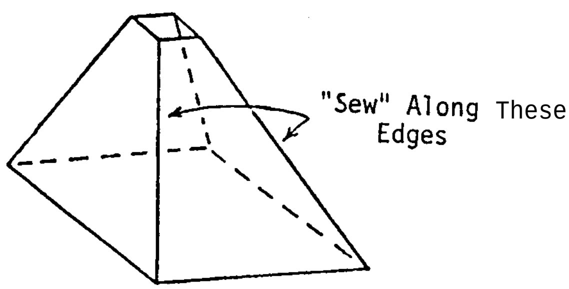
(2) Funnel



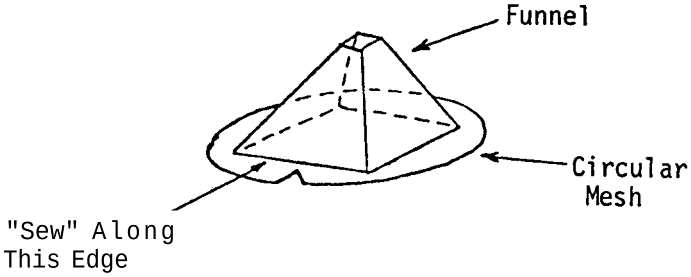
Cut a square 17 cm on a side from the center of the circular piece of wire mesh (H). Also, cut a V-shaped notch 2.5 cm deep in one edge of the piece of mesh.



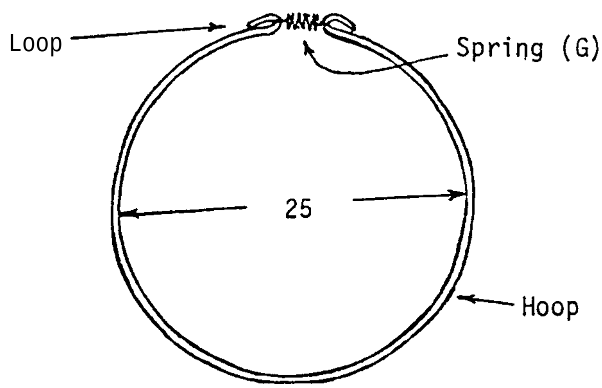
Cut the four pieces of wire mesh (I) into triangular-shaped pieces 17 cm at the base and 5 cm at the apex. Sew the four pieces together along their long edges with fine wire (J) to form a pyramid-shaped funnel.



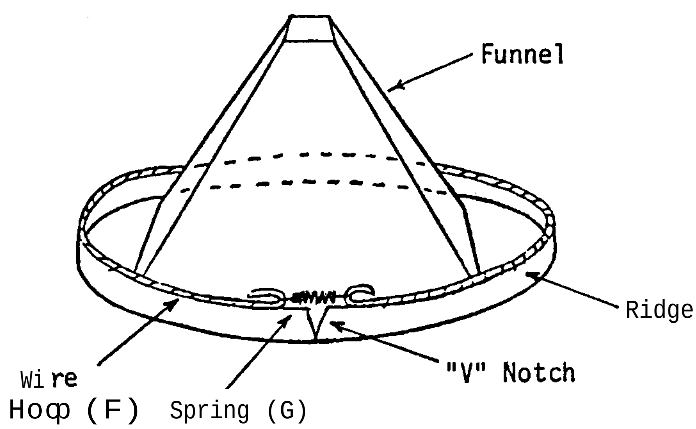
Mesh Funnel



Sew the funnel to the circular piece of mesh (H) with the square cutout.



Form a hoop from the stiff wire (F) 25 cm in diameter with small loops at both ends. Connect these two ends of the hoop with the spring (G). (Springs can easily be made by wrapping stiff wire around a pencil or other round object.)

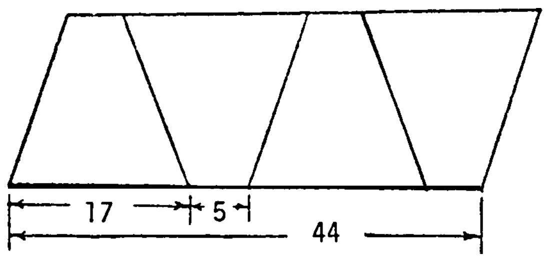


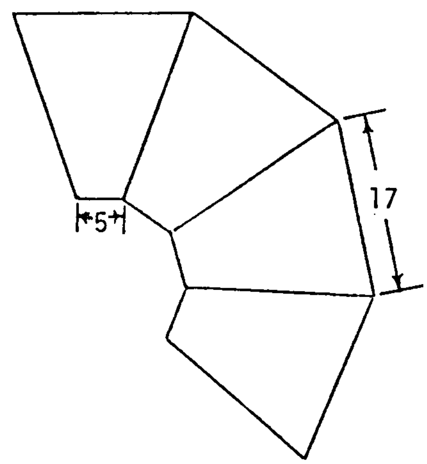
Now, fold up a ridge 2.5 cm high all around the circumference of the circular piece of mesh (H). Wire the hoop (F) to this ridge making certain the spring (G) on the hoop aligns with the "V" notch in the mesh. Fit this funnel assembly over the end of the cylindrical body by pulling the spring open slightly. Slip the funnel over the end of the cylinder and let the spring snap back. The tension of the spring should hold the funnel assembly to the cylinder relatively tightly.

c. Notes

(i) Use of the funnel trap is simple.. Just remove the funnel portion of the trap by spreading open the spring slightly and pulling the funnel off the cylinder. Place some rocks or other weights in the trap to hold it down in the water, and place a suitable bait (e.g., pieces of fish, old cheese wrapped in a cloth bag) in the cylinder. Replace the funnel, and tie a length of rope to the handle. Drop the trap into a stream or pond, and tie the other end of the rope to an object on the bank or a float (a plastic bottle makes an excellent float). Check the trap periodically to remove captured animals and replace baits.

(ii) The following two patterns can also be used for the funnel:





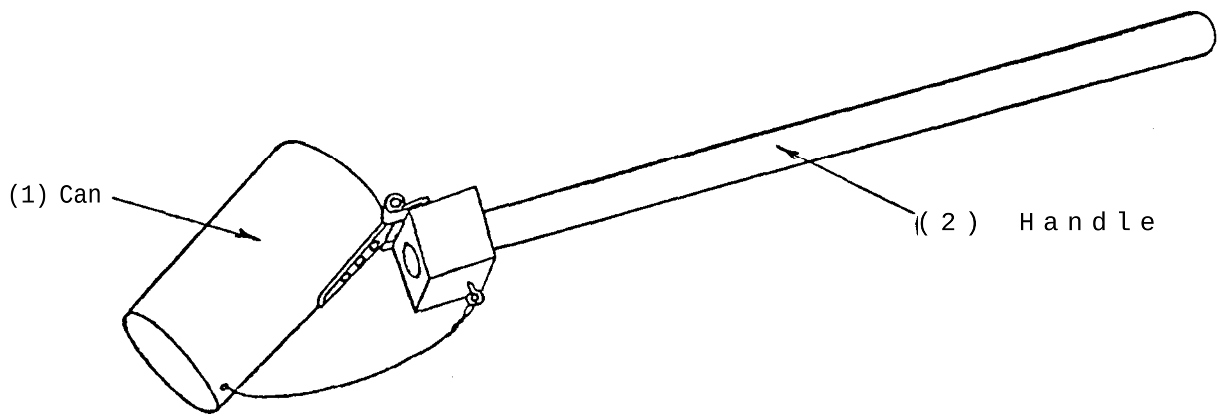
The first pattern is used because it wastes less material while the second is good because only one seam needs to be sewn while the others are merely folded.

(iii) Wherever possible, use rustproof materials like aluminum screening in the construction of this item.

(iv) The circular and other shapes can more easily be cut from the wire mesh if a pattern is first cut from paper and taped to the mesh. Then cut around the paper rather than attempting to draw a pattern on the mesh as this is extremely difficult to do.

C. SUPPLEMENTARY AQUATIC MATERIALS

Cl. Bottom Sampler

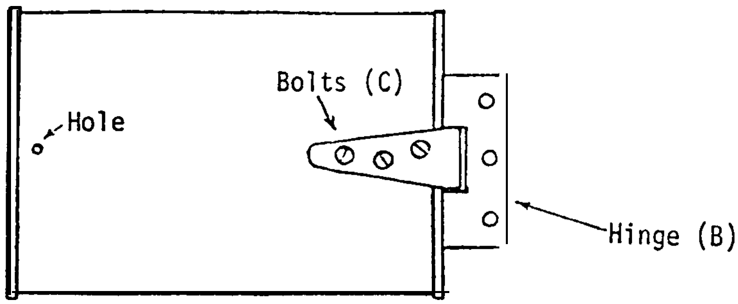


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	12 cm long, 8 cm diameter
	1	Hinge (B)	--
	3	Bolts (C)	1.0 cm long
	2	Nuts (D)	To fit bolts
	3	Wood Screws (E)	1.0 cm long
(2) Handle	1	Wood (F)	5 cm x 4 cm x 4 cm
	1	Wood Dowel (G)	2.5 cm diameter, length variable
	1	Eyed Screw (H)	--
	1	Wire (I)	18 cm long

b. Construction

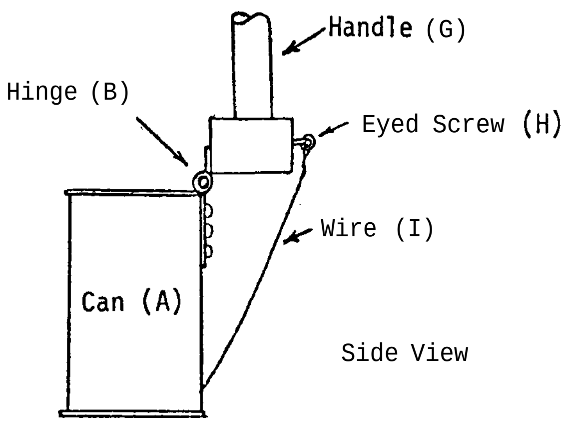
(1) Can



Top View

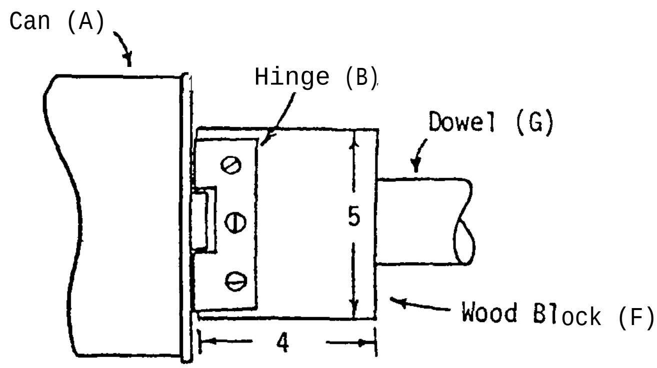
Remove one end of the tin can (A). Punch a small hole near the bottom of the can. At the open end of the can fasten one plate of the hinge (B) to the can with the bolts (C) and nuts (D). Holes will have to be drilled or punched through the can for the bolts to go through. The hinge may be fastened to the can with sheet metal screws if these are available.

(2) Handle



Side View

Drill or bore a hole the same diameter as the wood dowel (G) through the middle of the wood block (F). Insert one end of the dowel into the block and screw or glue them together. With screws (E), fasten the plate of the hinge (B) to the bottom of the block. Screw the eyed screw (H) into the other side of the wood block. Finally, make a knot in the end of the wire (I) and pass the free end through the hole in the bottom of the can (the knot must be inside the can) and tie the free end to the eyed screw.



Bottom View

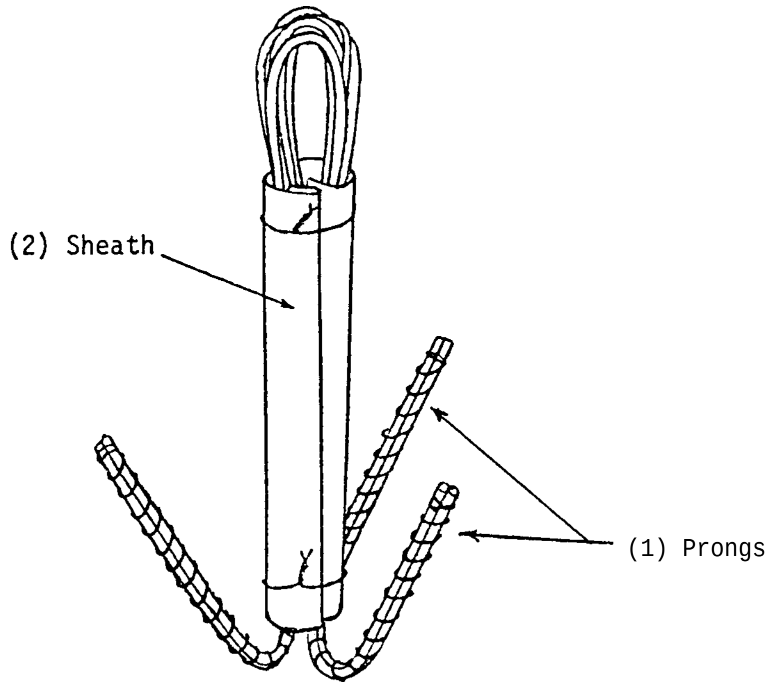
c. Notes

(i) To operate, simply lower the sampler into the water until the can hits bottom. Drag the can back and forth until it feels heavy, then pull it out of the water and remove the bottom sediment. The wire prevents the can from hitting bottom with the open end pushed against the handle so that no sediment can enter it. Collect bottom samples in different ponds and streams to check the sediment for the various organisms living in each.

(ii) The length of the handle will vary according to the depth of the water where the sample is to be taken.

(iii) The details of design of this item depend mainly on the type of hinge used.

C2. Grappling Hook

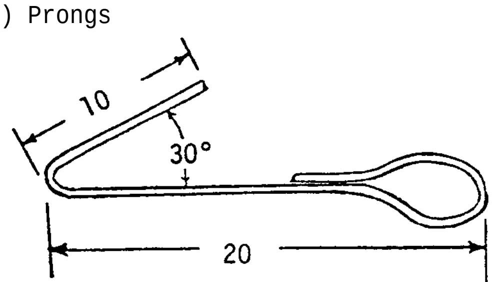


a. Materials Required

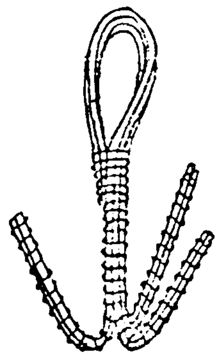
Components	Qu	Items Required	Dimensions
(1) Prongs	6	Stiff Wire (A)	40 cm long, 0.25 cm diameter
	1	Soft Wire (B)	About 100 cm long, 0.05 cm diameter
(2) Sheath	1	Sheet Metal (C)	12 cm x 8 cm x 0.05 cm
	2	Soft Wire (D)	8 cm long, 0.1 cm diameter

b. Construction

(1) Prongs



Bend each piece of stiff wire (A) to the shape of a hook with a loop at one end. Group the prongs together by twos and bind them together with the soft wire (B).



Then place the three resulting double prongs together and bind them so that the prongs are about at angles of 120° to each other.

(2) Sheath

To finish the grappling hook simply wrap the piece of metal sheet (C) around the middle of the hook and bind it in place with the soft wire (D).

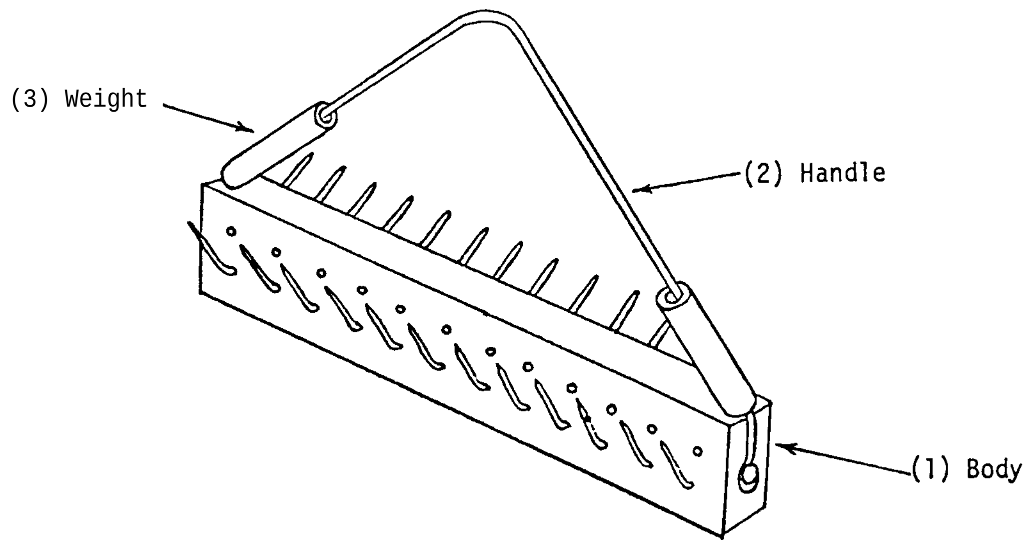
c. Notes

(i) To use the hook, just tie it to the end of a rope or cord, drop it into the water, and pull it up when it becomes entangled in vegetation.

(ii) Be careful when handling this item of the sharp edges of the sheet metal and the points of the wire used in binding it together.

(iii) If heavy steel wire is available, only one piece is needed per hook rather than two.

C3. Grappling Bar

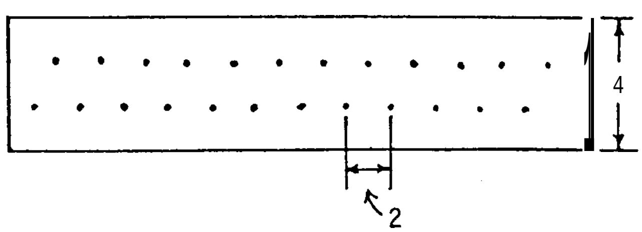


a. Materials Required

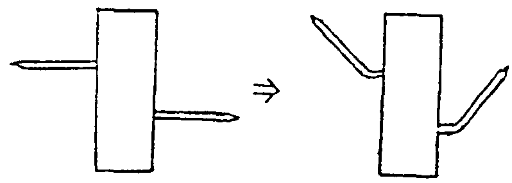
Components	Qu	Items Required	Dimensions
(1) Body	1	Wood (A)	25 cm x 4 cm x 2 cm
	24	Nails (B)	5 cm long, 0.2 cm diameter
(2) Handle	1	Soft Wire (C)	50 cm long, 0.2 cm diameter
	2	Nails (D)	3 cm long
(3) Weight	2	Lead Pipe (E)	8 cm long, 1.5 cm diameter

b. Construction

(1) Body



Drive the nails (B) through the wood (A) in two rows, staggering them so that they don't align directly above one another. One row of nails is nailed through from one side while the other row is

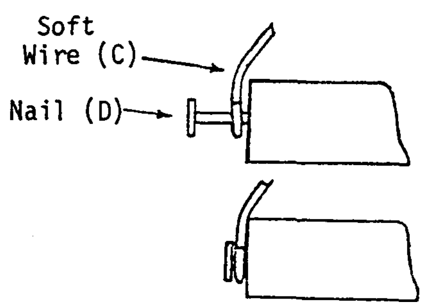


Side Views

nailed through the opposite side.

Where the nails have been driven through the wood, bend them upwards at approximately 45° angles as close to the base as possible.

(2) Handle



Detail

Hammer one of the nails (D) into the end of the body and let it protrude about 1 cm. Twist one end of the soft wire (C) around the nail, then hammer it down completely.

(3) Weight

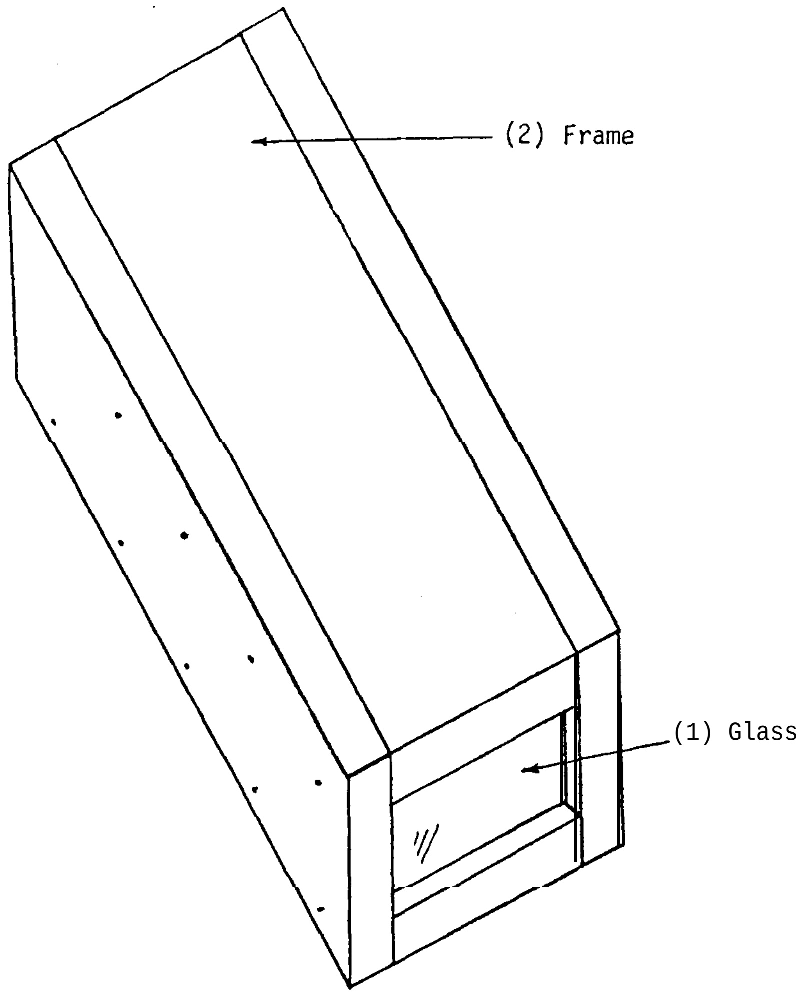
Slip the two pieces of lead pipe (E) over the free end of the handle, and fasten the free end to the opposite end of the body. Bend the handle at its middle allowing one weight to slide down each arm of the handle.

c. Notes

(i) To use the grappling bar, tie the end of a long, stout rope or cord to the handle. Drop the bar in water, allow it to reach bottom, and drag it along until resistance is-felt, then haul it up. The bar works well for retrieving plant specimens from pond and river bottoms.

(ii) Be certain the weights are sufficient to sink the bar easily, as wood can be extremely buoyant.

C4. Water Glass



a. Materials Required

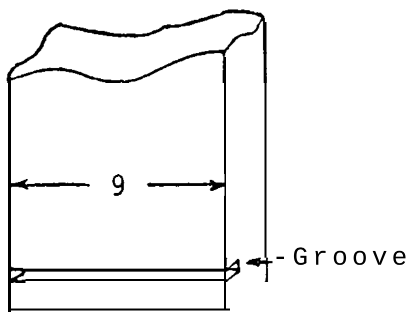
Components	Qu	Items Required	Dimensions
(1) Glass	1	Glass Plate (A)	6.3 cm x 10.3 cm x 0.3 cm
(2) Frame	4	Wood (B)	20 cm x 9 cm x 2 cm

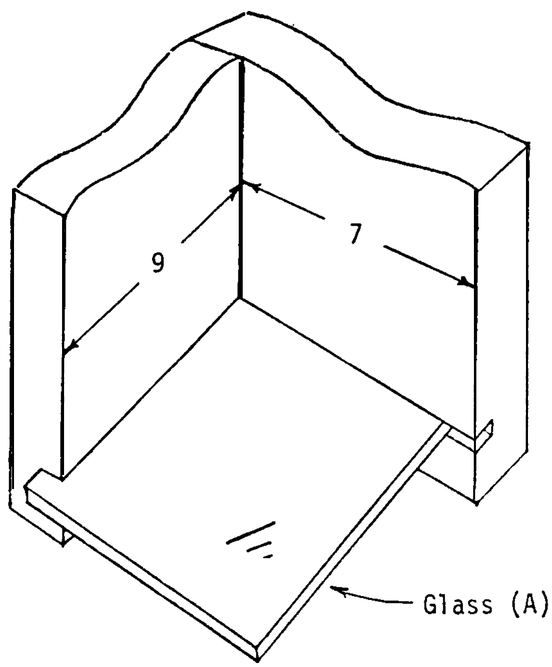
b. Construction

(1) Glass Plate

Cut the piece of glass (A) to the specified dimensions, making sure that all the edges are smooth and free of burrs.

(2) Frame





Cut a groove, 0.3 cm wide and 0.7 cm deep, across the width of each piece of wood (B), 1.2 cm from one end. Fasten two of the pieces of wood together at right angles using waterproof cement along the point of contact. Be sure that the grooves are lined up and that they face to the inside. Use nails or screws to reinforce this joint. Glue two sides of the glass plate with waterproof cement into the two grooves, placing the long side of the glass plate into the groove in the piece of wood with a width of 9 cm. The next piece of wood should be placed so that the groove holds the larger of the two free sides remaining on the glass plate. The last piece of wood then fits over the final free end. These last two pieces of wood should be glued and nailed to the previously assembled structure as they are put into place. Seal the ends of the grooves on the outside of the water glass with waterproof cement. Make certain all seams are waterproof.

c. Notes

(i) The water glass is designed to view the bottom organisms of a body of water. When the end with the glass plate is inserted into the water, glare from the sun as well as surface ripples are eliminated.

IV. TERRESTRIAL COLLECTING APPARATUS

These items are designed for use in collecting land invertebrates, vertebrates, and plants. Instructions for killing, preserving, and storing these organisms can be found in a variety of books and journals.

A. INSECT COLLECTING APPARATUS

Insects are the most common, familiar organisms everywhere in the world. Iterns described in this section are used in collecting and treating them.

B. SOIL ORGANISM COLLECTING APPARATUS

These pieces of equipment enable students to discover the multitude and diversity of living things in the soil.

C. SMALL VERTEBRATE COLLECTING APPARATUS

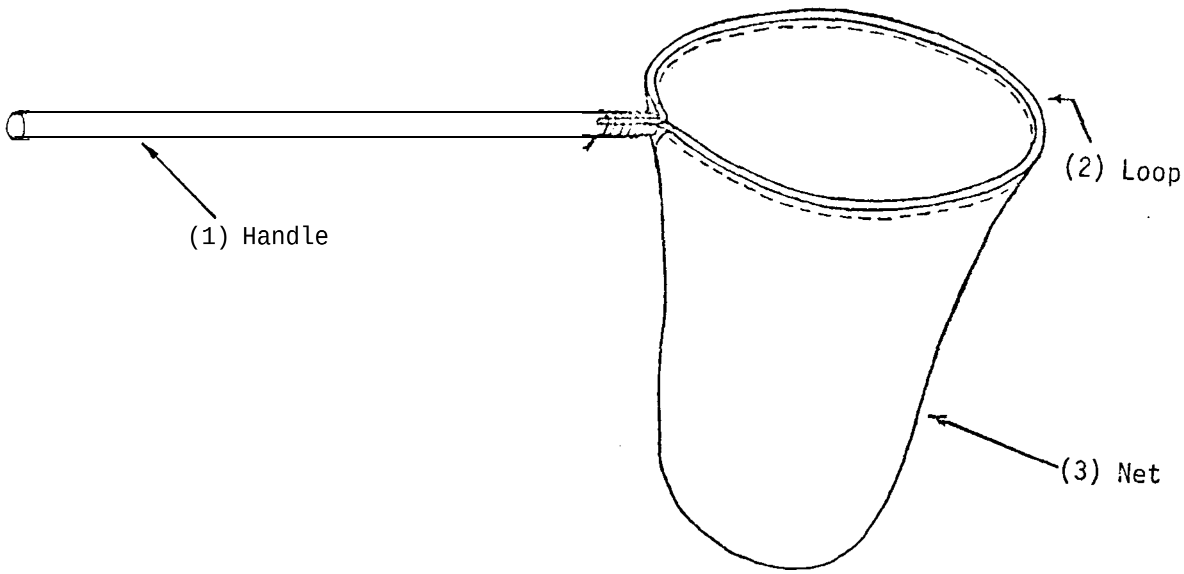
Small lizards, snakes, birds and mammals may be captured alive using these devices.

D. PLANT COLLECTING APPARATUS

The vasculum and plant presses in this section are used in collecting and preserving plant materials.

A. INSECT COLLECTING APPARATUS

Al. Butterfly Net

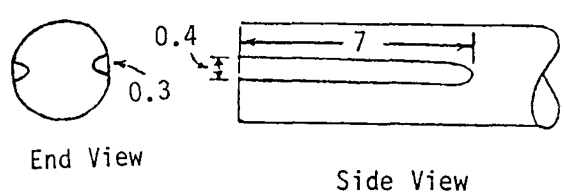


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	100 cm long, 2 cm diameter
(2) Loop	1	Heavy Wire (B)	115 cm long, 0.3 cm diameter
	1	Stiff Wire (C)	About 80-90 cm long, 0.1 cm diameter
(3) Net	1	Nylon Bag (D)	50 cm wide, 60 cm long

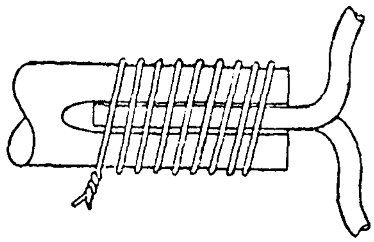
b. Construction

(1) Handle



The length of the dowel (A) from which the handle is made may be varied according to personal preference. Cut two grooves in one end of the handle, one opposite the other. Make these grooves about 7 cm long, 0.3 cm deep, and about 0.4 cm wide.

(2) Loop



Binding of Loop
to Handle

Form a loop 30 cm in diameter from the heavy wire (B). Leave about 7 cm of excess wire at each end which will fit into the grooves in the handle. Bend these 7 cm portions to 90° angles. Fit the wire ends into the grooves in the handle and bind them in place with the stiff wire (C).

(3) Net

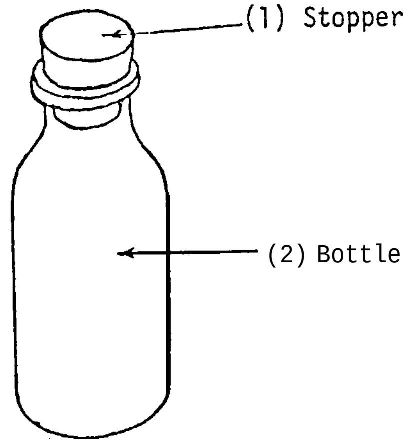
Select a finely meshed nylon laundry bag (D) or sew a net from a piece of nylon cloth or similar sturdy cloth with a relatively open weave. Whether a bag is used or a net sewn specifically for the butterfly net, make sure the opening of the net is 5 - 10 cm greater in circumference than that of the loop. Simply sew the open portion of the net around the loop with strong thread.

c. Notes

(i) Use the butterfly net to collect flying insects of all kinds. If it is sturdily made, it can also be swept through high grass to collect insects living in the grass. Consult a good source book for information on preserving, mounting, and storing collected insects.

(ii) The material used for the net must have a fine mesh through which insects cannot escape. At the same time, the mesh must be open enough to permit air to easily pass through it with little resistance. Parachute nylon is especially good for this purpose.

A2. Killing Jars



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stopper	1	Stopper (A)	To fit bottle
(2) Bottle	1	Glass Pill Bottle (B)	Approximately 10 cm long, 4 cm diameter

b. Construction

(1) Stopper	Select a cork or rubber stopper (A) which will effectively seal the bottle airtight.
(2) Bottle	Use a glass bottle (B) with a wide mouth.

c. Notes

(i) Killing bottles for insects can be made in several ways. Some are exceptionally dangerous and should only be used by the instructor. Be certain to label all jars as to their contents.

(ii) The following are methods of preparing killing jars:

(A) Cyanide Killing Jar - This is extremely dangerous and should only be used by the instructor. First, put a thin layer (0.5 cm) of potassium or sodium cyanide crystals in the bottom of the bottle. Cover this with a similar layer of fine sawdust or dry plaster of Paris. Finally, cover both layers with a layer of wet plaster of Paris. The jar is ready to use when the plaster hardens. Be sure to keep it tightly stoppered except to kill insects. Use only rubber stoppers.

(B) Ethyl Acetate Killing Jar - Put a thin (0.5 cm) layer of wet plaster of Paris in the bottom of the jar. When it has dried, put some ethyl acetate over the plaster and cover it with a small amount of tissue paper. This is also especially dangerous and should be kept tightly stoppered.

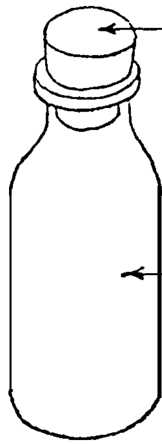
(C) Carbon Tetrachloride Killing Jar (1) - Pin a small piece of blotting paper or cotton to the bottom of the stopper. Saturate this with carbon tetrachloride just before putting the insects in the jar. This is a much safer jar for student use as the carbon tetrachloride quickly evaporates.

(D) Carbon Tetrachloride Killing Jar (2) - Use a one-hole stopper for the jar with a short piece of glass tubing extending through the hole. Plug one end of the tube with cotton. Place the insect in the jar, and replace the stopper. Then, carbon tetrachloride can be dripped through the tube onto the cotton plug where the fumes will kill the insect.

(E) Carbon Tetrachloride Killing Jar (3) - Place several rubber bands in the bottom of the jar and soak them overnight in carbon tetrachloride. Pour off the excess liquid and put a tight-fitting piece of blotting paper over the bands to keep them in place. This jar is relatively long lasting in its killing power.

(iii) The cork or rubber stoppers may absorb the toxic fumes from the jar so be sure to destroy them when the jars are discarded. Be absolutely certain that no fumes escape through the cork. It may be necessary to dip cork stoppers in melted paraffin wax to seal them completely.

A3. Relaxing Jar



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stopper	1	Cork Stopper (A)	To fit bottle
(2) Bottle	1	Glass Pill Bottle (B)	Approximately 10 cm long, 4 cm diameter

b. Construction

(1) Stopper — Select a cork or rubber stopper (A) which will effectively seal the bottle airtight.

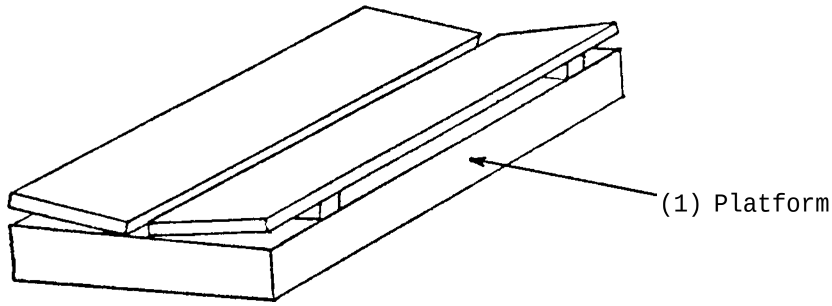
(2) Bottle — Use a glass bottle (B) with a wide mouth.

c. Notes

(i) Relaxing bottles are used to make dead insects more flexible so that they can be manipulated into a desirable mounting position.

(ii) The following is a method for preparing a relaxing jar: Place some moist sand in the bottom of the jar and add a few drops of carbolic acid to inhibit mold growth. Cover the sand with a piece of moist blotter paper. Leave the insects in the jar overnight to relax them.

A4. Insect Spreading Board

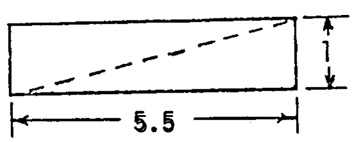


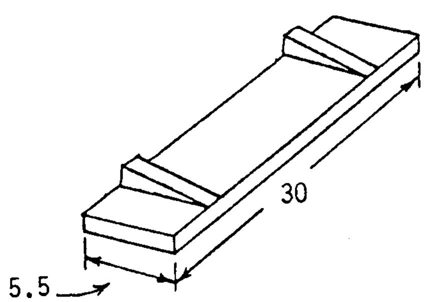
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Platform	1	Wood (A)	12 cm x 30 cm x 1.0 cm
	2	Wood (B)	5.5 cm x 30 cm x 0.5 cm
	2	Wood (C)	5.5 cm x 1 cm x 2 cm

b. Construction

(1) Platform



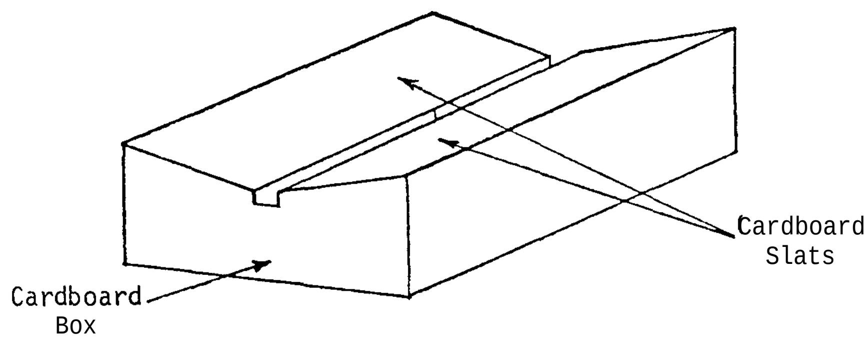


Cut the two small pieces of wood (C) in half diagonally, yielding four wedge-shaped pieces. Glue two of the wedges to the backs of each of the two slats (B). Turn the two slats over and glue them to the base (A). Leave a 1.0 cm gap between the two slats.

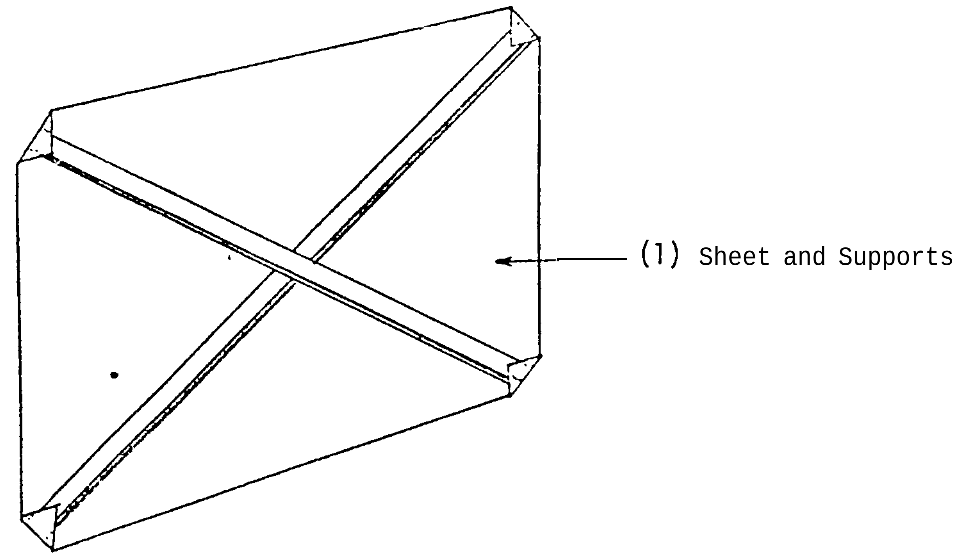
c. Notes

(i) Make the slats (B) from the softest wood available (e.g., balsa). Consult a good biological source book for details on preparing insects to be pinned and prepared on the spreading board.

(ii) A simple, inexpensive spreading board can be made from a cardboard box. Remove the top and cut the ends as shown in the illustration. Then glue two pieces of cardboard to the box to complete the spreading board.



A5. Beating Sheet *



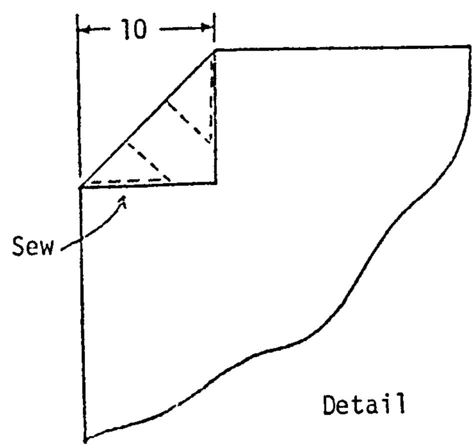
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Sheet and Supports	1	Heavy Cloth (A)	100 cm x 100 cm
	2	Wooden Slats (B)	125 cm x 4 cm x 1.0 cm

b. Construction

(1) Sheet and Supports

Fold back about 10 cm of the heavy cloth (A) (muslin will work) at each corner and sew a pocket into each such that the tips of the wooden slats (B) will fit into them.



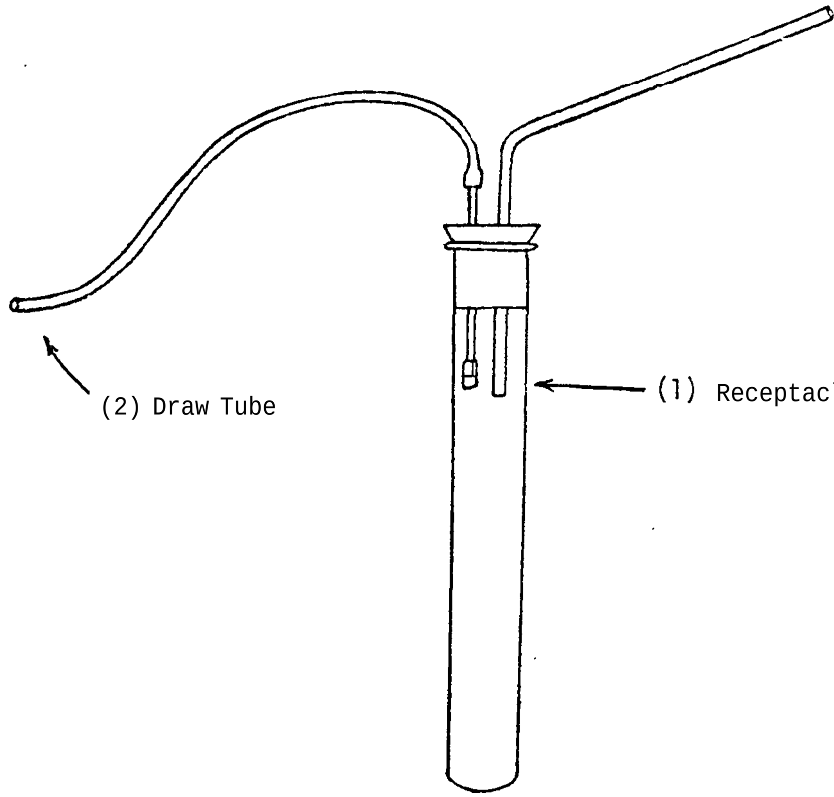
*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 209.

c. Notes

(i) The sheet is held under shrubbery and insects are shaken off onto it where they can easily be captured.

(ii) Bamboo, wooden dowels, broom handles, etc. can be substituted for the wooden slats. In any case, the crosspieces can be removed after use to permit compact storage.

A6. Aspirator



a. Materials Required

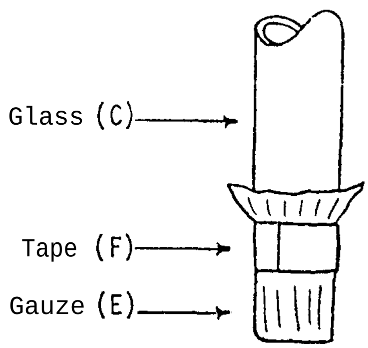
Components	Qu	Items Required	Dimensions
(1) Receptacle	1	Test Tube (A)	15 cm long, 1.6 cm inside diameter
	1	2-Hole Stopper (B)	To fit test tube
(2) Draw Tube	1	Glass Tube (C)	6 cm long, 0.2 cm inside diameter
	1	Rubber Tube (D)	35 cm long, 0.3 cm inside diameter
	1	Gauze (E)	1 cm x 2 cm
	1	Tape (F)	2 cm long
(3) Intake Tube	1	Glass Tubing (G)	16 cm long, 0.3 cm inside diameter

b. Construction

(1) Receptacle

Plug the end of the test tube (A) with a two-hole stopper (B).

(2) Draw Tube



Detail

Use the tape (F) to hold the gauze (E) in place over the end , of the glass tube (C). Be certain air still flows freely through the end of the tube. Insert the end of the tube through one of the holes in the stopper. Attach the end of the rubber tube (D) to the glass tube (C).

(3) Intake Tube

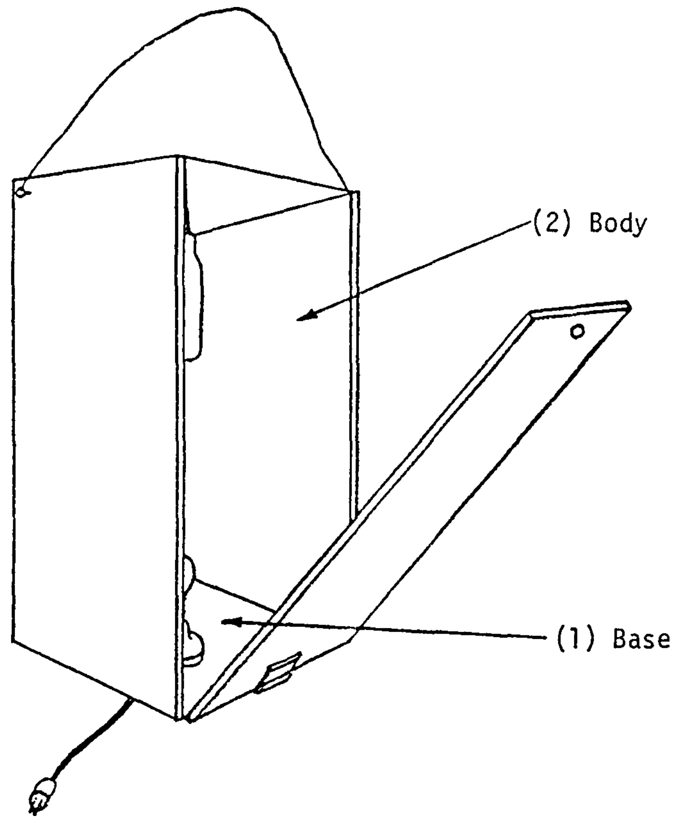
Bend the glass tube (G) to an 120° angle about 6 cm from one end, and insert this end into the remaining hole in the stopper.

c. Notes

(i) The aspirator is a useful instrument when collecting insects which are too small or too fragile to be collected by hand. To operate, place the draw tube between one's teeth and the intake tube near the insect to be collected. The collector then sucks in and the insect is captured. The gauze prevents the insect from entering the draw tube.

(ii) A glass bottle or vial may be used in place of a test tube, but in any case a tight-fitting stopper is required. The stopper may be either rubber or cork, and cotton may be used in place of the gauze.

A7. Night Flying Insect Collector



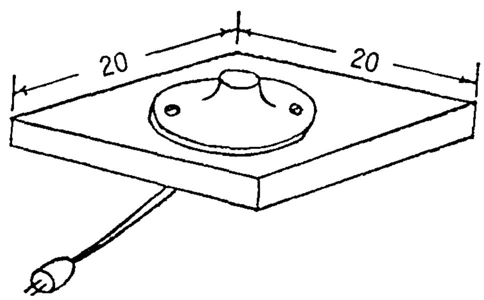
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	20 cm x 20 cm x 2 cm
	1	Electric Lightbulb Socket (Porcelain) (B)	12 cm diameter
	2	Electrical Wire (C)	50 cm long, 0.3 cm diameter
	1	Electrical Plug (D)	--
(2) Body	2	Wood (E)	22 cm x 50 cm x 1.0 cm
	2	Wood (F)	20 cm x 50 cm x 1.0 cm
	1	Hinge (G)	--
	4	Fine Wire Mesh (H)	20 cm x 17 cm
	1	Thick Rubber Band (I)	--
	1	Glass Container with Lip (J)	500 ml
	1	Light Bulb (K)	100 watts
	2	Screw Eyes (L)	2.5 cm long, 0.2 cm diameter
	1	Wire (M)	60 cm long, 0.1 cm diameter

1	Thin Sheet Metal (N)	10 cm x 10 cm
1	Wire (O)	10 cm long, 0.1 cm diameter
2	Wood Screws (P)	1 cm long

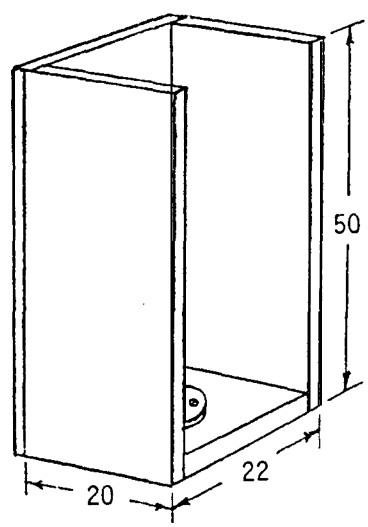
b. Construction

(1) Base

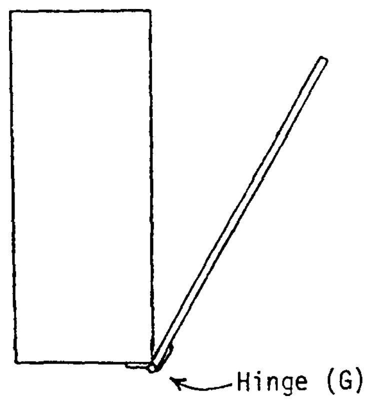


The electric light bulb socket (B) is centered on the base (A) and two holes are drilled through the base for the attachment of the electrical wires (C) to the terminals on the electric light socket. Attach the electrical wires to these terminals and extend them through the base. The socket is then screwed into place on the base using wood screws. Attach the electrical plug (D) to the wires to complete the base.

(2) Body

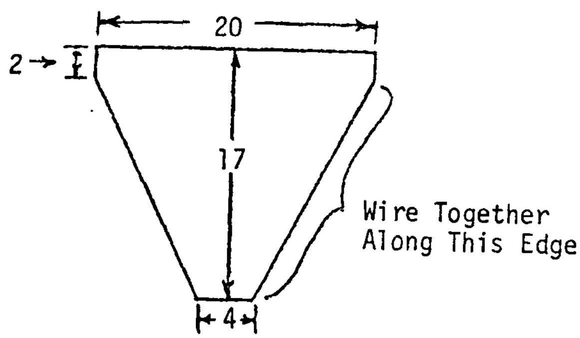


The two pieces of wood (F) are nailed into place on opposite sides of the base. One of the pieces of wood (E) is nailed onto the third side of the base where it overlaps the two ends of the sides already attached. It is then nailed to the other two sides. Take the last piece of wood (E) and attach the hinge (G) to the bottom of it and to the bottom of the base so that it forms a door which opens downward.

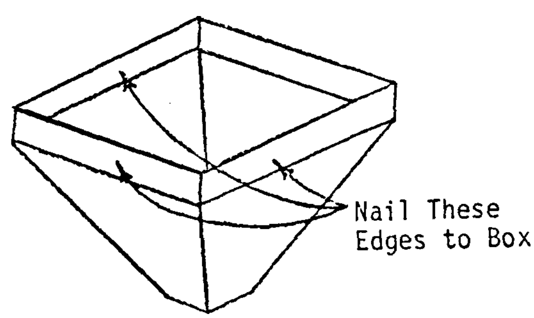


Side View

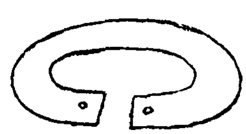
Take the four pieces of wire mesh (H) and cut them to the pattern shown, then wire them together along their edges to form a square funnel. The opening at the bottom of the funnel (4 cm square) should be the same width as the diameter of the neck of the collecting bottle (J) used. Nail three of the edges of the funnel along the top edges of the fixed sides of the trap. Of course, do not nail the fourth edge to the door or the door will not open.



Pattern

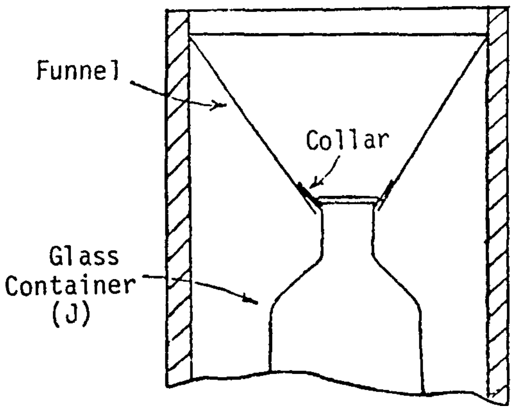


Completed Funnel

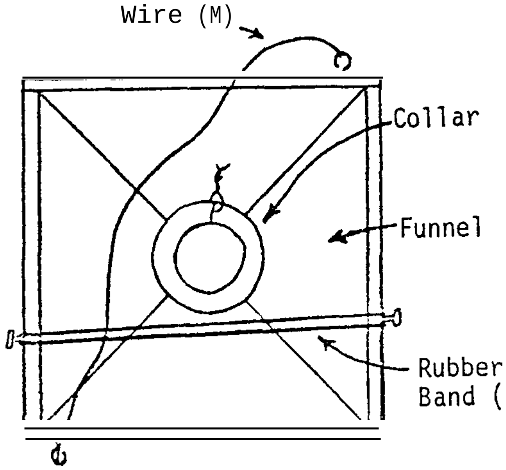


Collar

Next, cut a collar from the piece of sheet metal (N) so that it will fit under the lip on the glass container (J). Cut this collar in such a way so that it



Side View



Top View

does not form a continuous circle, but instead has a break in it. Now, wrap the collar tightly around the neck of the glass container just under the lip. Pull the two free ends together and overlap them. Then punch a hole through the ends and place the piece of wire (0) through the holes and bend it so that it holds the collar tightly closed. The glass container can now be picked up by the collar without falling through it. Remove the collar, force the mouth of the glass container up through the bottom of the hole in the funnel, and replace the collar so that it holds the glass container in place.

Place two screws (P), one on the outside of the door about 2 cm down from the top, and the other in the same position on the side opposite the door. Then, close the door and stretch the rubber band (I) from one screw to the other over the top to hold the door closed. Finally, attach the two screw eyes (L) to opposite corners on the sides of the top and secure the wire (M) to them, and screw the light bulb (K) into the socket.

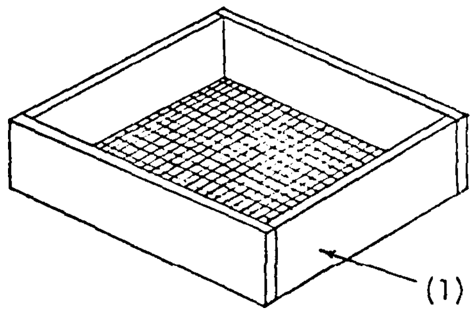
c. Notes

(i) To operate, simply hang the trap at night outside from a fixture (e.g., a tree limb), and attach the electrical wires to a power supply. Be sure to hang it in an area where there are a large number of night-flying insects. The light will attract the insects and they will fall into the glass container. When a sufficient number have become trapped in the container, place a wad of cotton soaked in carbon tetrachloride over the opening, thus killing the insects.

(ii) By placing two hinges on the side of the door, it can be opened to the side if so desired.

B. SOIL ORGANISM COLLECTING APPARATUS

B1. Soil Organism Sieve

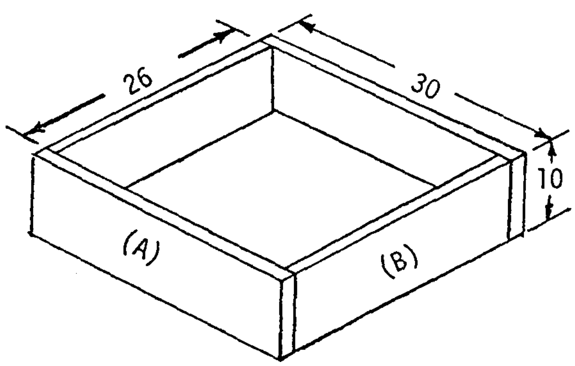


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Sieve	2	Wood (A)	30 cm x 10 cm x 2 cm
	2	Wood (B)	26 cm x 10 cm x 2 cm
	1	Wire Screen (C)	30 cm x 30 cm

b. Construction

(1) Sieve



Frame

Simply nail or screw the four wood boards (A,B) together to form a frame and nail the piece of screen (C) to the bottom of the frame.

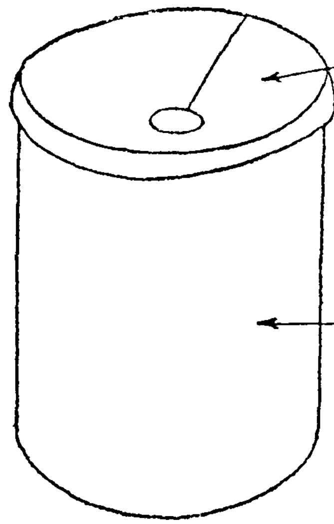
c. Notes

(i) Use the sieve to separate out soil organisms such as worms, grubs, etc., from the material in which they are living.

(ii) Carefully choose the size of wire mesh used in the sieve. A mesh or screen with too fine a weave will become clogged with soil and rendered useless. A relatively wide mesh will work well if the soil is coarse, allowing the organisms to fall through the mesh while holding back the soil.

(iii) A frame for the sieve can also be made by knocking out the bottom from an old drawer or wooden box.

52. Soil Insect Trap



a. Materials Required

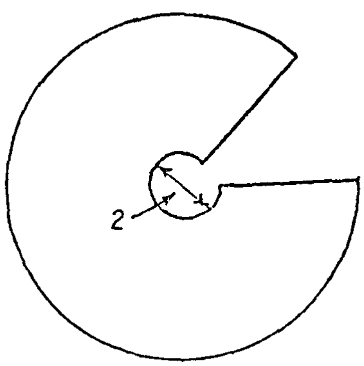
Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	0.5 liter capacity
(2) Funnel	1	Wire Mesh (B)	About 15 cm x 15 cm

b. Construction

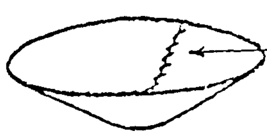
(1) Can

Remove one end from a tin can (A).

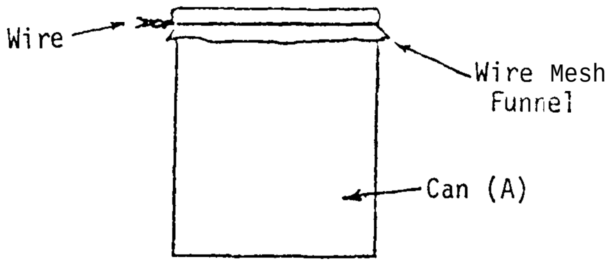
(2) Funnel



Cut a pattern for the funnel from the wire mesh (B). The outside diameter of the pattern should be approximately 2 cm wider than the diameter of the can (A) used.



Connect the two edges of the cutout portion of the pattern by "sewing" them together with wire. This will result in a cone with a hole at the apex. Complete the soil insect trap



Side View

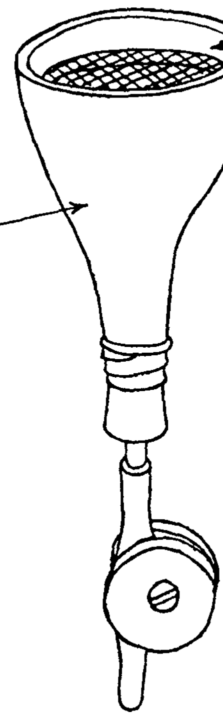
by inserting the funnel in the open end of the can and folding the excess wire mesh down around the outside of the can to hold it in place. If necessary, a piece of wire wrapped around the outside of the can and twisted tightly will help hold the funnel in place too.

c. Notes

(i) Place the trap in a hole in the ground so that the top edge of the trap is even with the soil level. Thus, small insects and other ground organisms crawling across the trap will fall through the hole in the funnel into the can. Check the can periodically for captured organisms.

(ii) The trap can be varied by making the funnel portion from aluminum foil, waxed paper, or other materials which are smooth and will help prevent the organisms from crawling out of the trap. Also, dusting the inside walls of the can with fine powder (e.g., talcum powder) will prevent organisms from crawling up the walls and out of the cage.

B3. Baermann Funnel

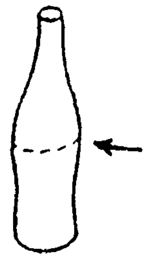


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	About 7 cm diameter, 20 cm long
	1	Glass Tube (B)	5 cm long, 0.5 cm inside diameter
	1	l-Hole Stopper (C)	To fit bottle opening
	1	Rubber Tube (D)	12 cm long
(2) Screen	1	Fine Wire Mesh (E)	7 cm diameter
	1	Stiff Wire (F)	16 cm long, 0.3 cm diameter
(3) Clamp	1	Screw Clamp (G)	Chem/IV/A4

b. Construction

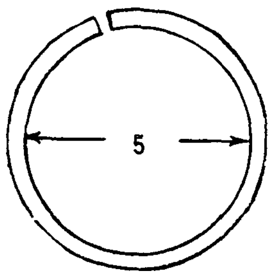
(1) Funnel



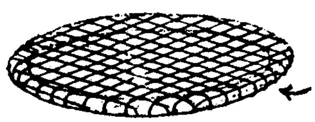
Soda Pop Bottle

Cut the top of a glass soda pop bottle (A) off (See CHEM/I/F2 Force a short piece of glass tubing (B) through the one-hole stopper (C) and seal the opening with the stopper. Next, attach the rubber tube (D) to the glass tube.

(2) Screen



Ring



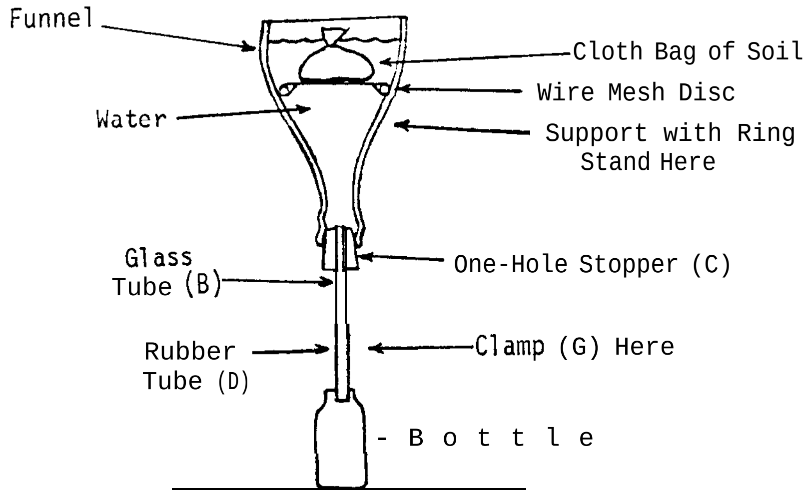
Make a ring slightly smaller in diameter (i.e., about 5 cm diameter) than the bottle with the stiff wire (F). Fold the edge of the circular piece of wire mesh (E) under the wire ring. The wire mesh will probably be stiff enough to hold itself in place without being wired to the ring.

(3) Clamp

Use the clamp (G) to seal the rubber tube airtight.

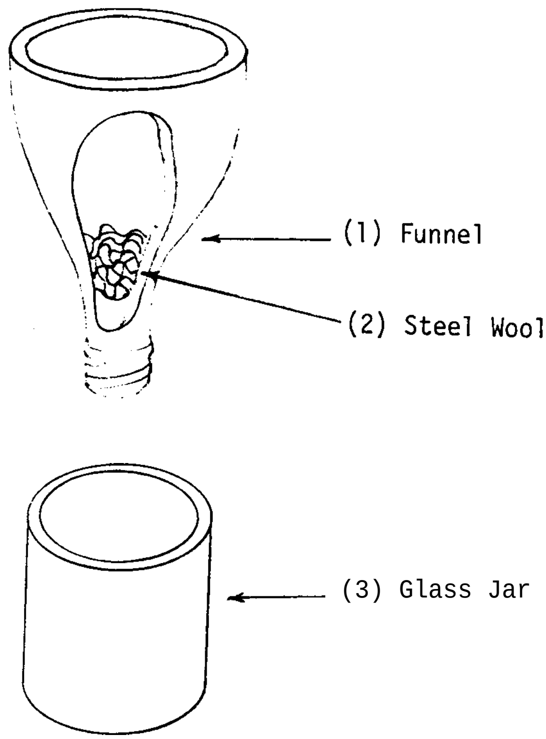
c. Notes

(i) The Baermann funnel is designed to extract soil nematodes from soil. To use it, it must be supported by a ring stand. Clamp off the tubing, and let the end of the tube extend into a small vial or bottle. Set the wire mesh disc into the funnel, put a small cloth bag of soil on the disc, and fill the apparatus with water. After an hour or so, release the clamp to collect a small sample of water which can be examined for soil nematodes. (See illustration on next page.)



(ii) If commercial funnels of the correct size are available and inexpensive, they can be substituted for the bottle funnel. Also, the end of the rubber tube can be sealed off with a pencil stub or piece of wooden dowel if a good clamp is not available.

B4. Berlese Funnel

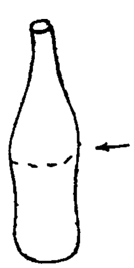


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	About 7 cm diameter, 20 cm long
(2) Steel Wool	1	Steel Wool (B)	30 g
(3) Glass Jar	1	Glass Jar (C)	50 ml capacity

b. Construction

(1) Funnel



Cut the top of a soda pop bottle (A) off (See CHEM/I/F2 to make the funnel. Alternately, use a commercial glass or metal funnel, or make one using metal foil or heavy paper.

(2) Steel Wool

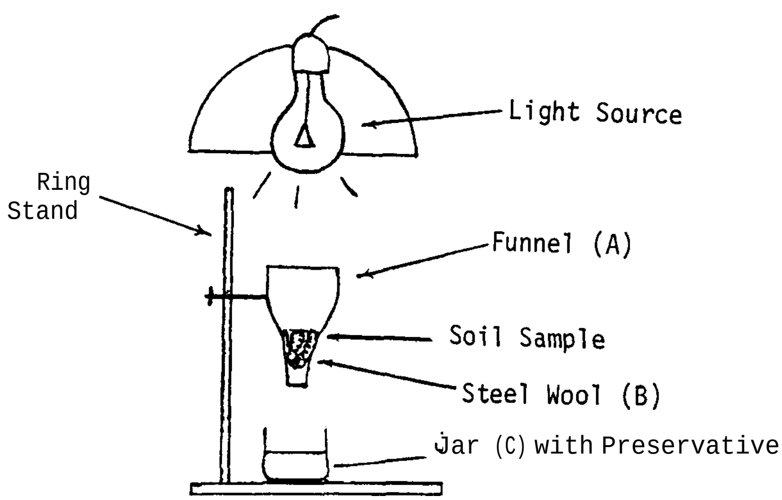
Place the steel wool (B) inside the funnel so that it blocks off the opening.

(3) Glass Jar

Fill the jar (C) about 1/2 full of alcohol or formalin and place it directly under the funnel.

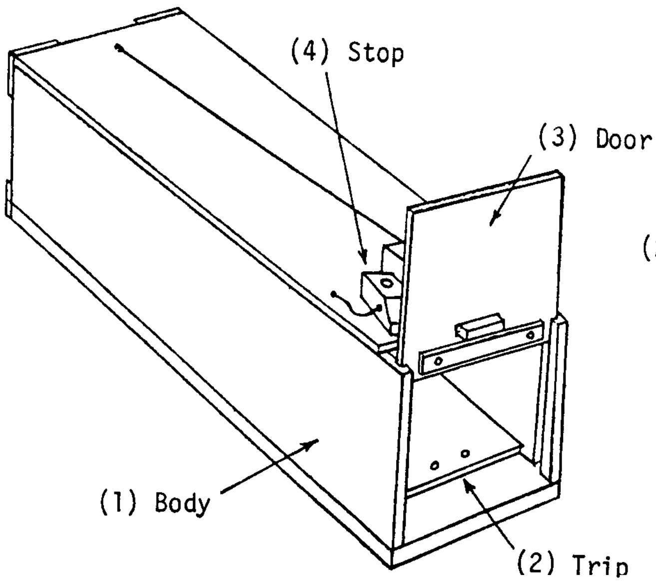
c. Notes

(i) To use the Berlese funnel, a ring stand and light source are needed. Support the funnel with the ring stand so that the neck of the funnel is directly over the glass jar. Place a 25 watt light directly above the funnel and close enough to the funnel that the heat from the bulb will warm the contents of the funnel. Place the soil sample in the funnel so that it rests on the steel wool. Pick out the larger soil organisms with forceps. The smaller organisms will be driven down by the light and heat of the bulb until they drop through the steel wool into the preservative in the jar. The apparatus should be left in place several days to insure that most of the organisms are collected.

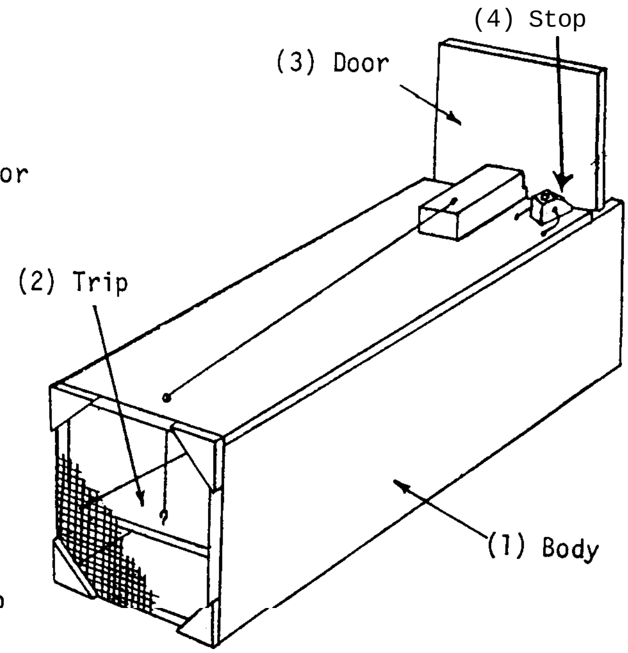


C. SMALL VERTEBRATE COLLECTING APPARATUS

Cl. Simple Box Trap



Front View



Back View

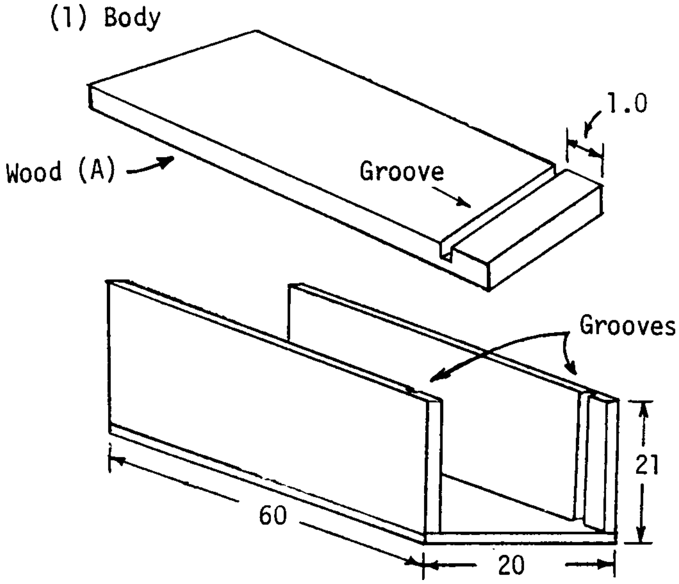
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	3	Wood (A)	60 cm x 20 cm x 1.0 cm
	1	Wood (B)	58 cm x 20 cm x 1.0 cm
	2	Wood (C)	5 cm x 5 cm x 0.5 cm
	1	Wire Mesh (D)	20 cm x 22 cm
(2) Trip	1	Wood (E)	17.5 cm x 55 cm x 0.5 cm
	1	Metal Hinge (F)	5 cm x 5 cm
	1	Eyed Screw (G)	2 cm long
	1	String (H)	85 cm
	1	Wood (I)	10 cm x 4 cm x 1.5 cm
	4	Round-headed Screws (J)	Approximately 1.0 cm long
(3) Door		Construction Board (K)	19 cm x 20.5 cm x 0.25 cm
	1	Flat Metal (L)	15 cm x 1.5 cm x 0.5 cm

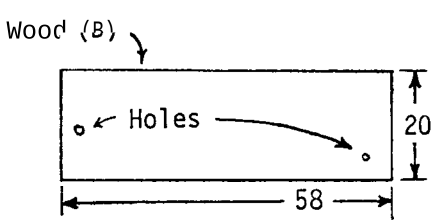
	2	Bolts (M)	1.25 cm long
	2	Nuts (N)	To fit bolts
(4) Stop	4	Tacks (0)	1.0 cm long
	1	String (P)	7 cm
	1	Rubber Band (Q)	--
	1	Wood (R)	6 cm x 2 cm x 2 cm
	1	Bolt (S)	5 cm long
	1	Nut (T)	To fit bolt

b. Construction

(1) Body

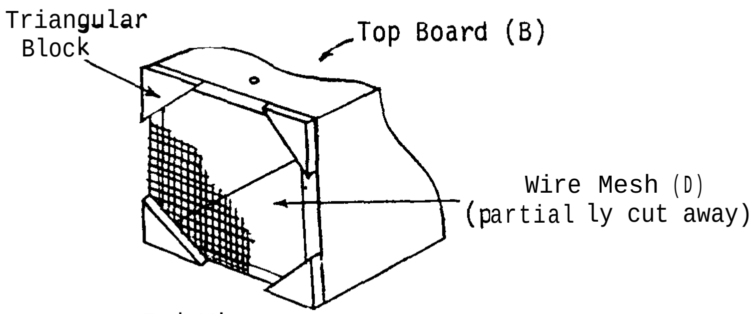


Begin the body by cutting a goove 0.3 cm wide and 0.5 cm deep parallel to the end of two of the pieces of wood (A). This groove is 1.0 cm from the end. Nail or screw these two boards to the third board (A).



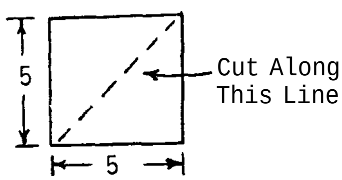
Top View

In the corner of the board (B) to be used as the top, drill a hole 0.7 cm in diameter about 3 cm from each edge, and drill a hole about 0.5 cm in diameter through the other end of the top, 1.0 cm from the edge and centered. Set this board (B) aside until the trip (2) is completed.

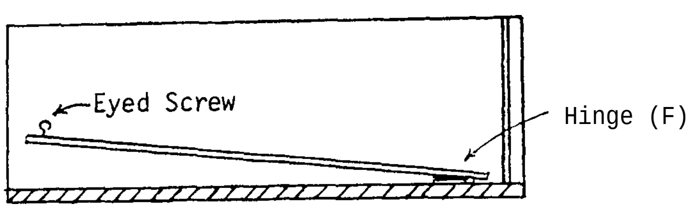


End View

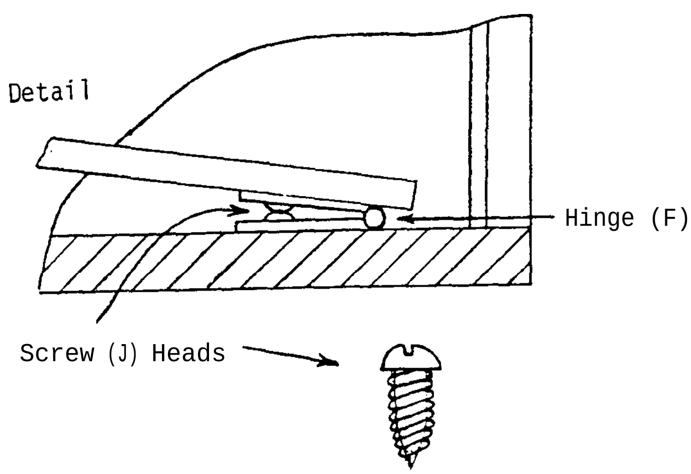
Seal off one end of the body by nailing the wire mesh (D) to it. Reinforce the corners with triangular pieces of wood gotten by cutting the wood pieces (C) in half diagonally. Again, do not seal the end until the trip (2) and top board (B) are in place.



(2) Trip

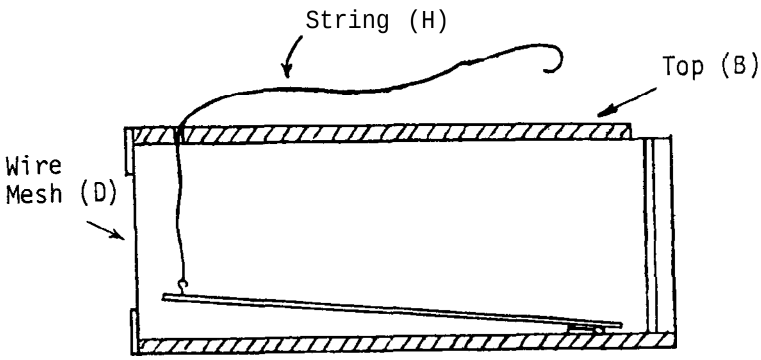


Side View (Cross-section)



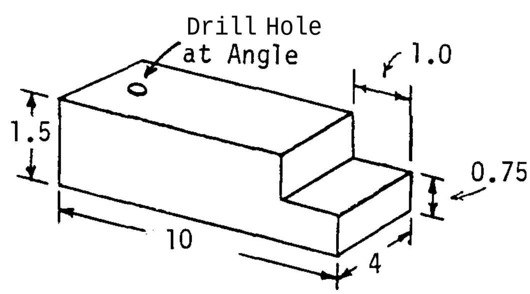
Screw the eyed screw (G) into one end of the wood (E) about 1.0 cm from the edge and centered. To the back of this board, fasten the hinge (F) which also should be about 1.0 cm from the edge and centered. Next, fasten the other half of the hinge to the bottom of the body so that the board is centered in the bottom of the body (i.e., it should be 2.5 cm from each end and 0.25 cm from each side of the body). Use round-headed screws (J) so that the hinge cannot close completely flat. In this way, the trip will be held up at a slight angle, which is needed in the design of this trap. Alternately, the length and tension of the trip string (N) can be adjusted to hold the trip in the desired position without the necessity of using this type of hinge and screws.

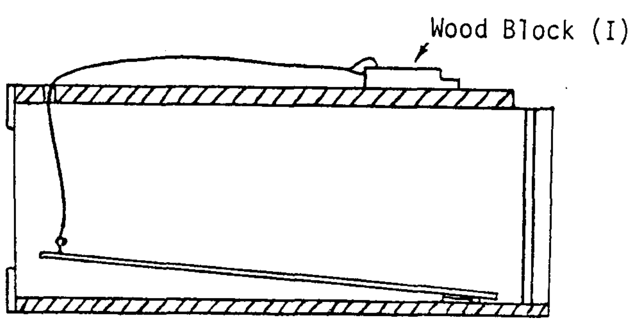
Now tie one end of the string to the eyed screw (G) in the trip (H). Run the other end of the string through the hole in the top board (B) of the body which may now be nailed or screwed into place. Also, the wire mesh (D) for the end of the body may be fastened in place after the top is finished.



Side View(Cross-section)

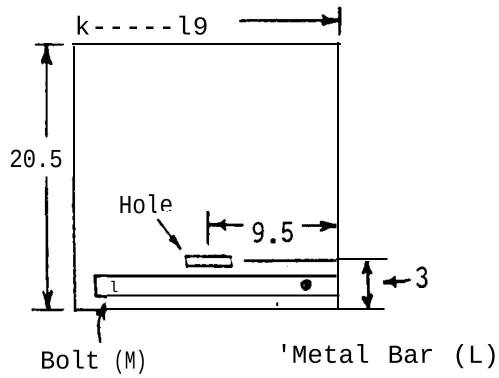
To complete the trip, cut a notch from the block of wood (I) and attach the free end of the string to the block by tying it through a hole drilled in the block.

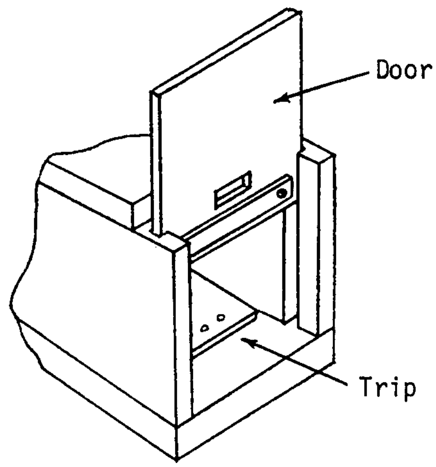




Side View (Cross-section)

(3) Door

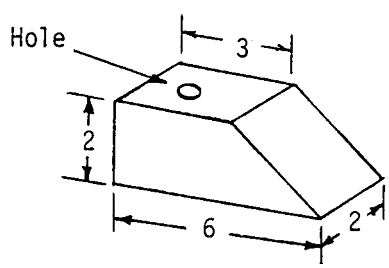




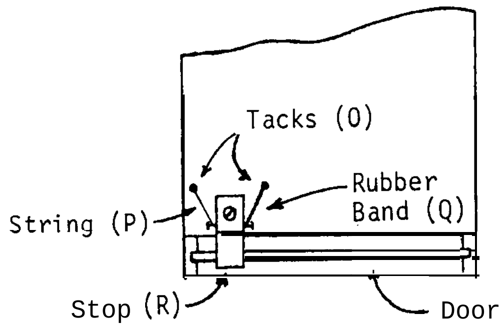
Detail

Cut a hole 4.25 x 1.0 cm in the construction board (K) 3 cm from the end of the board and centered. Next, using the nuts (N) and the bolts 90, bolt the flat metal bar (L) into position just under the hole. Holes will have to be drilled through the board for the bolt to go through. The door is now finished and should slide easily up and down in the notches in the sides of the body.

(4) Stop



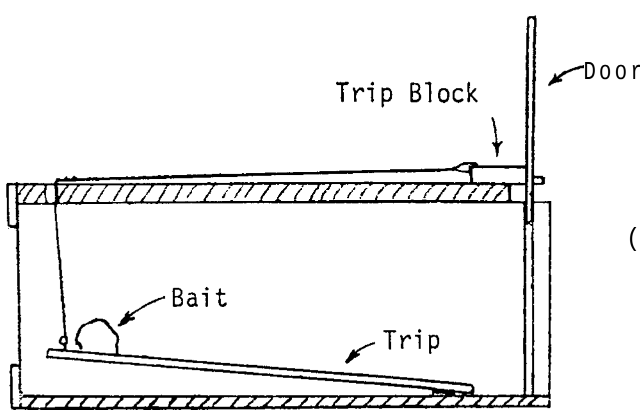
Cut the piece of wood (R) as shown and drill a hole in the wood slightly larger in diameter than the bolt (S) used.



Hammer a tack (O) into each side of the stop (R), and run a bolt (S) through the stop and the hole in the corner of the top. Screw the nut (T) loosely onto the bolt. Hammer two other tacks (O) into the top of the body, one to either side of the stop and slightly behind it. Finally, tie the piece of string (P) between the tack in the left side of the stop and the tack to the left in the top, and similarly attach the rubber band (Q) on the right side. Fix the tension in the rubber band so that the stop will be held out over the door when the door is closed, thus preventing the door from being raised after the trap has been sprung.

c. Notes

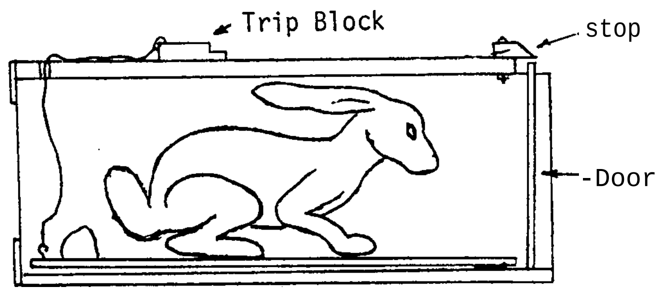
(i) To set the trap up, place it where small animals are likely to be found. Push the stop out of the way and put the door between the grooves in a raised position. Next, push the notched portion of the trip block through the hole in the door to hold the door up. Release the stop, allowing the rubber band to pull it against the door. At this point, the string attaching the trip block to the trip should be taut. Finally, place a suitable bait in the extreme rear of the cage on the trip.



Side View
(Cross-section)

Trap in "Set' Position

Because the round heads of the hinge screws hold the trip up at a slight angle, the animal entering the trap must move to the rear of the trap before the combination of its (the animal's) weight and leverage causes the rear of the trip to drop down, pulling the trip block back out of the hole in the door. The door then drops down in the grooves, the metal bar aiding in a faster drop. Finally, the stop is pulled out over the top of the door once the door is out of its way, and is held over the door because the rubber band pulls against the string.



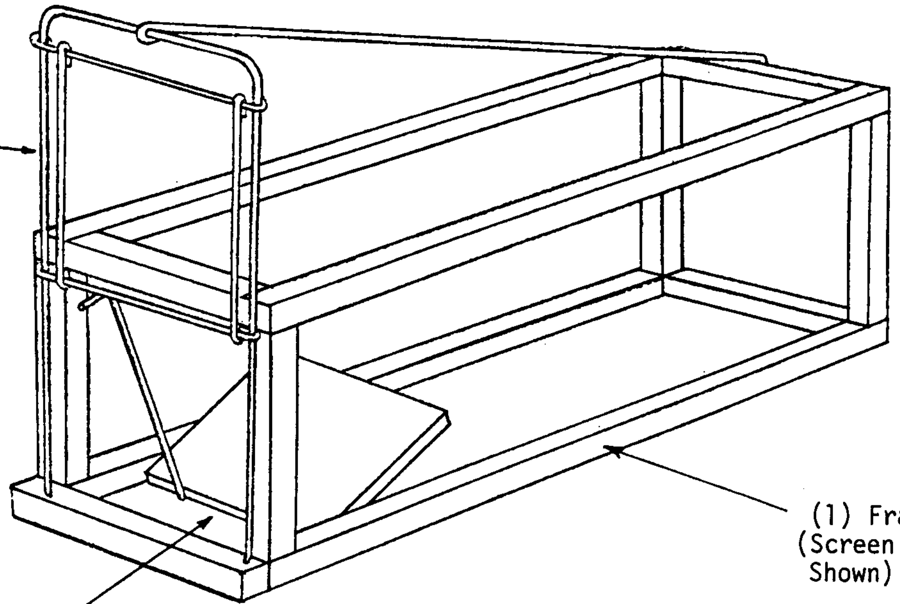
Side View
(Cross-section)

Trap in "Sprung"
Position

(ii) It may be desirable to modify the construction of this trap by making it with wire mesh sides as many animals are difficult to entice into enclosed spaces.

(iii) This design can be altered in many ways, especially with respect to proportion, dimensions, and materials used, including plywood or other thin but strong construction materials.

C2. Potter Bird Trap *



a. Materials Required

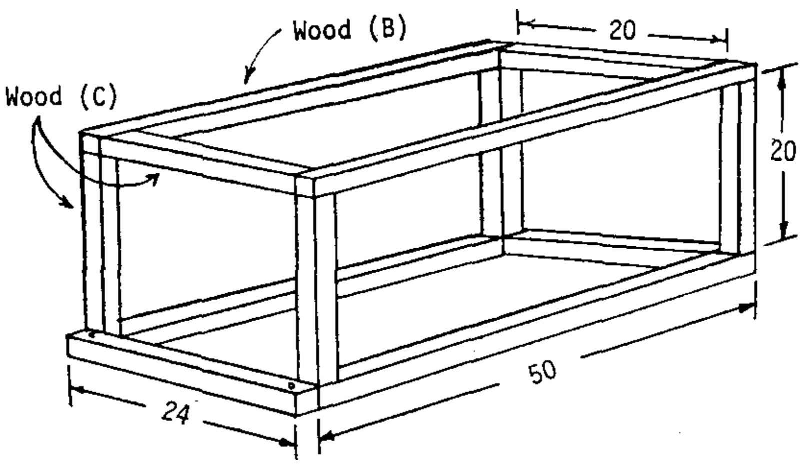
Components	Qu	Items Required	Dimensions
(1) Frame	1	Wood (A)	24 cm x 2 cm x 2 cm
	4	Wood (B)	50 cm x 2 cm x 2 cm
	7	Wood (C)	20 cm x 2 cm x 2 cm
	4	Wire Screen (D)	23 cm x 49 cm
	1	Wire Screen (E)	23 cm x 23 cm
(2) Door	1	Stiff Wire (F)	125 cm long, 0.3 cm diameter
	1	Stiff Wire (G)	60 cm long, 0.3 cm diameter
	4	Stiff Wire (H)	27 cm long, 0.3 cm diameter
	1	Wire Screen (I)	22 cm x 22 cm
(3) Trip	1	"U" Tack (J)	1 cm long
	1	Stiff Wire (K)	25 cm long, 0.3 cm diameter

*Adapted from Nuffield Foundation, Teacher's Guide III: The Maintenance of Life, (England: Longmans/Penguin Books, 1966), p 201.

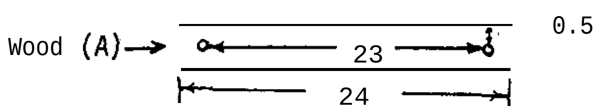
3	"U" Tacks (L)	1 cm long
1	Hood (M)	19 cm x 12 cm x 1.0 cm

b. Construction

(1) Frame



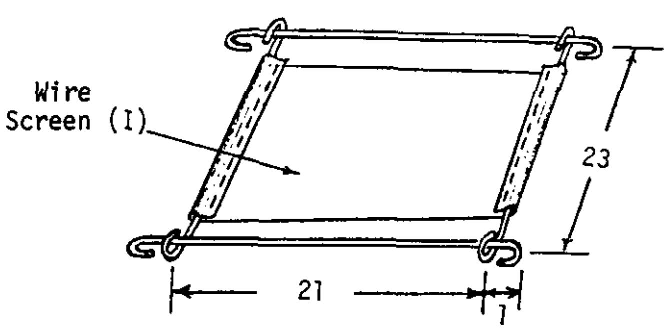
Nail and glue the basic framework together as shown. Begin by nailing one piece of wood (C) to the ends of two long pieces (B). Nail four of the remaining short pieces (C) to the U-shaped piece already made. Nail one in an upright position at each end of each long piece (B) to form the comers of the trap. Next, nail the two remaining pieces of both the short (C) and long (D) wood to the ends of the four upright pieces to complete the basic trap framework.



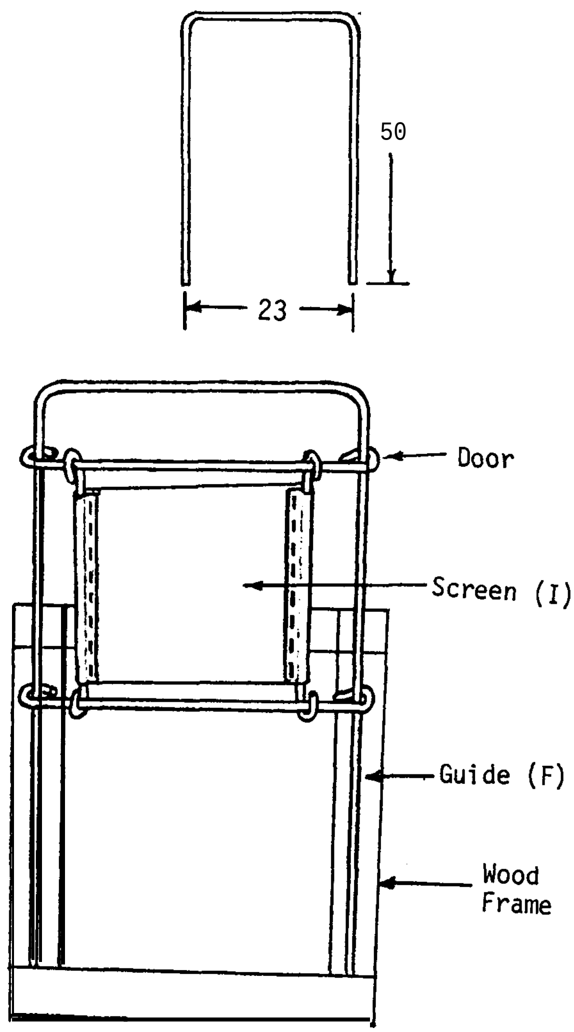
Top View

Drill holes the same diameter (0.3 cm) as the stiff wire (F) used for the door in the piece of wood (A) to act as "seats" for the door frame. Drill these holes 1.5 cm deep. Nail the four long pieces of screen (D) to the sides, bottom and top of the trap and nail the square piece (E) to the rear end to enclose all but the front of the trap in screening.

(2) Door



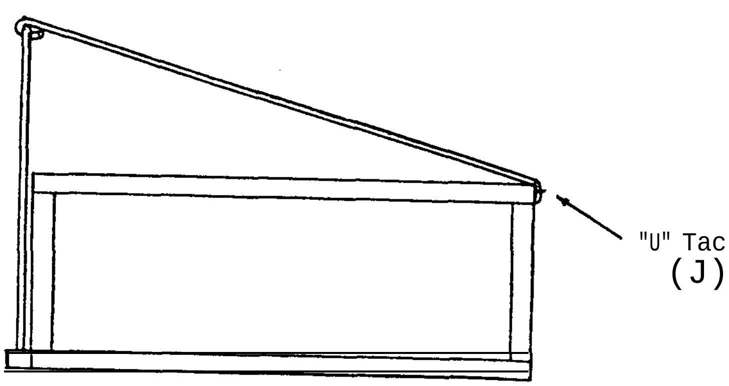
Bend the ends of two pieces of wire (H) over about 2 cm from each end. Bend the ends of the other two pieces (H) around the first two pieces to form a square framework. Fold two edges of the wire screen (I) around two sides of the frame



Front View

and "sew" the screen together with wire.

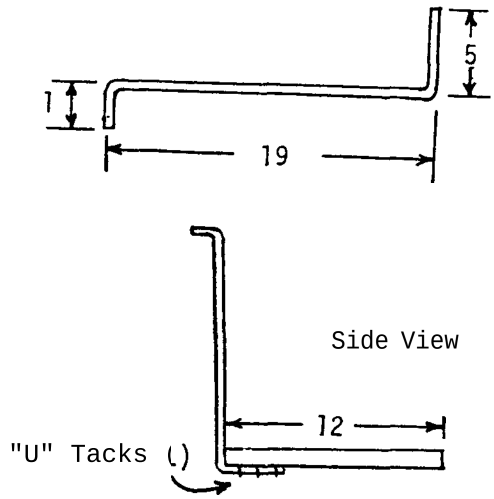
Bend the piece of wire (F) to a "U" shape. Slip the ends of this wire through the open ends of the wires in the door frame. The door should slide up and down easily with the U-shaped wire acting as a guide. Next, imbed the ends of the "U" into the holes in the front piece (A) of the wooden frame. They may be glued in place if necessary. When the door slides down the guide, it should effectively block the entrance of the trap with little or no gap.



Side View

Tack the end of the piece of wire (G) to the rear of the cage with a "U" tack (J) and bend it down until it touches the top of the door frame. Bend the remaining end around the wire (F) to help stabilize and support the door frame.

(3) Trip



Bend up 5 cm of the wire (K) to a right (90°) angle and bend 1.0 cm of the other end of the wire to a right angle in the opposite direction. Tack the wire to the wood (M) with the three "U" tacks (L) as near to one of the 12 cm edges as possible.

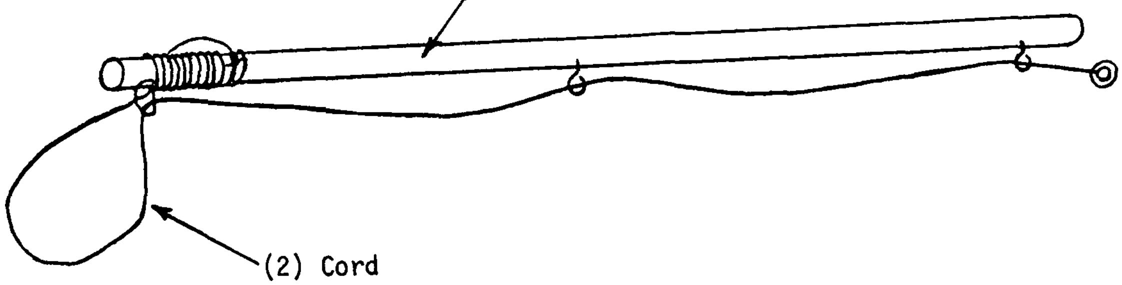
C. Notes

(i) To use the Potter bird trap, place it in a place where the desired type of bird is known to congregate. It may be necessary to anchor the trap in some manner in order to prevent it from being disturbed. The trap is set by pulling the sliding door all the way up and placing the trip inside the trap at such an angle that, when the door is lowered, the lower cross wire of the door rests on the bent portion of the trip wire. The slight pressure of the door on the trip should both hold the door up (and open) and keep the trip at a slight angle. Finally, bait the trap with a suitable attractant for the particular type of birds desired. A bird entering the trap for the bait will hop on the wooden part of the trip causing the wire to be pulled out from under the door which will drop down in place and trap the bird.

(ii) This trap, unlike others, doesn't require the hunter to hide in a blind waiting for a bird to enter.

(iii) The dimensions of this trap can be altered according to the size of the birds being trapped. Also, the trap may be baited in such a way as to attract other animals besides birds.

C3. Snare

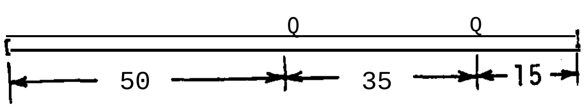


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Rod (A)	100 cm long, 2 cm diameter
	2	Eyed Screws (B)	1 cm diameter opening
(2) Cord	1	Insulated Copper Wire (C)	250 cm long, 0.3 cm diameter
	1	Washer (D)	3 cm diameter
	1	"U" Tack (E)	1 cm long

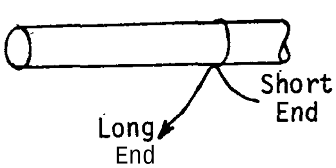
b. Construction

(1) Handle

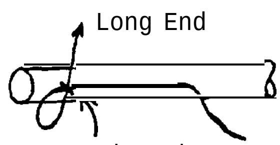


Screw one eyed screw (B) 15 cm from the end of the wooden rod (A) and screw the second screw (B) 50 cm from the other end.

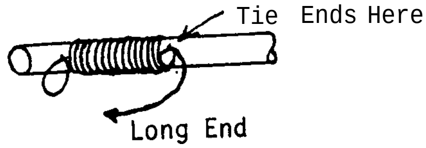
(2) Cord



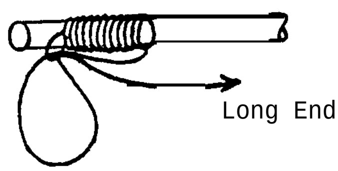
Tie the cord (C) securely to the rod at a point approximately 10 - 15 cm from the end. The short end should be at least 10 cm long as it will be used again to be tied to the long end.



Run the long end of the cord up to the end of the rod and form a loop. Hold the loop in place with a U-shaped tack (E).



At the end of the loop, begin wrapping the long end of the cord tightly around the rod until the short end has been reached. At that point, tie the long and short ends securely.



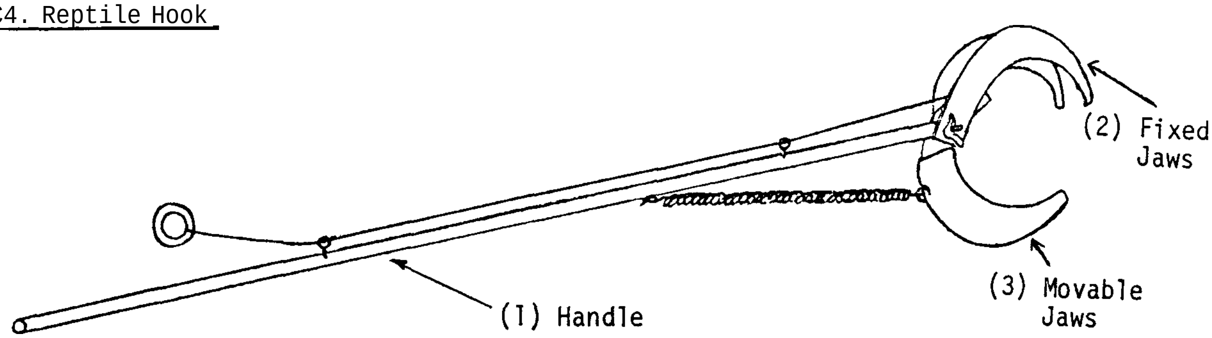
Extend the long end through the loop and then extend it back to form the snare. The long end is kept in position by extending the ends through the eyes on the rod. When the long end of the cord extends through the second eyed screw, tie the large metal washer (D) to it to make a pull ring.

C. Notes

(i) Use the snare to capture snakes, lizards, and other small animals which are difficult or dangerous to capture by hand. The loop must be placed over the animal's head, then pulled tight to hold it fast.

(ii) Bamboo or other materials may be used instead of wood for the rod. Rope can be used instead of insulated wire, but the wire is better since it is stiff and this helps keep the snare loop open instead of hanging limp.

C4. Reptile Hook

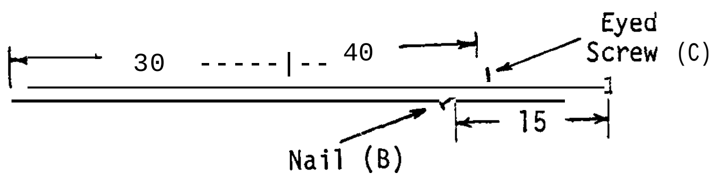


a. Materials Required

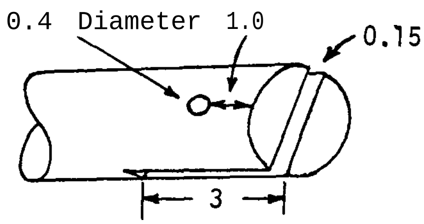
Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Dowel (A)	100 cm long, 1.5 cm diameter
	1	Nail (B)	1.5 cm long, about 0.2 cm diameter
	2	Eyed Screws (C)	2 cm long, 1 cm diameter opening
(2) Fixed Jaws	2	Sheet Metal (D)	10 cm x 6 cm x 0.1 cm
	2	Tape (E)	About 50 cm
(3) Movable Jaw	1	Sheet Metal (F)	10 cm x 9 cm x 0.1 cm
	1	Spring (G)	12 cm x 0.5 cm
	1	Steel Wire (H)	100 cm long
	1	Washer (I)	3 cm diameter
	1	Bolt (J)	0.4 cm diameter, 2.5 cm long
	1	Wing Nut (K)	0.4 cm internal diameter
	1	Tape (L)	About 50 cm
	1	Rubber Tubing (M)	7 cm long, 1.0 cm diameter

b. Construction

(1) Handle

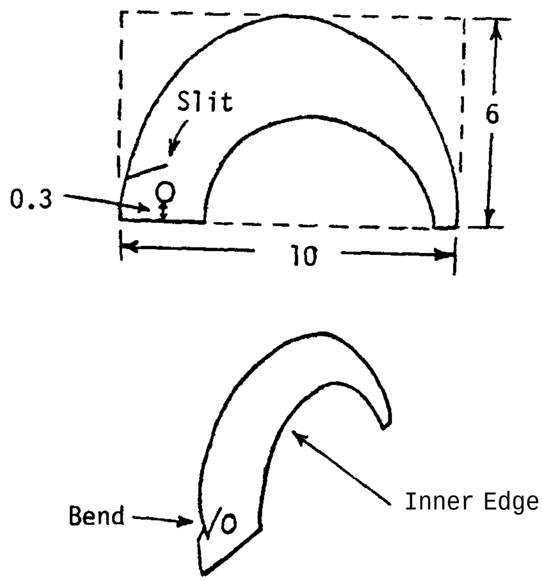


Screw the two eyed screws (C) into the wooden dowel (A) so that the opening of the "eye" faces the ends of the dowel. Hamner the nail (B) into the opposite side of the dowel at the angle indicated.



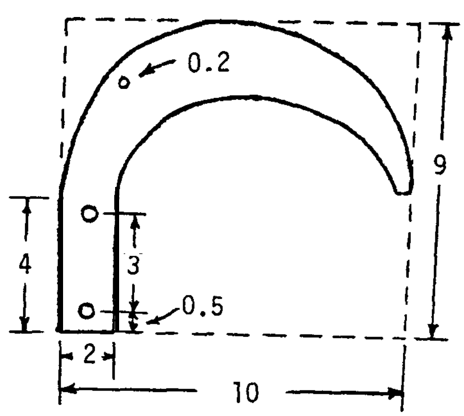
Cut a notch into the end of the dowel nearest the nail. This notch needs to be 3 cm deep and about 0.15 cm wide (i.e., slightly wider than the sheet metal (F) used for the movable jaw). Finally, drill a hole 0.4 cm in diameter 1 cm from the end, and perpendicular to the notch.

(2) Fixed Jaws

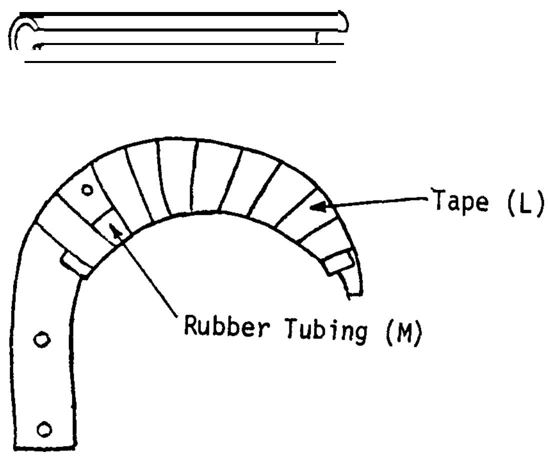


Cut the two fixed jaws to shape from the sheet metal (D). Drill or punch a hole 0.5 cm in diameter through the wide portion of each jaw, centered, and 0.3 cm from the flat edge. Cut a slit into each jaw about 0.7 cm long and in approximately the position indicated. Bend the resulting point of metal in on one jaw and out on the other (i.e., in opposite directions). To complete the jaws, cover at least the inner edge with tape (E), cloth, etc., to protect the animals being collected from cuts.

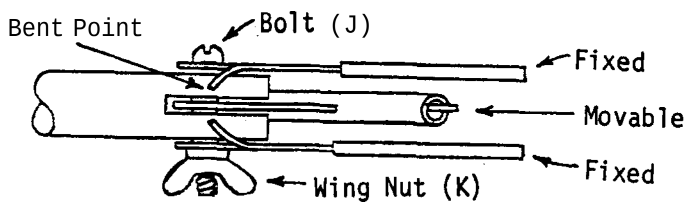
(3) Movable Jaw



The movable jaw, made from sheet metal (F), is identical in shape to the fixed jaws except that one arm is extended for 4 cm. Three holes must be drilled or punched in the jaw. The two lower holes need to be 0.5 cm in diameter while the third need only be about 0.2 cm in diameter. Pad the inner edge of the movable jaw by slitting one side of a 7 cm long piece of rubber tubing (M), and slipping it over the edge of the jaw. Use tape (L) to hold the tubing in place. Alternatively, the jaw may simply be padded with cloth and tape or other materials.

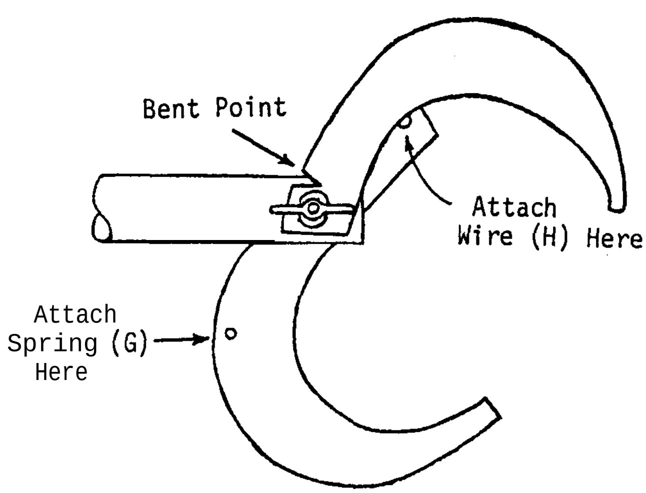


Attach the jaws to the handle in this order: Run the bolt (J) through one fixed jaw, halfway through the handle, through the middle hole of the movable jaw, through the rest of the handle and through the second fixed jaw. Screw on the wing nut (K) to secure the whole assembly. Be certain that the "bent points" of the fixed jaws both point in, rather than out. Fix tension on the wing nut such that the jaws are not loose, but the movable jaw still can be freely moved. The "bent points" of the fixed jaws prevent them from rotating backwards about the bolt.



Top View

Next, attach the steel wire (H) to the upper hole of the movable jaw and run the free end through both eyed screws (C). Fasten the free end to the washer (I). Fasten one end of the spring (G) to the remaining hole in the



Side View

movable jaw, stretch out the spring, and fasten the free end to the nail (6). The movable jaw should be held wide open, and the reptile hook is ready for use. [Note: If a spring of the correct size and tension is not available, one can easily be made by winding steel wire (about 0.08 cm diameter) around a pencil or other cylindrical rod.]

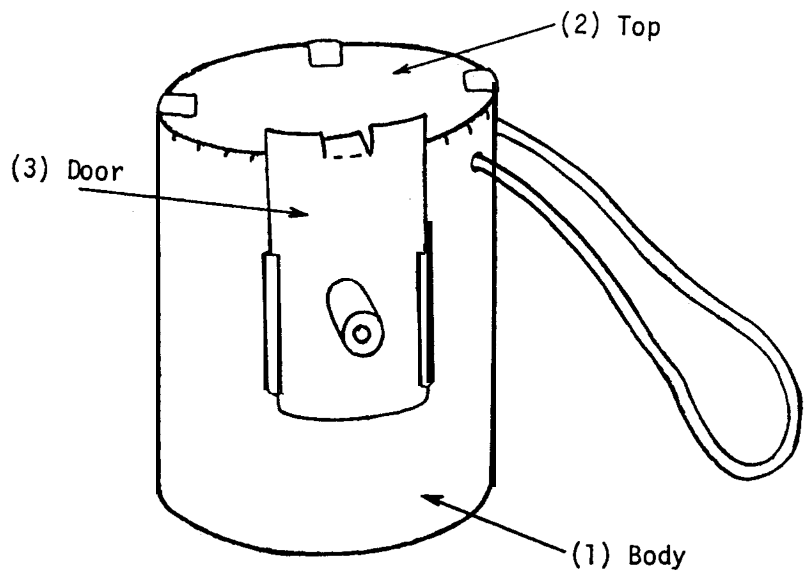
c. Notes

(i) Other materials such as bamboo, broom handles, etc., may be used for the handle. Also, a strong rubber band may be substituted for the spring.

(ii) If the sheet metal used for the jaws is sufficiently stiff and strong, only one fixed jaw may be required instead of two.

D. PLANT COLLECTING APPARATUS

D1. Vasculum

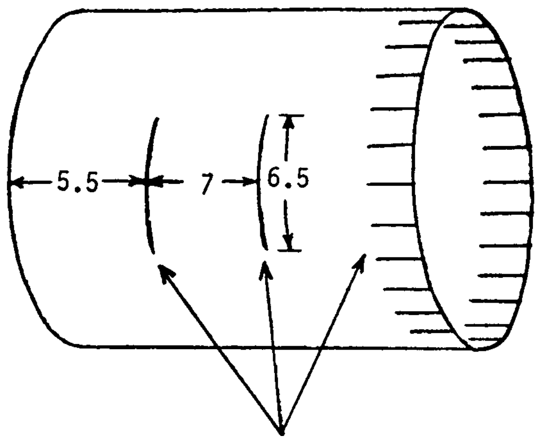


a. Materials Required

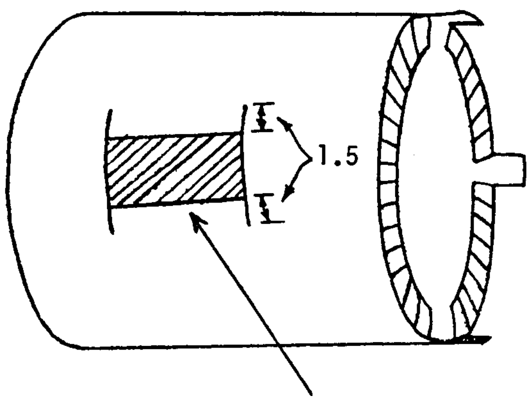
Components	Qu	Items Required	Dimensions
(1) Body	1	Tin Can (A)	4 liter capacity (about 18 cm long by 15 cm diameter) or larger
	1	Rope (B)	50 cm x 0.5 cm
(2) Top	1	Tin Sheet (C)	15 cm diameter, 0.05 cm thick
(3) Door	1	Tin Sheet (D)	14 cm x 8 cm x 0.05 cm
	1	Wood Dowel (E)	2.5 cm long, 2.5 cm diameter
	1	Nail (F)	3 cm long, 0.3 cm diameter

b. Construction

(1) Body

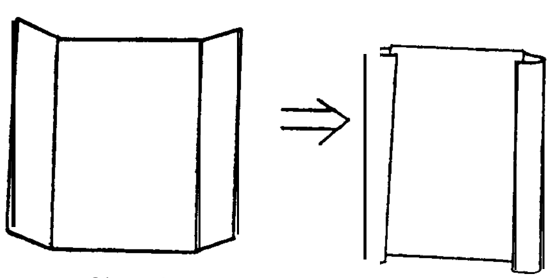


Use a hacksaw to make two slits in the side of the can (A). Each slit is 6.5 cm wide. The first slit is 5.5 cm from the bottom of the can, and the second slit is 7.0 cm from the first. Also, around the top edge (the top being the end which has been removed) make a series of slits approximately 2 cm deep and 2 cm apart.



Remove Shaded Portion

After these initial slits have been made, remove part of the can between the two slits leaving about 1.5 cm of metal to either side of the opening. Further, bend down all of the flaps made in the top edge of the can except for three, specifically those three which are 90°, 180°, and 270° from a point directly above the door.



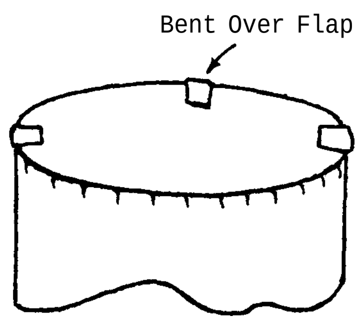
Step 1 Step 2

Detail of Door Guides

To make the guides for the door, first bend the 1.5 cm flaps out until they touch the can, then double them over so that the door will slide between them without falling out. This second step is best done by holding the door in place and bending the flaps over it.

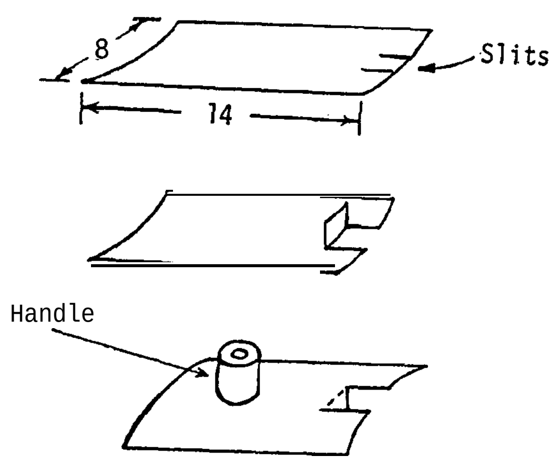
Finally, drill or punch two holes (about 1 cm diameter) in one side of the can. Pass an end of the rope (B) through each hole and knot the ends inside the can so that the rope cannot pull out.

(2) Top



Merely cut out a circular piece of tin sheet (C) the same size as the end of the can. Place this piece on top of the bent down flaps and bend down the remaining three flaps. The top should slide in and out easily.

(3) Door



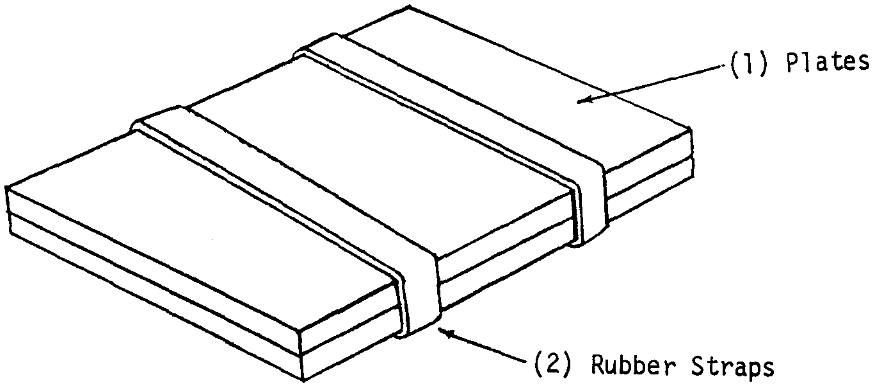
Roll the sheet metal (D) slightly until the slight curvature conforms to the side of the can. Make two slits 2 cm deep and 2 cm wide in one end, and bend the flap down. Make the door handle from the dowel (E) and nail (F). Simply drive the nail through the end of the dowel and through the door itself. Flatten the point of the nail like a rivet to hold the handle in place. When finished, the door should slide easily between the guides on the side of the can. The flap on the end of the door serves to help hold down the top as well as preventing the top from sliding out by accident.

c. Notes

(i) The vasculum is used to keep plant materials from excessively drying out when collecting in the field. Put the plants in the vasculum through the door when collecting, and remove them by removing the top.

(ii) If large tin cans with replacable lids are available, these will do nicely and will eliminate the need for cutting out the door and lid. Also, see VII/A2 (Sterilizer) for an alternate method of making the lid for a tin can of this type.

D2(1).Plant Press (Field Type)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Plates	2	Wood (or Plywood) (A)	25 cm x 20 cm x 1.0 cm
(2) Rubber Straps	2	Heavy Rubber Bands (B)	2.5 cm wide, 15 cm diameter

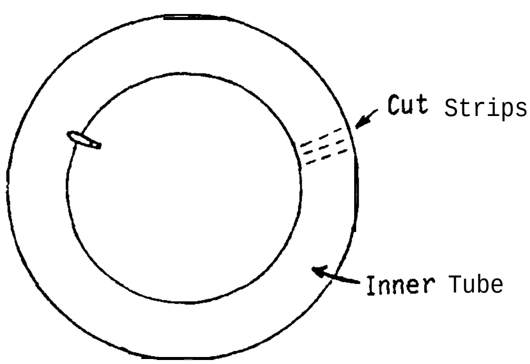
b. Construction

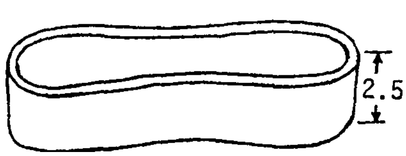
(1) Plates

Cut the wood (A) to size. Smaller or larger sizes may be made according to personal preference.

(2) Rubber Straps

Cut the rubber straps (B) from old automobile tire inner tubes.





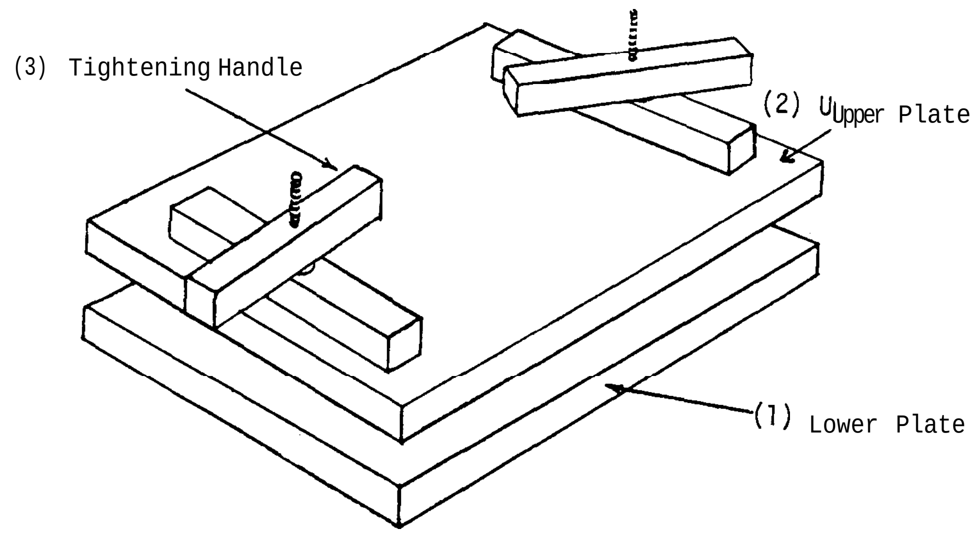
Section of
Inner Tube

c. Notes

(i) Use the field plant press to hold plant materials until they can be returned to the laboratory. Place the plants between several layers of newspaper, and place the newspapers between the press plates. Wrap the rubber straps around the plates and newspapers to hold them securely until they are returned to the laboratory.

(ii) Lengths of rope or belt-like straps can be used to tighten the press rather than the rubber straps.

D2(2). Plant Press (Laboratory Type)

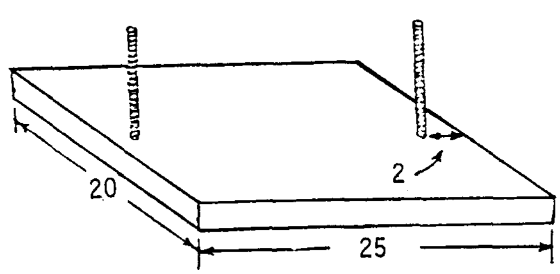


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Lower Plate	1	Plywood (A)	25 cm x 20 cm x 1.25 cm
	2	Bolts (B)	15 cm long, 0.7 cm diameter
(2) Upper Plate	1	Plywood (C)	25 cm x 20 cm x 1.25 cm
	2	Wood (D)	15 cm x 1.75 cm x 1.75 cm
(3) Tightening Handles	2	Nuts (E)	0.7 cm inside diameter
	2	Wood (F)	15 cm x 1.75 cm x 1.75 cm
	2	Washers (G)	1 cm inside diameter, 2 cm outside diameter

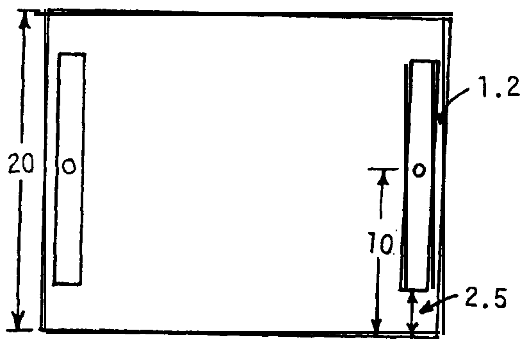
b. Construction

(1) Lower Plate

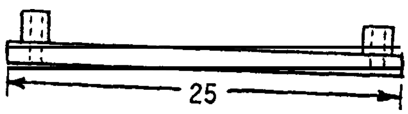


Drill a hole through each end of the plywood (A) (regular wood may be used as well) 2 cm from the end and centered. The holes should be 0.8 cm in diameter. Pass the bolts (B) through these holes as far as they will go.

(2) Upper Plate



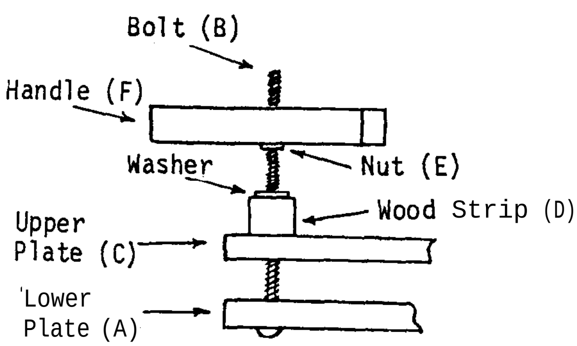
Top View



Side View

Nail or glue the two wood strips (D) to the plywood(C) 1.2 cm from the ends and parallel to the edge. Drill a hole 0.8 cm in diameter through the wood strip and plywood at each end. Put the upper plate into position by running the two bolts (B) in the lower plate through the holes in it (the upper plate).

(3) Tightening Handles



Side View

Drill a hole 0.8 cm in diameter through the center of each strip of wood (F). Then, place a nut (E) directly over the hole in the wood and give it a sharp rap with a hamner. Re-move the nut from the depression thus formed, put some epoxy resin cement in the depression and glue the nut in place in the depression. When the glue has hardened, place a washer (G) over each bolt, and screw on the tightening handles. The laboratory plant press is now ready for use.

c. Notes

(i) To use the laboratory plant press, place collected specimens between several layers of newspaper and tighten the two plates of the press together very tightly. Leave the plants in the press until they are thoroughly dried out.

V. AQUARIA AND TERRARIA

A. CLASSROOM DEMONSTRATION AQUARIA

This is the most common type of aquarium and is used for student observation of the various relationships demonstrated by an ecosystem. Therefore, this type of aquarium is characterized by the use of glass.

B. BREEDING AQUARIUM

This is used to provide places for maintaining and growing a supply of aquatic organisms. Since the purpose is not primarily that of student observation, glass sides are not necessary.

C. TEMPORARY AQUARIUM

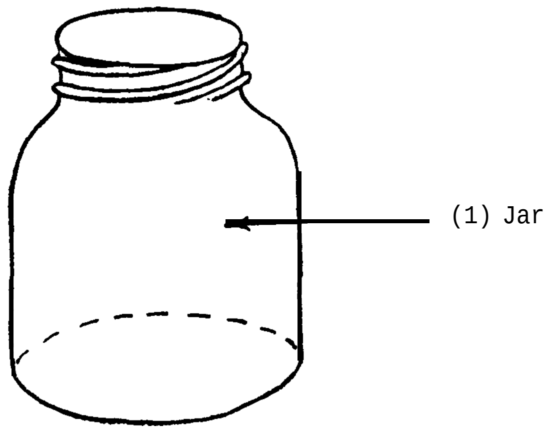
This is useful for short-term storage of fish and aquatic plants. Depending on the materials used, the temporary aquarium will suffice to hold plants and animals for approximately one to seven days, or much longer if care is taken in its construction.

D. TERRARIA

Any container in which plants can be grown will serve as a terrarium. The chief criterion for such a structure is that it be large enough to give the desired plants room to grow without crowding.

A. CLASSROOM DEMONSTRATION AQUARIA

Al. Quickly Made Demonstration Aquarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	2 liters or larger

b. Construction

(1) Jar

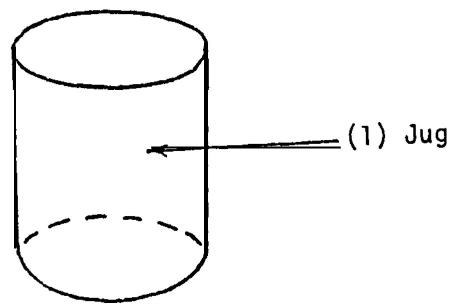
Simply clean out the jar (A), add water and fish. Sand and small plants may also be added.

c. Notes

(i) The number and size of fish which can be kept in a non-aerated aquarium varies, but a general rule is at least 2 liters of water per each centimeter of fish. Remember that the amount of oxygen available to the fish depends on the surface area of the water so that jars with narrow necks should be filled only to the point where the neck begins to narrow.

(ii) This or any aquarium may be covered to prevent fish from jumping out, but remember to allow some air flow under the cover to insure that oxygen will dissolve from the air into the water.

A2. Jug or Carboy Aquarium

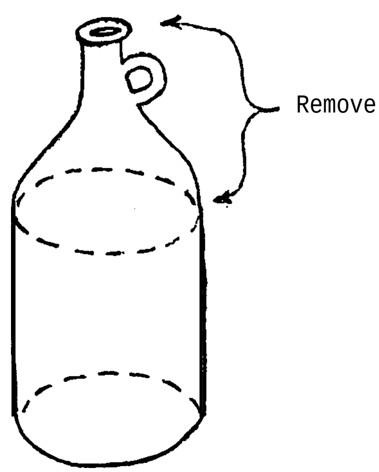


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jug	1	Glass Jug or Carboy (A)	3-4 liters or larger

b. Construction

(1) Jug



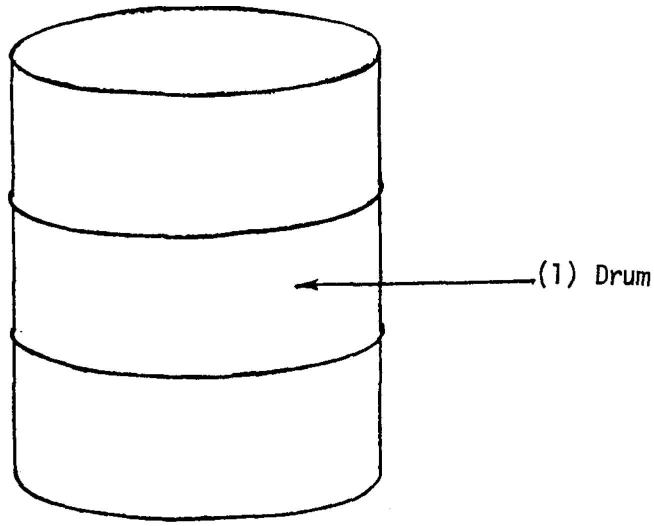
Remove the top portion of a jug or carboy (A) by either method described under item CHEM/I/F2.

c. Notes

(i) When the neck is removed, add water, sand, plants and fish. Remember, at least 2 liters of water is required for each centimeter of fish.

B. BREEDING AQUARIUM

Bl. Breeding Aquarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Drum	1	Oil Drum (A)	100 liters or larger

b. Construction

(1) Drum

Remove the top from a large oil drum (A) or any similar container. Clean the drum thoroughly before adding water, plants, sand and fish.

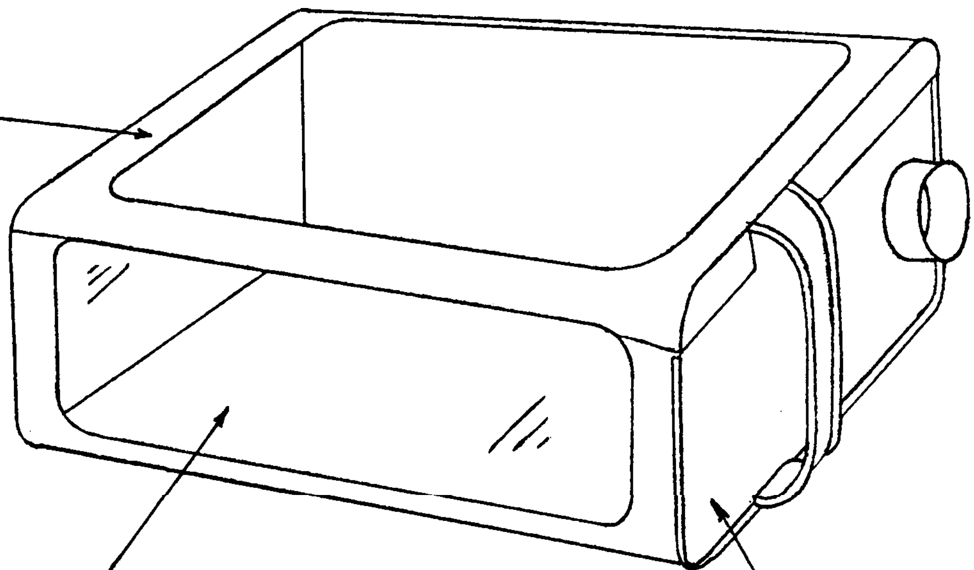
c. Notes

(i) Since many fish breed best or only when plants are present in the aquarium, a light source may have to be placed over the top of the drum to provide for healthy plants.

(ii) Most fish are extremely sensitive to water containing a high concentration of metallic ions, so the drum should be lined with a plastic bag, or the inside painted with non-leaded paint or other non-toxic coating.

C. TEMPORARY AQUARIUM

Cl. Plastic Bag Aquarium



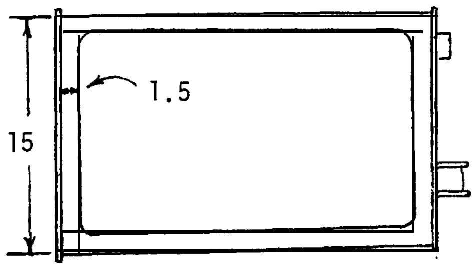
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Rectangular Tin Can (A)	4 liter capacity or larger (at least 10 cm x 15 cm x 25 cm)
(2) Plastic Bag	1	Plastic Bag (or Sheeting) (B)	50 cm x 60 cm
(3) Tape	2	Masking Tape (C)	30 cm
	2	Masking Tape (D)	20 cm

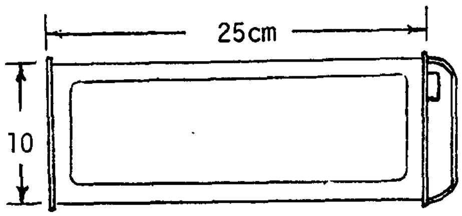
b. Construction

(1) Can

Cut the top and one side out of a four liter rectangular tin can (A) leaving about 1.5 cm of metal remaining to provide rigidity. Such cans can easily be cut with metal snips or shears. Begin each hole by



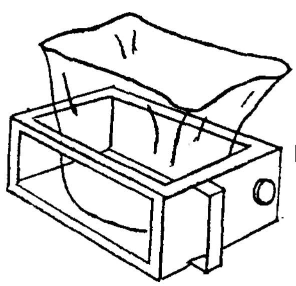
Top View



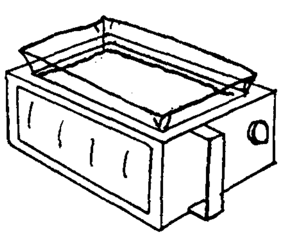
Side View

holding the can firmly, placing the edge of a screwdriver against the side, and striking the screwdriver sharply with a hammer. The sharp edges of the metal should be taped to prevent them from cutting the plastic.

(2) Plastic Bag



Place Plastic (B) in Can



Fill With Water

Use a large clear plastic bag or piece of plastic sheeting (B). Carefully place the middle of the plastic on the bottom of the inside of the can (A) and spread the plastic out so it fills up tfie inside. Let the excess plastic extend above the can. Next, carefully pour water into the center of the plastic until the can is filled to the level desired.

(3) Tape

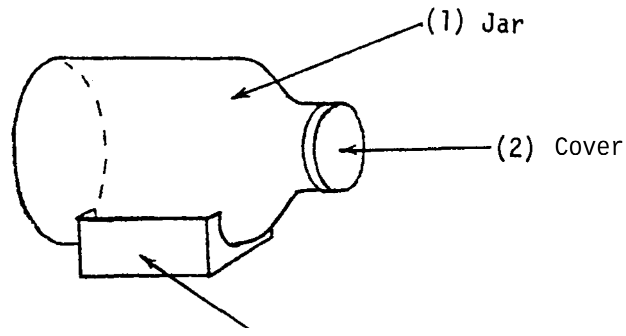
Use the four pieces of masking tape (C,D) that hold down the excess plastic sheeting. Waterproof plastic tape is recommended instead of masking tape if it is available.

c. Notes

(i) With this design, fish and other aquatic organisms can be easily viewed while the three sides of the can provide excellent rigidity. Gravel, plants, rocks, etc., may be placed in the aquarium to provide a more natural environment.

D. TERRARIA

D1. Simple Terrarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	4 liters or larger
(2) Cover	1	Plastic Sheeting (B)	Approximately 12 cm diameter
	1	Adhesive Tape (C)	40 cm long
(3) Stand	1	Cardboard Box (D)	15 cm x 15 cm x 10 cm

b. Construction

(1) Jar

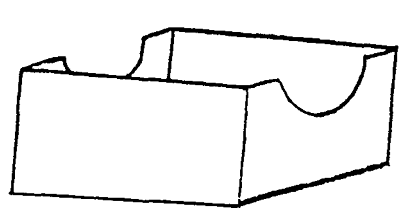
Select a wide-mouthed glass jar (A), the larger the jar and the wider the mouth, the better.

(2) Cover

Tape a circular piece of plastic sheeting (B) over the mouth of the jar with the tape (C) to make it fairly airtight.

(3) Stand

Cut two semicircular pieces from the cardboard box (D) so the terrarium can be set on it without rolling off.

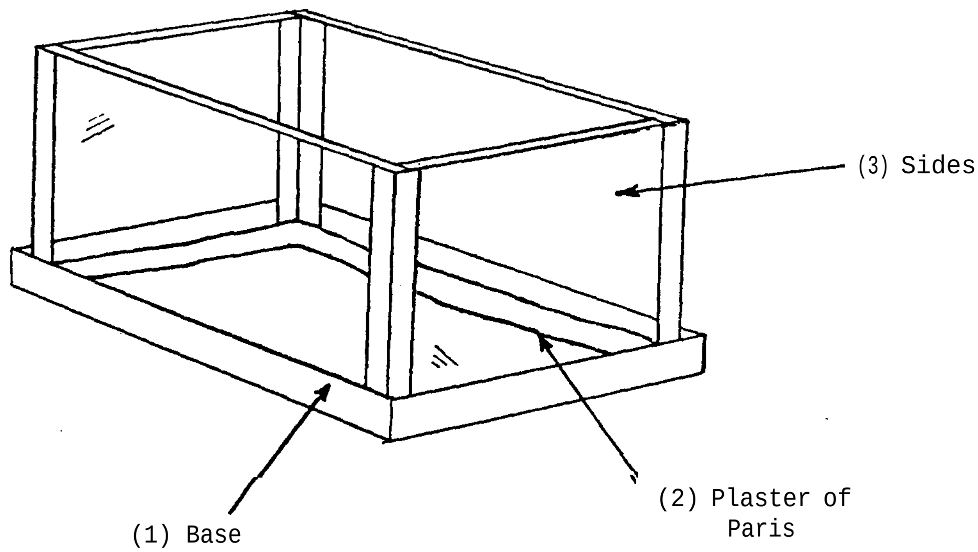


C. Notes

(i) Fill the bottom of the terrarium with rich soil and add plants or seeds. The plastic cover will prevent moisture loss and permit some gas exchange. The jar lid may be used instead, but it has a tendency to rust.

(ii) More durable stands made from metal or wood may be constructed if desired.

D2. Glass Terrarium

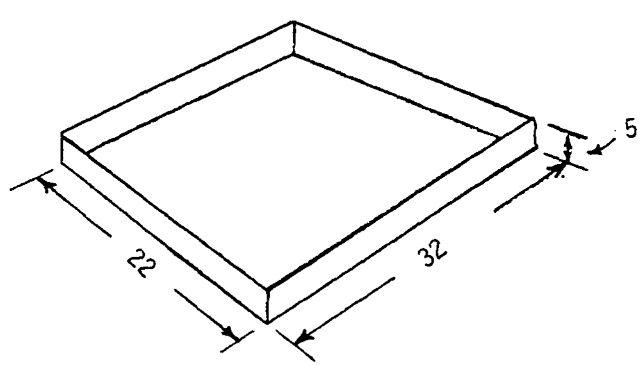


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Tin Can (A)	32 cm x 22 cm x 5 cm
(2) Plaster of Paris	--	Plaster of Paris (B)	--
(3) Sides	2	Glass Plates (C)	30 cm x 20 cm x 0.3 cm
	2	Glass Plates (D)	20 cm x 20 cm x 0.3 cm
	1	Plastic Sheet (E)	35 cm x 25 cm
	4	Tape (F)	--

b. Construction

(1) Base

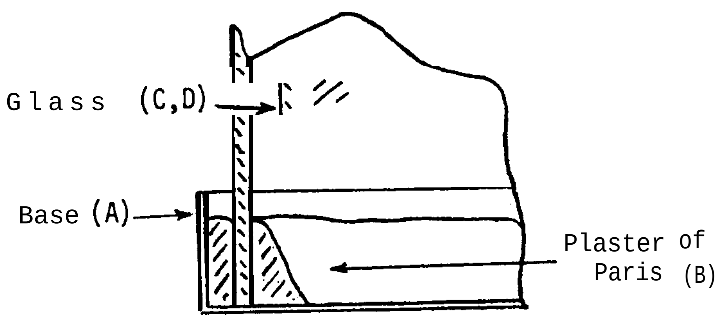


Cut the base from a rectangular tin can (A) to the approximate dimensions given. Adequate bases can also be made from wood, cardboard, sheet metal, etc.

(2) Plaster of Paris

Mix about 1 liter of dry plaster of Paris (B) with enough water to make it workable but stiff.

(3) Sides



Partial Cross-Section

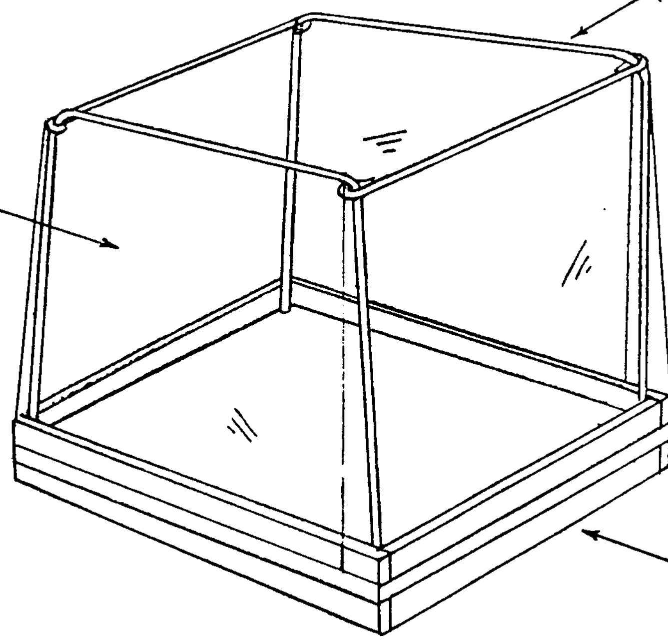
Spread the plaster of Paris (B) thickly around the sides of the base (A). Set the plates of glass (C,D) in the plaster while it is wet. Tape the corners where the glass plates come together with tape (F) to hold the sides upright while the plaster is drying. Cover the terrarium with the plastic sheet (E) when plants are kept in it to prevent moisture loss.

c. Notes

(i) The dimensions of this terrarium may be varied in order to meet special needs or to fit materials available.

(ii) Plants may be placed in the terrarium in pots or planted in soil. If they are planted in soil, be certain that the plaster used is impervious to water.

D3. Plant Growth Chamber

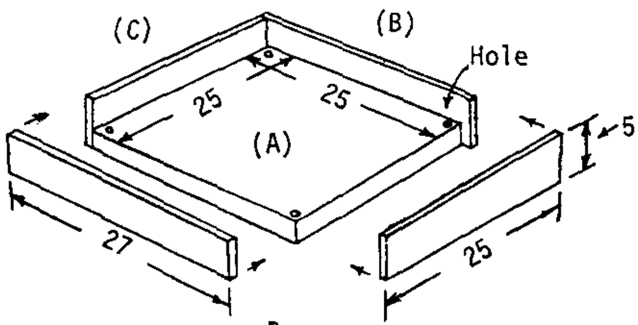


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	25 cm x 25 cm x 2 cm
	2	Wood (B)	27 cm x 5 cm x 1.0 cm
	2	Wood (C)	25 cm x 5 cm x 1.0 cm
(2) Frame	2	Soft Wire (D)	75 cm long, 0.2 cm diameter
	2	Soft Wire (E)	25 cm long, 0.2 cm diameter
	4	Wire (F)	10 cm long, 0.1 cm diameter
(3) Plastic Cover	5	Transparent Plastic Sheeting (G)	30 cm x 30 cm
	--	Tape (H)	--

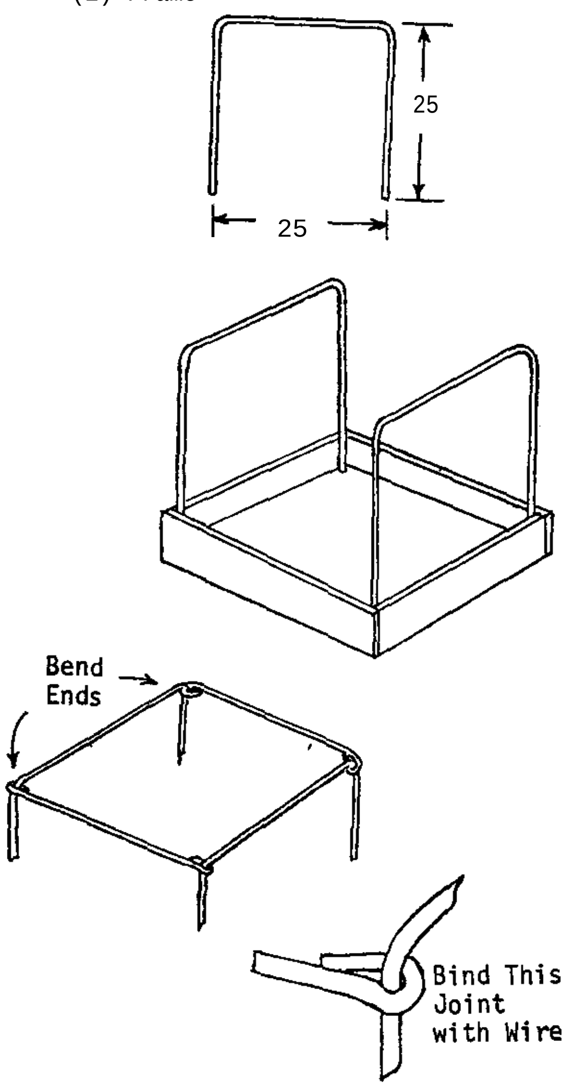
b. Construction

(1) Base



Nail or glue the four rectangular pieces of wood (B,C) to the square piece (A). Drill four holes, 0.2 cm diameter, in the square piece (A), one hole near each corner of the wood.

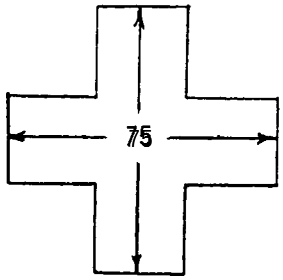
(2) Frame



Detail

Bend the two longest pieces of soft wire (D) into a "U" shape, and insert the ends into the holes in the base. Fasten the shorter pieces of soft wire (E) to the frame by bending about 1 cm of each end around the bends in the longer wires (D). Bind the joints together with the short, thinner wires (F).

(3) Plastic Cover



Cut a piece of transparent plastic sheeting (G) to the pattern shown or use five separate pieces of sheeting. Whether using the single or separate sheets, cover the frame with plastic and seal the joints between the sheeting with tape (H). Leave one side of the sheeting loose to be used as a "door" in order to easily remove the plants.

c. Notes

(i) Plants may be placed in the chamber in pots or soil may be placed in the base in order to hold the plants.

(ii) Dimensions for the plant growth chamber may be altered in any way depending upon the purposes to which it will be put. Especially, the base needs to have more depth than 3 cm if plants are to be grown in soil rather than pots.

VI. CAGES

A. GLASS CAGES

These cages, made wholly or largely of glass, can be used to house a large variety of small animals, from insects to small mammals.

B. WOODEN CAGES

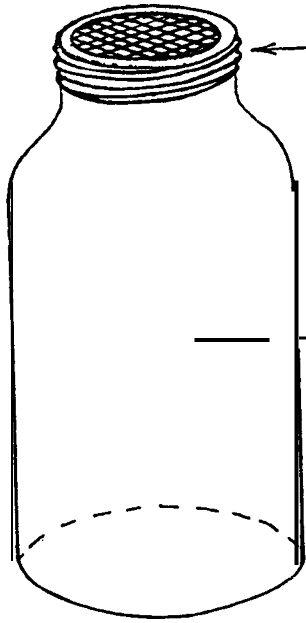
Two wooden cages are offered, one to house insects and the other designed for small mamals or birds. Both are somewhat more elaborate and permanent than their equivalent glass cages.

C. TEMPERATURE CONTROLLED CAGES

The vivarium and egg incubator are heated with light bulbs to serve the needs of animals and eggs which require relatively higher temperatures to live or hatch, respectively. Use a thermostat to control the internal temperature of heated cages and incubators, especially in classrooms which are not themselves thermostatically temperature controlled.

A. GLASS CAGES

Al. Glass Jar Cage

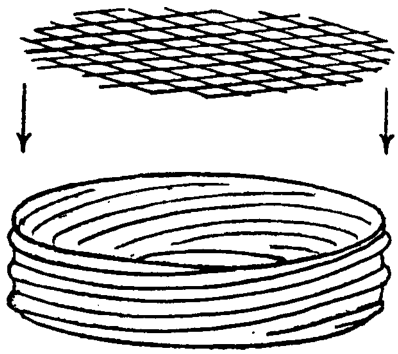


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	4 liters capacity or larger
(2) Top	1	Glass Jar Top (B)	To fit jar
	1	Wire Screening (C)	Same diameter as jar top

b. Constructi on

(1) Jar	Thoroughly clean the large glass jar (A). Select one with as large a mouth as possible.
(2) Top	Cut out a circular piece from the metal top (B) of the glass jar. The diameter of the hole in the top should be about 1 cm less than that of the top itself.



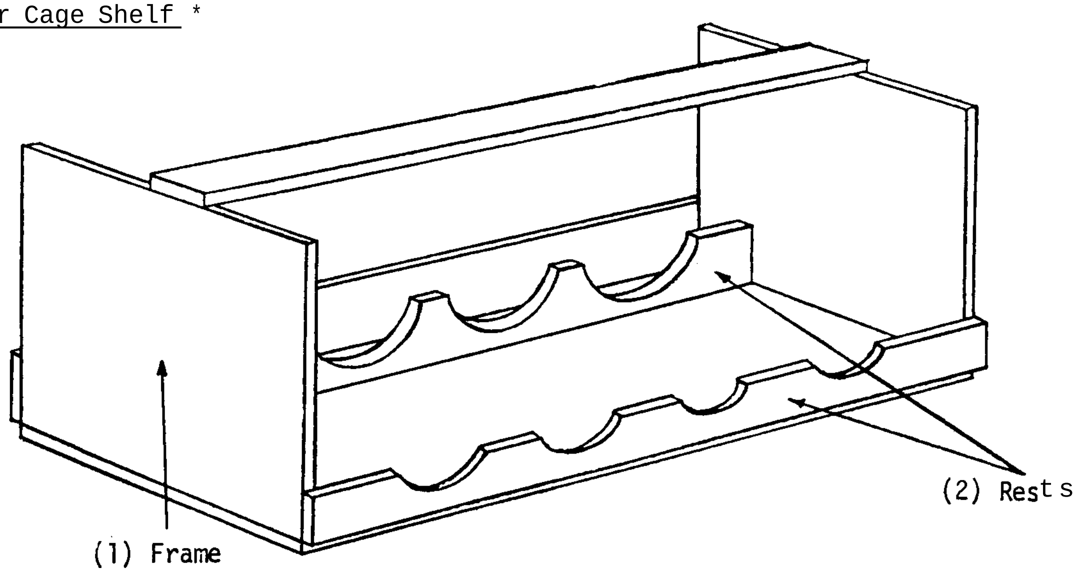
Next, cut out a circular piece of wire screen (C) the same diameter as the top. Insert this wire screen inside the top and glue it in place if it does not stay in place by itself.

C. Notes

(i) If the wire screening is cut to a diameter very slightly larger than that of the metal top, it will tend to stay in place within the top, and doesn't need to be cemented. In fact, once the top is screwed to the jar, the screen will be held tightly between the glass and top, and no cement is necessary.

(ii) Grass, sand, soil, twigs, etc., can be added to this cage depending on what type of animal is to be kept. If small amphibians are housed in it, lay it on its side and partially fill it with water. Most amphibians are best housed in shallow aquaria, however.

A2. Jar Cage Shelf *

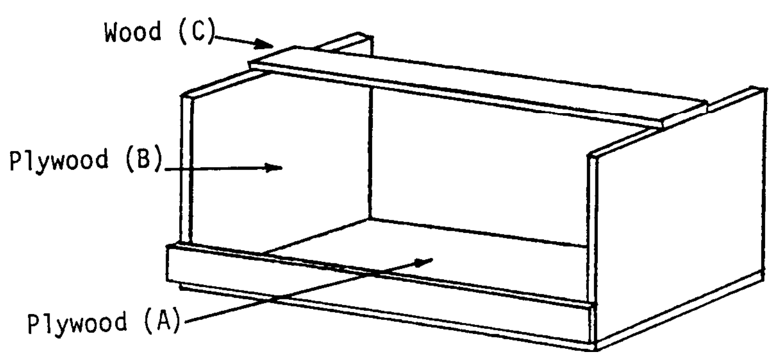


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	18 cm x 47 cm x 1.0 cm
	2	Plywood (B)	18 cm x 15 cm x 1.0 cm
	2	Wood (C)	4 cm x 47 cm x 1.0 cm
(2) Rests	1	Wood (D)	4 cm x 45 cm x 1.0 cm
	1	Wood (E)	2 cm x 47 cm x 1.0 cm

b. Construction

(1) Frame

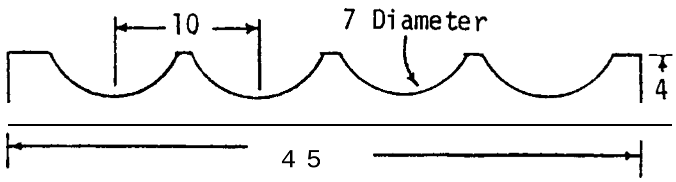


Back View

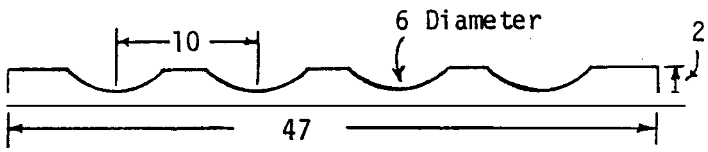
Nail or screw the two small pieces of plywood (B) to the ends of the large piece (A). Nail one of the wood strips (C) to the back with the lower edge even with the back. Screw the other strip (C) to the top to act as a carrying handle.

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 28.

(2) Rests

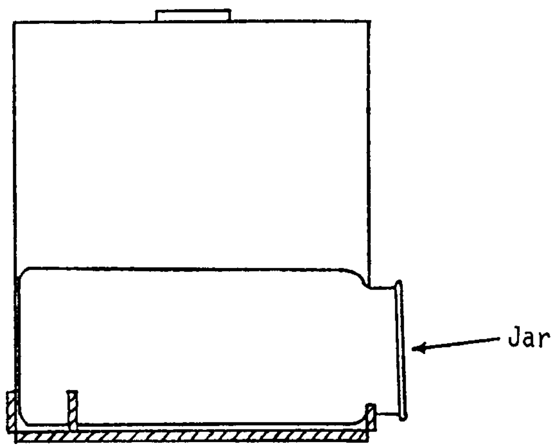


Wood Strip (D)



Wood Strip (E)

Wooden rests are needed to prevent the jar cages from rolling. Cut four arcs spaced 10 cm on center from the wide piece of wood (D). The diameter of the arcs should be the same as that of the body of the jar cages (in this description, the jars used had a body diameter of 7 cm and a neck diameter of 6 cm).



Side View
(Cross-section)

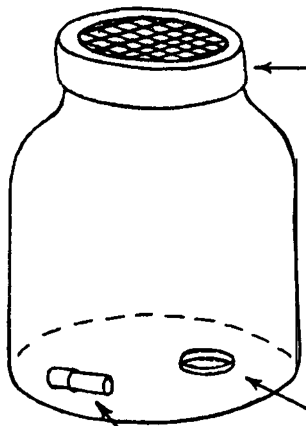
Similarly, cut four arcs of the same diameter as the neck of the bottle (in this case, 6 cm) from the narrow strip (E), also 10 cm on center. Nail the wide strip (D) to the sides and base about 3 cm from the back strip. Nail the narrow strip (E) to the front with its lower edge even with the base.

C. Notes

(i) Use this item as a storage rack for several jar cages (VI/Al). The handle permits several cages to be carried with little disturbance.

(ii) All dimensions given here are subject to change depending on the size, shape, and number of jar cages to be stored.

A3. Cockroach Cage *



a. Materials Required

Components		Items Required	Dimensions
(1) Cage	1	Glass Jar Cage (VI/Al) (A)	At least 1.0 liter capacity
(2) Food Container	1	Jar Top (B)	2-3 cm diameter, 1 cm deep
(3) Watering Device	1	Glass Vial (C)	4 cm long, 2 cm diameter
	1	Cotton (D)	Small plug

b. Construction

(1) Cage — Use the Glass Jar Cage (VI/Al) (A) as is.

(2) Food Container — A small jar top (B) will hold the small amount of food necessary for small insects like cockroaches.

(3) Watering Device — Insert the cotton plug (D) into the open end of the vial (C) containing a small amount of water. The cotton will stay

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 22-23.

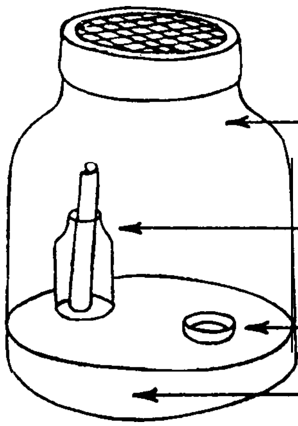
damp and provide water for the insects.

c. Notes

(i) If desired, the upper portion of the jar can be coated with talcum powder to prevent the insects from crawling out when the jar is open.

(ii) Providing small objects which the insects can climb on or conceal themselves in is recommended.

A4. Housefly Cage *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cage	1	Glass Jar Cage (VI/A1) (A)	4 liters or larger
(2) Watering Device	1	Glass Jar (B)	Approximately 25 ml
	1	Absorbent Paper (C)	Approximately 10 cm x 3 cm
(3) Food Container	1	Jar Top (D)	4 cm long, 2 cm diameter
(4) Culture Medium	1	Culture Medium (E)	50 ml or enough to fill the cage to a depth of approximately 2 cm

b. Construction

(1) Cage

Use the Glass Jar Cage (VI/Al) (A) as is. Be sure to select a glass jar with as wide a mouth as possible.

(2) Water Device

This is merely a small glass jar (B) or other small container which holds a "wick" of absorbent paper (C). Water in the jar will soak into the paper

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques in the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 23.

where it can be obtained by flies and other flying insects.

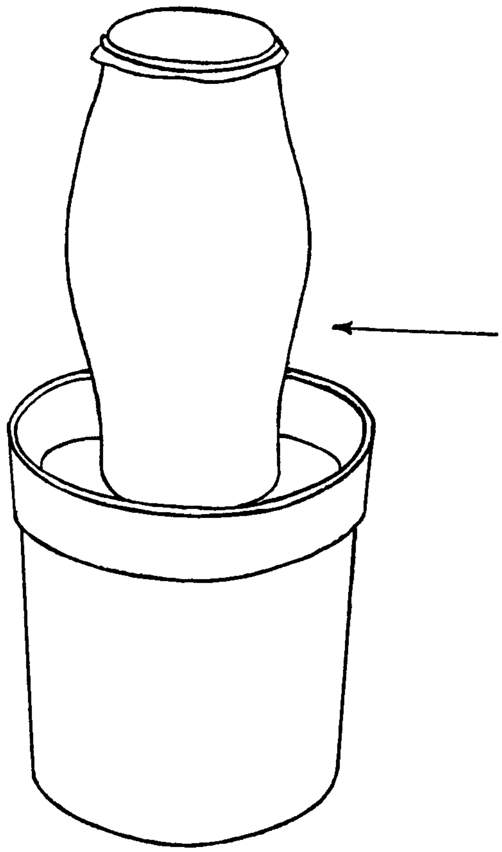
(3) Food Container — A small jar top (D) will suffice as a container for food for the flies.

(4) Culture Medium — This is a growth medium (E) for the insect larvae, and should contain all the necessary growth ingredients.

c. Notes

(i) For suitable growth media for houseflies , see the following BSCS publications: Barthelemy et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory; and Glenn, The Complementarity of Structure and Function (BSCS Laboratory Block).

A5. Cylinder Cage



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cylinder Cage	1	Potted Plant (A)	--
	1	Lamp Chimney (B)	8 cm diameter, 30 cm long
	1	Cloth Mesh (C)	10 cm diameter
	1	Rubber Band (D)	--

b. Construction

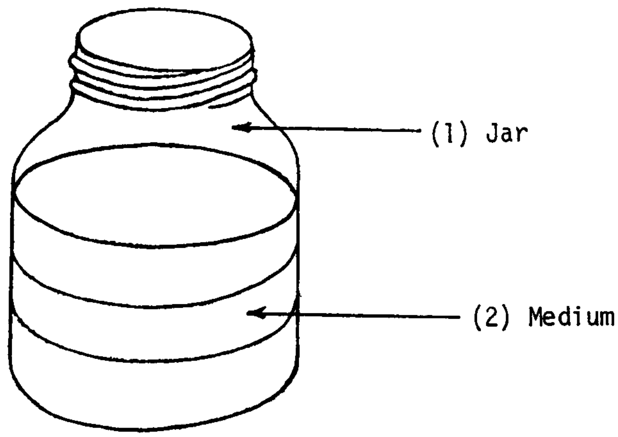
(1) Cylinder Cage

This is a quickly made cage. Simply put the lamp chimney (B) or other large diameter glass tube over the potted plant (A). Add the insects, and cover the top with cloth mesh (C) or gauze held in place with the rubber band (D).

c. Notes

(i) This is a good, simple cage in which to rear insects which feed on plants.

A6. Jar Wormery



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	1-4 liters
(2) Medium	1	Sand (B)	1/4-1 liter
	1	Leaf Mold (C)	1/4-1 liter
	1	Loam (D)	1/4-1 liter

b. Construction

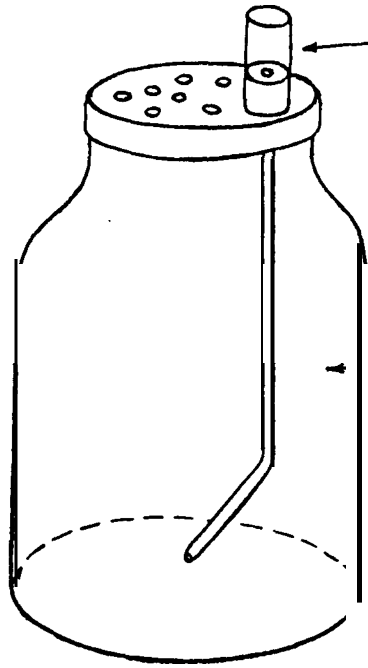
(1) Jar — Thoroughly clean the glass jar (A).

(2) Medium — Each layer of the medium should have a volume approximately one fourth that of the total for the jar. The bottom layer is sand (B), the middle is leaf mold (C), and the top layer is loam (D).

c. Notes

(i) Place the worms in the wormery along with some dead leaves, lettuce, carrots, etc. Keep the contents damp.

A7. Jar Cage



a. Materials Required

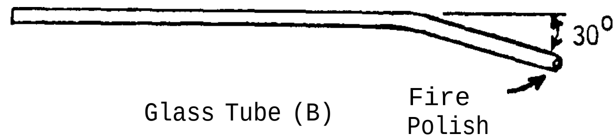
Components	Qu	Items Required	Dimensions
(1) Jar	1	Large Glass Jar (A)	4 liter capacity
(2) Water Bottle	1	Glass Tube (B)	25 cm long, 0.5 cm outside diameter
	1	Vial (C)	50-100 ml capacity
	1	l-Hole Stopper (D)	To fit vial

b. Construction

(1) Jar

Use a large capacity glass jar (A) with a metal or plastic lid. Punch several holes in the lid for ventilation. Make certain one of the holes is slightly larger in diameter than the glass tube (B) used in the water bottle.

(2) Water Bottle



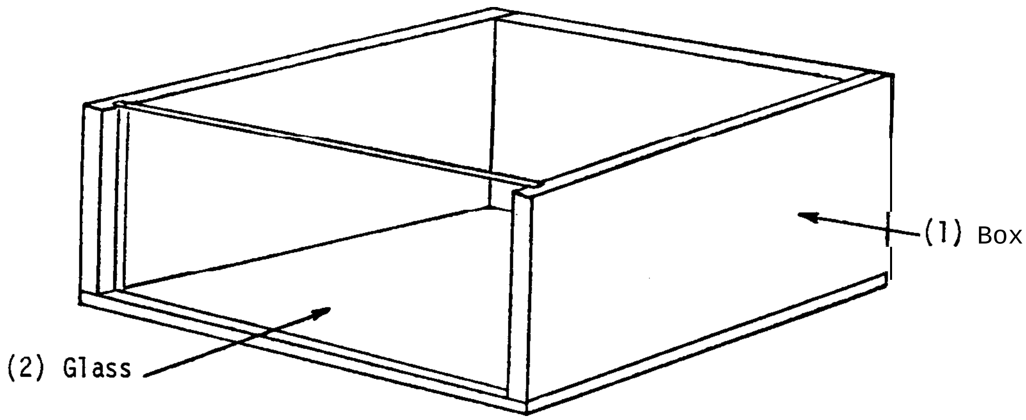
Heat the glass tube (B) about 7 cm from one end and make a slight bend in it (about 30°). Fire polish this end until the opening constricts very slightly. Insert the other end of the tube through the one-hole stopper (D), and plug the vial (C) with the stopper. Insert the completed water bottle through a hole in the lid of the jar. Be sure the tip of the glass tube is low enough for the animals to reach.

C. Notes

(i) This cage is designed for small mammals like mice or gerbils. Spread a layer of sawdust or newspaper shreds on the bottom to absorb wastes. Fill the water bottle and the animals soon learn to lick water from the end of the tube. Pieces of food can be dropped through the holes in the lid.

(ii) This cage is meant to be a temporary, not permanent, container for small mammals. Large jars of 4 liter capacity may be obtained from restaurants and other places which buy food in large quantities.

A8. Box Wormery

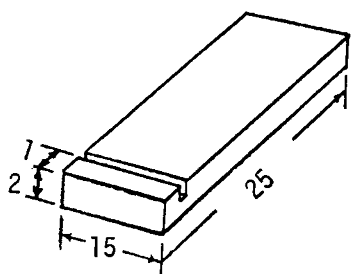


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Box	1	Wood (A)	25 cm x 25 cm x 1 cm
	2	Wood (B)	25 cm x 2 cm x 15 cm
	1	Wood (C)	21 cm x 2 cm x 15 cm
(2) Glass	1	Window Glass (D)	23 cm x 15 cm x 0.3 cm

b. Construction

(1) Box



With a saw, cut a groove 1.0 cm deep and 1.0 cm from the end of the two pieces of wood (B). These grooves should be slightly wider (about 0.4 cm) than the glass (D) used. Nail these two pieces and the piece (C) to the base (D) to form an open-ended box with the two grooves facing each other,

(2) Glass

Insert the glass (D) into the grooves in the sides of the box. The box wormery is now complete.

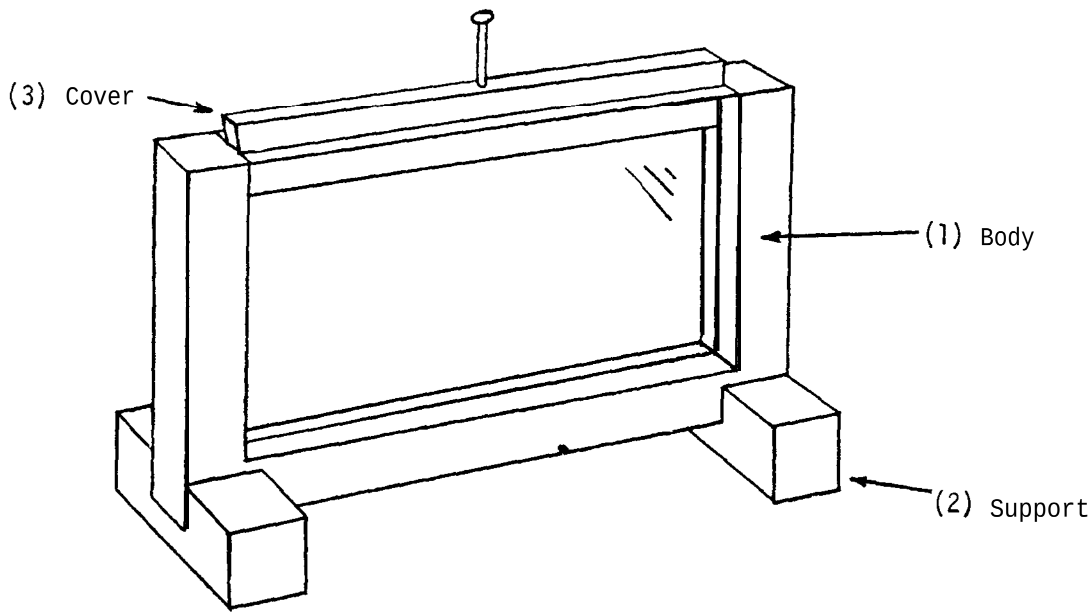
c. Notes

(i) Put a 5 cm deep layer of sand in the box, cover this with 5 cm of leaf mold, and finally cover this with about 5 cm of loam. Add worms, dead leaves, pieces of lettuce and carrots to the top. Cover the glass front with dark paper or cloth and keep the soil damp. After several days, worms and tunnels should be visible when the paper or cloth is removed.

(ii) There is no real need for the glass plate to be removable so all the joints between the wood and glass can be sealed with waterproof sealant (e.g., pitch, caulk).

(iii) If it is desired to simply raise worms rather than observe them, then the glass may be omitted and any suitable box can be used for the wormery.

A9. Ant Observation Cage

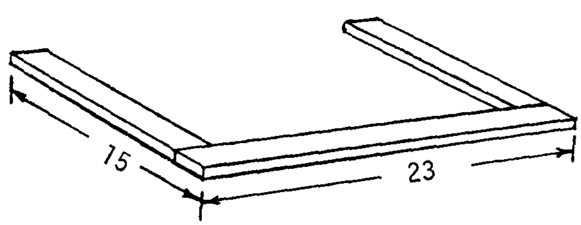


a. Materials Required

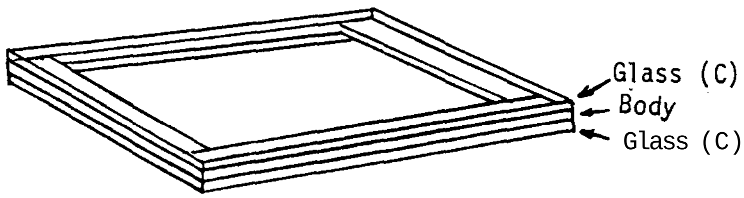
Components	Qu	Items Required	Dimensions
(1) Body	2	Wood (A)	13 cm x 2 cm x 0.7 cm
	1	Wood (B)	23 cm x 2 cm x 0.7 cm
	2	Glass Plates (C)	23 cm x 15 cm x 0.3 cm
	6	Tape (D)	19 cm x 2 cm
	3	Tape (E)	27 cm x 2 cm
(2) Support	2	Wood (F)	7 cm x 2 cm x 2 cm
(3) Cover	1	Wood (G)	19 cm x 2 cm x 0.7 cm
	1	Nail (H)	4 cm long, 0.3 cm diameter

b. Construction

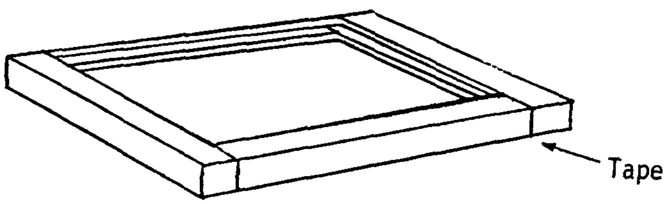
(1) Body



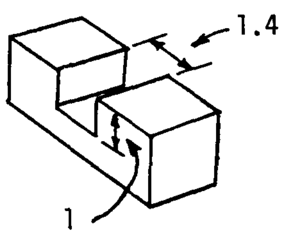
Glue, nail, screw or otherwise fasten the two short pieces of wood (A) to the ends of the longer piece (B). When the glue has dried, place the wood frame between the two pieces



of glass (C) forming a "sandwich". Use the six short pieces of tape (D) to tape each end together and use the three long pieces of tape (E) to tape the bottom.

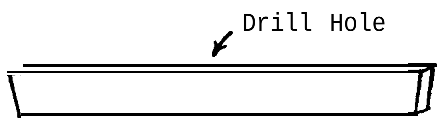


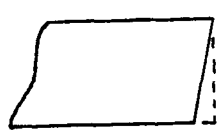
(2) Support



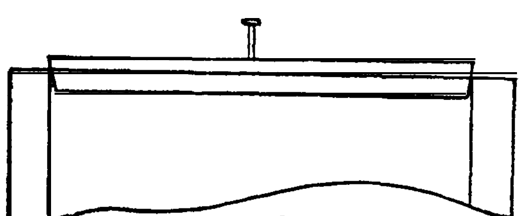
Cut a notch 1.4 cm wide and 1.0 cm deep into the center of each wooden support (F). Set the body into place.

(3) Cover





Detail



Detail

Drill a hole approximately 0.3 cm in diameter through the middle of the piece of wood (G). Cut off a small portion of each end so that the ends are slightly tapered. This cover should now effectively seal the body, and the wedge shape of the cover insures that it need not be perfectly accurate in order to seal the cage. Complete the ant observation cage by sticking the nail (H) in the hole.

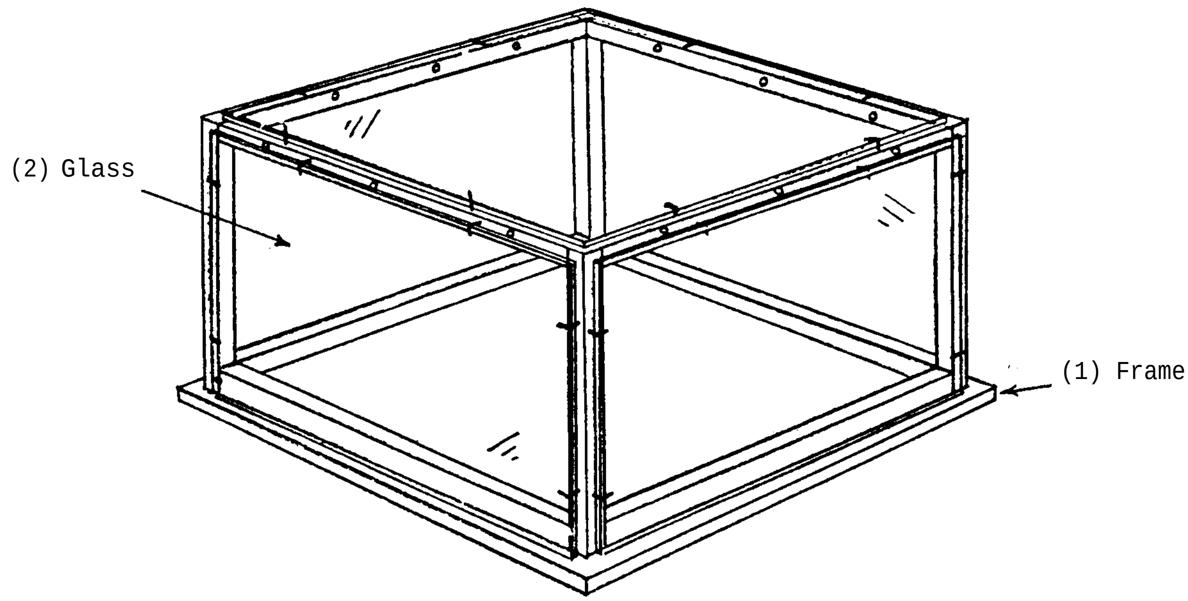
c. Notes

(i) Prepare the cage for use by filling it to within 2 - 3 cm of the top with soil. The soil should be firm, but not tightly packed. Add the ants (include a "queen" ant), and feed them by dropping moistened sugar, bread crumbs, etc., through the hole in the cover. Keep the cage covered when not actually observing the ants as this will encourage their tunneling activity.

(ii) The soil ought to be kept moist, so the cage should be taped with waterproof tape. Taping allows the cage to be easily dismantled, cleaned and reassembled.

(iii) Ant observation cages of different dimensions from those given here can be made, but the basic design need not be altered.

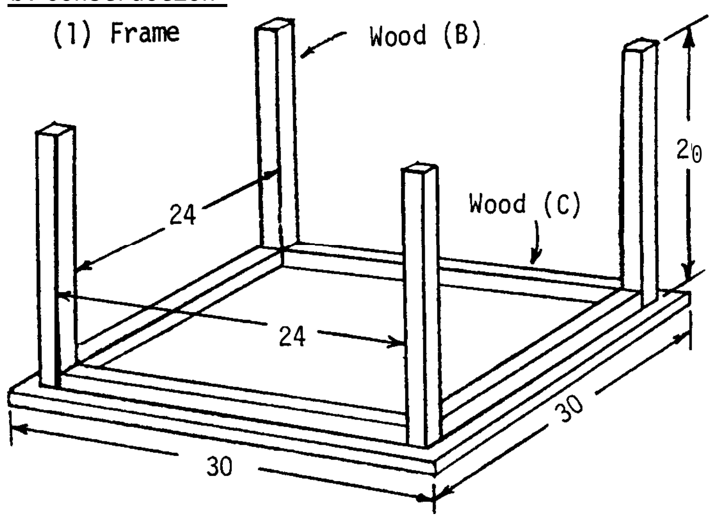
A10. Glass Cage



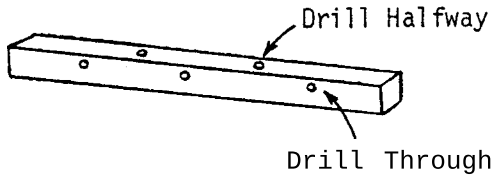
a. Materials Required

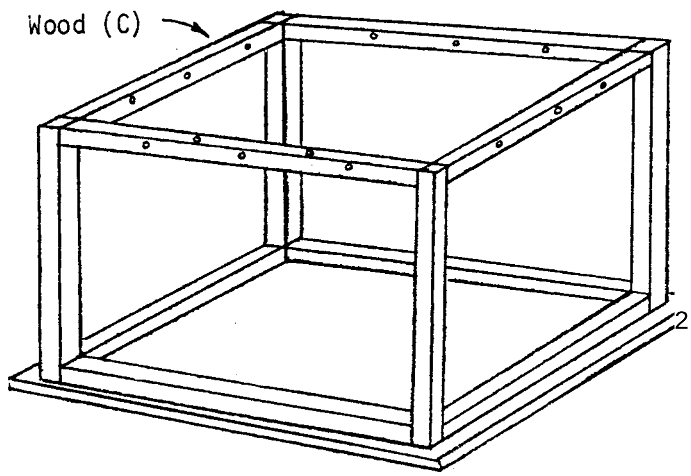
Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	30 cm x 30 cm x 1.0 cm
	4	Wood (B)	20 cm x 2 cm x 2 cm
	a	Wood (C)	24 cm x 2 cm x 2 cm
(2) Glass	32	Nails (D)	2.5 cm long
	4	Glass (E)	25.5 cm x 18.75 cm x 0.3 cm
	1	Glass (F)	25.5 cm x 25.5 cm x 0.3 cm

b. Construction



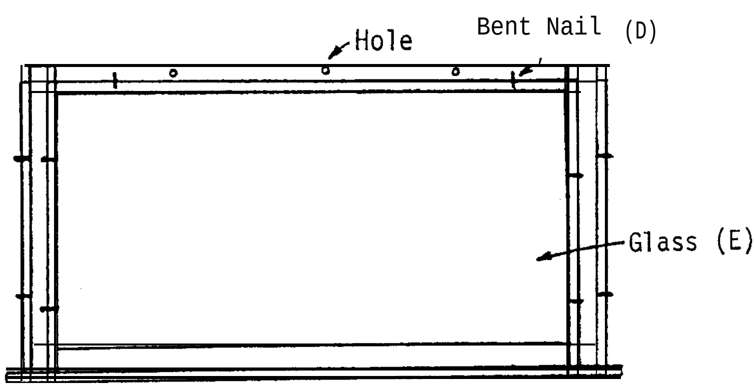
Use the plywood (A) as the cage base. Screw the four short pieces of wood (B) to the base from the back side of the base so that each of their edges is 1.0 cm from the edge of the base. Nail four of the remaining pieces (C) to the base (A) and uprights (B), between the uprights and 1.0 cm from the edge of the base.





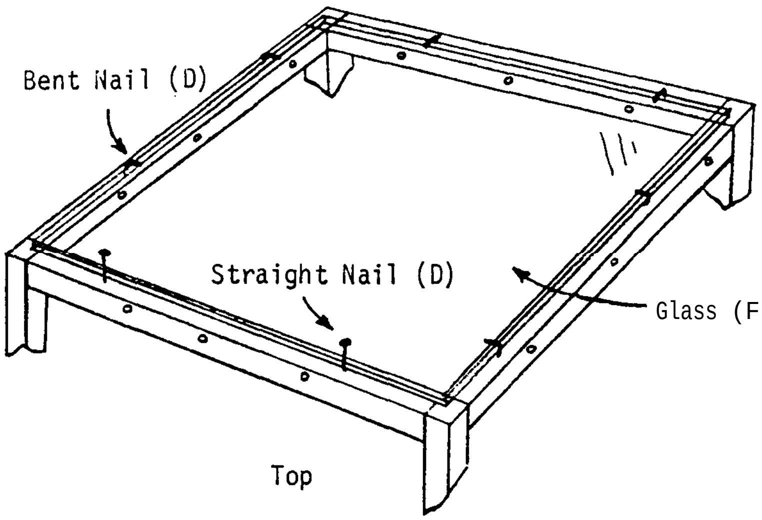
Drill three holes (0.2 cm in diameter) through each of the four remaining pieces of wood (C). Space the three holes about 6 cm apart and 0.5 cm from one edge. In one of these pieces of wood, drill two additional holes 0.2 cm in diameter. Drill them 0.5 cm from the same edge the other three holes are near, but only drill them halfway through the wood. Nail these four pieces to the uprights so that the holes are parallel to the base, and the holes must be closest to the top edge of the wood rather than the bottom. These three holes serve to ventilate the cage.

(2) Glass



Side View

Position one of the glass pieces (E) against the side of the frame so that it overlaps the edges of the frame by about 0.75 cm on all three sides. Drive four nails (D), two per vertical side, into the frame as close to the glass as possible. Only drive them in about halfway and remove the glass. Bend each nail over at right angles, and replace the glass. The nails should overlap the glass and hold it upright against the frame. Nail two more nails (D) above the glass and bend them down in a similar manner to keep the glass side firmly in place. Be



careful not to break the glass.

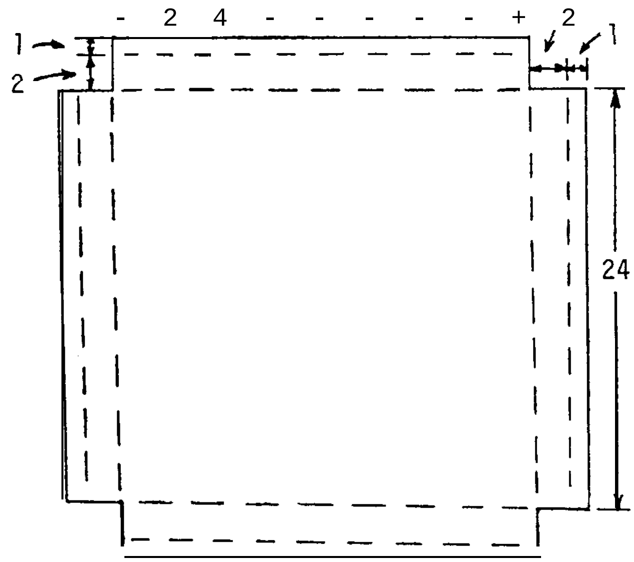
Fasten the remaining piece of glass (F) to the top in a similar manner as was done with the sides. Nail six nails (D), two per side, and bend them over to hold the glass in place. Put two nails in the holes in the remaining side of the frame. These two nails should slip easily in and out the holes so that they can be removed and the top glass plate removed by sliding it out from under the bent nails. Do not bend these last two nails.

c. Notes

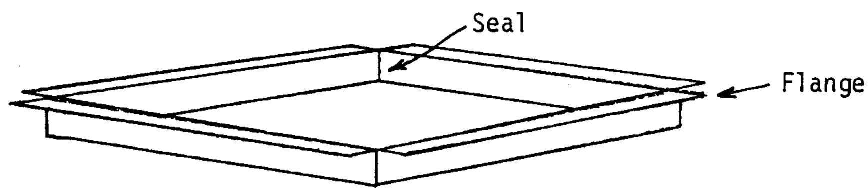
(i) This cage is designed primarily to house small reptiles (especially lizards and snakes) and other small, non-gnawing animals. The bottom of the cage can be filled with 1.5 - 2 cm of clean sand or gravel. If burrowing animals are to be kept, build the bottom of the frame higher so that the sand or gravel may be made deeper. Water may be provided in a jar lid and food simply dropped in from the top.

(ii) The dimensions of this cage can easily be altered depending on the number, size, and habits of the animals to be housed in it.

(iii) If it is so desired, a metal tray can be fashioned for the bottom of the cage to hold the sand or gravel. This makes the cage much easier to clean as the tray can simply be lifted out of the cage, the sand or gravel cleaned by running it through a seive, and replacing it. The tray prevents the wood from absorbing liquid wastes and spilled water and food. The pattern given here will fit the cage as described above. (See illustration on next page.)



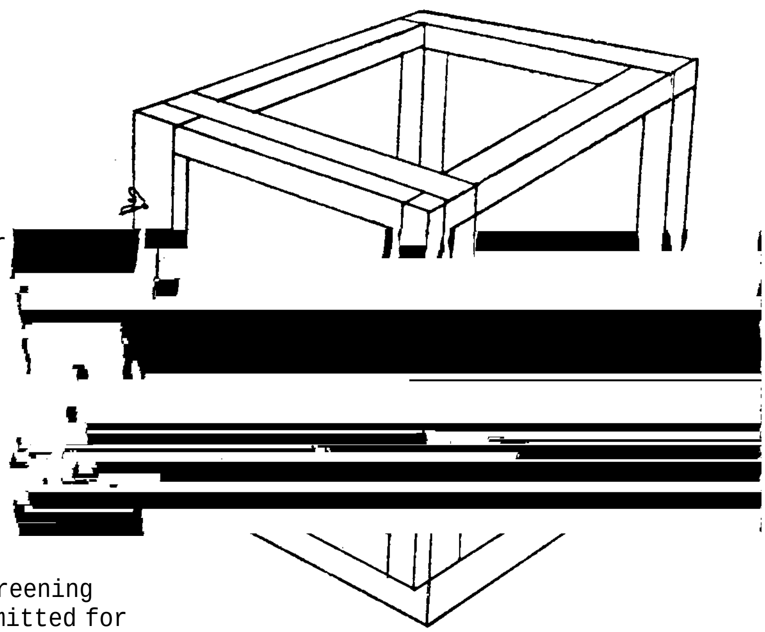
Fold the pattern along the dotted lines to the following shape.



Seal the inside corner joints with a waterproof sealant (e.g., pitch) and set the tray in place in the bottom of the cage. The flanges should overlap the bottom portion of the frame.

B. WOODEN CAGES

B1. Wooden Frame Cage

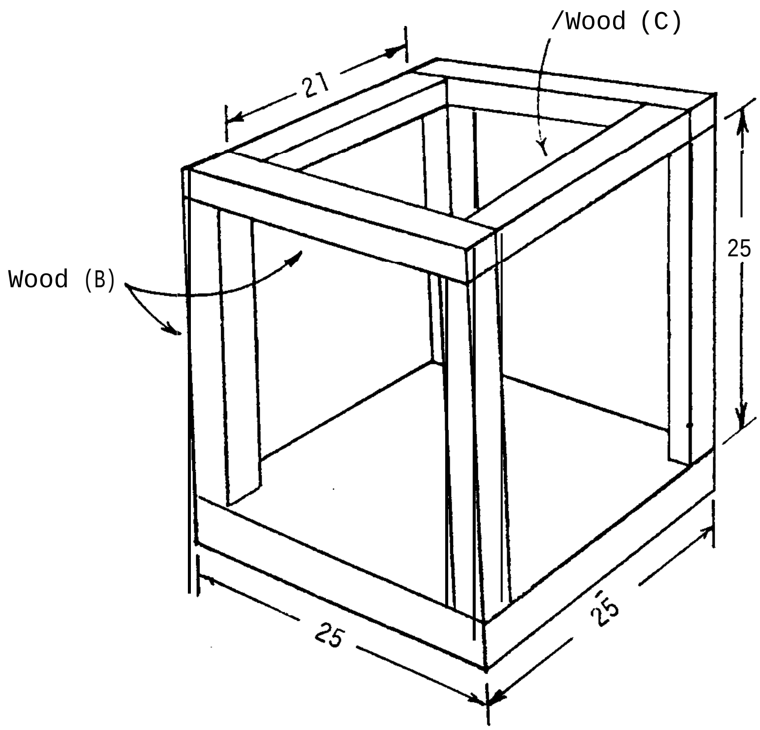


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Wood (A)	25 cm x 25 cm x 1.0 cm
	6	Wood (B)	25 cm x 2 cm x 2 cm
	2	Wood (C)	21 cm x 2 cm x 2 cm
(2) Door	2	Wood (D)	27 cm x 3 cm x 1.0 cm
	2	Wood (E)	19 cm x 3 cm x 1.0 cm
	2	Hinges (F)	About 3 cm x 2 cm
	4	Nails (G)	2 cm long
	2	Rubber Bands (H)	--
(3) Screening	1	Wire Mesh (I)	24 cm x 24 cm
	3	Wire Mesh (J)	26 cm x 24 cm
	1	Cloth (K)	85 cm x 25 cm
	1	Rubber Band (L)	--

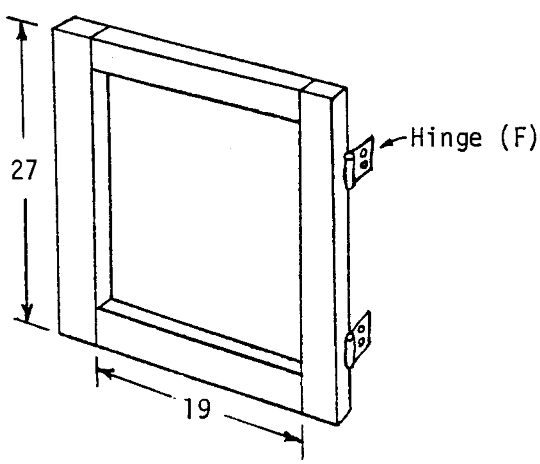
b. Construction

(i) Frame

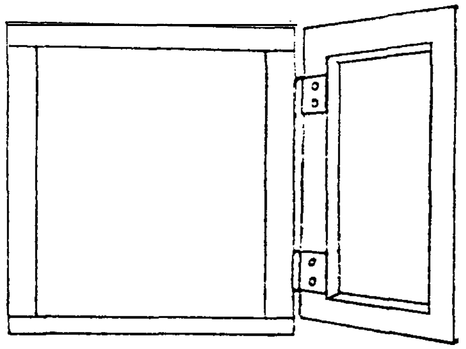


Glue, nail, or screw four of the long pieces of wood (B) to the four corners of the square piece (A) to form the uprights of the cage. Nail the two remaining long wooden pieces (B) to the tops of adjacent uprights. Then, nail the two short pieces (C) into place to complete the basic cage frame.

(2) Door

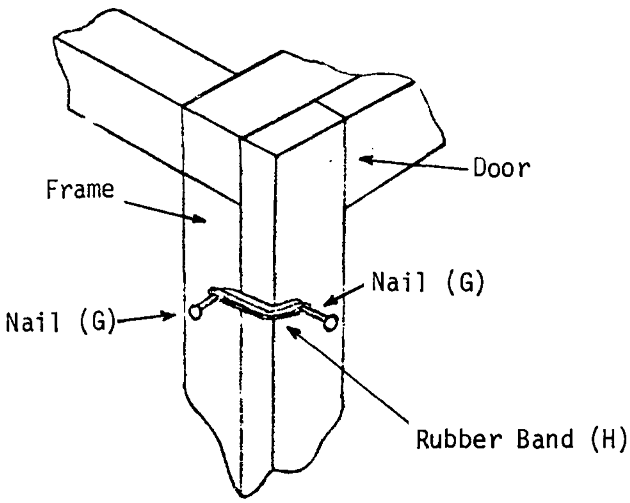


Glue, nail, or screw the short pieces of wood (E) between the long pieces (D) to form the frame for the door. Attach two small hinges (F) to the back of the door.



Front View

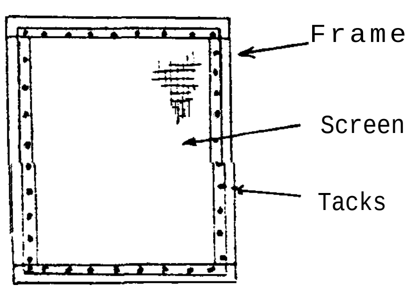
Next, fasten the door to the frame by use of the two hinges.



Detail

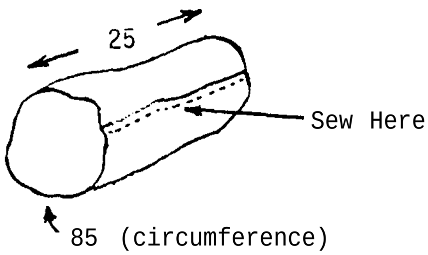
To keep the door shut, hammer nails (G) at both top and bottom of the door and frame. When the door is shut, wrap a strong rubber band (H) around each set of nails to keep the door shut.

(3) Screening

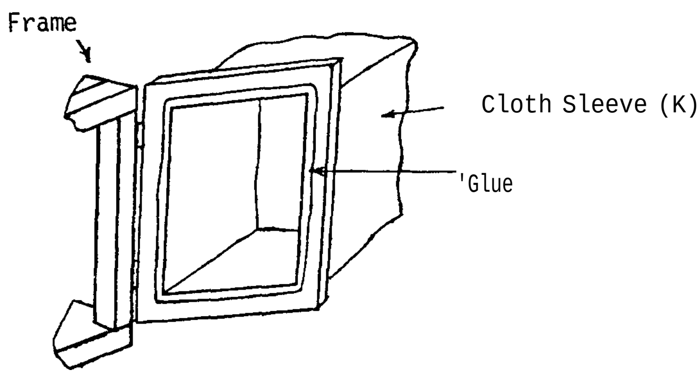


Side View

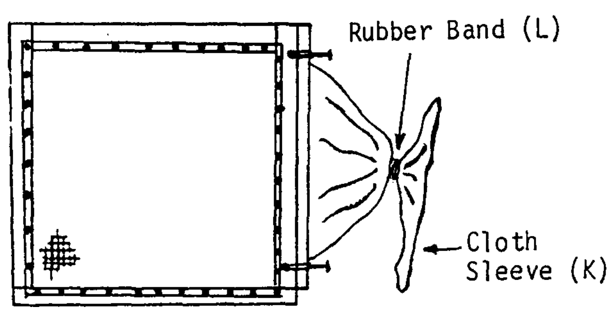
Attach the three pieces of screening (J) (cloth mesh may also be used) to the three sides and the fourth (I) to the top of the frame by gluing or tacking them in place. Liberal use of glue helps seal the joint between the screen and wood, especially if cloth mesh is used instead of wire mesh.



Sew the piece of cloth (K) along the short (25 cm) edge to make a kind of tube or "sleeve". Then, glue one end all around the inside edge of the door, making certain there are no gaps in the glue seam.



Detail



Side View

To complete the cage, close and latch the door, twist the protruding end of the cloth tube tight, and close it off with the rubber band,(L).

I

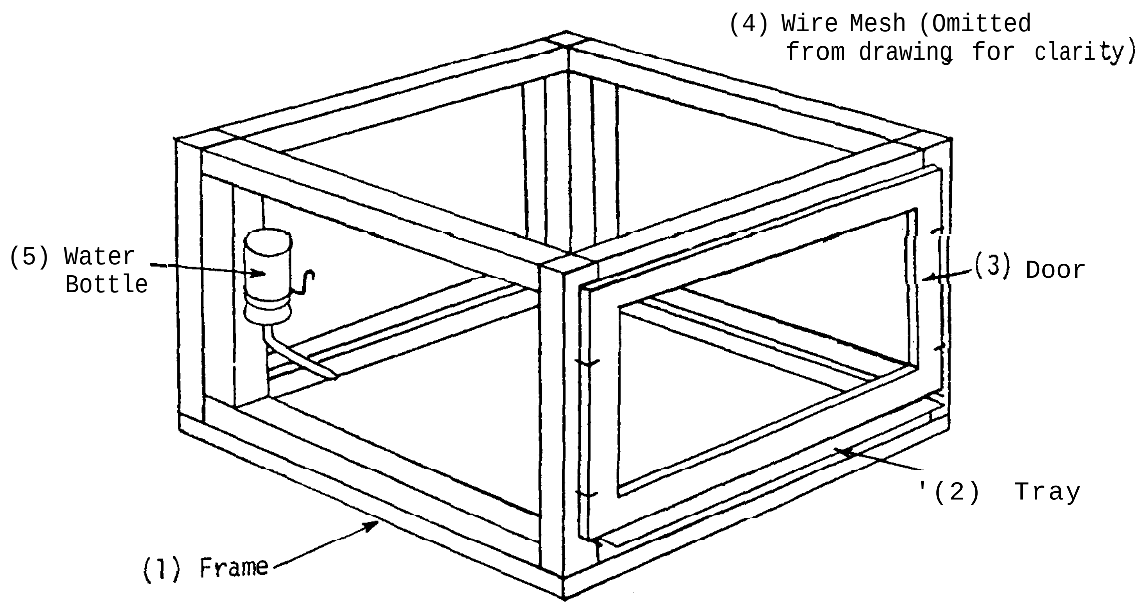
C. Notes

(i) The door can be opened to allow the cage to be cleaned, rearranged, etc. However, when the cage contains insects, items such as food, water, and the insects themselves can be put into and taken out of the cage by undoing the rubber band, slipping one hand through the cloth sleeve into the cage, and holding the cloth tightly around the arm in the sleeve with the other hand; this method prevents the insects from escaping.

(ii) See insect cages VI/A3 and VI/A4 for making watering and feeding devices for insects.

(iii) Since cloth is used for the sleeve and may be used for the sides, keep only insects or other small animals which are unable to chew their way through cloth in this cage.

B2. Wire Cage



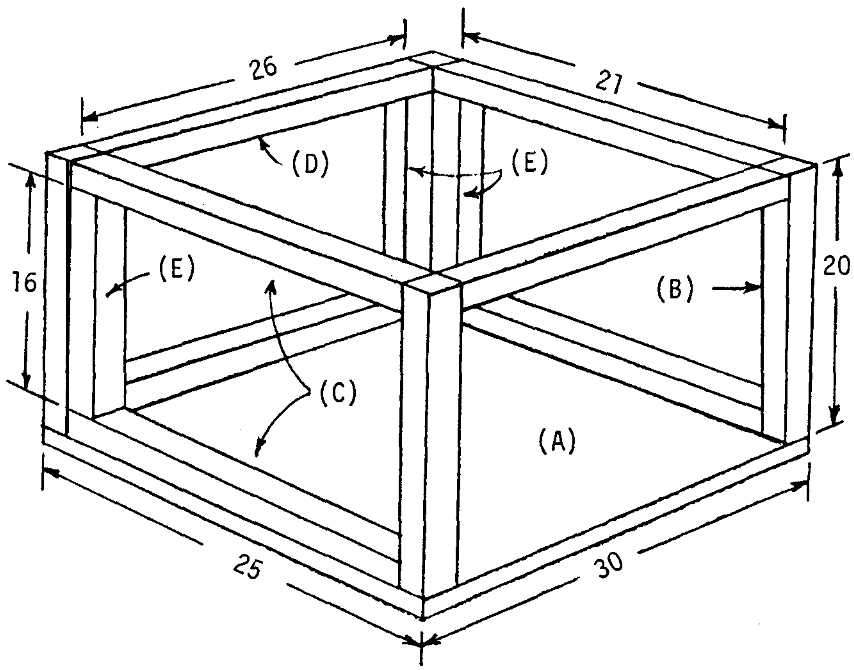
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	25 cm x 30 cm x 0.5 cm
	4	Wood (B)	20 cm x 2 cm x 2 cm
	4	Wood (C)	21 cm x 2 cm x 2 cm
	3	Wood (D)	26 cm x 2 cm x 2 cm
	4	Wood (E)	16 cm x 2 cm x 2 cm
(2) Tray	1	Sheet Metal (F)	30 cm x 30 cm x 0.05 cm
(3) Door	2	Wood (G)	28 cm x 3 cm x 1.0 cm
	2	Wood (H)	l8 cm x 3 cm x 1.0 cm
	1	Wire Mesh (I)	28 cm X18 cm
	6	Nails (J)	2.5 cm long
(4) Wire Mesh	1	Wire Mesh (K)	23 cm x 62 cm
	1	Wire Mesh (L)	23 cm x 28 cm
	1	Wire Mesh (M)	20 cm x 26 cm
(5) Water Bottle	1	Vial (N)	50-100 ml capacity
	1	l-Hole Stopper (0)	To fit vial

1	Glass Tube (P)	10 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
1	Stiff Wire (Q)	About 20 cm long

b. Construction

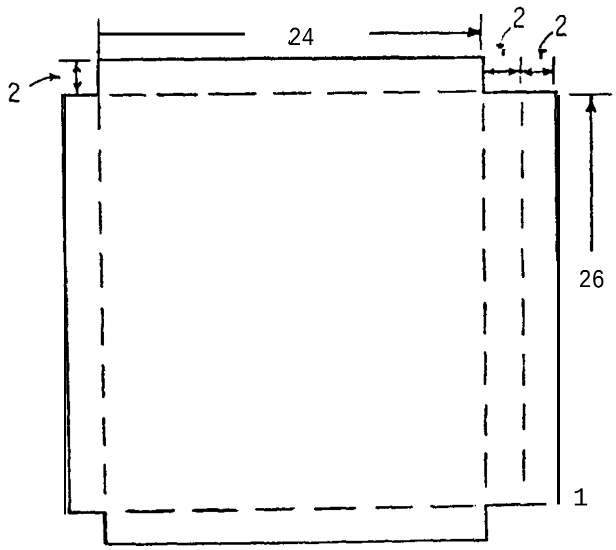
(1) Frame

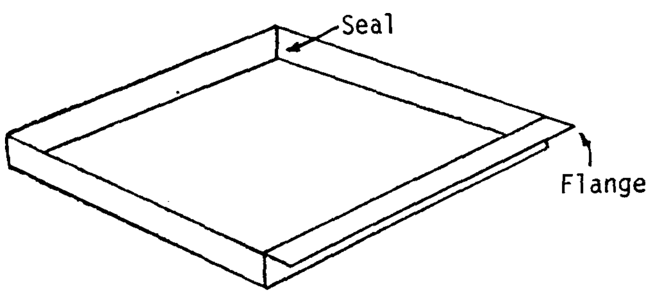


Nail or screw the four 20 cm pieces of wood (B) onto the four corners of the piece of plywood (A) used as the base. Make certain they are even with the edges of the base. Next, nail the four 21 cm pieces (C) into position between the.upright pieces, two at each side of the cage. Nail the lower ones to both the base and uprights. Nail the three 26 cm pieces (D) between the uprights, one at the top front, and two in the rear, top and bottom. Finally, nail the four 16 cm pieces (E) into position at the two back corners of the cage, one on each side of each upright.

(2) Tray

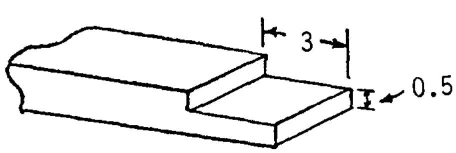
Cut the sheet metal (F) to the given pattern. Bend up the sides along the dotted lines and bend down the flange at the front. Seal the corners with a waterproof sealant (e.g., pitch). The tray should slide easily into the cage and protrude from the front for 1.0 cm.

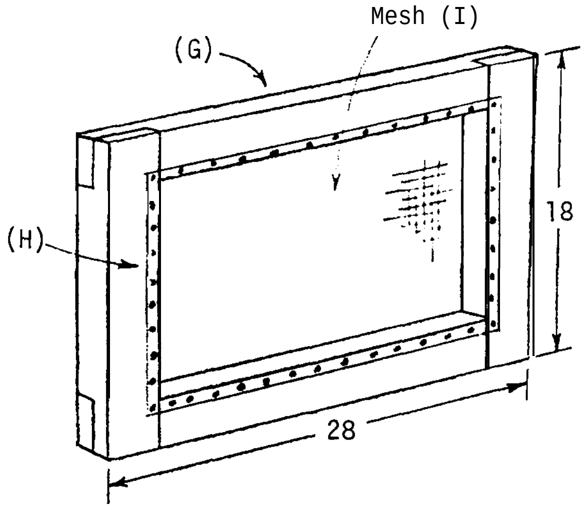




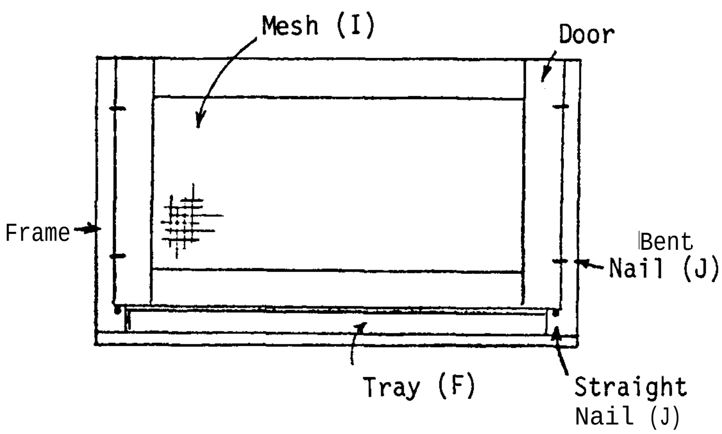
3) Door

Make the door from the four pieces of wood (G,H) by using half-lap joints. This simply involves cutting away half the piece of wood where the two pieces to be joined overlap.





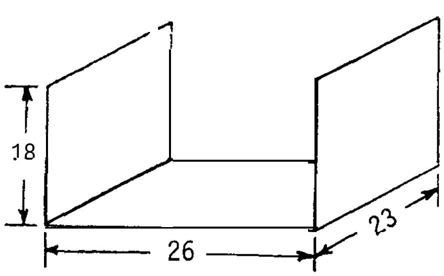
Nail the wire mesh (I) to the back of the door making certain that it covers all wood portions completely to discourage gnawing animals like mice. If possible, use mesh with openings about 0.5 cm square rather than regular wire screening that is used in house screens.



Front View

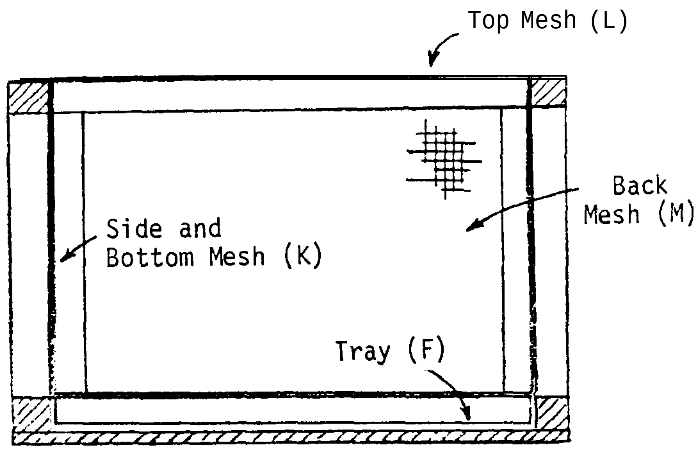
To form a holder for the door, first hammer two nails (J) into the front of the frame at a level even with the top of the tray. Drive. them in 1 - 1.5 cm but do not bend them. Set the door on these two nails and be certain that it com- pletely covers the opening. Nail two nails (J) on each side of the door as close to it as possible and bend them over so that they hold the door in an upright position. The door should slide easily in and out of position. Remove the door while completing the cage con- struction.

(4) Wire Mesh



Mesh (K)

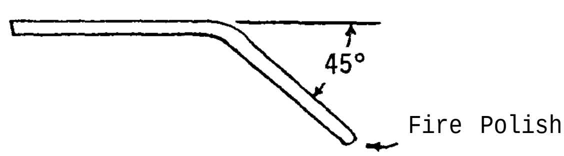
Fold the long piece of wire mesh (K) (again, use the 0.5 cm square size if possible) to the shape shown. Then, nail the 20 cm piece (M) into position to seal off the rear of the cage. Next, nail the folded piece (K) into position so that



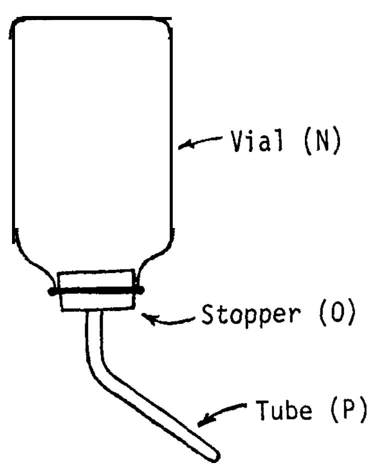
Cross Section View

the sidepieces cover the sides of the cage completely. The bottom of the screen will be 2 cm above the floor of the cage (actually, it will be level with the top edge of the tray). Properly done, wire mesh should cover the inside of the cage so that no wood is exposed. Finally, nail the remaining piece of mesh (L) onto the top of the cage.

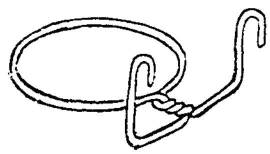
(5) Water Bottle



Begin the water bottle by bending the glass tube (P) in the middle to about a 45° angle. Fire polish one end until the opening constricts very slightly. Insert the other end of the tube into the stopper (0). Fill the vial (N) with water and seal the opening with the stopper.



When the vial is upside down water should flow down into the tube and stop at the end. One may have to tap the tube lightly with a finger to break up air bubbles in the tube.



Hanger (Q)
(Vial not shown for clarity)

To make a hanger for the water bottle, use the piece of stiff wire (Q). Twist the wire around the stopper, then bend the loose ends as shown. The water bottle can then be hung on the outside of the cage with the glass tube sticking through the wire mesh. Animals such as mice and gerbils soon learn to lick the end of the tube to obtain water.

C. Notes

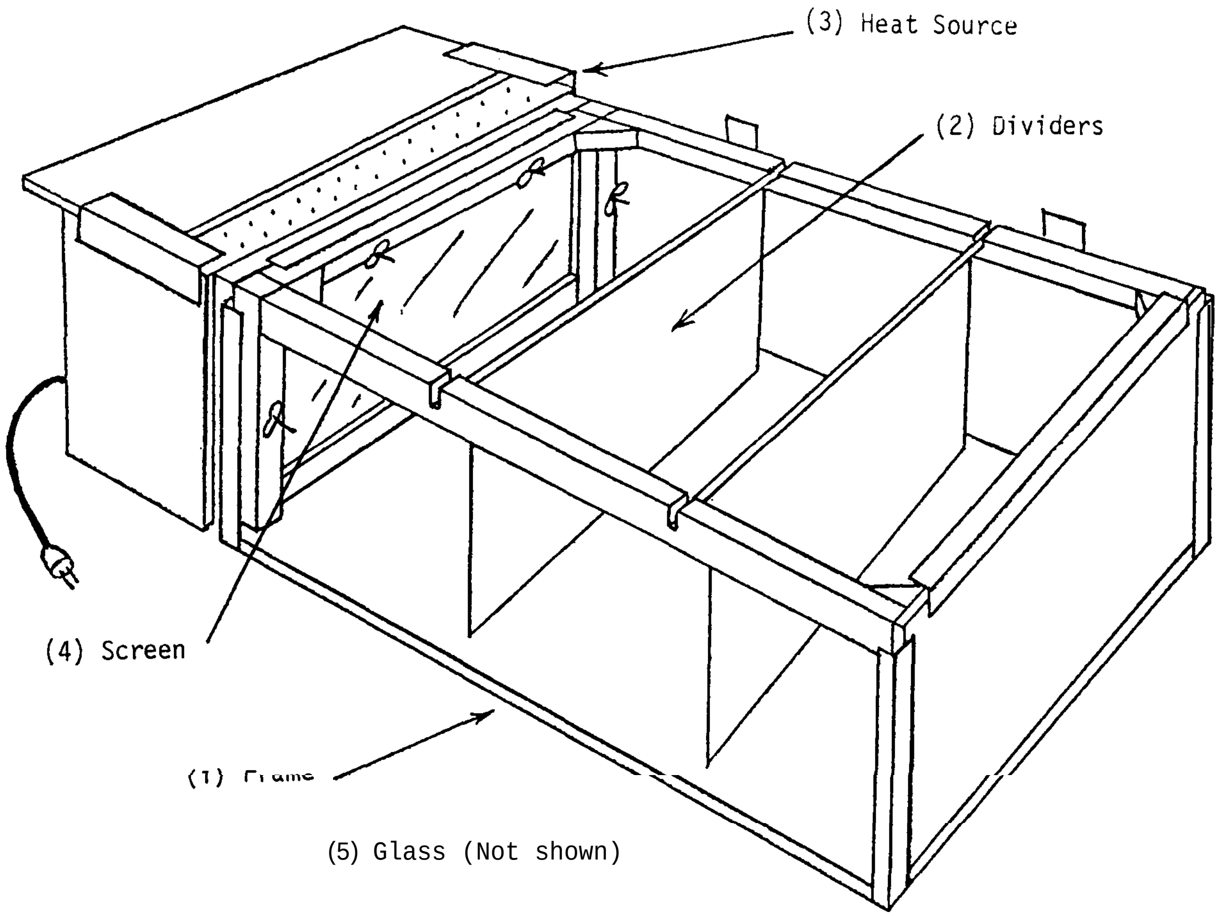
(i) This cage is intended for long-term housing of small mammals. Cover the screen floor with shredded newspaper or sawdust. Wastes fall through the screen floor onto the tray so they can easily be removed. Food can be simply put into a jar lid or shallow tin can.

(ii) The basic design of this cage can be retained and the dimensions altered to accomnodate other animals, especially birds. Remember to provide the basic requirements for each different type of animal (e.g., perches for birds).

(iii) If space is limited, these cages will stack one upon the other. However, the door must be hinged to swing open if it is undesirable to unstack them each time a lower cage is to be opened.

C. TEMPERATURE CONTROLLED CAGES

Cl. Vivarium



(5) Glass (Not shown)

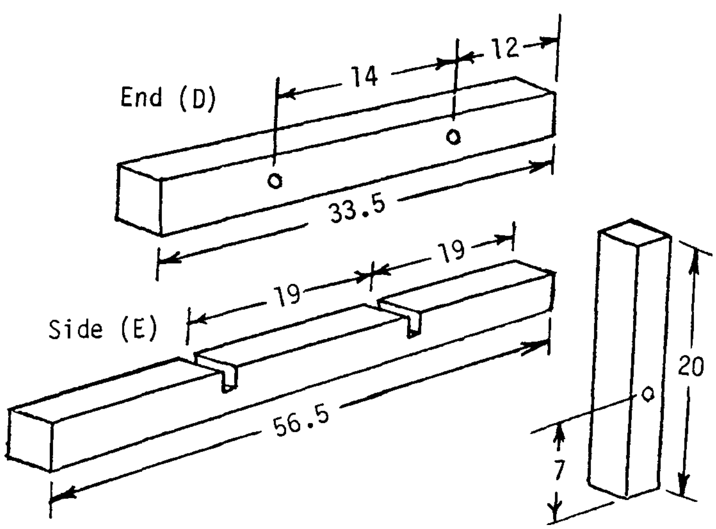
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	60 cm x 45 cm x 1.0 cm
	1	Plywood (8)	43.5 cm x 20 cm x 1.0 cm
	2	Wood (C)	20 cm x 2.5 cm x 2.5 cm
	1	Wood (D)	38.5 cm x 2.5 cm x 2.5 cm
	2	Wood (E)	56.5 cm x 2.5 cm x 2.5 cm
	2	Wood (F)	4 cm x 4 cm x 2 cm
	4	Sheet Metal (G)	5 cm x 21 cm x 0.05 cm
	2	Sheet Metal (H)	40 cm x 5 cm x 0.05 cm
(2) Dividers	2	Wood Dowels (I)	42 cm long, 0.75 cm diameter
	2	Cloth (Cotton) (J)	38 cm x 25 cm

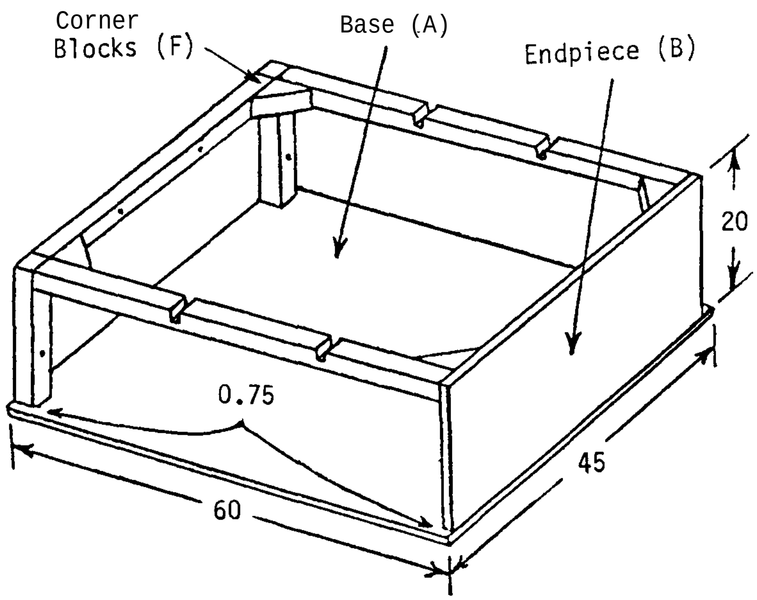
(3) Heat Source	1	Plywood (K)	44 cm x 16 cm x 1.0 cm
	1	Hardboard (L)	16.5 cm x 45 cm x 0.3 cm
	1	Plywood (M)	20 cm x 44 cm x 0.5 cm
	2	Plywood (N)	16.5 cm x 21 cm x 0.5 cm
	2	Wood (O)	20 cm x 4 cm x 1.0 cm
	1	Wood (P)	36 cm x 4 cm x 1.0 cm
	2	Sheet Metal (Q)	14 cm x 5 cm x 0.05 cm
	1	Plywood (R)	44 cm x 15 cm x 0.5 cm
	1	Light Bulb Socket (S)	Varies
	1	Light Bulb (T)	Varies
	1	Electric Cord (U)	150 cm long
		Plug (V)	Varies
(4) Screen	4	Bolts (W)	8 cm long, 0.5 cm diameter
	4	Wing Nuts (X)	0.5.cm inside diameter
	1	Wire Screen (Y)	20 cm x 45 cm
	2	Wood (Z)	21 cm x 3 cm x 0.5 cm
	2	Wood (AA)	39 cm x 3 cm x 0.5 cm
	2	Wood (BB)	45 cm x 3 cm x 0.5 cm
	2	Wood (CC)	15 cm x 3 cm x 0.5 cm
(5) Glass	1	Window Glass (DD)	59 cm x 44 cm x 0.25 cm
	2	Window Glass (EE)	19 cm x 59 cm x 0.25 cm
	2	Sheet Metal (FF)	12 cm x 4 cm x 0.05 cm

b. Construction

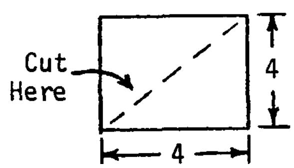
(1) Frame



Notches must be made in the two sidepieces (E) into which the dividers will be fit, Also, holes need to be drilled through the end (D) and the two uprights (C) through which the bolts hold the frame, screen, and heat source are put. However, these holes should be drilled when the three components (frame, screen, heat source) are held together in place with clamps in order to insure that the holes will be aligned.

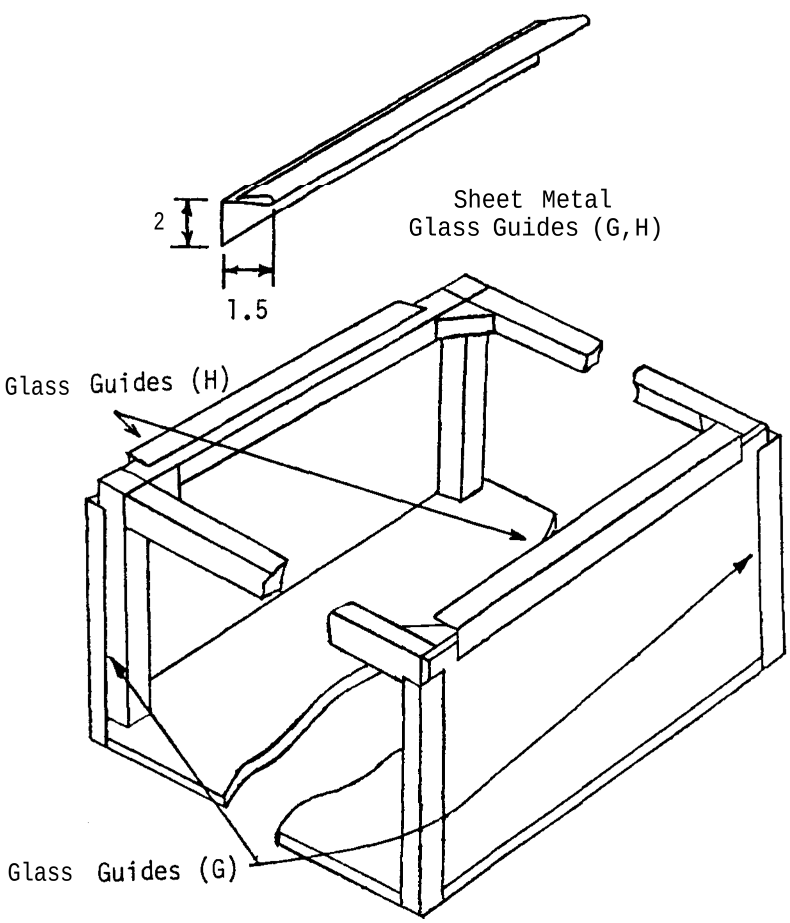


Nail, screw and/or glue the endpiece (B) to the base (A), flush to one edge and 0.75 cm from the other two edges. Nail two uprights (C) to the base, flush to the opposite end and each 0.75 cm from the outside edge. Nail the sidepieces (E) into position between the uprights and endpiece, and also nail the end (D) between the two uprights.



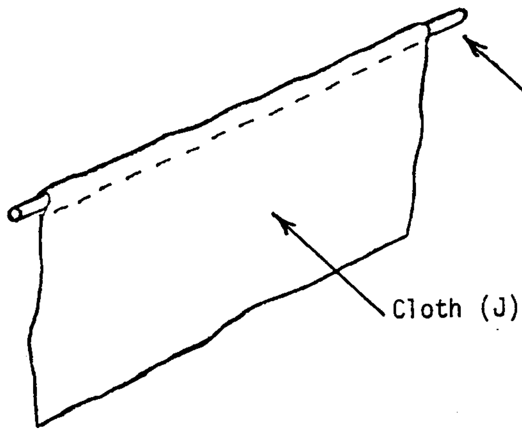
Corner Blocks (F)

Two square pieces of wood (F) cut into triangular shapes are used as corner blocks to provide additional support and strength.



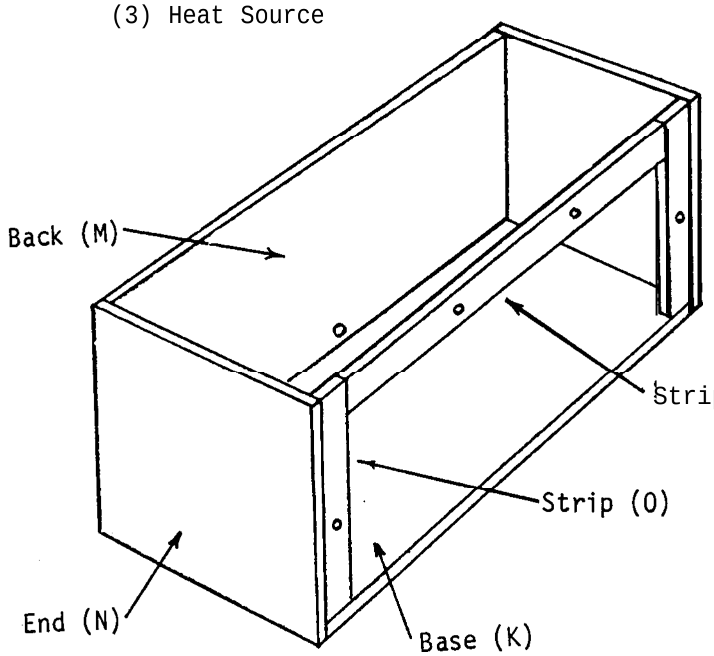
To provide guides for the glass, six rectangular pieces of aluminum sheeting (G, H) (0.05cm thick) are required. They are folded to the shape shown. Four (G) are nailed to the upright and endpiece. The remaining two (H) are nailed to the end and endpiece. These guides should be fastened in such a way as to provide approximately a 0.75 cm gap between wood and metal so that the glass can slide easily in and out.

(2) Dividers



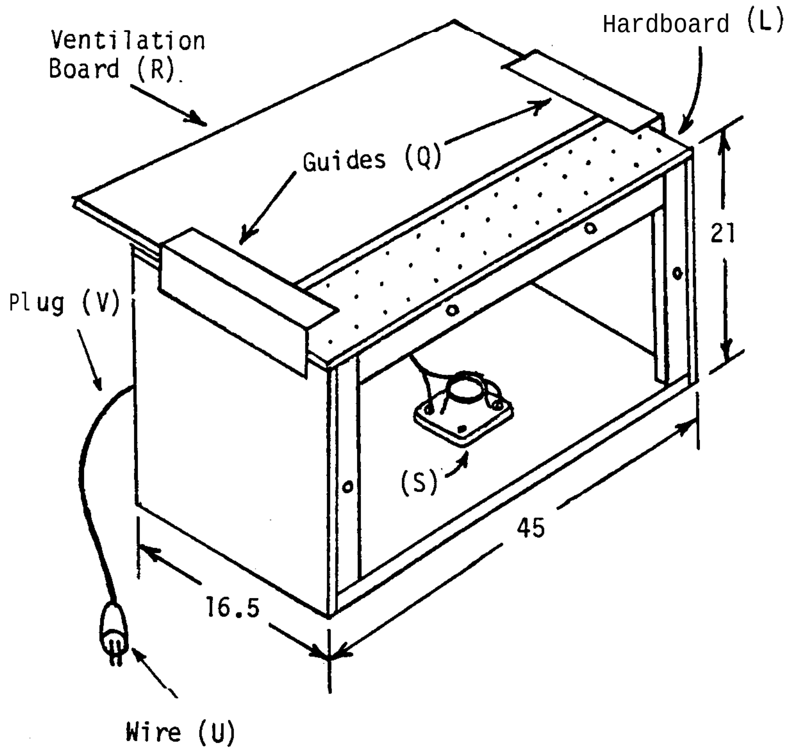
The dividers are simply made with wooden dowels (I). A piece of cotton cloth (J) is sewn around the dowel, and hangs down to within 1 or 2 cm of the base. The dividers (two are needed) are fit into the notches in the frame sides.

(3) Heat Source



Use the piece of plywood (K) as the base of the heat source. Fasten the two plywood pieces (N) to the ends of the base and the third plywood piece (M) to the back. Nail two of the wood strips (O) to the base and ends,and nail the remaining strip (P) between these two pieces (O).

Nail the piece of hardboard (L) to the top of the frame to enclose it. This hardboard should be the perforated type with 0.5 cm holes spaced every 2.5 - 3.0 cm. If such hard-board is not available, it can easily be made by making holes in regular board. Holes must also be made in the heat source, but again, these should be



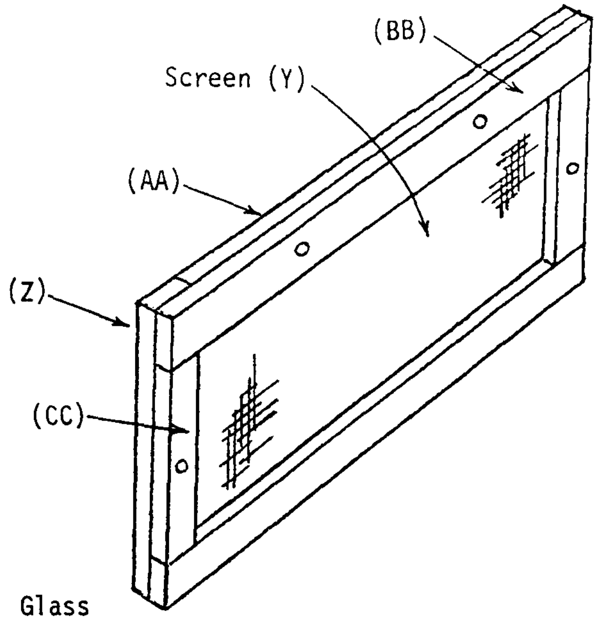
drilled when the frame, screen, and heat source can all be held together with clamps to insure alignment of the holes. Drill another hole in the back to allow the wire to the light bulb socket to run through.

Two guides (Q) are needed for the ventilation board, and are nailed to the sides of the heat source. Make these like the glass guides described in construction step (1). The ventilation board (R) is made of thin plywood slightly shorter in length and width than the top of the heat source. It should slide easily in and out between the guides (Q).

Finally, fasten a light bulb socket (S) in the middle of the heat source. Wire a plug (V) to the socket with the wire (U) and lead it out of the box through a small hole drilled in the back. Screw a bulb (T) in place.

(4) Screen

The screen is made with eight pieces of wood. Form two rectangular frames. Make one by nailing two pieces of wood (CC) between the two pieces (BB), and the second frame by nailing two pieces (AA) between the shorter pieces (Z). The aluminum screening (Y) (wire mesh) is fastened between the two frames with nails, and the frames are nailed and glued

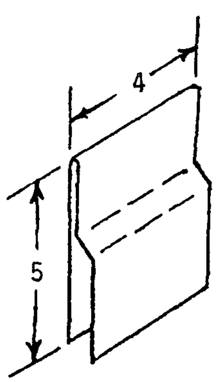


(5) Glass

together. The four holes for the connecting bolts (W) will be made when the three components (frame, screen, heat source) are clamped together, and the holes are drilled through all three parts at once.

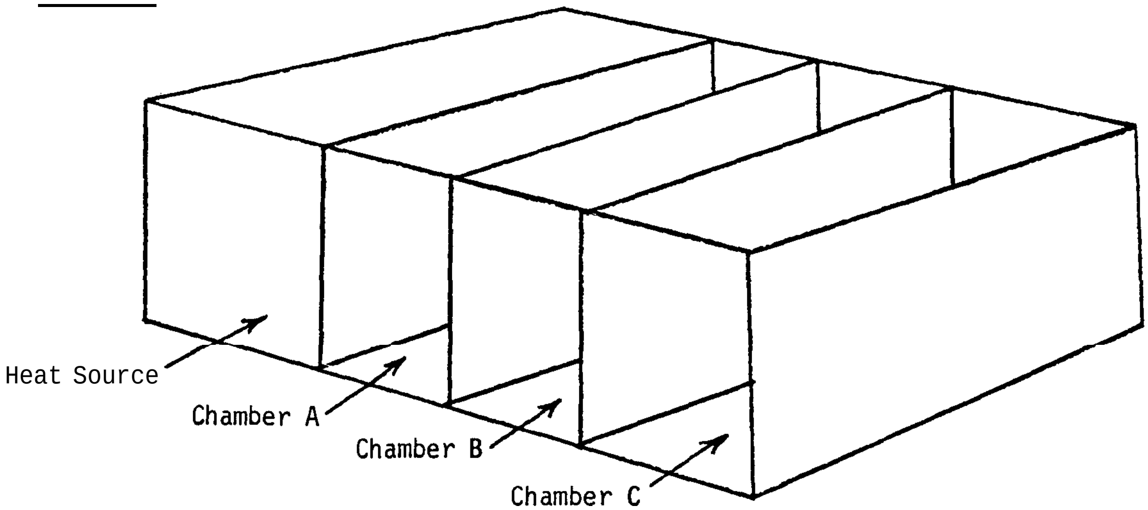
The heat source, screen, and frame are connected together with the bolts (W) and wing nuts (X).

Three glass plates are not shown in the main illustration in order to preserve clarity. However, the two side plates (EE) are made from standard window glass (0.2 cm in thickness). They fit between the glass guides on the frame sides. The top plate is also window glass (DD). The top plate of glass fits between the two glass guides on the top of the frame. Any of the three pieces of glass should slide easily in and out of place when the other two are in position. Additionally, air gaps should be kept to a minimum.



Finally, two pieces of aluminum sheeting (FF) can be folded to the shape shown and slipped over the top edge of one of the side pieces of glass (EE). These pieces of aluminum then act as stops to keep the top glass plate (DD) from sliding out.

C. Notes



(i) The vivarium is a cage in which the cloth dividers are used to loosely partition the interior into three chambers. The heat source employs light bulbs as the heating elements. A desirable result would be to maintain an even temperature gradient (i.e., 35°, 30°, 25° C) in the three chambers so that animals placed in the vivarium could seek their own optimal temperature level. For instance, the temperatures given above would imply that it was thought that the optimal environmental temperature for a given animal was 30°C (the temperature maintained in Chamber B). In this case, even if the vivarium were placed out-of-doors and subjected to temperature fluctuations of ± 5°C, one of the chambers would still maintain the 30°C level (e.g., temperatures in the vivarium might be depressed to 30°, 25°, 20° or elevated to 40°, 35°, 30° C). In order to insure that the desired temperature is maintained in at least one chamber, it may be necessary to increase the number of chambers from the three used in this experimentation, In fact, all the conclusions given here must be qualified by the limited nature of the experimentation.

(ii) Following construction of a vivarium, experimentation was carried out to determine which variables affect the establishment of the temperature gradient, and how these variables affect this gradient, both separately and in combination. Variables found to influence the temperature gradient included bulb size (wattage), divider material, height of the dividers above the floor of the cage, use of a reflector in the heat source and ambient (room) temperature.

(iii) Generally, increasing the bulb size (wattage) caused a marked increase in temperature in Chamber A, less so in Chamber B, and little or no change in temperature in Chamber C. The result was that the temperature gradient, rather than increasing in equal increments (i.e., 34°, 30°, 26° C), tended to increase in unequal increments (e.g., 36°, 26°, 23° C).

(iv) The material from which the dividers are made was found to have little effect on the temperature gradient maintained in the cage, but the amount of space left between the bottom of the dividers and the vivarium floor did have a compacting effect on the temperatures, i.e., bringing those in Chambers A and C closer to that in B.

(v) As might be expected, using a reflector in the heat source caused an overall rise in temperature in the vivarium. The last variable to be investigated, ambient (surrounding) temperature, was seen to have a profound influence on the internal temperatures in the vivarium, and is probably the most important variable to be considered. No doubt, the vivarium walls will have to be altered using better insulating materials (e.g., wood rather than glass) in order to reduce the influence of the ambient temperature,

(vi) Some other variables which were not investigated also may have an effect on temperature control. Among these is the material in the screen between the heat source and cage itself. It was aluminum screening for all the experimentation described here, but may well have different effects if it were made from steel rods or other materials. The type and amount of ventilation will also be an influence.

The dimensions of the vivarium are also important since a larger cage will obviously be harder to heat and maintain. The number and size of the chambers are variables to be reckoned with.

Finally, the most important factor will be the animals and their requirements. Testing must be done to see if a reasonable range of temperatures can be maintained for a variety of animals (e.g., baby chickens, mice, lizards, etc.). If experiments are to be run involving the determination of optimal temperature requirements for a particular animal, the range of temperatures provided must be narrow enough so that there will be some assurance that the animal has indeed chosen its favorite temperature, and not simply chosen the lesser of three evils. For example, if the optimal temperature for a certain lizard is thought to be 30°C, then the range should be 30°C plus or minus 2° or 3°C rather than plus or minus 6° or 8°.

(vii) Experimentation was also done with the cloth partitions removed, making the vivarium a single chamber. Three conditions were checked using three different bulb wattages (60, 100, 175). In the first condition, the vivarium was used as described above, only without the cloth partitions. In the second condition, one half of the glass top was removed and replaced by wood, and in the third case, the entire top was wood, leaving only the front piece of glass. In all three instances, the aluminum foil reflector was used, and the ventilated top of the heat source was fully closed. The results of this experimentation are tabulated below.

Table I

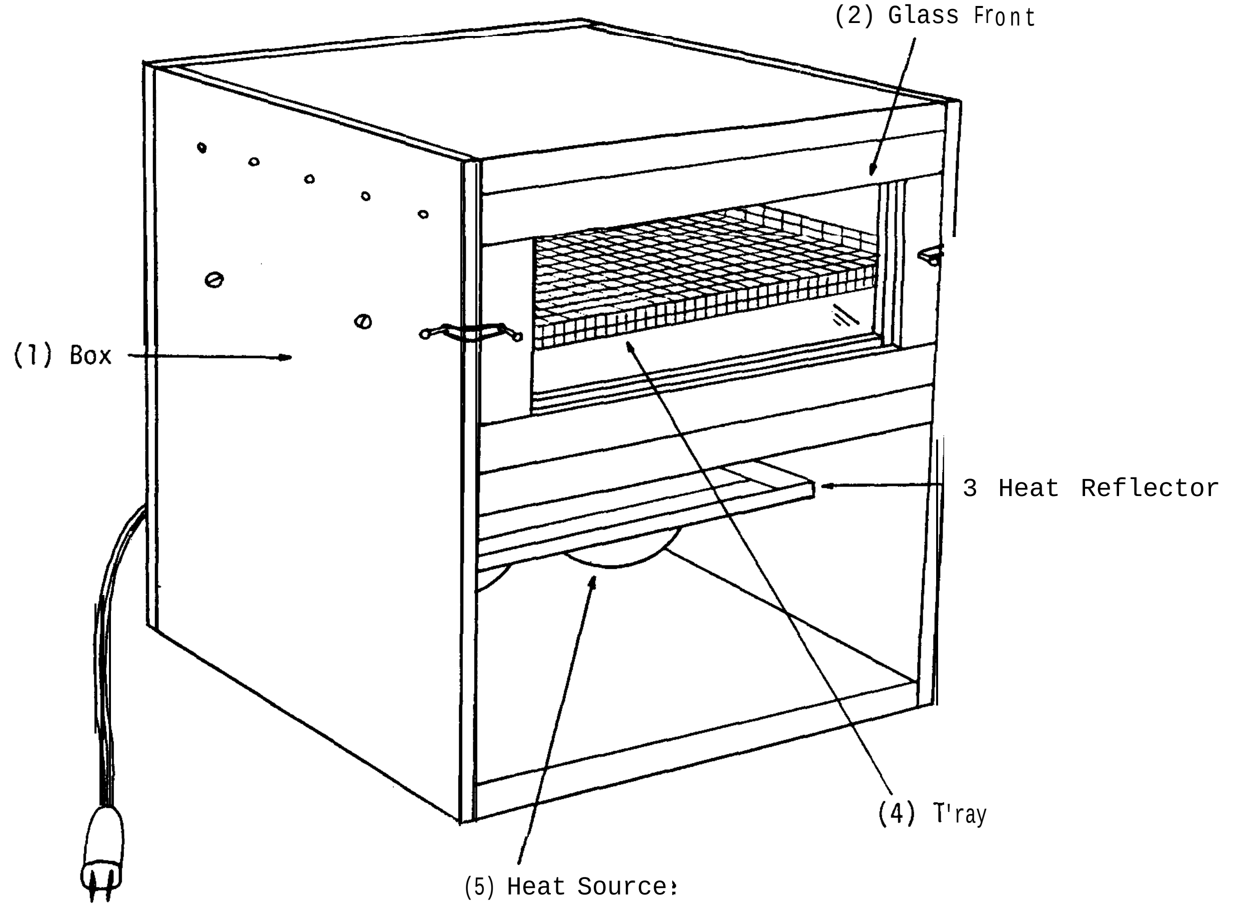
Condition	Wattage	Vivarium Temperature (°C)	Room Temperature (°C)
Top Completely Glass	60	26	22
	100	28	22
	175	33	22.5
Top One Half Glass, One Half Wood	60	26	22
	100	29	22.5
	175	38	24
Top Completely Wood	60	26	22
	100	30	22
	175	37	23

As the data show, there appears to be little significant difference in the various temperatures, although the additional wood does help hold the heat slightly better than the all glass top.

The vivarium will serve adequately as a controlled temperature environment as long as the ambient (room) temperature is kept relatively constant.

(viii) If the vivarium is to be used in a room where the outside temperature varies greatly, it is desirable to control its internal temperature more accurately. Therefore, use the thermostat, item VI/C3. Wire the heat source to the thermostat which should be mounted in the back panel of the vivarium if no wood is used in the top. Keep the thermostat as far from the heat source as possible. In addition, a screen or other protective device must be placed over the thermostat to prevent the animals (and students) from touching the exposed portions of the thermostat which carry current of 110 volts.

C2. Egg Incubator



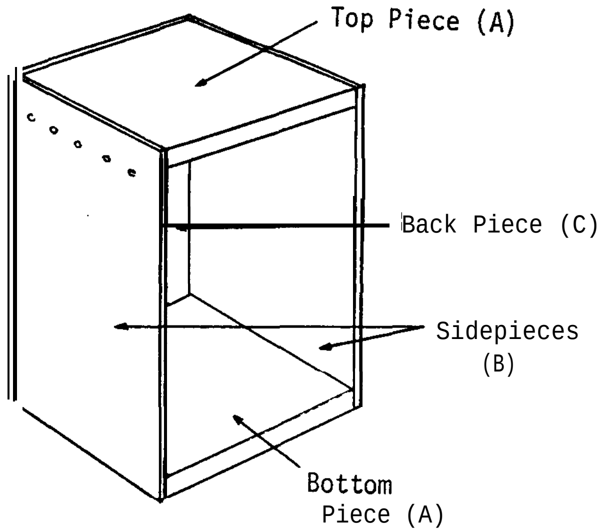
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Box	2	Wood (A)	23 cm x 20 cm x 1.5 cm
	2	Plywood (B)	20 cm x 36 cm x 1.0 cm
	1	Plywood (C)	25 cm x 36 cm x 1.0 cm
	1	Wood (D)	23 cm x 2 cm x 2 cm
	2	Wood (E)	14 cm x 1.0 cm x 1.0 cm
	1	Wood (F)	23 cm x 1.0 cm x 1.0 cm
	1	Plywood (G)	19 cm x 25 cm x 1.0 cm
(2) Glass Front	2	Glass (H)	18 cm x 10 cm x 0.3 cm
	2	Wood Strips (I)	10 cm x 0.5 cm x 0.5 cm
	2	Wood Strips (J)	17 cm x 0.5 cm x 0.5 cm
	2	Wood (K)	23 cm x 2.5 cm x 2 cm
	2	Wood (L)	15 cm x 2.5 cm x 2 cm
	4	Screws (M)	Approximately 2 cm long
	2	Rubber Bands (N)	--

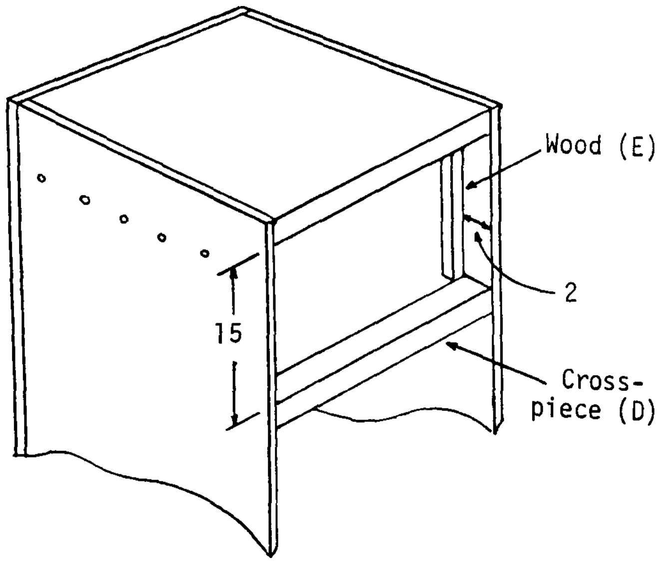
(3) Heat Reflector	1	Plywood (O)	23 cm x 15 cm x 1.0 cm
	1	Aluminum Foil (P)	28 cm x 20 cm
(4) Tray	1	Wire Mesh (Q)	26 cm x 20 cm
	4	Bolts (R)	Approximately 2 cm long
	4	Nuts (S)	To fit bolts
(5) Heat Source	2	Bulb Sockets (T)	10 cm diameter (base)
	4	Bolts (U)	Approximately 3 cm long
	4	Nuts (V)	To fit bolts
	1	Electrical Wire (W)	Approximately 100 cm
	1	Plug (X)	--
	2	Bulbs (Y)	--

b. Construction

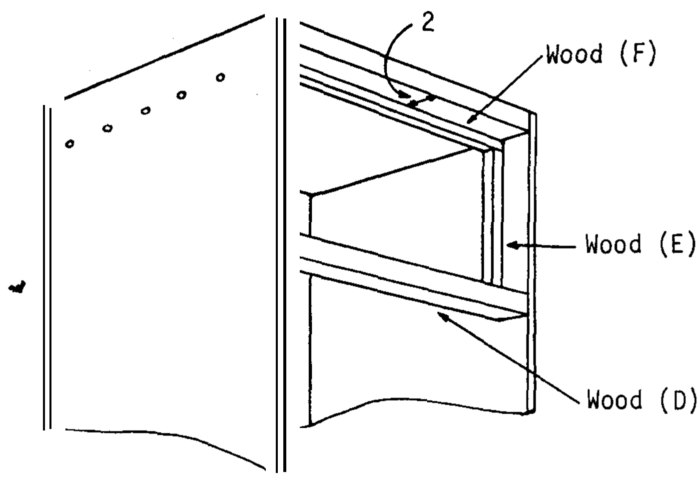
(1) Box

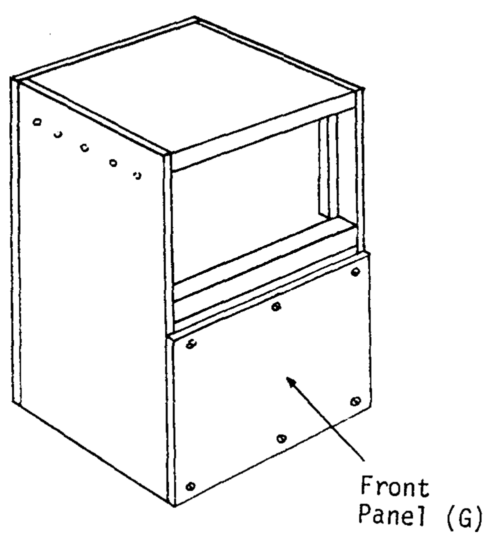


Nail or screw the two sidepieces of plywood (B) to the two pieces of wood (A) serving as the top and bottom of the box. Nail or screw the back (C) into position. Small ventilation holes (0.4 cm diameter) should be drilled along the tops of the sidepieces (B).



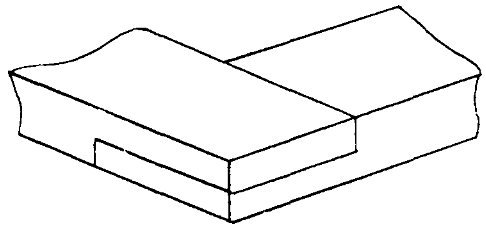
Make certain the crosspiece (D) fits very tightly, and nail or screw it into place. Nail or glue the wood strip (F) to the top (A), 2 cm from the front edge of the top. Likewise, nail or glue the other two wood strips (E) to the sidepieces (B), 2 cm from their front edges between the top (A) and cross-piece (D).



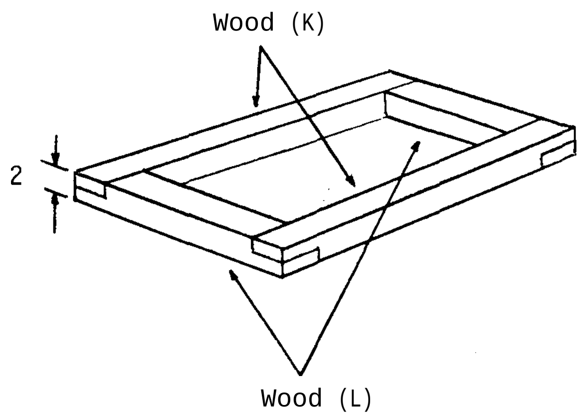


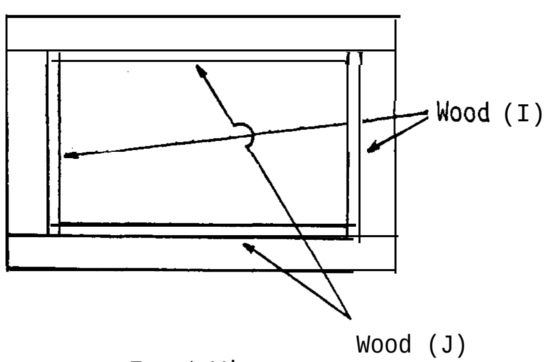
The front panel (G) is screwed into place so it may be easily removed to permit completing the construction of the incubator, and to permit changing the light bulb in the heat source.

(2) Glass Front

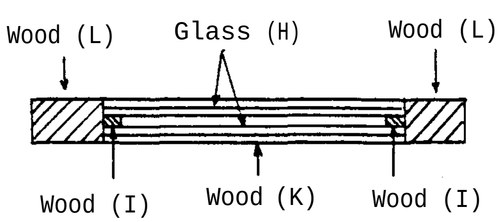


Half-lap Joint





Front View

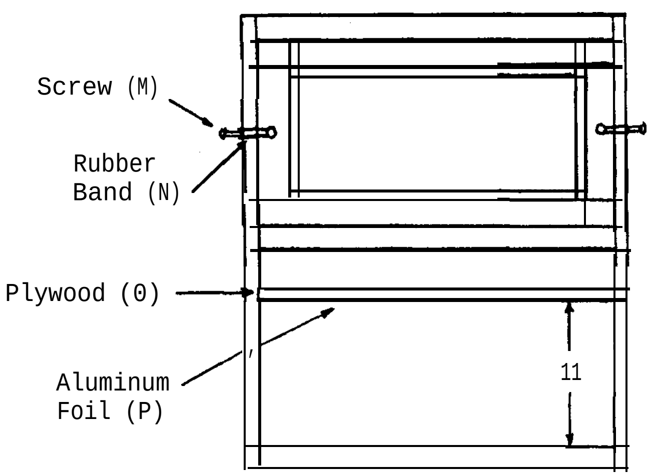


Cross Section

Make the frame for the glass front with half-lap joints (see drawing). Use this type of joint to connect the two short pieces of wood (L) to the two longer ones (K). Glue the two wood strips (I) down the center of the inner surface of the short wood pieces (L), and similarly, glue the longer strips (J) down the center of the inner surface of the long pieces (K). These thin strips serve to separate the two pieces of glass (H) which can now be glued into place with epoxy resin cement.

The glass front should fit tightly in the recess in the front of the box. To hold it in place, fasten one screw (M) on each side of the frame of the glass front and each side of the box adjacent to the glass front. Rubber bands (N) stretched tightly between adjacent screws should hold the glass front firmly in position.

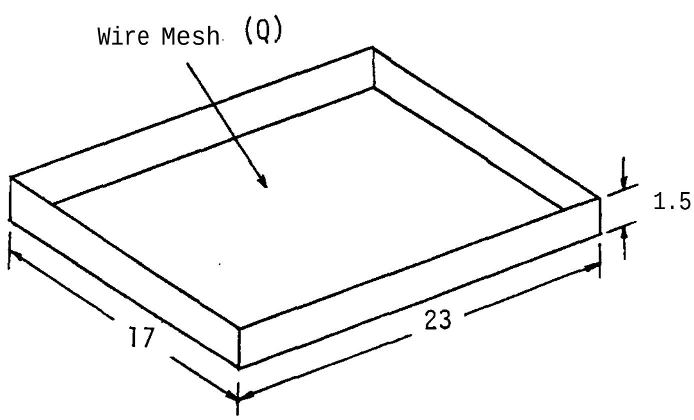
(3) Heat Reflector



Front View

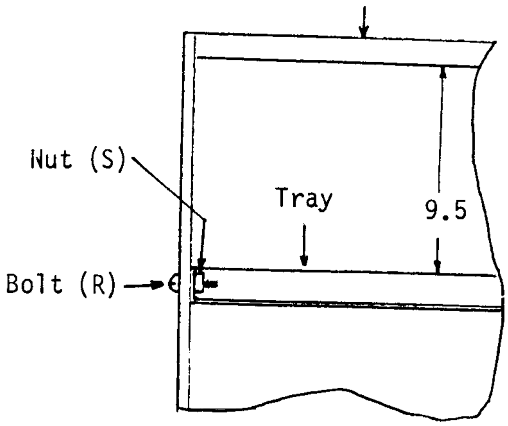
Cover the lower surface of the plywood (0) with the aluminum foil (P) and nail the heat reflector into position as shown. Be sure the rear edge is touching the back (C) of the box.

(4) Tray



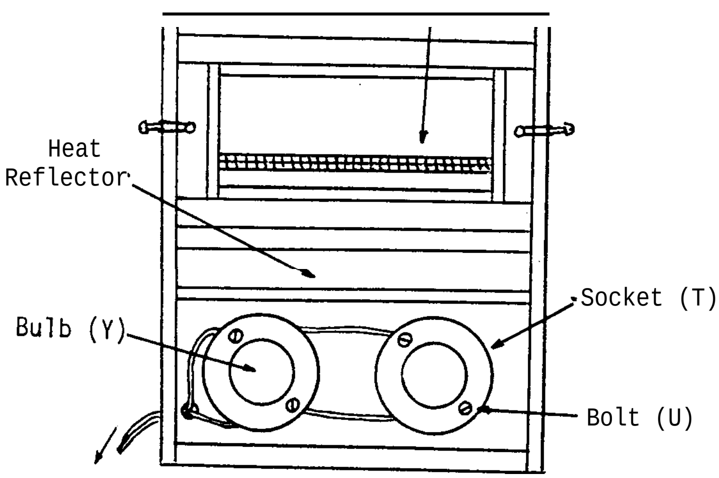
Tray (Diagram)

Use the wide (0.5 cm square) wire mesh (Q) for the tray and fold it so there is a 1.5 cm edge all around. Fasten it to the inside of the box by pinning the side edges of the mesh to the sides of the box with the nuts (S) and bolts (R). Obviously holes will have to be drilled through the sides of the box to permit passage of the bolts. The rear edge of the tray should touch the back (C) of the box.



Front View

(5) Heat Source



Front View

Drill four holes in the back of the box near the bottom through which the bolts (U) will be passed to hold the bulb sockets (T) in position. Wire the sockets together in parallel with short lengths of wire (W) and pass the remaining wire out of the box through a fifth hole drilled in the back. Wire the plug (X) in place, and tighten the nuts (V) onto the bolts (U) now that the bulb sockets are wired. Finally, place the desired number and power (wattage) of light bulbs (Y) in the sockets.

c. Notes

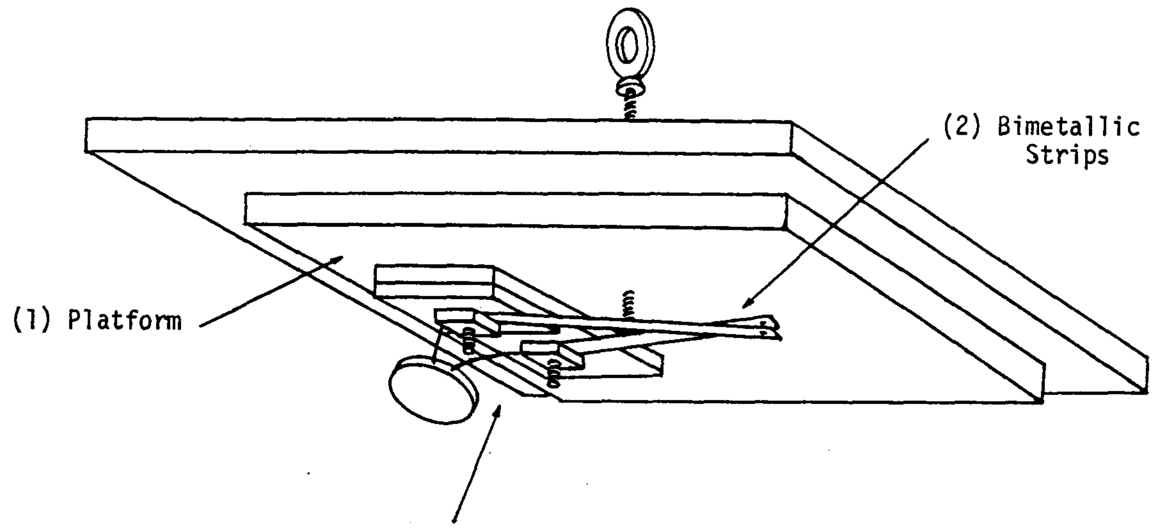
(i) Use the egg incubator in the study of the embryology of chicken or other eggs. The double glass front permits visual observation of the eggs on the tray without undue heat loss.

(ii) The temperature in the incubator will remain constant using varying wattages of light bulbs as long as the room temperature is relatively constant (see the table).

Watts	Incubator Temperature (°C)	Room Temperature (°C)
40	37.5	23.0
60	46.0	25.5
80	51.0	23.0
120	67.0	23.0

(iii) The thermostat (VI/C3) should be used with the incubator to insure that the internal temperature maintains itself at the correct level. Mount it in the top of the incubator, protected by a wire screen which will prevent hatchlings (and people) from touching the live wires. In fact, if the incubator is definitely to be used with the thermostat, increase the height of the top above the egg tray to insure that the hatchlings cannot touch the thermostat.

C3. Thermostat



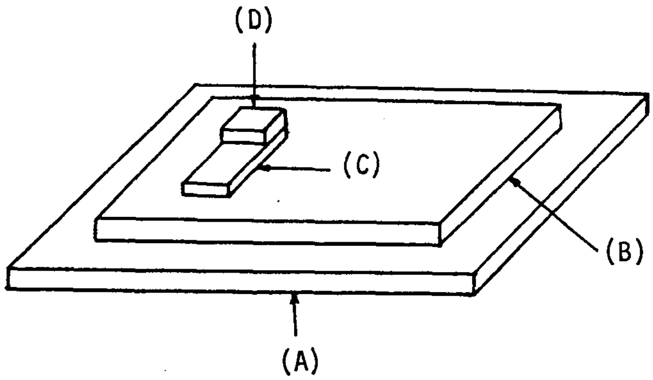
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Platform	1	Wood (A)	10 cm x 10 cm x 1.0 cm
	1	Wood (B)	6 cm x 6 cm x 1.0 cm
	1	Wood Strip (C)	3 cm x 2 cm x 0.5 cm
	1	Wood Strip (D)	2 cm x 1.5 cm x 0.5 cm
(2) Bimetallic Strips	2	Bimetallic (Brass/Steel) Strips (E)	Approximately 3.5 cm x 0.5 cm
	1	Platinum Wire (F)	#20, 3 cm long
	2	Bolts (G)	0.2 cm diameter, 4 cm long
	2	Nuts (H)	0.2 cm internal diameter
	4	Washers (I)	--
	1	Bolt (J)	0.3 cm diameter, 5 cm long
	1	Nut (K)	0.3 cm internal diameter
	1	Washer (L)	1 cm external diameter
	1	Plastic Tube (M)	0.3 cm internal diameter, 0.5 cm long
	--	Insulation Tape (N)	--
(3) Electrical System	1	Capacitor (O)	0.01 microfarads
	1	Roll of Copper Wire (P)	#20

1	Bolt (Q)	0.3 cm diameter, 2.5 cm long
2	Nuts (R)	0.3 cm internal diameter
1	Double Electrical Cord (S)	300 cm long
1	Plug (T)	110 volt

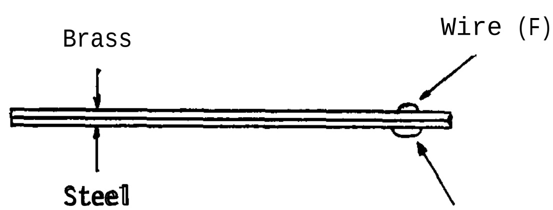
b. Construction

(1) Platform

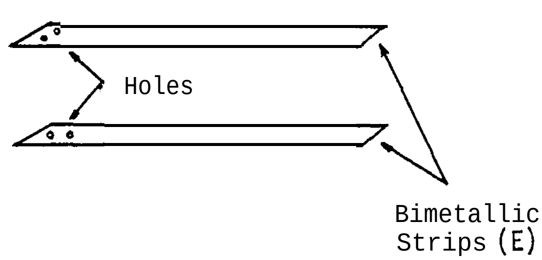


Glue the smaller wood piece (B) to the middle of the larger one (A). Next, glue wood strip (D) at one end of the other wood strip (E), and glue this resulting section near one edge of wood square (B).

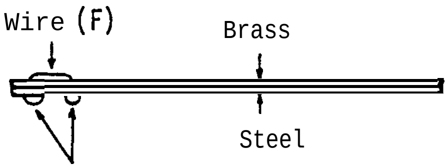
(2) Bimetallic Strips



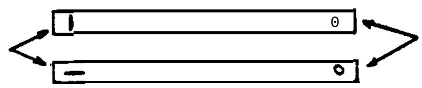
Side View



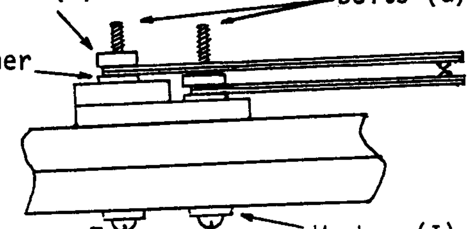
Drill a small hole (0.2 cm diameter or smaller) in one end of each bimetallic strip (E). Purchase these strips locally from a radio or electrical shop. Place a short piece of the platinum wire (F) through this hole and with a hammer, flatten each protruding piece of the wire flat as if the wire were a tiny rivet. Place a small drop of solder on the flattened portion of wire on the steel side of the bimetallic strip to insure good electrical contact. Alternatively, drill two very small holes in the end of each bimetallic strip, those in one strip in line with the short side of the strip and those in the other in line with the long side of the strip (see illustra-



Side View



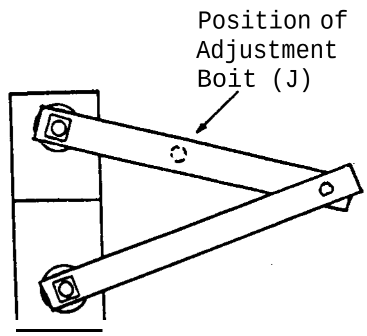
Top Views



Side View

tion). Place one end of a short piece of the platinum wire through each hole from the brass side of the strip and solder these ends to the steel side of the strip to provide good electrical contact. Flatten each wire slightly with a hammer to help make a greater surface area for electrical contact. Regardless of the manner in which the platinum is fixed to the end of the bimetallic strips, drill a small (0.2 cm diameter) hole in the opposite end of each strip. Also, make certain no solder is on the brass side of the bimetallic strips since this is likely to contaminate the surface of the platinum contacts.

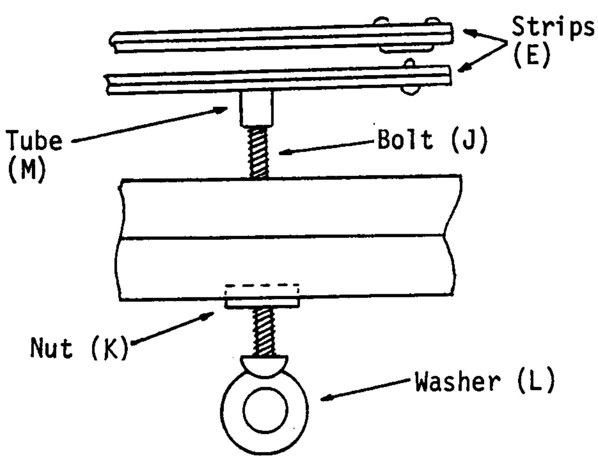
Next, drill two holes (0.2 cm diameter) through the platform, one through all four pieces of wood and the other through all but piece (D). Attach the bimetallic strips to the platform with the two bolts (G), two nuts (H), and four washers (I) as shown. The platinum contact point of the lower strip should face up while that of the upper strip should face down.



Top View

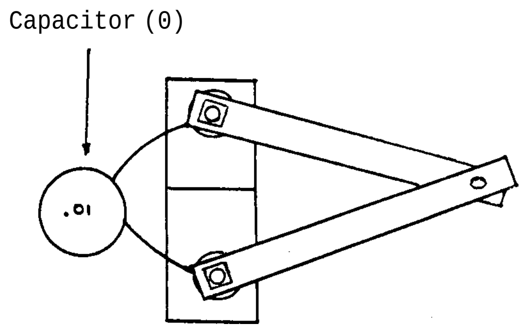
Pivot the free ends of the bimetallic strips toward one another so that the platinum contact points will touch one another when the strips are pressed together.

Side View



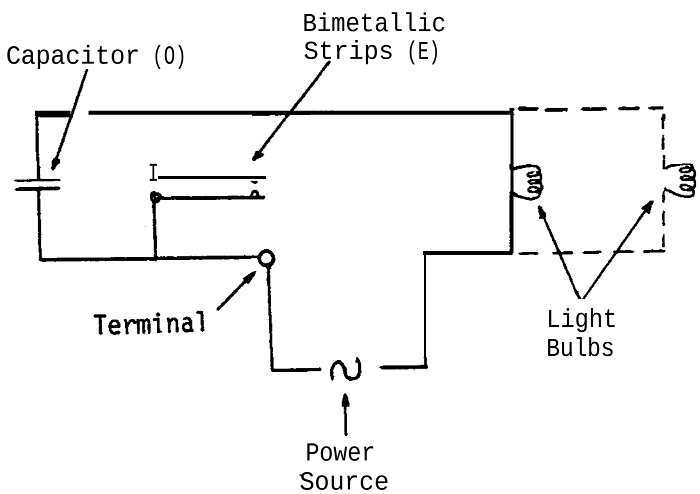
Drill a hole (0.3 cm diameter) through the platform directly below the middle of the lower bimetallic strip. Inset the nut (K) into the outside wood piece (A) directly over the hole. Thread the bolt (J) through the nut and hole. Place the piece of plastic tubing (M) on the end of the bolt (J) to prevent electrical contact between the bolt and metallic strip. Solder the washer (L) to the notch in the bolthead and cover both thoroughly with insulation tape (N). Make absolutely certain the bolt is completely insulated from the bimetallic strip as it will carry 110 volt current.

(3) Electrical System



Top View

Purchase the capacitor (0) locally, and connect it across the bimetallic strips. Cut a hole (6 cm x 6 cm) into the top of the container which is to be heated. The thermostat platform should fit firmly in the hole with the bimetallic strips beneath the platform.



Wiring Diagram

Use one piece of copper wire (P) to connect one of the bimetallic strips to one contact of the bulb socket of the heating source, and use another piece of the wire to connect the other bimetallic strip to a terminal [made from bolt (Q) and two nuts (R)] which must be put in the back of the cage or incubator which is to be heated. Then, connect the double electrical cord (S), with the plug (T) attached, to the terminal and the remaining contact on the bulb socket. The wiring circuit as shown in the diagram is now complete, and the thermostat is ready for use.

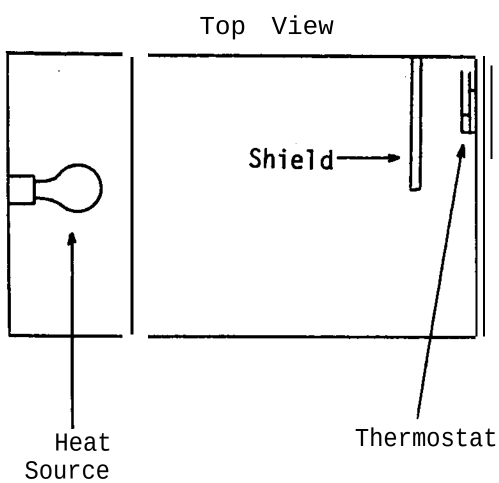
C. Notes

(i) It should be noted that due to lack of time the thermostat described here was tested out with the Microorganism Incubator (VII/A4) only. Care should therefore be taken to test the thermostat carefully when used in conjunction with either the Egg Incubator (VI/C2) or Vivarium (VI/Cl).

(ii) It was noted that using the thermostat the temperature of the Micro-organism Incubator took about 25 minutes to stabilize.

Time Minutes	Cage Temperature °C
0	40.5
5	39.0
10	38.5
15	38.0
20	38.0
25	37.0
30	37.0 stabilized

(iii) Do not permit direct radiation from the heat source to fall on the thermostat, otherwise the thermostat will switch itself off before the air temperature has risen to the desired level. Where there is a possibility of direct radiation falling on the bimetallic strips of the thermostat make an appropriate shield to stop the radiation without restricting the circulation of air around the bimetallic strips.



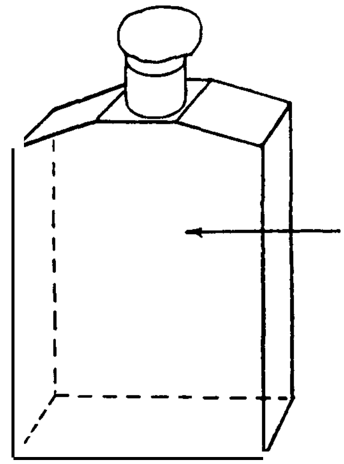
VII. MICROBIAL GROWTH APPARATUS

A. BASIC APPARATUS

Included here are improvised versions of the equipment necessary to perform elementary investigations in microbiology. Information on culturing microorganisms should be obtained from standard texts on the subject.

A. BASIC APPARATUS

Al. Culture Flask

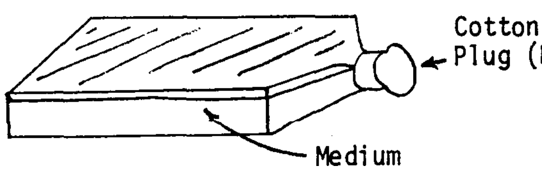


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Medicine Bottle (A)	About 100 ml or larger
	1	Cotton Plug (B)	--

b. Construction

(1) Bottle



Sterilize the bottle (A) and fill it 1/6 full of either liquid or gelatin culture medium. Stopper it with the cotton plug (B). I gelatin medium is used, lay the bottle on its side and allow the medium to set. Store the flask with the medium on the upper side of the flask so that no moisture film will form on the medium.

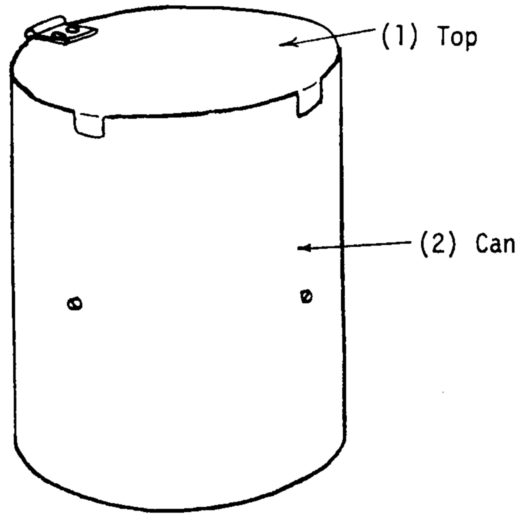
c. Notes

(i) Consult a standard microbiological text or source book for deta il in work ing with bacteria and other microorganisms.

(ii) Use glass medicine bottles with flat sides if these are available.

(iii) Petri dishes are invaluable in working with microbes. See CHEM/V/A6 for instructions in making petri dishes.

A2. Sterilizer



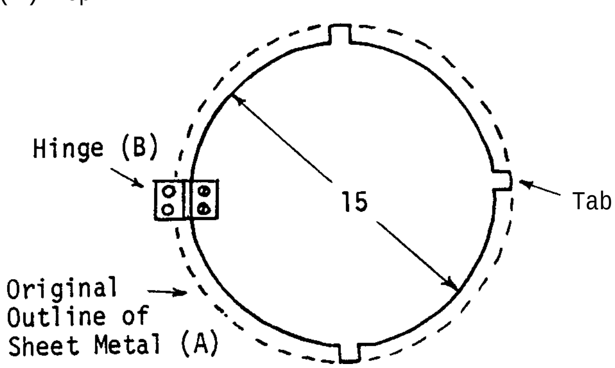
(3) Rack (Not visible)

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Top	1	Sheet Metal (A)	17 cm diameter, 0.075 cm thick
	1	Hinge (B)	3 cm x 2 cm
(2) Can	1	Tin Can (C)	15 cm diameter, 18 cm high
	4	Screws (D)	1.5 cm long
(3) Rack	1	Sheet Metal (E)	14.5 cm diameter, 0.075 cm thick

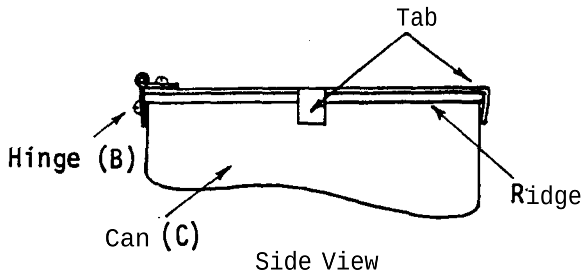
b. Construction

(1) Top



Cut the top from a circular piece of sheet metal (A). Leave three tabs to be bent down at right (90°) angles. The tabs are 1.0 cm long. Screw the small hinge (B) to the top directly opposite the middle tab.

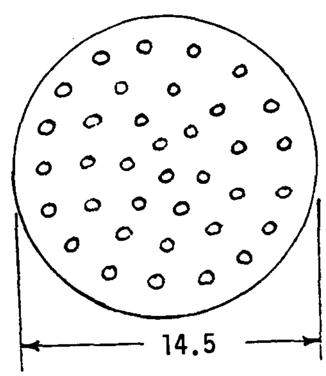
(2) Can



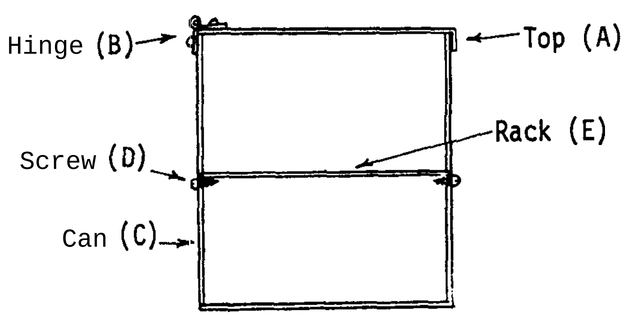
Side View

Remove one end from the tin can (C). Attach the top to the can by means of the hinge. Most tin cans have a ridge around the edge so that when the top is closed, the three tabs should catch on this ridge and hold the top down rather firmly. Finally, screw the four screws (D) through the outside into the inside of the can, 9 cm from the bottom and spaced about 12 cm apart.

(3) Rack



Punch a number of holes into the sheet metal disc **(E).** Set this disc inside the can so that it is supported by the four screws extending into the can.



Side View

(Cross-section)

C. Notes

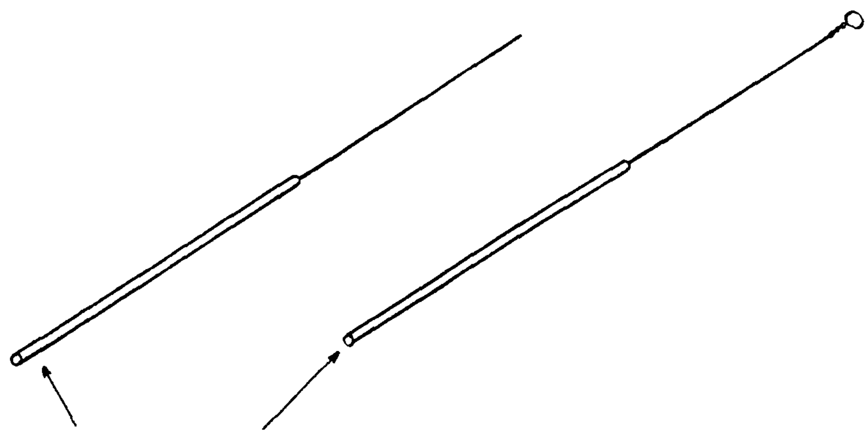
(i) To use the sterilizer, simply put 3 - 4 cm of water in the can and place the items to be sterilized on the rack. After the water has begun to boil, leave the items in the steam for about 90 minutes.

(ii) If the can used is large enough, two or more racks can be made for it to allow a larger number of articles to be sterilized at the same time.

(iii) This sterilizer will kill most, but not all, common bacterial contaminants. If pure sterility is desired, an autoclave or ordinary pressure cooker is needed. Place the articles on a rack and autoclave or pressure cook them for about 20 minutes.

(iv) An alternate rack can be made by fastening a circular piece of wire mesh to a frame of stiff wire.

A3. Inoculating Needles



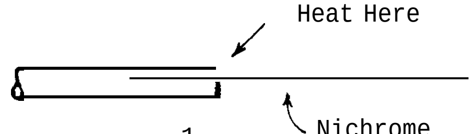
(1) Needle

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Needle	1	Glass Tube (A)	0.3 cm diameter, 12 cm long
	1	Nichrome Wire (B)	10 cm long, #24 gauge

b. Construction

(1) Needle



Side View

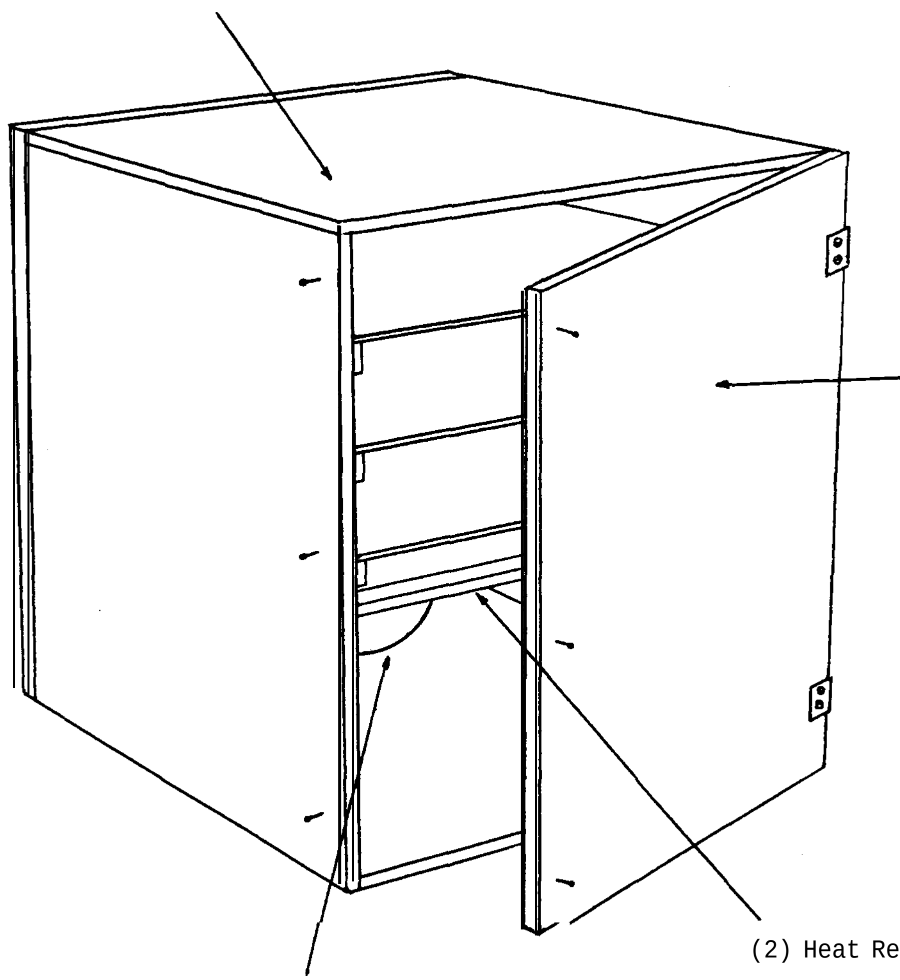
Use soft glass tubing (A) with a small diameter bore. Insert about 2 cm of the wire (B) in one end of the tube and heat this end in a hot flame until the end of the glass constricts and holds the wire fast.

c. Notes

(i) The nichrome wire may be left straight or a 0.3 cm loop may be made in the end by twisting the wire around a 0.3 cm round object with pliers.

(ii) Use inoculating needles for transferring small amounts of bacterial cultures from one medium to another.

A4. Microorganism Incubator



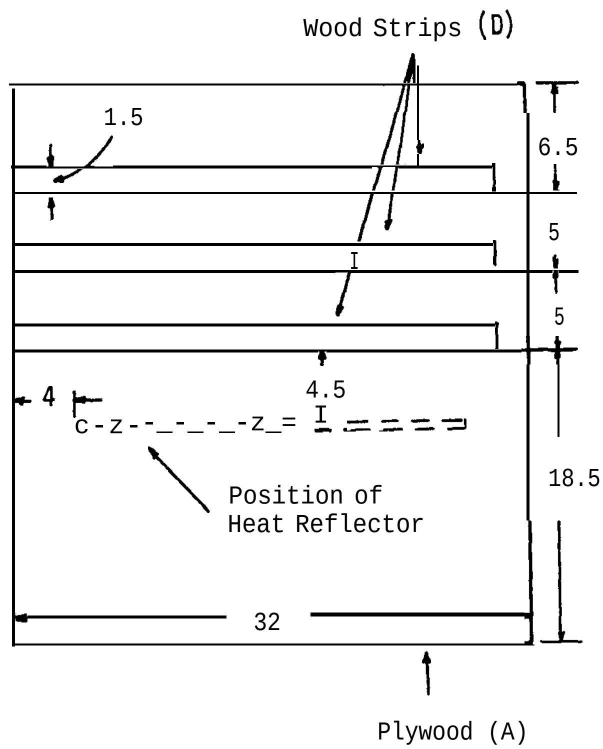
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame and Trays	3	Plywood (A)	35 cm x 32 cm x 1.0 cm
	1	Plywood (B)	33 cm x 32 cm x 1.0 cm
	1	Plywood (C)	35 cm x 36 cm x 1.0 cm
	6	Wood Strips (D)	30 cm x 1.5 cm x 1.0 cm
	3	Perforated Hardboard (E)	32.5 cm x 31 cm x 0.3 cm
(2) Heat Reflector	1	Plywood (F)	33 cm x 24 cm x 0.5 cm
	1	Aluminum Foil (G)	37 cm x 28 cm

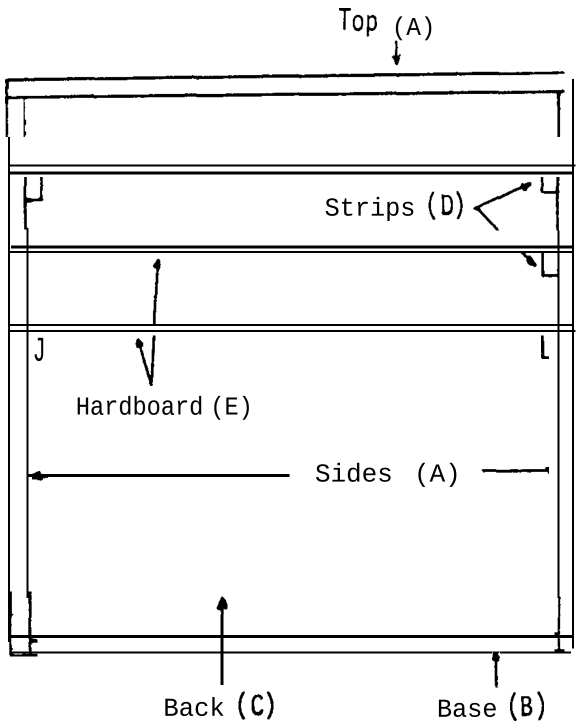
(3) Heat Source	1	Egg Incubator, Heat Source (H)	VI/C2, Component (5)
(4) Door	1	Plywood (I)	35 cm x 36 cm x 1.0 cm
	2	Hinges (J)	Approximately 4 cm long
	8	Screws (K)	0.7 cm long
	6	Nails (L)	1 cm long
	3	Rubber Bands (M)	--

b. Construction

(1) Frame and Trays



Nail three of the wood strips (D) to each of two of the pieces of plywood (A) as illustrated to make the two side pieces of the frame. Nail the bottom edges of the completed side pieces to the wood (B) used as the base. Nail the back piece (C) into position as well as the top piece (A). When the frame is finished, the pieces of perforated card-board (E) which serve as the trays should slide easily into the frame on the wood strips (D).



Frame and Trays

(Front view)

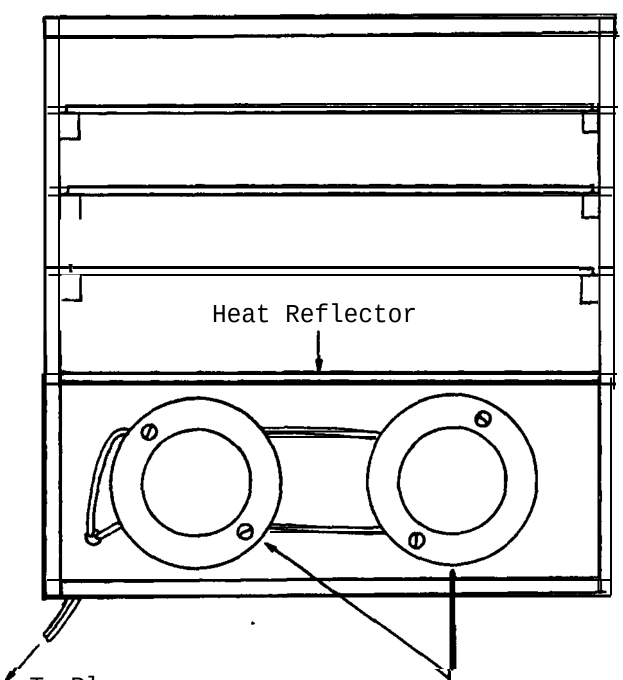
(2) Heat Reflector

Cover one side of the plywood (F) with aluminum foil (G) to make the heat reflector. Nail the reflector into place 13 cm above the base (B) of the frame with a 4 cm gap between the rear edge of the reflector and the back (C) of the frame.

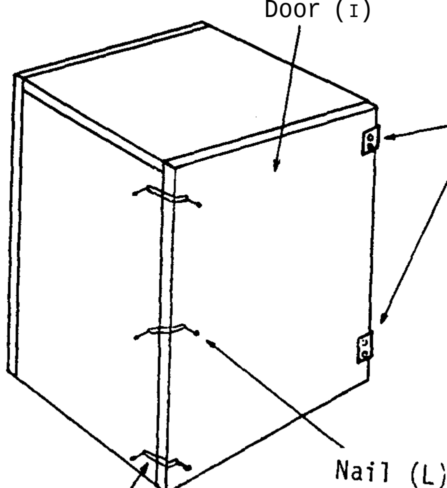
(3) Heat Source

Use two light bulbs as the heat source (H) exactly as described for item VI/C2, Component (5).

Front View



(4) Door



Fasten one edge of the plywood (I) to the side of the frame with the hinges (J) and screws (K) making certain the door shuts as closely to the frame as possible. Felt strips may be used as insulation between the door and frame if necessary, both to conserve heat loss and prevent the introduction of airborne contaminants. The door may be held closed by using rubber bands (M) which are stretched between adjacent pairs of nails (M) in the frame and door.

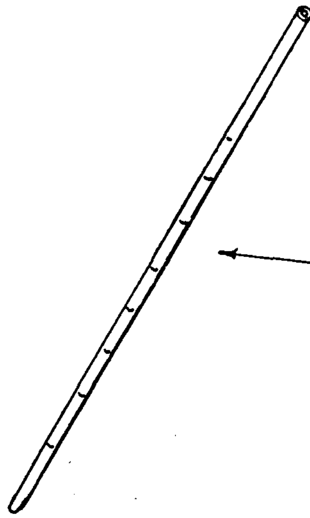
C. Notes

(i) Use the microorganism incubator to provide a proper environment for growing bacteria, mold, and other cultures. The dimensions of the incubator as given are to enable each tray to hold nine (three rows of three) standard petri dishes (9 cm diameter).

(ii) If the incubator is used in a constant temperature room, the temperature in the incubator can be held relatively constant. Using the correct combination of bulbs will yeild an internal temperature close to that desired. Rather than drilling ventilation holes to cool the incubator if it is too hot, it might be better to paint part of the light bulbs with black paint to cut down their heat, Ventilation holes would allow contaminants into the incubator. The following gives a few examples of temperatures which can be maintained in the incubator.

Wattage	Incubator Temperature (°C)	Room Temperature (°C)
40	35.0	23.5
60	40.5	22.0
80	48.0	23.5

(iii) The **thermostat(VI/C3)** should be used with the incubator to insure that the internal temperature maintains itself at the correct level. Mount it in the top of the incubator, protected by a wire screen which will prevent persons from touching the live wires, In fact, if the incubator is definitely to be used with the thermostat, increase the height of the top above the uppermost tray in order to insure that people placing cultures in the incubator have less chance of touching the thermostat, A5. Transfer Pipette

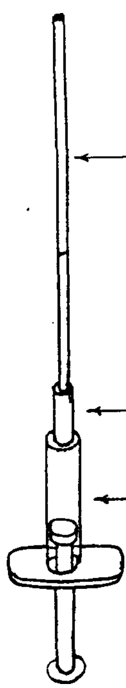


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pipette	1	Glass Tube (A)	35 cm long, 0.4 cm inside diameter

b. Construction

(1) Pipette



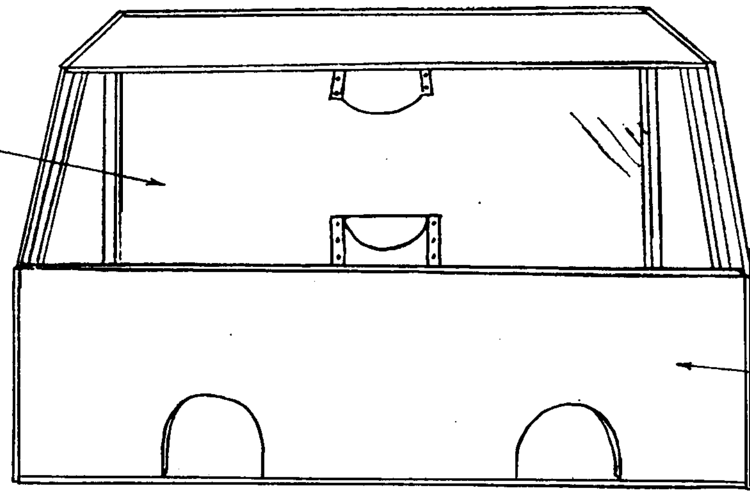
Hold one end of the glass tube (A) in a flame until the opening begins to constrict slightly. Remove it from the flame and let it cool when the opening is about 0.1 cm wide. To calibrate the pipette, a 10 cc (ml) syringe and short piece of rubber or plastic tubing is needed. Connect the ends of the pipette and syringe with the short (4 - 5 cm) piece of tubing. Fill the syringe and pipette with 7 or 8 cc of water and eliminate air bubbles by gently tapping the pipette. Hold the pipette vertically (syringe at the bottom) and withdraw the syringe plunger until the water empties from the pipette. Note the position of the syringe plunger on the scale and reinject water into the pipette 0.5 ml at a time until a total of 5 ml is reached. At each injection, mark the position of the water meniscus with a triangular file to form a permanent scale.

C. Notes

(i) This pipette is used in transferring exact amounts of culture broth from one container to another. Draw broth into the pipette with mouth suction and force the liquid out by gently blowing through the tube.

(ii) If desired, numbers may be written by the filed marks to indicate the capacity at that point. These numbers will last longest if they are drawn with waxed crayons or other types of pencils designed for writing on glass.

A6. Transfer Chamber *



a. Materials Required

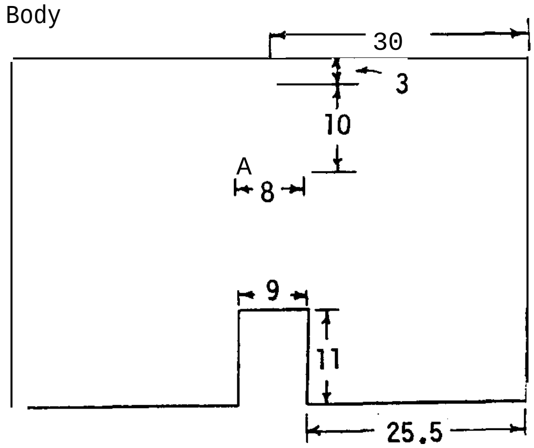
Components	Qu	Items Required	Dimensions
(1) Body	2	Plywood (A)	60 cm x 40 cm x 0.75 cm
	1	Plywood (B)	60 cm x 20 cm x 0.75 cm
	2	Plywood (C)	40.75 cm x 40 cm x 0.75 cm
	1	Plywood (D)	61.5 cm x 18 cm x 0.75 cm
	2	Wood (E)	60 cm x 2 cm x 2 cm
	2	Wood (F)	24 cm x 2 cm x 2 cm
	2	Wood (G)	36 cm x 2 cm x 2 cm
	2	Wood (H)	16 cm x 2 cm x 2 cm
	2	Wood (I)	37.25 cm x 2 cm x 2cm
	2	Wood (J)	28 cm x 2 cm x 2 cm
	2	Wood (K)	15 cm x 2 cm x 2 cm
	2	Wood (L)	6 cm x 2 cm x 2 cm
	1	Wood (M)	20 cm x 2 cm x 2 cm
	1	Aluminum Sheet (N)	25cmx11 cmx 0.05 cm
	1	Aluminum Sheet (0)	20 cm x 14 cm x 0.05 cm

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), pp 12-14.

(2) Glass	1	Window Glass (P)	28.5 cm x 58.5 cm x 0.3 cm

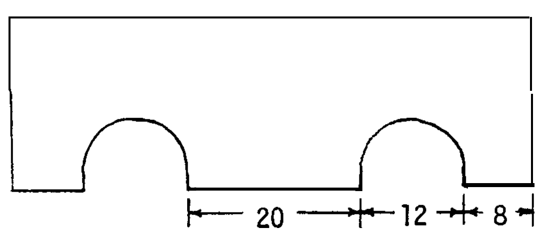
b. Construction

(1) Body



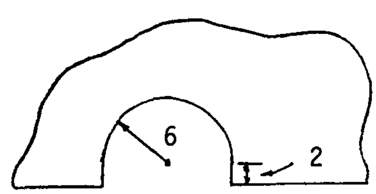
Plywood (A)

Begin the transfer chamber by cutting two holes into one of the large pieces of plywood (A). These will serve as ventilating holes when the chamber is enclosed.

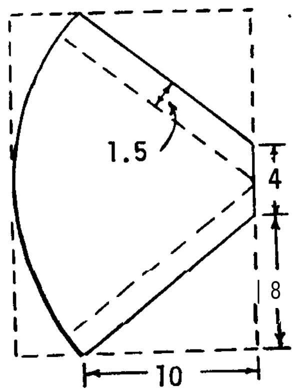


Plywood (B)

Cut two holes in the piece of plywood (B) to serve as arm-holes. The size and distance apart of these holes may be varied to suit personal prefer-ences.

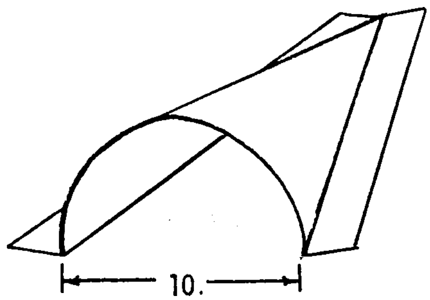


Detail of Hole



Pattern

Cut the piece of aluminum sheeting (0) (other metal sheeting may be substituted) to the given pattern. Bend up the straight sides along the dotted lines to form two flanges, each 1.5 cm wide.

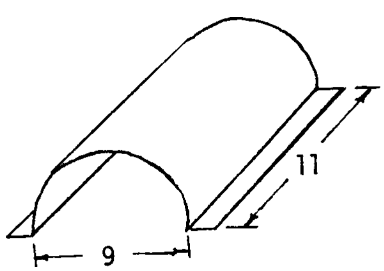


Half Cone

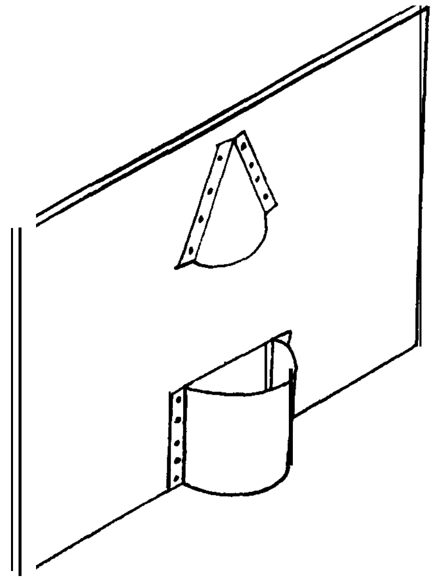
Poll the sheet metal (0) around a round object (e.g., a broom handle) until it takes the shape of a half cone.

Pattern

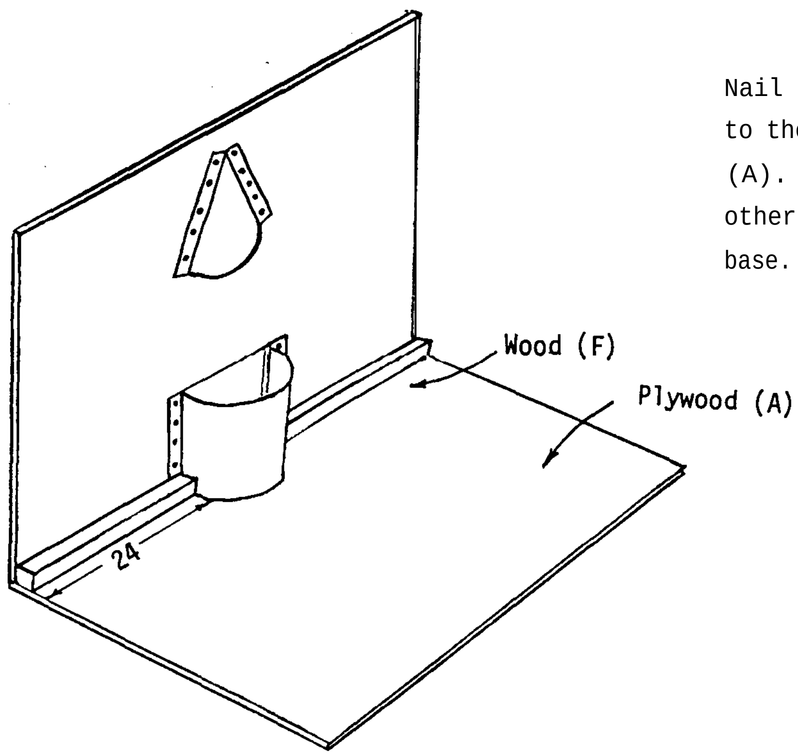
Similarly, bend up the two 11 cm sides of the other piece of aluminum (N), and roll it into a half-cylinder shape.



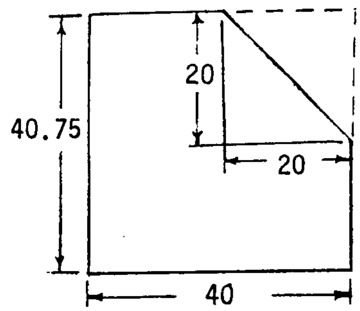
Half Cylinder



Nail the two aluminum pieces into position on the piece of plywood (A) in which the holes have been cut. Position the half cone directly over the triangular hole. Position the half cylinder so that its edges are even with the edges of the rectangular hole.

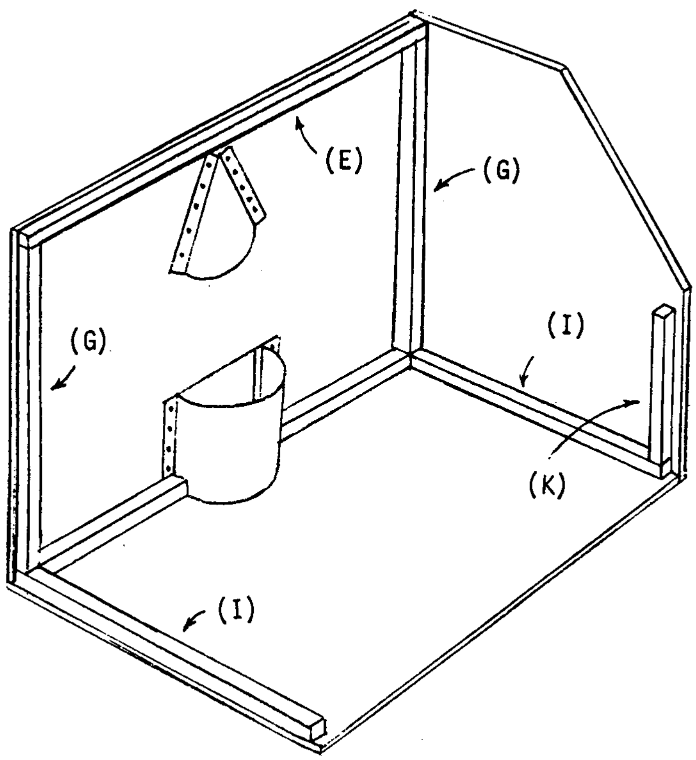


Nail the two wood strips **(F)** to the bottom edge of the back (A). Nail this in turn to the other plywood (A) used as the base.



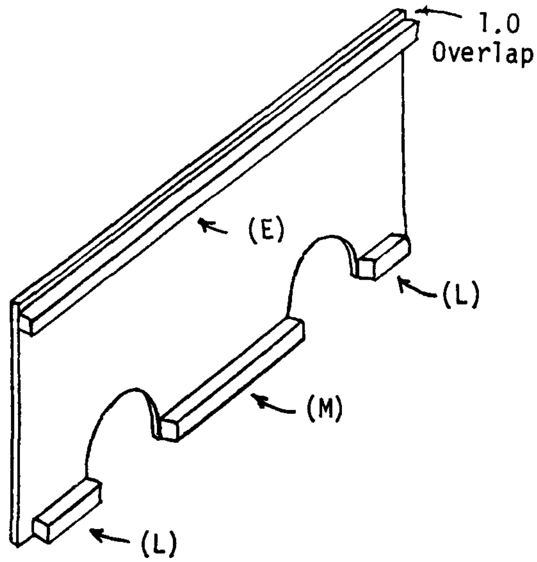
Endpiece (C)

Cut the two pieces (C) as shown. Use these pieces as endpieces for the chamber.

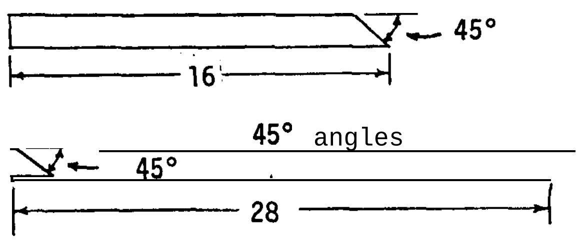


Frame

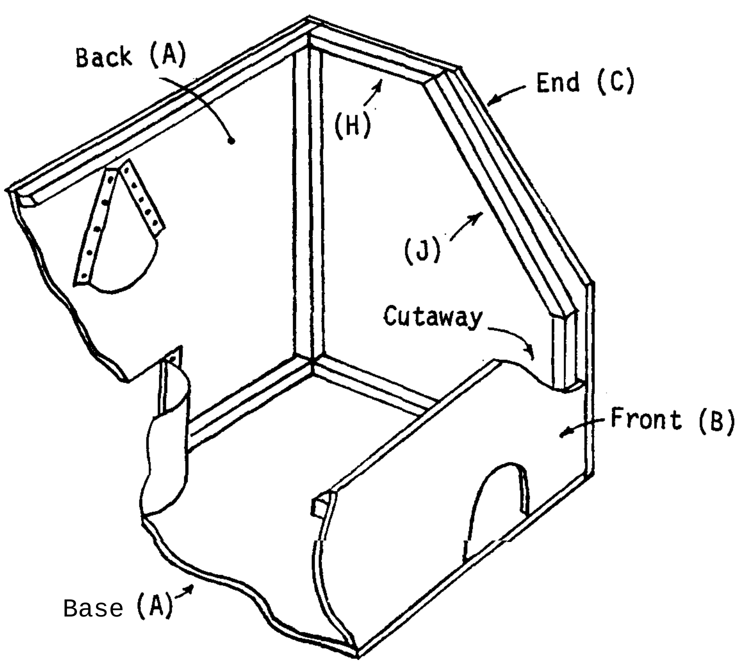
Nail two strips (G), two strips (I), and one strip (E) to the back and base. Then nail the two endpieces (C) into position. Nail the two strips (K) to the front edge of the end, being careful to leave a 0.75 cm overlap for the frontpiece to fit into.



Next, nail the two strips (L), and the other strip (E) and strips (M) to the back of the frontpiece (B) as shown. Properly done, this piece can now be nailed into the front of the chamber. Be sure there is about a 1.0 cm overlap of the plywood over the 60 cm strip.

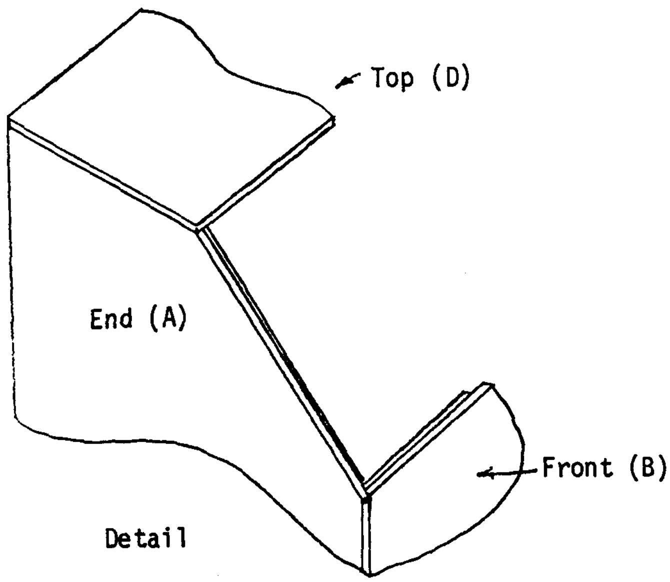


Cut one end of the wood strips (H) and wood strips (J) off at



Cutaway View of One End

Nail one each of strips (J) and (H) to the endpieces (C) insuring they fit as shown in the drawing.



Detail

To complete the body, nail the last piece of plywood (D) to be the top, even with the edges of the back and sides.

(2) Glass

Simply rest the glass (P) on the frame made of the three wood strips, one on the front (E) and one each (J) on each endpiece. There should be no gaps between the glass and frame.

C. Notes

(i) Use the transfer chamber when transferring microbiological cultures from one container to another. With it, such techniques can be performed in a draft-free environment, thus reducing the possibility of airborne contamination. The students' or instructors' arms fit through the armholes in front while the glass permits all operations to be viewed easily.

(ii) The holes in the back serve for ventilation when the chamber is used with a bunsen burner.

VII. PHYSIOLOGY MATERIALS

A. KYMlGRAPH

A wide range of,physiological experiments using larger organisms may be performed using the kymograph.

B. VOLUMETER

In addition to identifying pressure changes, one may calculate the volume of gas exchanged with this equipment.

C. FERMENTATION TUBES

Fermentation rate is measured indirectly by the measurement of carbon dioxide.

D. MANOMETER

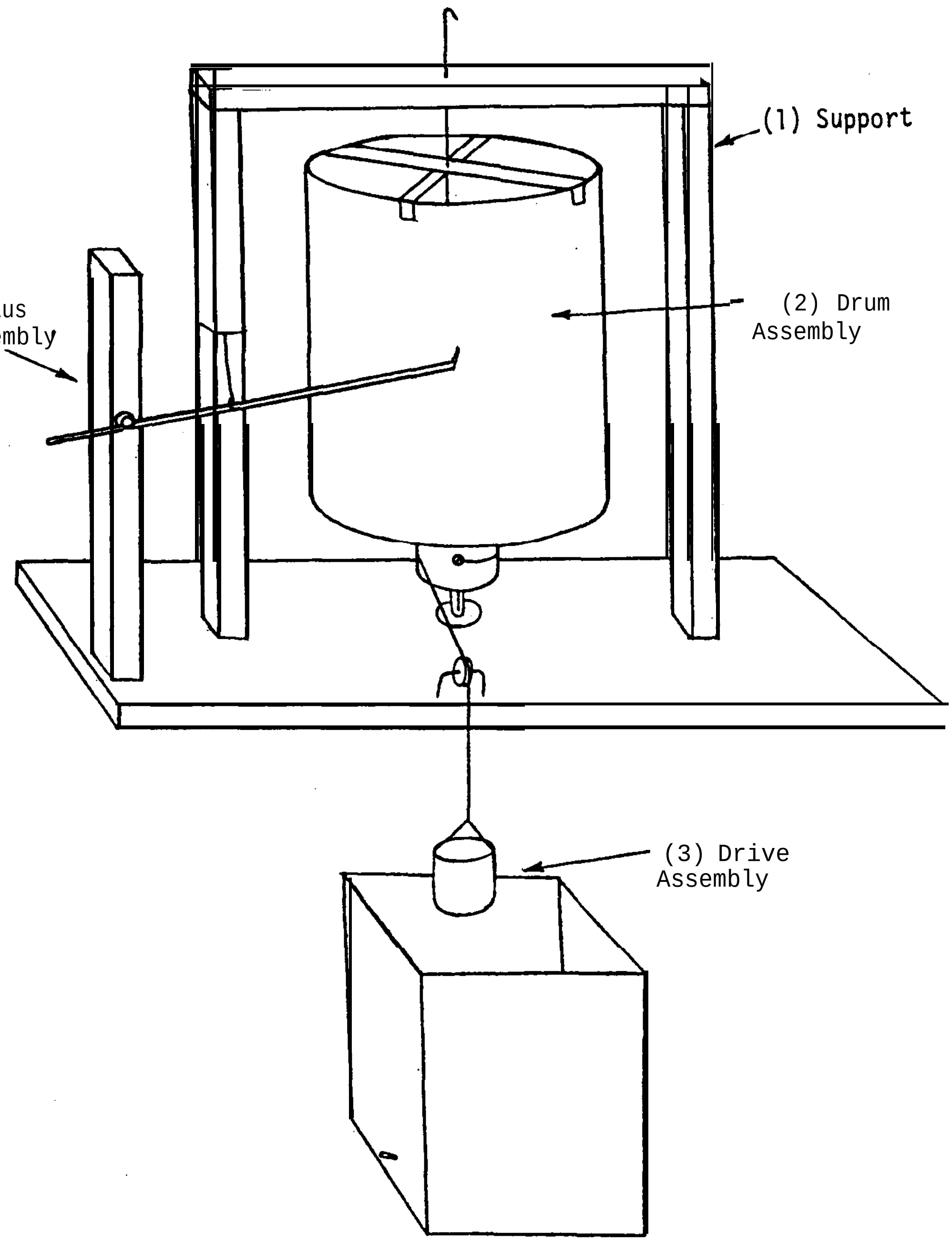
This apparatus enables one to identify changes in pressure within a biological system.

E. CHROMATOGRAPHY APPARATUS

Chromatography gives students useful insight into the techniques scientists use in investigating the biochemical composition of organisms.

A. KYMOGRAPH

Al. Kymograph



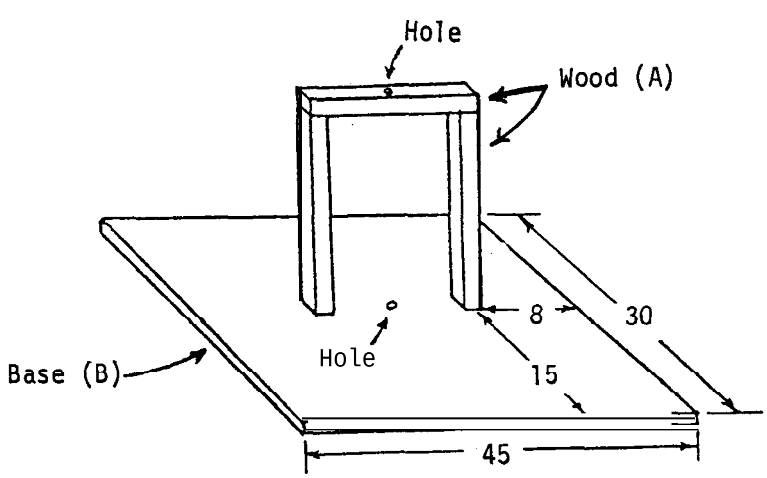
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	3	Wood (A)	25 cm x 2 cm x 2 cm
	1	Wood (B)	45 cm x 30 cm x 1.0 cm

	1	Sheet Metal (C)	2 cm diameter
(2) Drum Assembly	1	Tin Can (D)	4 liter (i.e., 15 cm diameter, 17 cm high)
	2	Sheet Metal (E)	17 cm x 2 cm x 0.05 cm
	1	Stiff Wire (F)	30 cm long, 0.2 cm diameter
	1	Tin Can (G)	5 cm diameter, 6 cm high
	3	Sheet Metal Screws (H)	1 an long
	1	Glass Tubing (I)	0.4 cm diameter, 1.0 cm long
(3) Drive Assembly	1	Wood (J)	3 cm diameter, 0.5 cm thick
	1	Stiff Wire (K)	16 cm long, 0.2 cm thick
	1	Tin Can (L)	1 liter capacity
	1	Sand (M)	600 g
	1	Stiff Wire (N)	20 cm long, #20 gauge (0.1 cm diameter)
	1	String (O)	100 cm
	1	Tin Can (P)	4 liter capacity
	1	Pencil Stub (Q)	--
(4) Stylus Assembly	1	Wood (R)	25 cm x 2 cm x 2 cm
	1	Stiff Wire (S)	30 cm long, 0.2 cm thick
	1	Nail (T)	1 cm long, 0.2 cm thick
	1	Rubber Band (U)	6 cm long

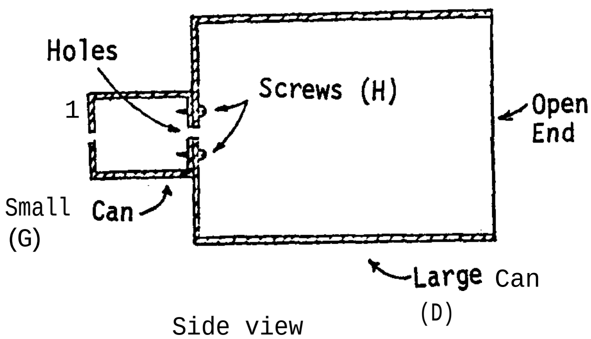
b. Construction

(1) Support



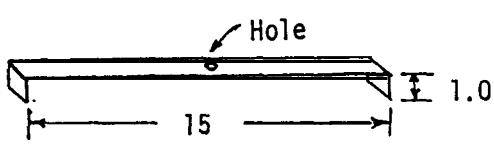
Drill a hole through one of the pieces of wood (A) directly in its center. Drill another hole in the base board (B) directly below the hole in the upper strip of wood. Each hole should have a diameter of about 0.3 cm. The hole in the base should be drilled only halfway through. Nail two of the strips (A) to the base and nail the crosspiece (A) so that the two holes are aligned. Finally, drill a 0.3 cm hole through the center of the disc of sheet metal (C) and nail the sheet metal to the base so that the hole in the base and the hole in the sheet metal are aligned.

(2) Drum Assembly



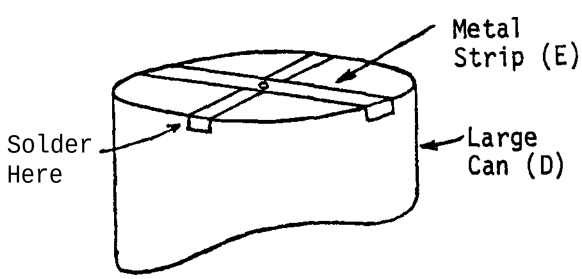
Side view
(Cross-Section)

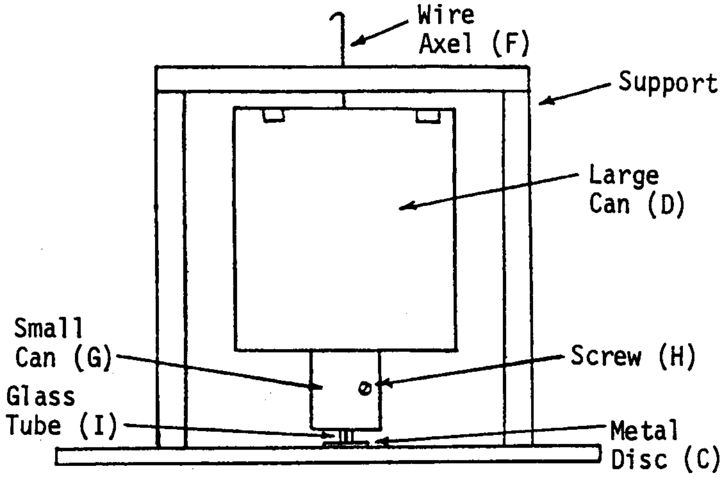
Try to select two tin cans (D,G) for the drum assembly which have both ends more or less intact. Otherwise, adjustments must be made to compensate for the open ends. At any rate, drill holes 0.3 cm in diameter in the center of both ends of each of the tin cans. Solder the two cans together making certain the holes in each align. If one of the ends of one or both cans has been removed, then the two cans can be screwed together with two sheet metal screws (H). Here, the illustrations show the situation when the small can (G) is intact and the large can (D) has one end removed.



Metal Strip (E)

To solve the problem of the open end of the large can (D), take the two sheet metal strips (E) and bend a flap down 1.0 cm from each end. Drill a 0.3 cm hole through each strip in its center. Put the two metal strips across the top of the can so that they are at right angles (90°) and their holes are aligned. The flaps can be adjusted so that the strips are



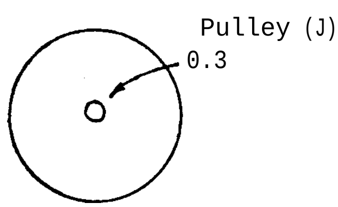


Front View

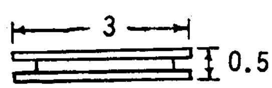
held tightly in place, or they may be soldered to the sides of the can.

Screw a short sheet metal screw (H) partway into the small can (G) to serve as an attachment point for the drive assembly string (0). Then, take the stiff wire (F) and insert it through the hole in the support, through the drum and through the glass tubing (I). Fire polish the ends of the glass to make them smooth. Finally, make sure the end of the wire rests in the hole in the base. The exposed end of the wire axle (F) may be bent for safety. The whole drum assembly should turn freely now.

(3) Drive Assembly



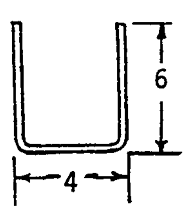
Top View



Side View

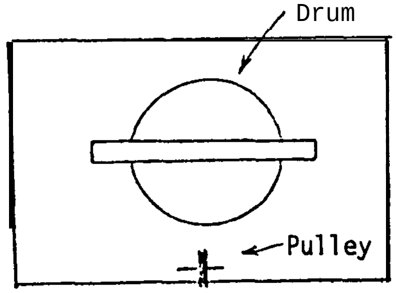
Saw a groove all around the circumference of the wood disc (J) to make it act as a pulley. Drill a hole 0.3 cm in diameter through its center. Make the pulley mount from the stiff wire (K) by bending it to a "U" shape.

1

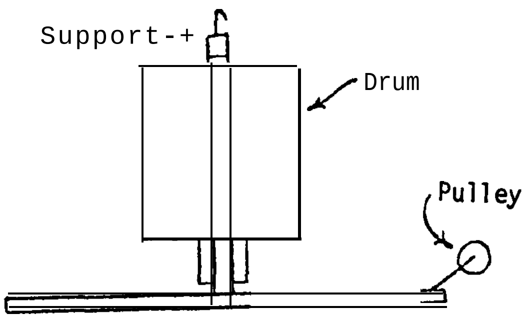


Pulley Mount (K)

Hammer the pulley mount into position on the base of the support after the pulley (J) has been slipped into place on the mount. It may be necessary

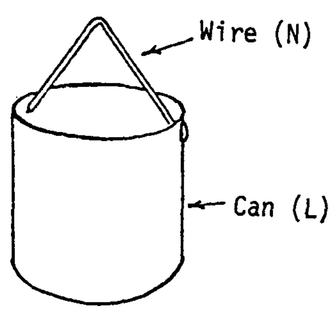


Top View

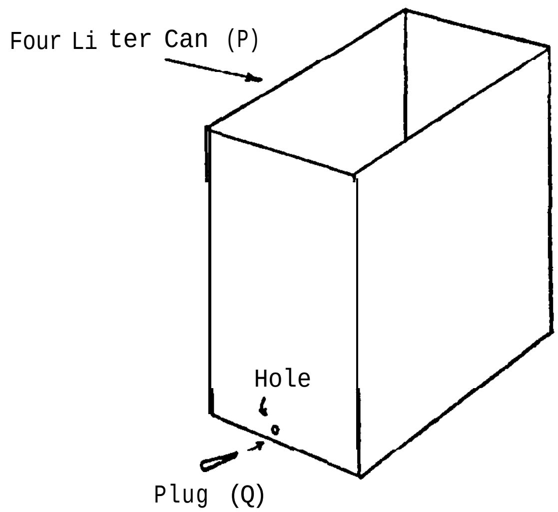


Side View

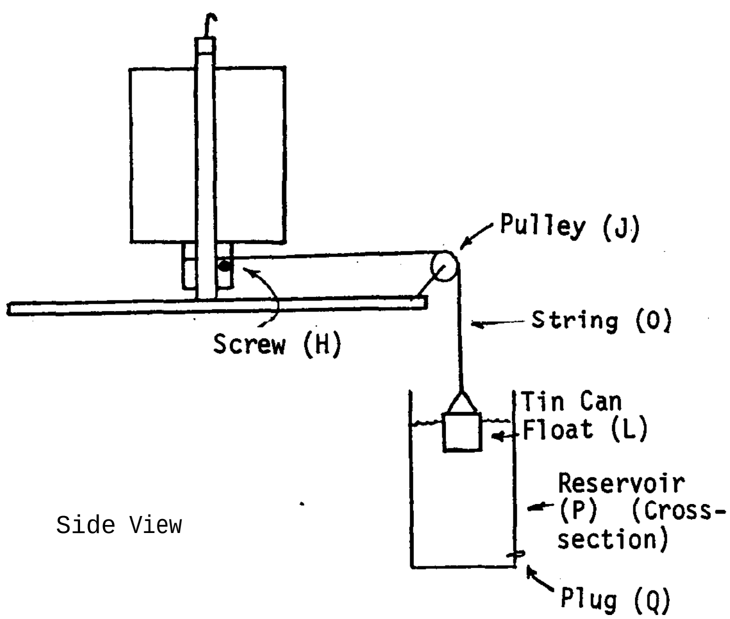
to drill small holes in the base for the pulley mount to fit into. The pulley and mount must be positioned at the front of the base directly in line with the drum assembly, and the pulley must extend beyond the edge of the base. The pulley mount can be bent over to insure that the pulley will extend out beyond the edge of the base, or alternatively, the holes into which the mount is inserted can be drilled at an angle.



Use the wire (N) to make a handle for the 1 liter can (L). Simply drill or punch two holes (0.2 cm diameter) near the top edge of the can, insert an end of the wire through each hole, and bend the ends up. Add the sand (M) to the can to act as ballast. This much weight should cause the can to float with only about 1 cm sticking above water level.

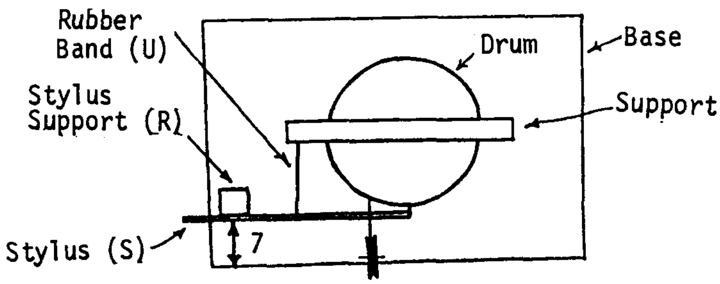


Make the 4 liter tin can (P) into a reservoir by removing its top. Tape the cut edges to prevent students from being cut. Drill or punch a small (0.15 cm diameter) hole at the bottom of the reservoir. Plug this hole with a pencil stub (Q) or piece of wood.

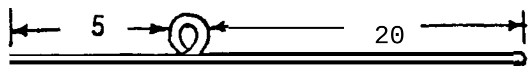


To set up the drive assembly, plug the hole in the reservoir (P) and fill it with water. Attach one end of the string (O) to the handle of the can (L) and make a small loop in the other end of the string. Put this loop around the screw (H) in the small tin can (G) under the drum, and wrap one turn of string around the small can. Run the string across the pulley (J), and float the tin can in the reservoir. Properly done, the float should lower gradually when the reservoir plug (Q) is pulled and water leaks out. As the float lowers, the string pulls on the drum causing it to slowly turn.

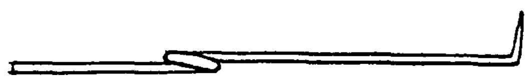
(4) Stylus Assembly



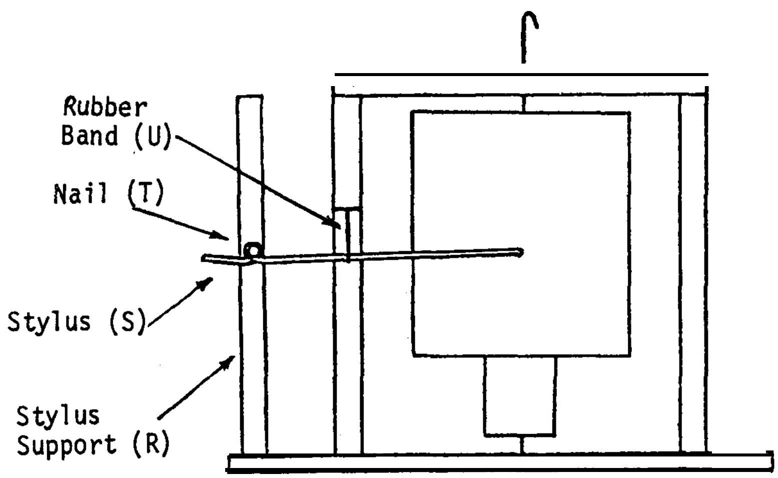
Top View



Side View of Stylus (S)



Top View



Front View

Nail or screw the stylus support (R) into position about 1.0 cm from one edge of the base, and 7 cm from the other edge. Make the stylus itself from the stiff wire (S) by making a loop in it about 5 cm from one end. Bend about 1 cm of the other end to a 90° angle to form the point. This point may be filed sharp to make a finer line. Position the stylus on the support by driving a nail (T) with a large head through the loop in the stylus. Drive the-nail in only enough to allow the stylus to pivot freely without twisting a great deal. The position of the stylus point on the drum depends upon where on the stylus support the stylus is nailed, i.e., the higher the pivot point on the support, the higher on the drum the point of the stylus will strike. Finally, tie the rubber band (U) (break it at one point) to the upright support and to the middle of the stylus. Adjust this rubber band so that the stylus point strikes the drum firmly, yet lightly enough not to interfere with the rotation of the drum.

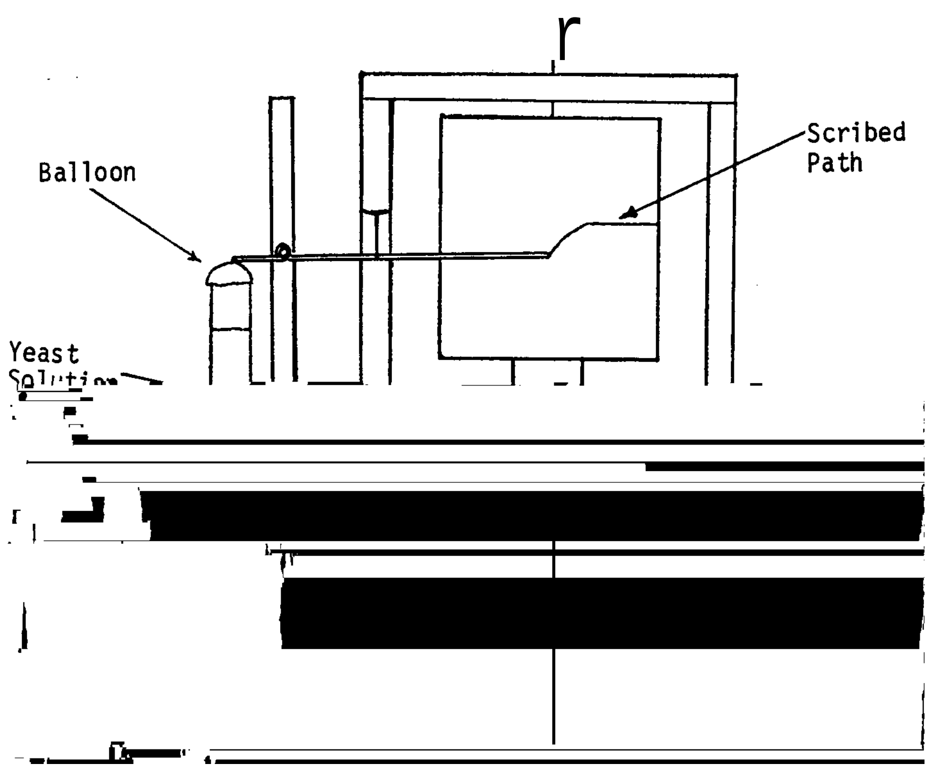
C. Notes

(i) To operate the kymograph, the drum must first be covered with a sheet of 17 cm x 50 cm glossy paper. Remove the drum from the support and attach the paper, glossy side out, to the drum with tape at the top and bottom. See that the seam where the two edges of the paper overlap is positioned in such a way that the stylus point will not catch on it (the seam) as the drum rotates.

Rotate the drum over a burning kerosene lamp. Hold the drum high enough so that the paper will not be scorched. Continue rotating it in the smoke until the drum is completely covered with carbon black. It takes about five minutes to cover the paper with carbon, requiring about 10 ml of kerosene. Handle the drum carefully since the carbon is easily scratched and rubbed off.

Replace the drum in the support, holding the stylus out of the way until the drum is in position. When the string to the float in the reservior is taut, the apparatus is ready to use.

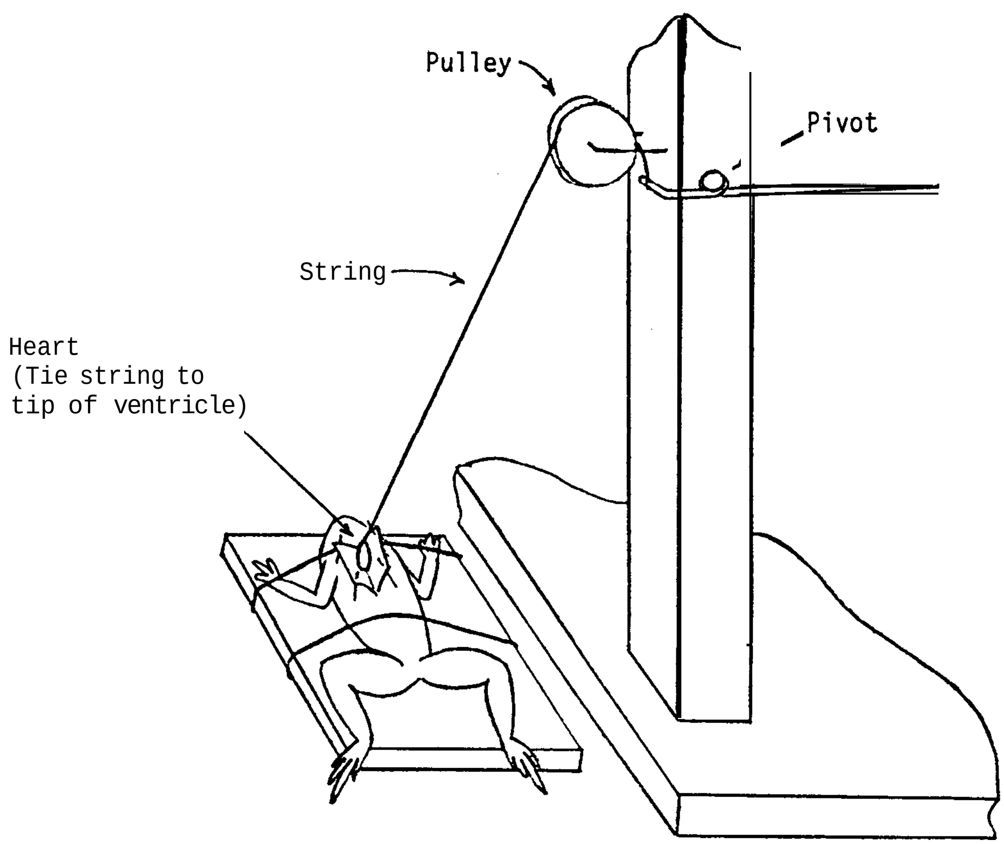
(ii) One example of the use of the kymograph will be given here. Refer to the drawing below:



Put some warm water, yeast, and sugar in a bottle or test tube and seal the end with an expandable membrane (a piece of balloon rubber works well). Place the solution under the end of the stylus so that the tip of the stylus rests on the balloon. Start the drum rotating by pulling the plug from the bottom of the reservoir. As the yeast respire, carbon dioxide gas is given off, gradually causing the balloon to expand, pushing the tip of the stylus up and its point on the drum down, leaving a scratch on the smoked paper. The slope of the scratched line indicates the rate of respiration of the yeast.

(iii) Use a clock, watch or other timing device to record time intervals (e.g., 30 seconds) and record these intervals by making a small mark on the drum each interval. These marks must be made as the drum revolves since the drum doesn't turn at a constant speed. This is because the velocity of the drum depends on the rate of flow of water from the reservoir which is not constant since the water pressure lowers as the depth lowers, thus causing the drum to slow down.

(iv) The stylus assembly may be altered to conform to requirements of other experiments. For example, the following illustration suggests how the stylus might be connected for studies of the heartbeat of an anesthetized frog:



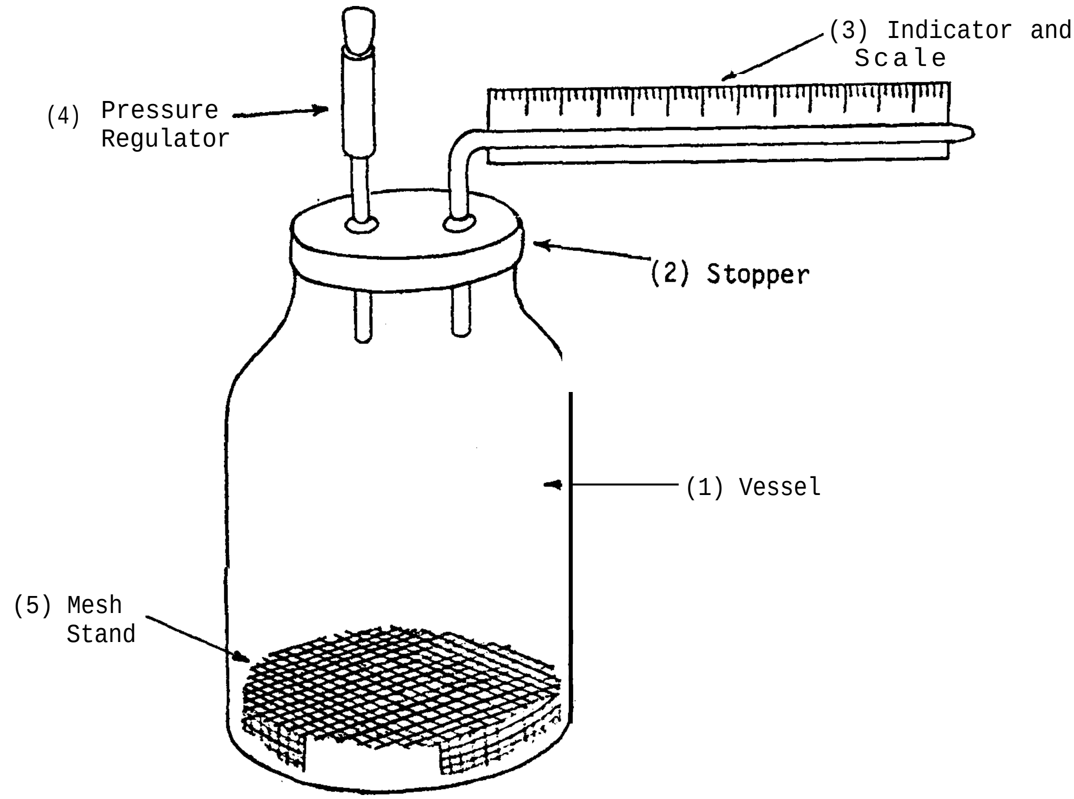
Here, as the frog's heart contracts and expands, its motion is translated into up and down movements of the stylus. Remember, the stylus acts as a lever, and the amount of movement of the pointer depends upon the relative lengths of the portions of the stylus to either side of the pivot point.

(v) The rate at which the drum revolves depends directly upon how fast the float lowers in the reservoir. Therefore, in order to make the float, and thus the drum, go faster, it is necessary either to enlarge the reservoir outflow hole or make several such holes. Conversely, to make the float and drum slower, a reservoir with a large cross-sectional area is needed. In this case, even though the float still drops the same distance per one revolution of the drum, more water must flow out of the larger can to cause it to drop the same distance as in a smaller can.

(vi) If, for any reason, it is necessary that the drum turn two or more consecutive revolutions, remember that the reservoir must be deep enough to allow the float to drop the additional distance required. To be precise, for each revolution of the drum, the float must lower a distance equal to the circumference of the small can which the drive string is wrapped around.

B. VOLUMETER

Bl. Volumeter



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Vessel	1	Wide Mouth Glass Jar (A)	Size depends on organism to be studied
(2) Stopper	1	2-Hole Rubber or Plastic Stopper or Screw Cap (B)	To fit vessel
(3) Indicator and Scale	1	Glass Tubing (C)	30 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Stiff Paper Strip (D)	20 cm x 2 cm
(4) Pressure Regulator	1	Glass Tubing (E)	4 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (F)	4 cm long, 0.75 cm inside diameter
	1	Tapered Wood or Glass Rod Plug (G)	To fit rubber tubing

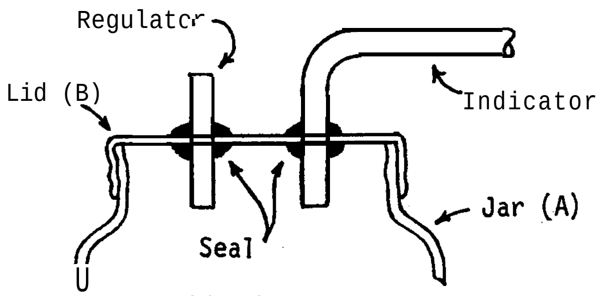
(5) Mesh Stand	1	Wire Mesh (H)	To fit vessel

b. Construction

(1) Vessel

Almost any container (A) from a vial, to a test tube, to a jar will suffice. It must be a convenient size for the organism to be studied - a liter jar would not be used for small insects - and should have a tight-fitting lid or stopper.

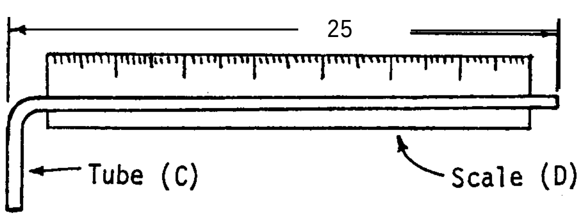
(2) Stopper



Side View
(Cross-section)

Depending on what vessel is used, the stopper (B) could be a two-hole rubber stopper or a tight-fitting screw cap with two holes drilled in for glass tubing. If a jar lid is used, the openings must be sealed with clay or paraffin after tbe indicator and pressure regulator have been inserted to prevent gas leak. Seal the underside, also.

(3) Indicator and Scale

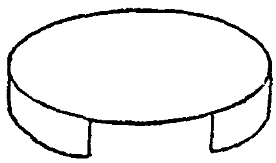


Bend a piece of glass tubing (C) at a 90° angle as indicated. Cement a paper scale (D) to the long arm, and add a drop of colored detergent solution to serve as an indicator.

(4) Pressure Regulator

This is a piece of glass tubing (E), topped with a section of rubber tubing (F) and a plug (G). To regulate the position of the indicator, one simply releases the plug for a short period of time.

(5) Wire Mesh



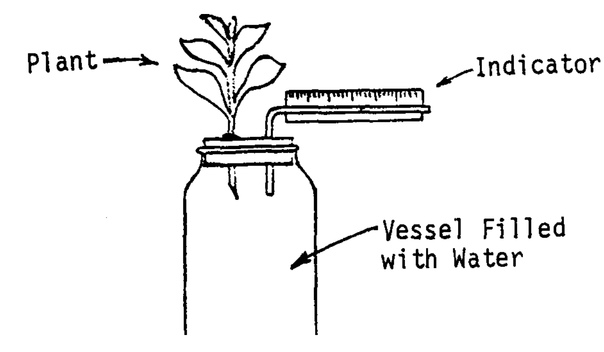
Fold to
This Shape

Cut the wire mesh (H) slightly larger than the diameter of the vessel. Bend the ends down to form a support on which the organism will be placed.

C. Notes

(i) If one wishes to study the oxygen uptake per unit time of an animal, a CO_2 absorber such as KOH should be placed in the vessel under the wire mesh support. As the animal respires, O_2 is taken up and pressure in the tube falls, causing the bubble to move toward the vessel. If one knows the size bore in the tubing, then one can compute the volume of gas being exchanged by noting the distance that the indicator moves per unit time.

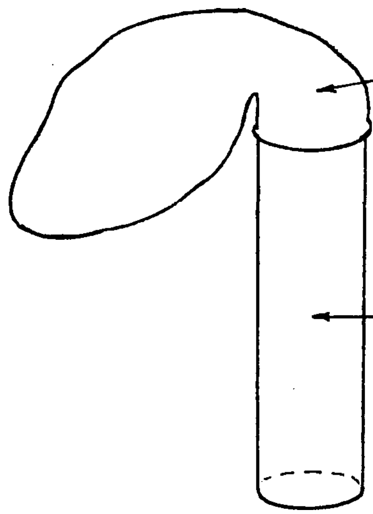
(ii) Transpiration may be measured by removing the pressure regulator from the top and inserting a broad-leaved plant cutting into the opening and sealing the joint with clay. Fill the container with water. Have the indicator bubble start at the open end of the sidearm tube. Allow the water to reach room temperature before setting the indicator bubble.



Volumeter Used as a
Transpirometer

C. FERMENTATION TUBES

Cl. Balloon Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Vial	1	Medicine Vial, Test Tube, or Small Bottle (A)	50 ml capacity
(2) Balloon	1	Balloon (B)	To fit vial opening

b. Construction

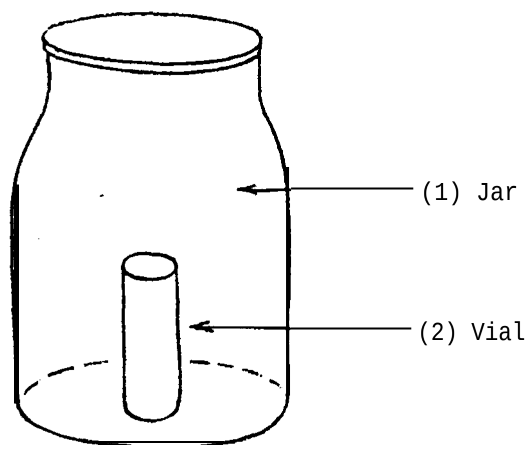
(1) Vial — Any small container (A) with a mouth narrow enough to stretch the open end of the balloon over will suffice.

(2) Balloon — Fit the open end of the balloon (B) over the bottle.

c. Notes

(i) Fill the vial with a yeast-sugar solution before attaching the balloon. As CO_2 is given off, it collects in the balloon from which it can be taken for analysis.

C2. Durham Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Wide-mouthed Glass Jar or Beaker (A)	500 ml capacity
(2) Vial	1	Medicine Vial or Test Tube (B)	50 ml capacity

b. Construction

(1) Jar

Any large wide-mouthed jar (A) or beaker will do. It must be large enough so that the small vial (B) can be covered completely with fermenting solution.

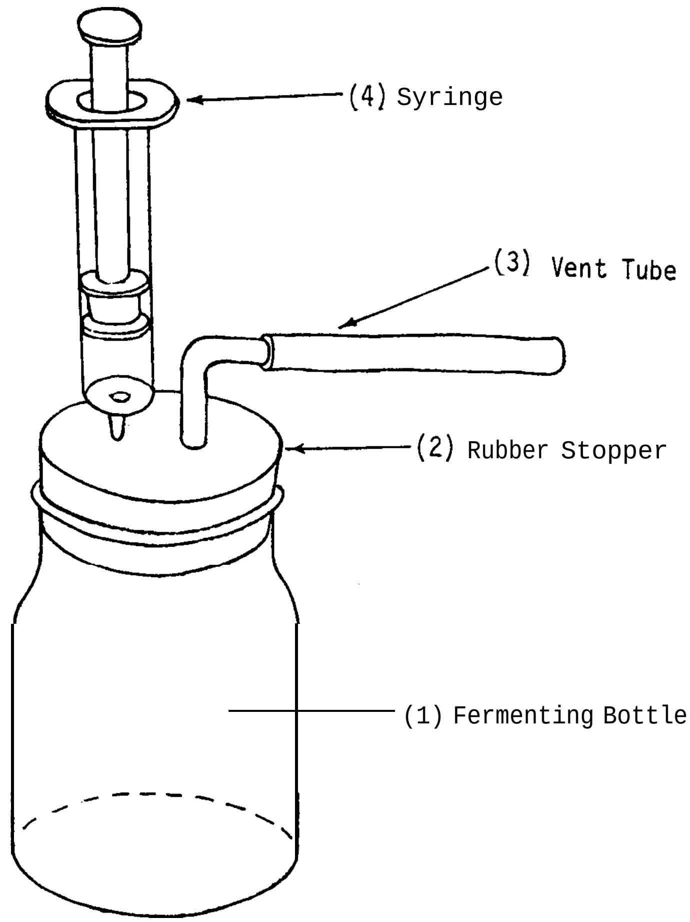
(2) Vial

The vial (B) should easily fit inside the jar where it can be completely submerged in solution.

C. Notes

(i) Fill both the jar and vial with a sugar-yeast solution. Place a finger over the open end of the vial, and invert it into the solution in the jar. As carbon dioxide is given off, some will be collected in the vial. This is useful for measuring relative amounts and rates of CO_2 production.

C3. Syringe Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fermenting Bottle	1	Wide-mouth Jar (A)	300-500 ml capacity
(2) Rubber Stopper	1	Z-Hole Rubber Stopper (B)	To fit fermenting bottle opening
(3) Vent Tube	1	Glass Tube (C)	6 cm long, 0.5 cm outside diameter
	1	Rubber Tube (D)	100 cm long, 0.5 cm inside diameter, 25-50 ml
	1	Plastic Syringe (E)	25-50 ml capacity

b. Construction

(1) Fermenting Bottle

Select a large glass or plastic container (A) with a wide mouth.

(2) Rubber Stopper

A two-hole rubber stopper (B) is needed to seal the bottle opening.

(3) Vent Tube

Bend the glass tube (C) to a right (90°) angle and insert it into one of the holes in the rubber stopper (B). Attach the rubber tubing (D) to the other end of the glass tube.

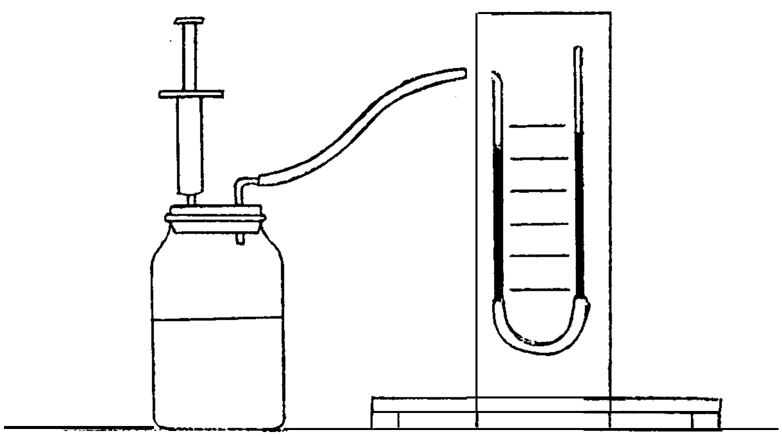
(4) Syringe

Insert the syringe nozzle (E) into the remaining hole of the stopper.

c. Notes

(i) One method of use for the syringe fermentation tube is as follows: Seal off the vent tube with a clamp or wood plug. Put about 250 ml of yeast solution in the fermenting bottle and put a known amount and concentration (e.g., 25 ml of 0.1 M) of glucose solution in the syringe. Inject the sugar water into the yeast solution and collect the carbon dioxide given off in the syringe.

(ii) Since it is difficult to accurately measure the amount of gas given off by the method described in (i) above, a further refinement is as follows:

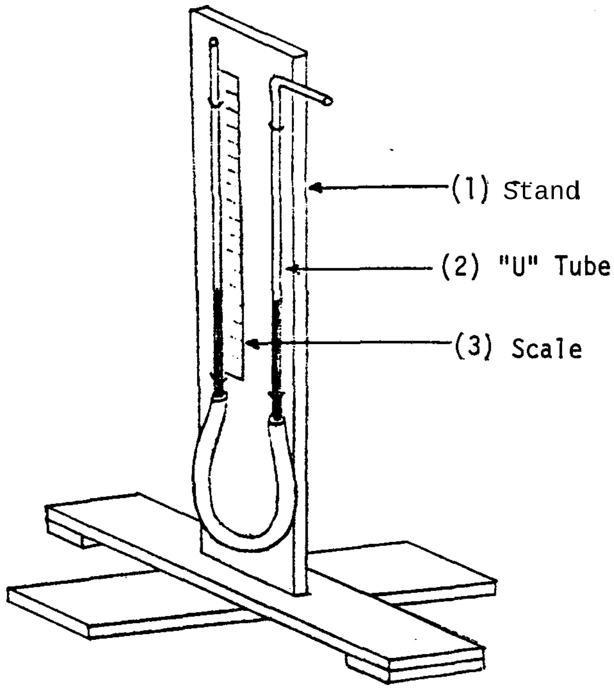


Fermentation Tube and
Manometer Combination

Connect the free end of the vent tube to a U-tube manometer (see VIII/Dl). Fill the fermenting bottle with yeast solution, and add a measured amount of sugar water. As carbon dioxide is given off, continually raise the syringe plunger so as to keep the two columns of the manometer equal height. Continue this until gas is no longer evolved. When the gas has stopped evolving, the amount of gas trapped in the syringe will be a very accurate measure of the total amount of gas given off since use of the manometer insures that pressure in the rest of the system is maintained at the original level.

D. MANOMETER

D1. Manometer

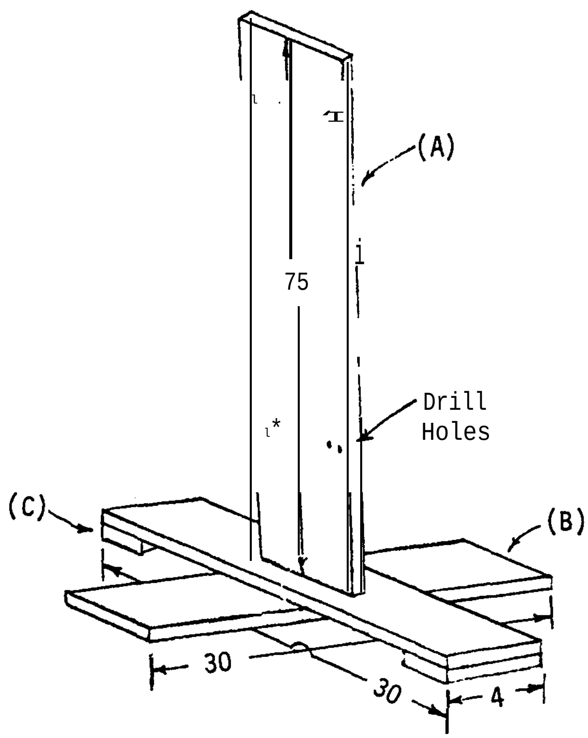


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stand	1	Wood (A)	75 cm x 8 cm x 2 cm
	2	Wood (B)	30 cm x 4 cm x 2 cm
	2	Wood (C)	4 cm x 4 cm x 2 cm
(2) "U" Tube	2	Glass Tubing (D)	60 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (E)	50 cm long, 0.7 cm inside diameter
	4	Fine Wire (F)	8 cm long
(3) Scale	1	Graph Paper (G)	40 cm long, 2 cm wide

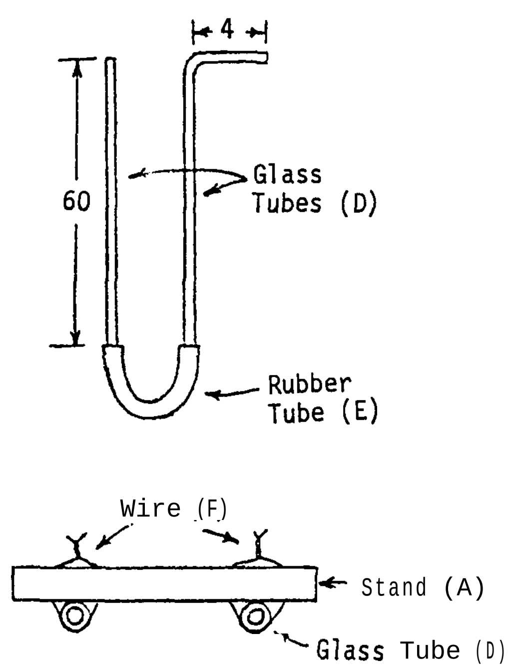
b. Construction

(1) Stand



Nail two pieces of wood (B) together at right angles to form the base of the stand. Nail the square blocks (C) under the upper board to provide stability. Finally, nail the other board (A) into an upright position on the base. Drill four pairs of small holes (0.2 cm in diameter) into the upright in such a position that each pair of holes will be in line with the position of the "U" tube when it is in place.

(2) "U" Tube



Top View

Heat one of the pieces of glass tubing (D) about 4 cm from one end and bend it to a right (90°) angle. Attach the rubber tubing (E) to the end of each piece of glass tubing (D). Fasten this "U" tube to the stand upright (A) by passing the fine wires (F) around the tubing, through the holes in the upright, and twisting the wires tight to hold the tubes in place. Do not fasten the straight tube too tight in order to allow it to slide up and down to adjust the height of the indicator liquid,

(3) Scale

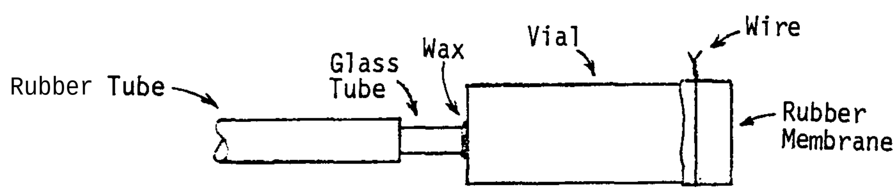
Glue or tape a piece of graph paper (G) between the two tubes to serve as a scale. Suitable scales can also be made by hand with plain paper and a rule.

C. Notes

(i) Use the manometer to detect and measure changes in pressure. To do so, it must be half filled with an indicator solution like colored water (use food coloring or ink) which serves as well as anything as an indicator. In normal usage, a rubber tube is used to connect the manometer to a closed system in which the pressure is changing (e.g., a jar containing a yeast-sugar solution or a jar containing a respiring animal with KOH to absorb the CO_2 given off. With the yeast solution, pressure in the jar will increase as the yeast oxidize the sugar. See VIII/C3 for further detail. In the case of the respiring animal, pressure will decrease as it takes up O_2 and gives up CO_2 which is taken up by the KOH.). As pressure changes, the indicator solution will move up or down depending on the direction of the pressure change.

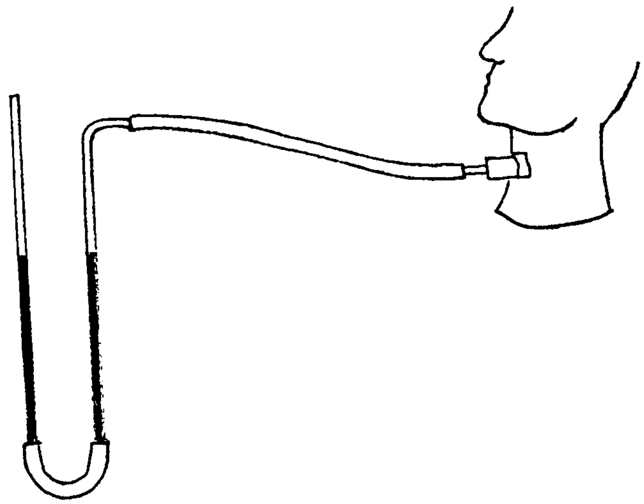
(ii) A detailed, specific example of the use of the manometer is as follows:

Drill a hole in the bottom of a plastic medicine vial. This hole needs to be large enough to insert a short piece of glass tubing (5 cm long). Attach a piece of rubber tubing (100 cm) to the glass tube, and insert the glass tube into the hole in the bottom of the vial. Seal the joint with melted wax from a candle. Stretch a rubber membrane or piece of toy balloon over the open end of the vial and fasten it securely with a string or rubber band to hold the membrane on the vial.



Side View

Attach the end of the rubber tubing to the bent piece of glass tubing on the manometer "U" tube. Slide the straight tube up or down to make the height of the indicator solution the same in both tubes. Place the rubber membrane against the carotid artery of the throat. A pulse can be seen by the rythmic rise and fall of the indicator solution. (See illustration on next page.)

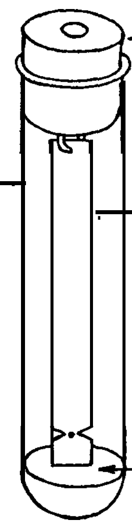


(iii) The manometer may be made from a single piece of glass tubing by bending it in a flame to a 180° angle. While this eliminates the need for a rubber tube, it also eliminates the possibility of adjusting the heights of the indicator solution.

(iv) Further instruction in the use of the manometer may be found in the Nuffield O-Level Biology, Teacher's Guide III, p 34, and the BSCS Blue Version text, p L8, L95, among other sources.

E. CHROMATOGRAPHY APPARATUS

El. Chromatographic Device



a. Materials Required

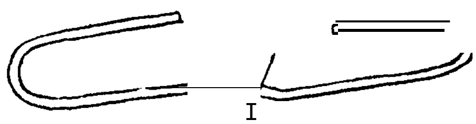
Components	Qu	Items Required	Dimensions
(1) Test Tube	1	Test Tube (A)	15 cm long, 2 cm diameter
(2) Paper Holder	1	l-Hole Stopper (B)	To fit test tube
	1	Paper Clip (C)	--
(3) Paper	1	Filter Paper (D)	1 or 2 cm shorter than the length of the test tube
(4) Solvent	--	Acetone (E)	2 ml
	--	Petroleum Ether (F)	23 ml

b. Construction

(1) Test Tube

Use a rack or holder to support the test tube (A).

(2) Paper Holder



Open up the paper clip (C) and cut it as shown. A short piece of wire can be bent to the same shape, too. Punch the U-shaped piece of clip or wire through one end of the paper (D) and force the ends of the wire up into the one-hole stopper (B) until it is held fast.

(3) Paper

Use standard filter paper (D) or chromatography paper if it is available. Cut it about 1.0 cm wide.

(4) Solvent

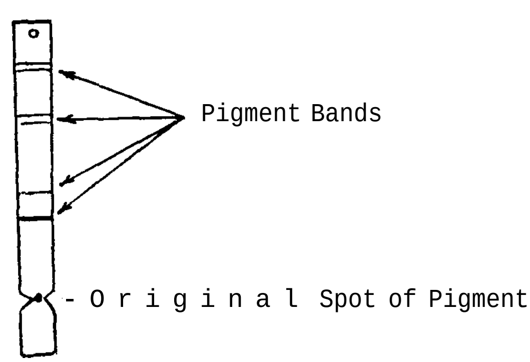
Mix the acetone (E) and petroleum ether (F) and add the mixture to the test tube.

C. Notes

(i) This chromatographic device is used to separate plant pigments. To prepare the sample of pigments, grind several heavily pigmented plant leaves together with some fine sand and about 5 ml of acetone. When thoroughly ground, filter this mixture through filter paper. Alternatively, heat several finely chopped leaves in about 5 - 10 ml of alcohol in a water bath. Do not heat the alcohol directly. Heat this mixture until the liquid is dark green.

Avoid both touching the surface of the paper with the fingers (oil affects the results) and having the paper touch the table where the pigment's to be placed. Thus, support the paper strip between two pencils or other small objects. About 1 cm from one end of the paper, place a small drop of pigment. This is most easily done with a fine-pointed pipette or a hypodermic syringe. When the first drop is dry, add another. Try to make the spot as small and as densely colored as possible. At least four drops should be placed one atop the other.

Make a notch in the paper on each side of the spot to mark its position. Attach the paper to the wire and put the wire into the stopper. Insert the paper holder in the test tube so that the end of the paper is in the solvent with the spot about 0.5 cm above the level of the liquid. It may be necessary to adjust the paper holder to keep the paper at the proper level. When the upper level of the solvent has soaked into the paper almost to the paper holder wire, remove the chromatogram and allow it to dry. The bands of color can be studied when the chromatogram is thoroughly dry. A number of excellent references exist describing additional exercises and information for chromatography.



Finished Chromatogram

IX. MULTIPURPOSE SYRINGES

Disposable plastic syringes afford a variety of uses in biological studies. A few of these will be given in this section. Additionally, syringes can be used as pipettes, burettes, etc., and for many of the functions normally taken by test tubes. They are potentially one of the most useful items in the laboratory. All syringes in this chapter are to be used without their needles. The categories given below have been arrived at according to the function of the syringe within the system.

Readers with special interest in disposable syringes are referred to Paul D. Merrick, Experiments with Plastic Syringes, and two articles by Andrew Farmer in the School Science Review.

A. INJECTION AND EXTRACTION SYSTEMS

In these devices, disposable syringes are used for accurately injecting or extracting precise amounts of materials into or out of closed systems.

B. COLLECTION APPARATUS

Here, syringes are used to collect gases in measurable quantities.

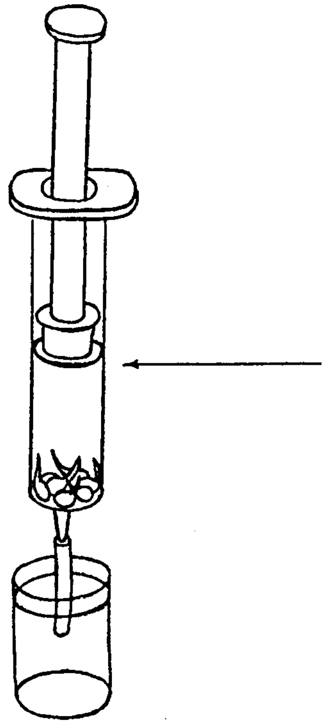
C. REACTION CHAMBER

In this device, the syringe itself is used as the container for the reactions.

D. RESPIROMETERS

Two versions of respirometers fashioned from plastic syringes are given.

B2. Seedling Gas Collection Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Syringe (A)	35-50 cc
	1	Beaker (B)	50-100 ml
	1	Rubber Tubing (C)	5 cm long, 0.4 cm diameter
	10	Day-old Bean Seedlings (D)	--

b. Construction

(1) Syringe

Fasten the rubber tubing (C) to the nozzle of the syringe (A) and place the bean seedlings (D) in the barrel of the syringe. Next, fill the beaker (B) with water and put the end of the tubing in the water to prevent gas from escaping from the syringe.

C. Notes

(i) Day-old bean seedlings carry on only respiration. Thus, the gas collected in the syringe after a period of six hours will be primarily carbon dioxide (CO_2). This can be shown by injecting the collected gas into a solution of limewater in which a white precipitate will be found. No reaction will occur if normal air is injected into the limewater. This same experiment can be done using insects.

BIBLIOGRAPHY

A number of texts have proved to be extremely valuable references to the Inexpensive Science Teaching Equipment Project, and these are listed below.

American Peace Corps, Science Teachers Handbook, (Hyderabad, India: American Peace Corps, 1968).

This handbook contains many ideas for improvising science teaching equipment.

Association for Science Education, The School Science Review, (London: John Murray).

A quarterly journal containing articles on science experiments and equipment in all the sciences at all school levels.

Association for Science Education, The Science Master's Book, (London: John Murray).

Part 2 of Series 1 and 2, and Part 3 of Series 3 and 4 of The Science Master's Book contain articles from The School Science Review dealing with experiments and equipment in biology.

Knudsen, Jens W., Biological Techniques, (New York: Harper and Row, 1966).

An excellent reference for those persons interested in collecting, preserving, and illustrating animals and plants.

Merrick, Paul D., Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968).

This book and accompanying materials form a good basis for developing curriculum materials based on disposable plastic syringes.

Morholt, Evelyn, Paul F. Brandwein, and Alexander Joseph, A Sourcebook for the Biological Sciences, (New York: Harcourt Brace, and World, 1966).

This book gives many ideas and methods concerned with the day-to-day teaching of biology.

The UNESCO Sourcebook in Science Teaching, (Paris, France: UNESCO, 1972).

This book, recently revised, contains many simple ideas for teaching science at a relatively elementary level.

In addition to the above texts, the materials from a large number of projects in the files of the International Clearinghouse on Science and Mathematics Curricular Developments at the University of Maryland have also been particularly valuable. Further details of these projects, and the three listed below, may be found in:

<u>The Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970,</u> (College Park, Maryland: University of Maryland, 1970).

> This is a source of information on curriculum projects throughout the world including project director, materials available, publishers, etc. The Eighth Report will be available in late 1972.

Biological Sciences Curriculum Study (BSCS).

> This is the major United States project concerned with the biological sciences at the secondary level. One publication, <u>Innovations in Equipment and Techniques in the Biology Teaching Laboratory,</u> (Boston: D. C. Heath, 1964) is especially useful to those interested in equipment development.

FUNBEC, <u>Science Education Projects for Primary, High School and College Level</u>.

> A Brazilian project, FUNBEC has developed an excellent series of inexpensive science kits including some dealing with biology.

Nuffield Foundation, <u>Nuffield Biology.</u>

> The Nuffield projects are the major British curriculum projects in science. Expecially interesting to the secondary biology teacher and administrator are the "O-level" and "A-level" material.

ALPHABETICAL INDEX