X. GALVANOMETERS

A. ELEMENTARY GALVANOMETERS

These are extremely simple instruments which illustrate the elementary principles of galvanometry. They may be used as simple measuring devices, but are not designed for accuracy of measurement.

B. FUNCTIONAL TANGENT GALVANOMETERS

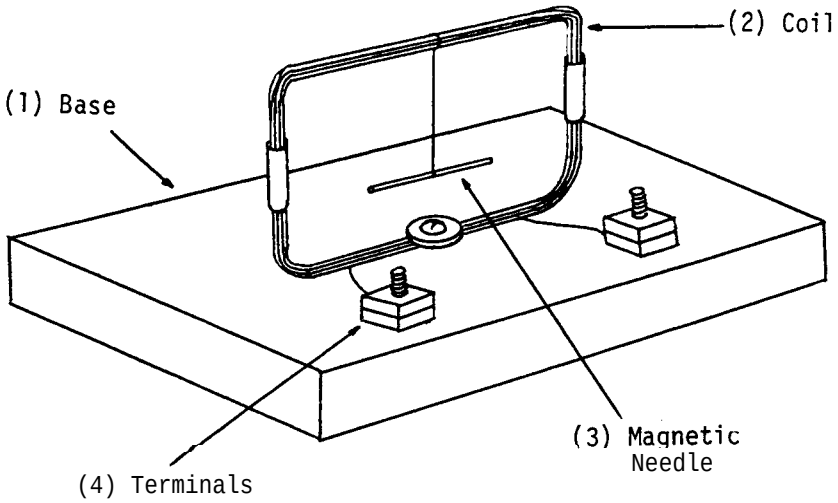
These instruments are probably the most suitable for general use in the school laboratory. They are simple to make and more durable than moving coil galvanometers. In addition, they are surprisingly sensitive,and with the help of shunts may be used for a multiple range of measurements.

C. FUNCTIONAL MOVING COIL GALVANOMETERS

These instruments are quite sensitive,and with the help of shunts may be used for a multiple range of measurements.

A. ELEMENTARY GALVANOMETERS

A1. Elementary Tangent Galvanometer



a. Materials Required

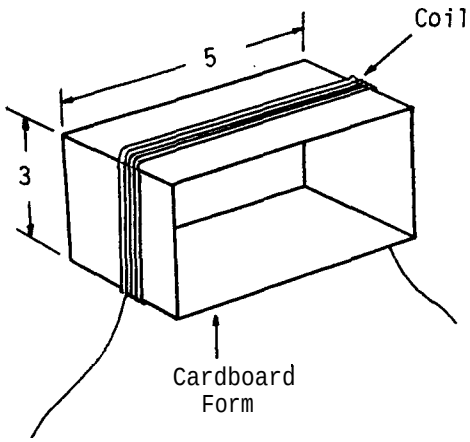
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	7 c m x 7 c m x l c m
(2) Coil	1	Magnet Wire (B)	#26, 400 cm long
	--	Masking Tape (C)	--
	1	Screw (D)	1 cm long
	1	Washer (E)	--
(3) Magnetic Needle	1	Needle (F)	0.1 cm diameter
	1	Cotton Thread (G)	5 cm long
(4) Terminals	2	Bolts (H)	0.3 cm diameter, 2.5 cm long
	4	Nuts (I)	0.3 cm internal diameter

b. Construction

(1) Base

Make the base out of wood (A).

(2) Coil



Wind 20 turns of the magnet wire (B) around a cardboard form to make a rectangular coil (5 cm x 3 cm), leaving about 5 cm of free wire at either end of the coil.

Remove the coil from the form, and wrap sufficient masking tape (C) around the coil to insure that it maintains its shape. Then separate the windings slightly on the bottom side of the coil, mount the coil on the base with the help of a washer (E) and a screw (D) passed through the separated windings.

(3) Magnetic Needle

Magnetize a needle (F) with the help of a magnetizing coil (IX/Al). Cut off about 4 cm of the needle, and suspend it horizontally at the middle of the coil by means of a cotton thread (G) attached to the top of the coil.

(4) Terminals

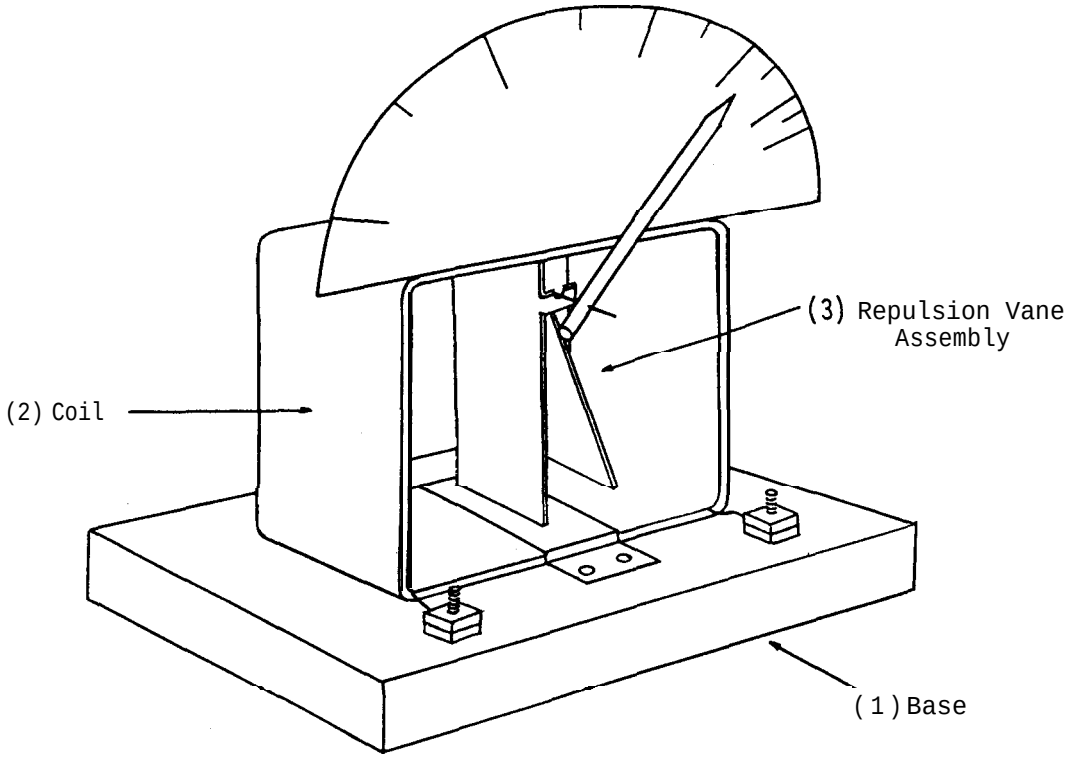
Use the bolts (H) and nuts (I) to make two terminals in the base as described under item VIII/AZ, Component (4). Clean

the ends of the coil wire with sandpaper, and fasten the wires to the terminals.

C. Notes

(i) Prior to using this apparatus it should be set so that the needle is suspended in the plane of the coil. A current passed through the coil will cause the needle to be deflected away from the plane of the coil, the deflection depending on the magnitude of the current carried by the coil. The apparatus simply illustrates the principle of the tangent galvanometer, and is too crude for specific measurements.

A2. Repulsion Type Galvanometer



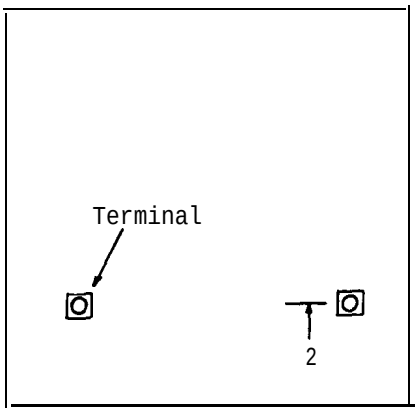
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	10 cm x 10 cm x 1 cm
	2	Bolts (B)	0.3 cm diameter, 2.5 cm long
	4	Nuts (C)	0.3 cm internal diameter
(2) Coil	1	Cardboard Sheet (D)	20 cm x 3.5 cm
	--	Masking Tape (E)	--
	1	Roll of Magnet Wire (F)	#26, (diameter 0.05 cm), 30 meters long
	1	Aluminum Sheet (G)	7 cm x 4 cm x 0.02 cm
	4	Screws (H)	1 cm long
(3) Repulsion Vane Assembly	1	Galvanized Iron Sheet (I)	7 cm x 3.5 cm x 0.02 cm
	1	Galvanized Iron Sheet (J)	4.3 cm x 2.5 cm x 0.02 cm
	1	Needle (K)	8 cm long, 0.1 cm diameter
	--	Masking Tape (L)	--

1	Soda Straw (M)	--
1	Cardboard Sheet (N)	12 cm x 12 cm

b. Construction

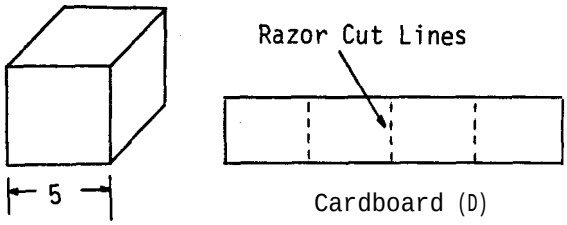
(1) Base



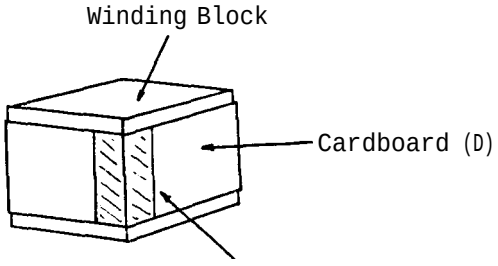
Top View

Make two terminals from bolts (B) and nuts (C) [as described under VIII/A2, Component (4)] and attach them at about 2 cm from the edge of the wood (A). The boltheads of the terminals should be countersunk into the base, so that the latter sits flat on any horizontal surface.

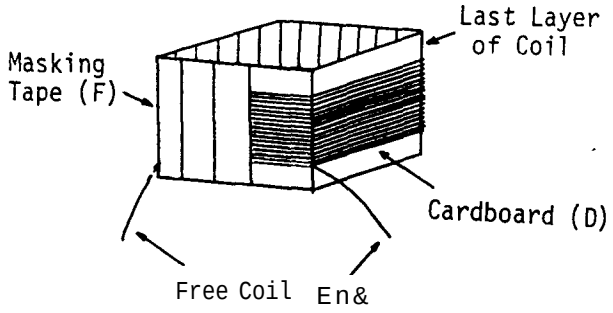
(2) Coil



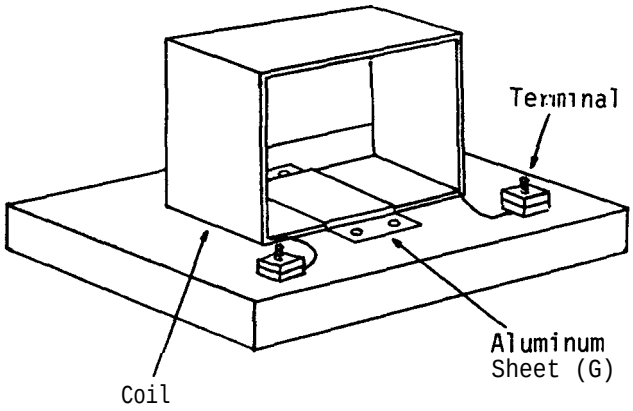
Cut a piece of wood (5 cm x 5 cm x 5 cm) to serve as a winding block for the coil. Use a razor blade to score parallel lines on the cardboard (D) at 5 cm intervals so that it may be readily bent into the shape of the wooden block.



Wrap the cardboard loosely around the block fastening the two loose edges together with masking tape (E).

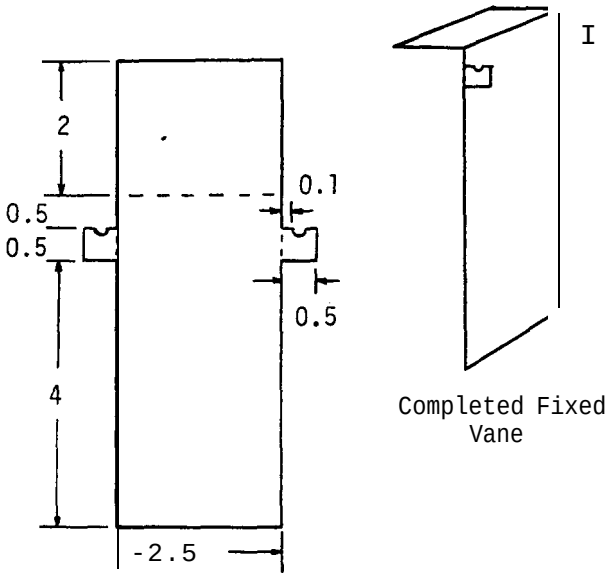


Wind approximately 150 turns of the magnet wire (F) onto the cardboard form. This will take three layers of turns. After winding the turns, remove the cardboard holder (and turns) from the winding block, and cover the turns with masking tape (E) to hold the wire in position. Make sure that about 10 cm of wire is free at both ends of the coil.

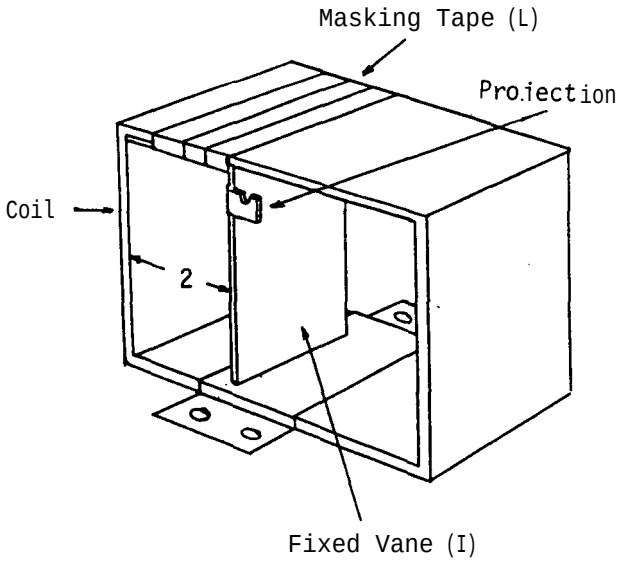


Drill two holes (diameter 0.2 cm) at either end of the aluminum sheet (G). Set the coil in a vertical plane on the base, and strap it in position with the help of the aluminum sheet (G) and four screws (H). Bare the ends of the wire, and attach them to the terminals on the base.

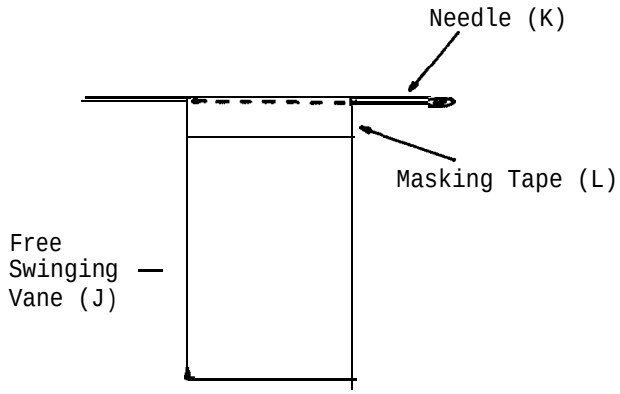
(3) Repulsion Vane Assembly



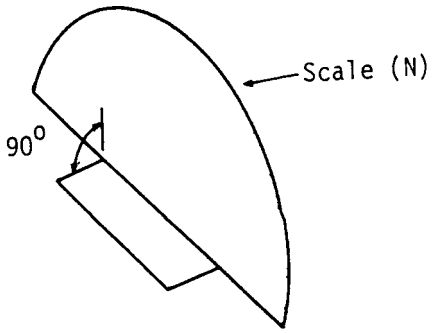
Two vanes are required, one fixed and one free swinging. The fixed vane may be cut from a sheet of galvanized iron (I) according to the dimensions indicated. The cut sheet resembles a vertical cross. Drill a hole (0.2 cm diameter) in the top edge of each of the horizontal portions of the cross (see illustration). Then bend the sheet at right angles along the lines indicated.



The completed vane may then be fixed vertically in position within the coil by wrapping masking tape (L) around the top of the coil, covering the horizontal portion of the fixed vane in the process.

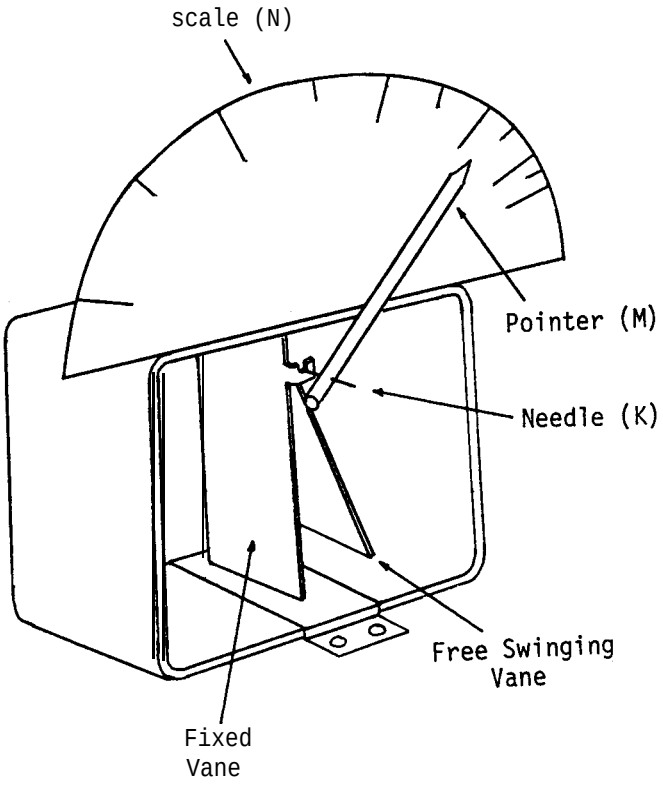


The free swinging vane is made from the other sheet of galvanized iron (J) and suspended from the middle of the needle (K) by wrapping a piece of masking tape (L) over the end of the vane. Suspend the vane from the projections on the fixed vane.



Back View

Make a pointer from the straw (M), and pivot it on the needle (K) at about 2 cm from the end of the straw. Make the scale from the cardboard (N), bending the bottom of the scale at right angles to form a horizontal flap. Use masking tape to attach the flap (and hence the scale) to the top of the coil.



c. Notes

(i) The ga vanometer may be calibrated by placing it in series with an ammeter (0 - 5 amps), a voltage supply (dry cells, battery, etc.) and a variable resistance

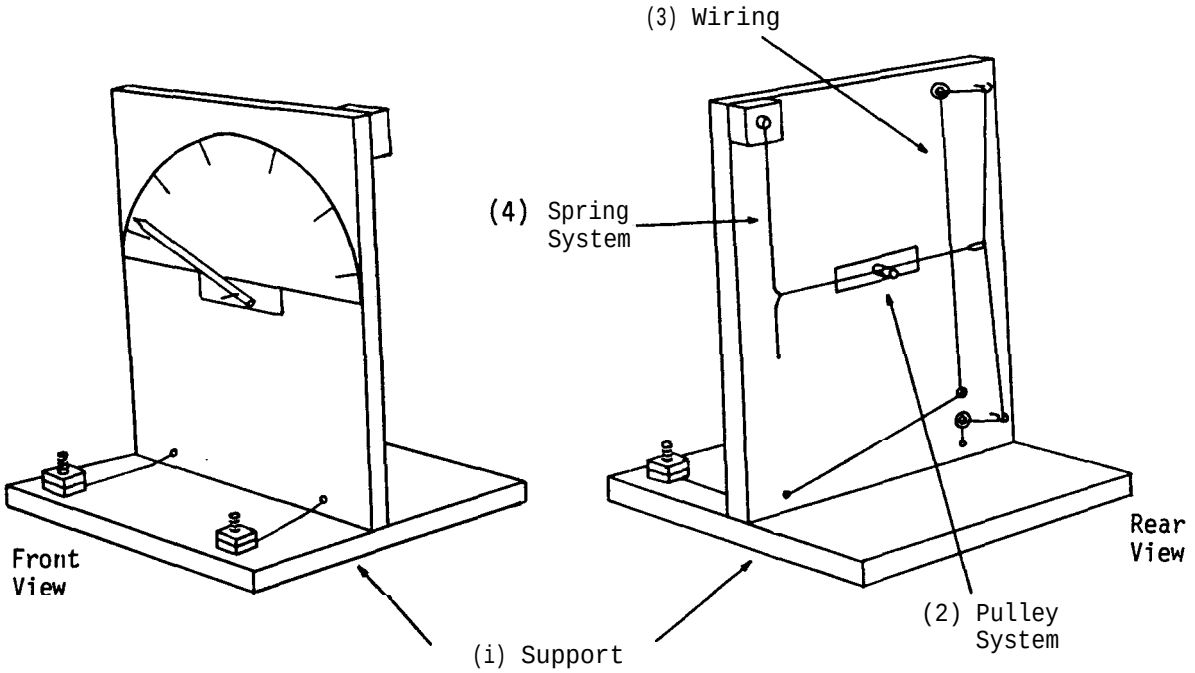
(ii) The resulting scale will be nonuniform,the separation of points on the scale increasing with increasing amperage. The range of the scale for this

particular design will be approximately 0 to 3 amps (DC).

(iii) The galvanometer will measure both DC and AC current equally well, since the repulsion of the vanes is independent of the direction of the current in the coil.

(iv) The resistance of the galvanometer is approximately 2.5 ohms. The current existing in a circuit will therefore be affected in general by the addition of the galvanometer to the circuit.

A3. Hot Wire Ammeter



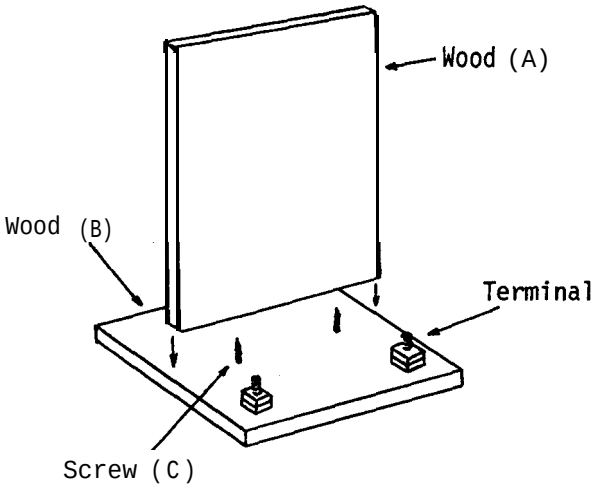
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	20 cm x 12 cm x 2 cm
	1	Wood (B)	12 cm x 12 cm x 2 cm
	2	Screws (C)	3 cm long
	2	Bolts (D)	0.3 cm diameter, 3.5 cm long
	4	Nuts (E)	0.3 cm internal diameter
(2) Pulley System	2	Aluminum Sheets (F)	5 cm x 2 cm x 0.05 cm
	4	Screws (G)	1 cm long
	1	Needle (H)	5 cm long, 0.1 cm diameter
	1	Wooden Dowel (I)	0.5 cm diameter, 1 cm long
	1	Soda Straw (J)	--
	1	Cardboard Sheet (K)	12 cm x 6 cm
(3) Wiring	2	Eye Screws (L)	--
	3	Wood Screws (M)	1.5 cm long
	2	Washers (N)	--
	1	Nichrome Wire (0)	#30, 22 cm long, 0.02 cm diameter

	1	Copper Wire (P)	#24, 50 cm long
(4) Spring System	1	Wood (Q)	2 cm x 2 cm x 11 cm
	1	Steel Wire (R)	#16, diameter 0.12 cm, length 12 cm
	1	Screw (S)	1 cm long
	1	Thread (T)	10 cm long
	1	Paper Clip (U)	Approximately 1 cm long

b. Construction

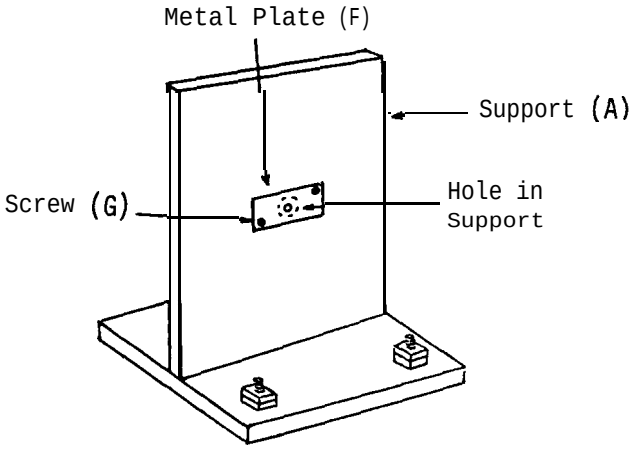
(1) Support



Attach the vertical component (A) to the middle of the base (B) with the help of screws (C) and wood cement.

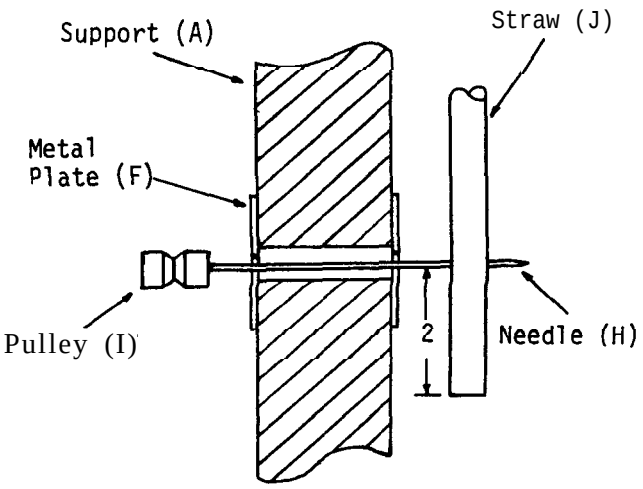
Use the bolts (D) and nuts (E) to make two terminals [as described under VIII/AZ, Component (4)] and attach these to the front of the base. The boltheads of the terminals should be countersunk into the bottom of the base (B) so that the latter sits flat on any horizontal surface.

(2) Pulley System



Drill a hole (diameter 0.5 cm) through the exact middle of the vertical component (A) of the support. Drill a hole (diameter 0.2 cm) through the center of each of the aluminum plates (F) to serve as pivot holes for the pointer. Drill two holes (diameter 0.2 cm) in diagonally opposite corners of each plate, so that the latter may be screwed onto either side of the support over the centrally drilled hole. The holes in the plates should be at the same height on both sides of

the support, so that the needle (H) may be pivoted horizontally through the holes.



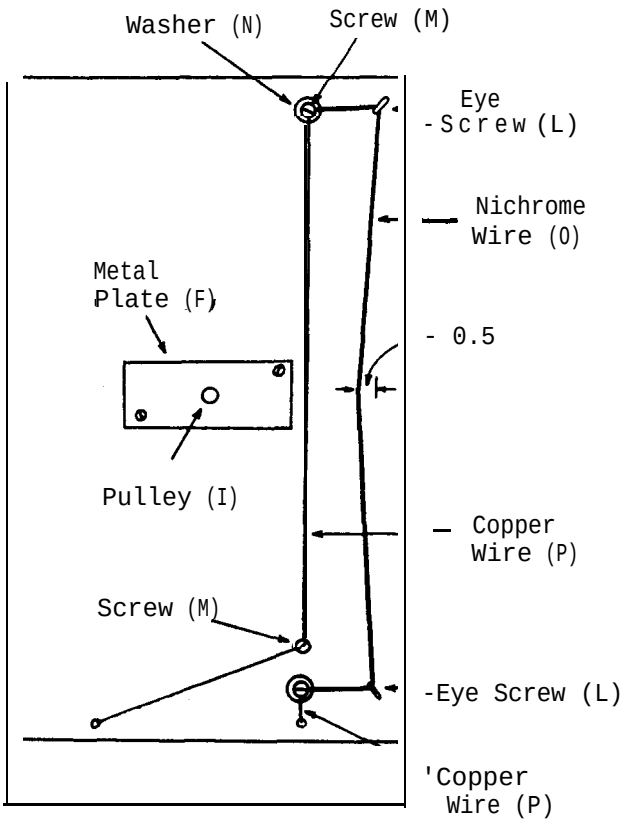
Cross Section

Use a file and sandpaper to make a groove in the wood dowel (I) forming a pulley, thus preventing string from slipping off it. Drill a small hole in the end of the pulley (I) so that it may be slipped onto the end of the needle (H), and fix it firmly in position with the help of glue.

Make a pointer from the soda straw (J) and attach it to the needle about 2 cm from the end of the straw.

Cut a semicircular scale (diameter 12 cm) out of cardboard (K), and glue it to the vertical support behind the pointer.

(3) Wiring



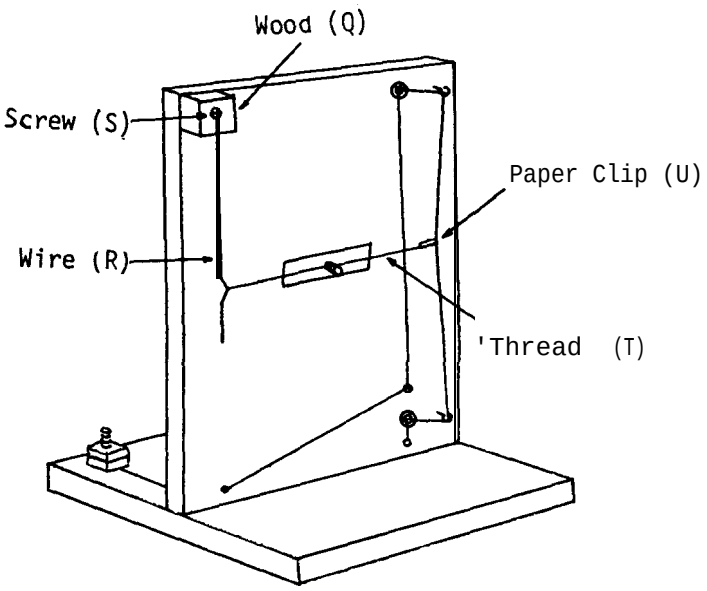
Back View

Fix two eye screws (L) into the rear right-hand side of the support. About 2 cm to the left of each eye screw fix a small wood screw (M) and a washer (N).

Connect the nichrome wire (0) from one wood screw, through both eye screws, to the other wood screw. The length of the wire should be adjusted so that it needs to be pulled about 0.5 cm from the vertical, at its center point, in order to make it completely taut.

Drill two holes in the vertical component of the support to carry electrical wire from the rear of the support to the front. Make one hole (0.2 cm diameter) through the support about 1 cm beneath the bottom wood screw and a second hole at the same height, but on the left side of the support. Connect a length of copper wire (P) from the lower wood screw, through the nearest hole in the support, to the nearest terminal at the front of the base. Connect a second length of wire (P) from the upper wood screw, through the second drill hole, to the remaining terminal. It is convenient to keep the second copper wire away from the middle of the support and the pulley system, with the help of a third wood screw (M).

(4) Spring System



Back View

Attach the small wood block (Q) to the rear of the support at the top left-hand corner. Insert a screw (S) into the block and fasten the end of a length of steel wire (R) between the screw and block so that the wire is held rigidly in a vertical position, thus serving as a spring.

Attach the thread (T) at one end to the middle of the hot wire (0) with the help of a small paper clip (U). Wrap the thread around the pulley (I) once, and then tie the free end onto the spring wire (R). In order to do this make a small kink in the steel wire at the point of attachment of the thread, thus preventing the latter from slipping, and during the tying of the thread, make sure that the spring wire is pulled towards the hot wire. This insures that the thread is always under tension, and that the pulley (and hence pointer) responds readily to any movement of the hot wire.

C. Notes

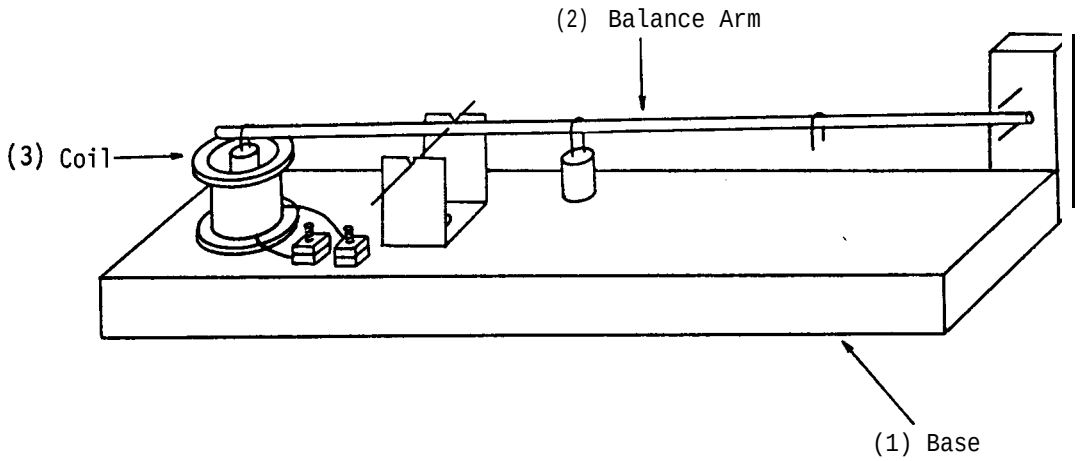
(i) The galvanometer may be calibrated by placing it in series with an amneter (0 - 5 amps), a voltage supply (dry cells, battery, etc.) and a variable resistance.

(ii) The resulting scale will be nonuniform,the separation of points on the scale increasing with increasing amperage. The range of the scale for this particular design will be approximately 0 to 1.5 amps (DC).

(iii) The galvanometer will measure both DC and AC current equally well, since the extension of the hot wire (and hence the movement of the pointer) is dependent on the heating of the wire, which in turn is proportional to the square of the current passing through the wire.

(iv) The resistance of this galvanometer is approximately 4.5 ohms.

A4. Current Balance

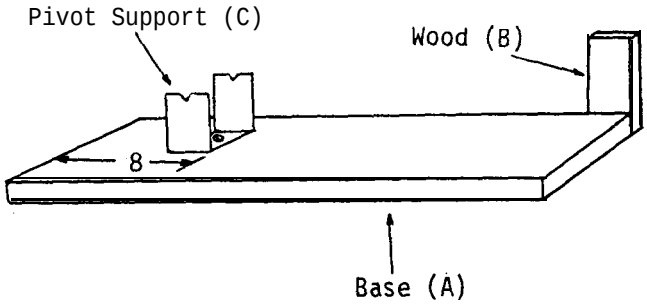


a. Materials Required

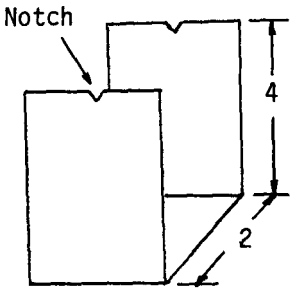
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	22 cm x 5 cm x 2 cm
	1	Wood Strip (B)	6 cm x 2 cm x 0.5 cm
	1	Aluminum Sheet (C)	10 cm x 2 cm x 0.05 cm
	1	Screw (D)	1 cm long
(2) Balance Arm	1	Needle (E)	4 cm long, 0.1 cm diameter
	1	Soda Straw (F)	21 cm long, approximately
	1	Nail (G)	0.4 cm diameter
	1	Magnet Wire (H)	#30, 10 cm long
	--	Masking Tape (I)	--
	2	Pins (J)	--
(3) Coil	1	Sheet of Paper (K)	10 cm x 2 cm
	1	Cardboard Sheet (L)	2 cm x 2 cm
	1	Magnet Wire (M)	#22, 400 cm long
	--	Masking Tape (N)	--
	2	Bolts (0)	0.3 cm diameter, 3.5 cm long
	4	Nuts (P)	0.3 cm internal diameter

b. Construction

(1) Base



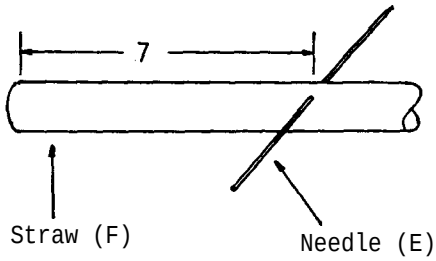
Fasten an upright piece of wood (B) to the rear of the base (A), and to one side. Make a pivot support from the sheet of aluminum (C). Drill a hole (diameter 0.2 cm) in the middle of the horizontal portion of the support, and attach it to the base with the screw (D).



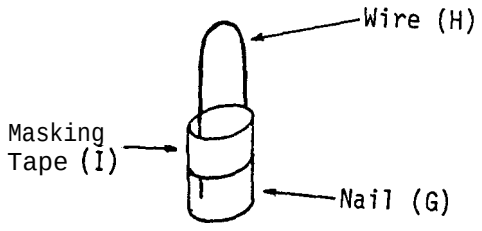
Pivot Support (C)

Using a small file cut a shallow, smooth notch in the top of each side of the support to hold a subsequent needle pivot in position.

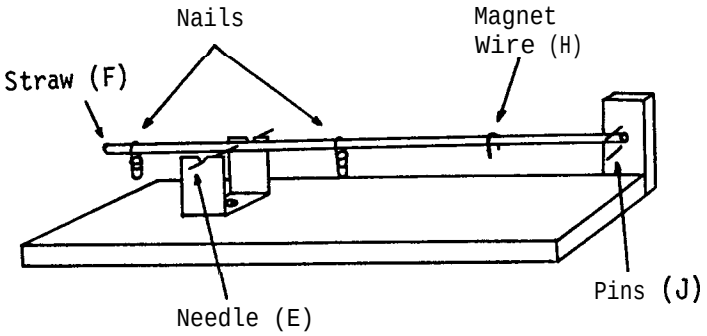
(2) Balance Arm



Insert the needle (E) through the top edge of soda straw (F) at a distance of 7 cm from one end. Balance the straw on the support.



Cut two lengths from the nail (G), one 1.0 cm long and one 2.0 cm long. Attach a three centimeter-long loop of the magnet wire to the end of each nail with the help of a strip of masking tape

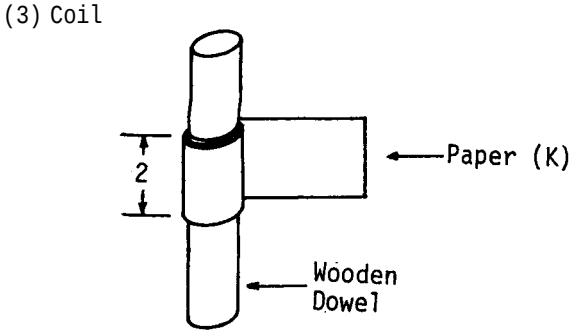


the short nail at the end of the short arm of the straw, and hang the long nail at an appropriate point on the other side of the pivot to serve as a counter-balance. A drop of glue (or a small piece of masking tape) can insure that the loops do not slip along the straw.

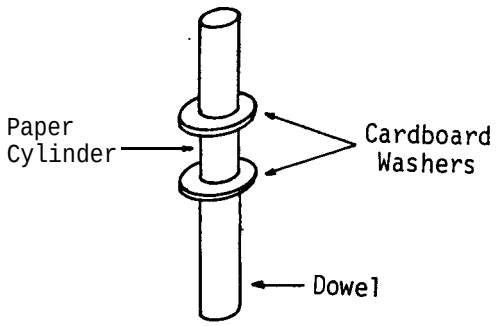
With the straw balanced horizontally note the corresponding point on the upright (B). Insert two pins (J) horizontally into the upright, one pin 0.5 cm above the top surface of the balanced straw, and the other 0.5 cm below the bottom surface, thus restricting the motion of the end of the straw to about 1 cm.

Set a length of magnet wire (M) on the straw to serve as a rider (see notes).

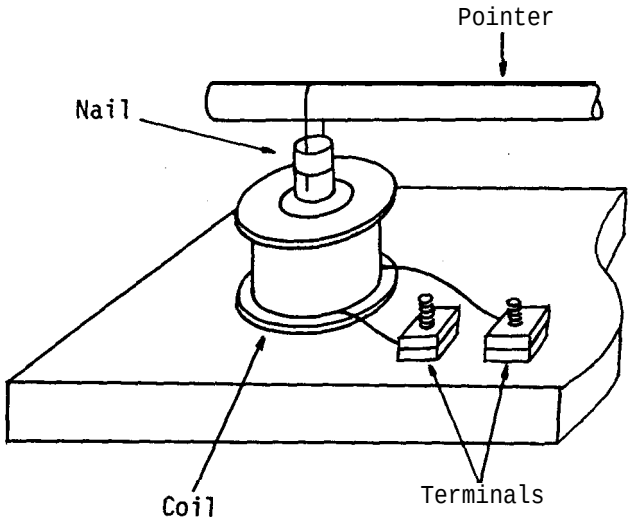
(3) Coil



Wrap the paper (K) around a wooden dowel (1.0 cm diameter) to make a paper cylinder. Secure the Joose ends of the paper with masking tape (N).



Cut two washers (internal diameter 1.0 cm, external diameter 2.0 cm) from the sheets of cardboard (L). Attach the washers to the ends of the paper cylinder with glue.



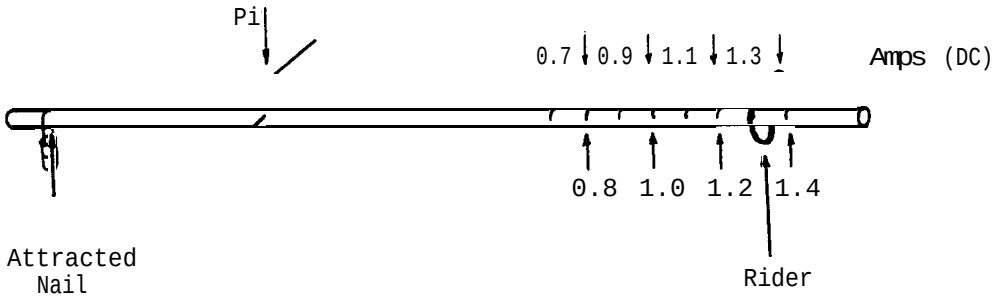
Wind the magnet wire (M) onto the paper cylinder to make a coil. Leave 10 cm of wire free at either end. Cover the last layer of wire with masking tape (N) to hold the coil in position. Remove the coil from the dowel, and mount it on the end of the base with glue in such a way that the axis of the coil is directly beneath the nail suspended from the end of the straw balance arm.

Drill two holes (diameter 0.3 cm) in the base at any convenient point close to the coil, and make two terminals from the nuts (P) and bolts (O) as described under VIII/A2, Component (4). Fit the terminals in the two holes, and connect the wires from the coil to the terminals.

c. Notes

(i) The galvanometer may be calibrated by placing it in series with an ammeter, a voltage supply and a variable resistance noting the position of the rider each time the straw balance arm is balanced and noting simultaneously the corresponding current through the coil.

(ii) A whole range of different scales may be produced simply by changing the mass of the rider on the balance arm. One such scale is illustrated below when the rider used was a 25 cm length of #26 magnet wire coiled into a loop, approximately 1 cm diameter.

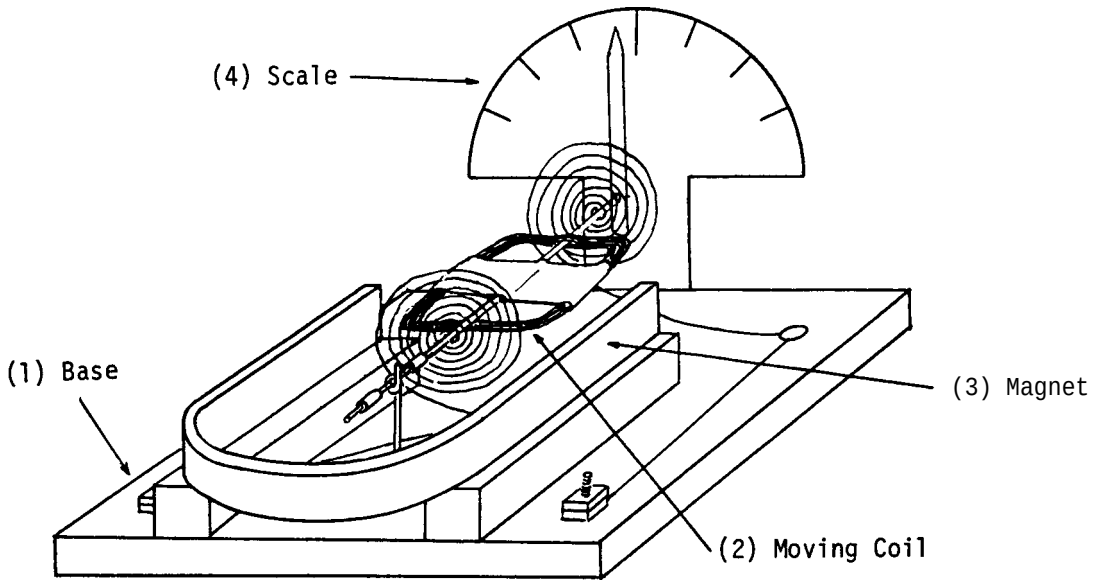


(iii) The resultant scale on the straw is linear. In other words, doubling the current passing through the coil doubles the force exerted by the coil on the nail, and the distance between the rider and pivot must be doubled to reestablish the balance of the straw.

(iv) The galvanometer will measure AC and DC currents equally well since the direction of the attraction exerted by the coil is not dependent on the direction of the current through the coil.

(v) The resistance of the galvanometer is approximately 0.1 ohms.

A5. Elementary Moving Coil Galvonometer

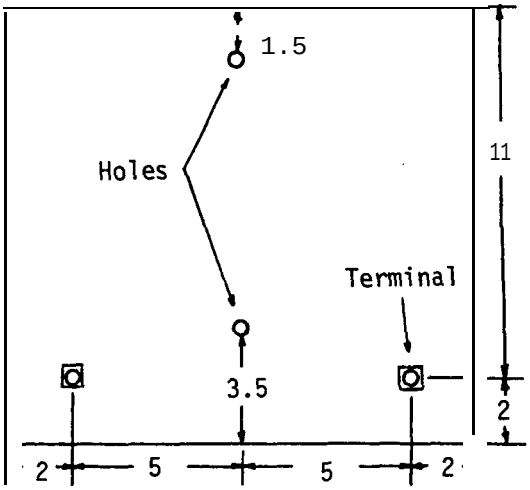


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	14 cm x 13 cm x 1.5 cm
	2	Bolts (B)	0.3 cm diameter, 3.0 cm long
	4	Nuts (C)	0.3 cm internal diameter
	2	Coat Hanger Wire (D)	7 cm long, 0.2 cm diameter
(2) Moving Coil	1	Roll of Magnet Wire (E)	#26
	1	Coat Hanger Wire (F)	10 cm long, 0.2 cm diameter
	1	Masking Tape (G)	--
	2	Thumbtacks (H)	--
(3) Magnet	1	Horseshoe Magnet (I)	--
	2	Wood Strips (J)	Approximately 8 cm x 1.5 cm x 1.0 cm
(4) Scale	1	Straw (K)	6 cm long
	1	Cardboard Sheet (L)	10 cm x 10 cm

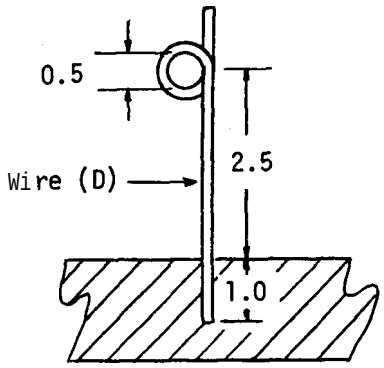
b. Construction

(1) Base



Wood (A)

Make two terminals [see VIII/A2, Component (4)] from the nuts (C) and bolts (B), making sure to inset the boltheads into the bottom of the wood (A). Drill two holes (0.2 cm diameter, 1.0 cm deep) into the base to hold the vertical supports.

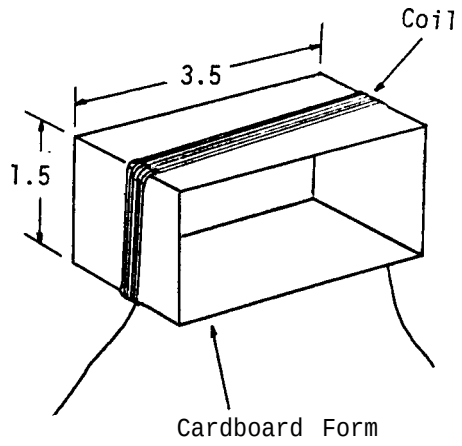


Side View

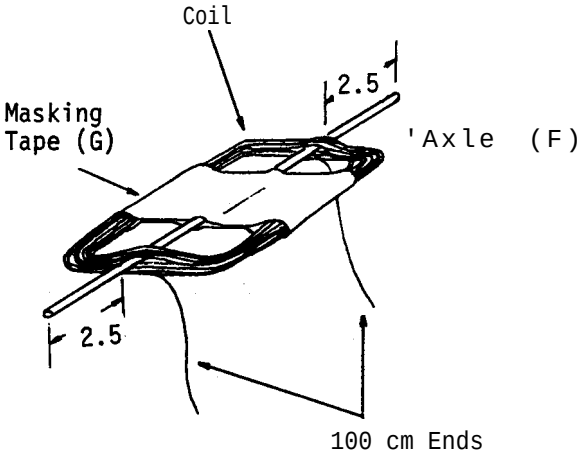
(Cross-section)

Make two vertical supports for the coil by twisting the coat hanger wire (D) into the shape indicated. Set the supports vertically upright in the newly drilled holes in the base.

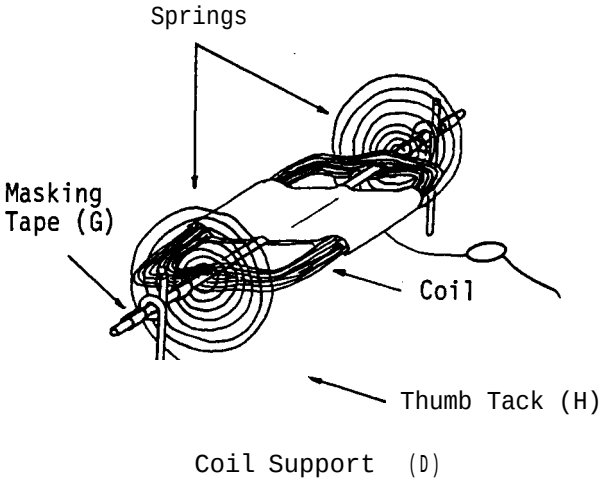
(2) Moving Coil



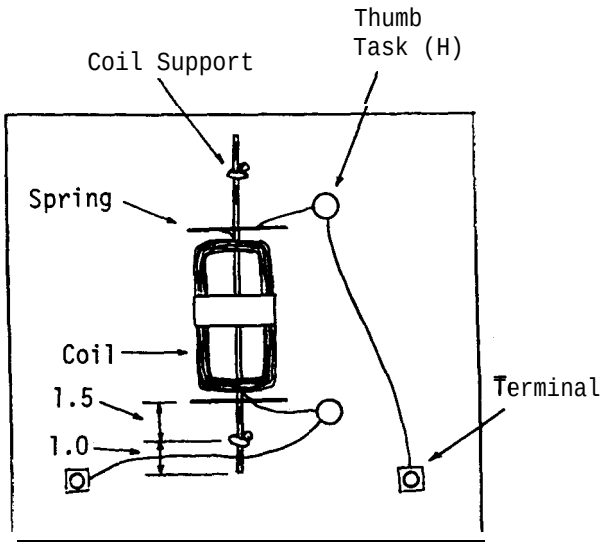
Wind 30 turns of magnet wire (E) around a cardboard form in order to make a coil of internal size 3.5 cm x 1.5 cm. Leave 100 cm of wire free at either end of the coil.



Thread the wire (F) through the middle of the coil to serve as the axle for the coil. Wrap masking tape (G) around the coil and axle to hold the coil firmly in position.



Fit the coil (F) into the coil supports (D) on the base. Wind the 100 cm of magnet wire (E) at either end of the coil into a spring, and attach the wire, just beneath each spring, to the base with the help of a thumb-tack (H). Each spring should contain about eight turns and be about 3 cm in diameter.



Top View

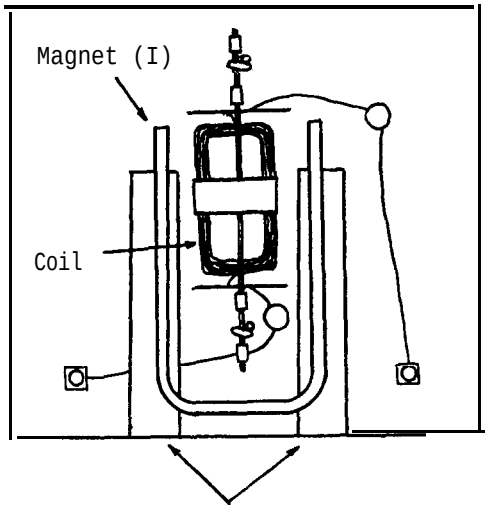
(The sensitivity of the moving coil increases with increasing number of turns and increasing diameter of the spring.) Connect the wire from the springs to the terminals on the base.

Prevent slipping of the axle on the supports by wrapping masking tape around the axle either side of one of the supports.

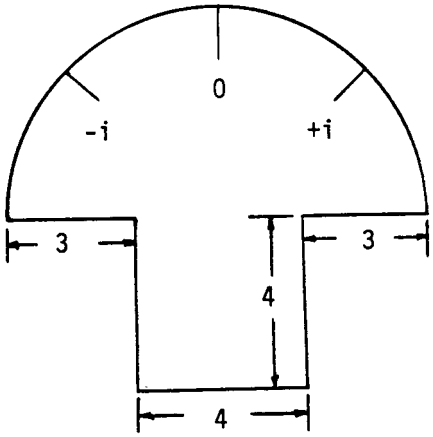
(3) Magnet

Procure a horeseshoe magnet (I) with pole heads at least 4 cm apart, and place it as shown around the coil. Make two wooden strips (J) which, when placed under the magnet, will bring the pole heads up to the same height as the coil. The ends of the magnet should be located opposite the middle of the coil.

Top View



(4) Scale



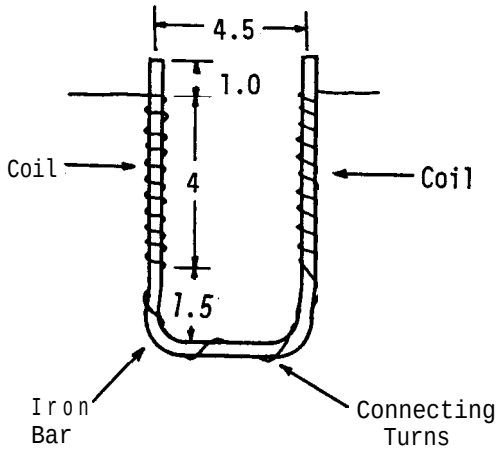
Take the straw (K) and, after piercing it 1 cm from one end, fit it on the end of the axle. A little glue will fix it firmly in position. Cut a suitable scale out of cardboard (L), and attach it to the base, so that it stands just behind the pointer.

C. Notes

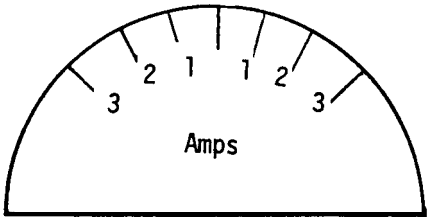
(i) The galvanometer may be calibrated by placing it in series with an ammeter, a voltage source and a variable resistance. The sensitivity of the galvanometer will depend very much on the strength of the horseshoe magnet used.

(ii) The galvanometer will measure DC current, but not AC.

(iii) If a suitable horseshoe magnet is not available, an electromagnet may readily be made. To do this, take a soft iron bar (17.5 cm x 2.0 cm x 0.3 cm), and bend it into a horseshoe shape as indicated. Take about 100 g of #26 magnet wire, and wind a coil on each side of the U-shaped bar. Each coil should be about 4 cm long, and should contain ten layers of wire. The coils should be connected in series to one another, simply by continuing the windings in the same direction around the bar from one coil to the other in a series of widely spaced connecting turns. The coils may be held in position by means of masking tape. If the coil is connected in series into a separate electrical circuit, it may be used in precisely the same way as the former horseshoe magnet.



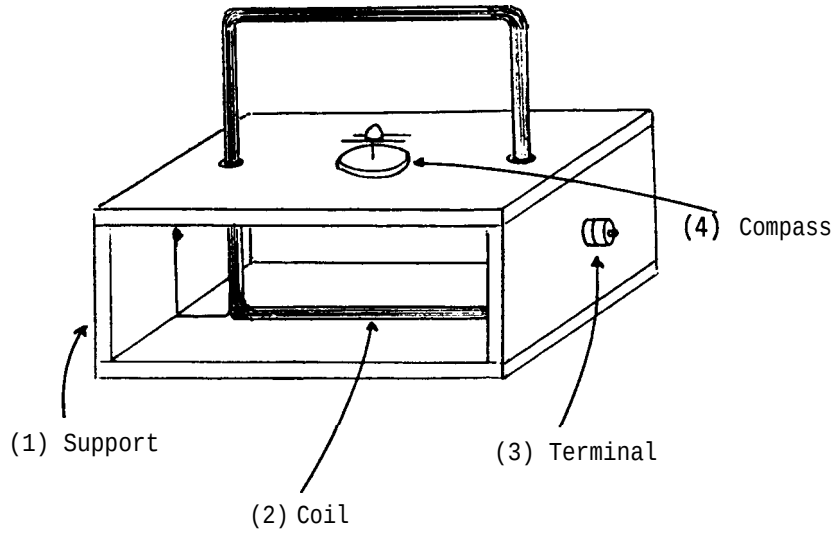
(iv) With a current of 0.5 amps through the electromagnet coils, a 2-amp current through the moving coil produced a deflection of approximately 30°. When the current through the electromagnet was increased to 1.0 amp, the deflection, due to a 3-amp current through the moving coil, increased to 45°.



Electromagnet Current Of Lamp

B. FUNCTIONAL TANGENT GALVANOMETERS

B1. Tangent Galvanometer ©



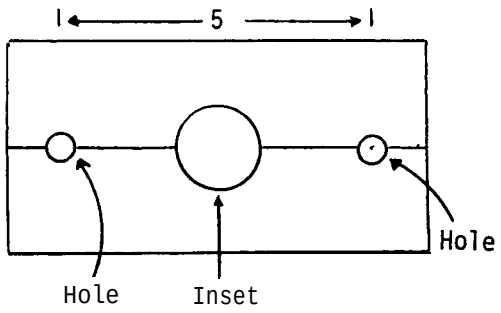
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Box Support	1	Wooden Base (A)	12 cm x 6 cm x l cm
	2	Wooden Sides (B)	6 cm x 2 cm x l cm
	1	Wooden Platform (C)	12 cm x 6 cm x l cm
	18	Small Wood Screws (D)	1.5 cm long
(2)Coil	1	Roll of Magnet Wire (E)	#24
	--	Varnish (F)	--
(3) Terminals	2	Brass Bolts (G)	0.3 cm diameter, 2 cm long
	4	Nuts (H)	0.3 cm internal diameter
(4) Compass	1	Wood Disc (I)	2.5 cm diameter, 0.3 cm thick
	3	Needles (J)	0.1 cm diameter
	1	Brass Rod (K)	0.5 cm diameter, 0.5 cm long

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 143-145.

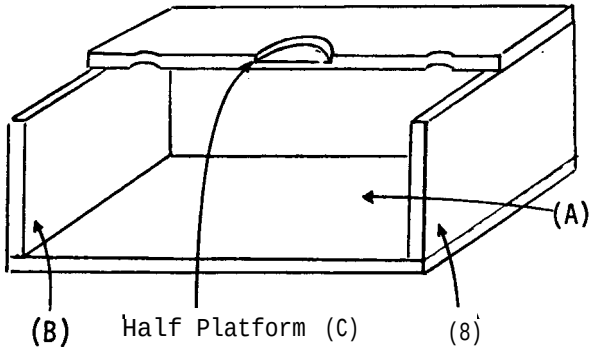
b. Construction

(1) Support

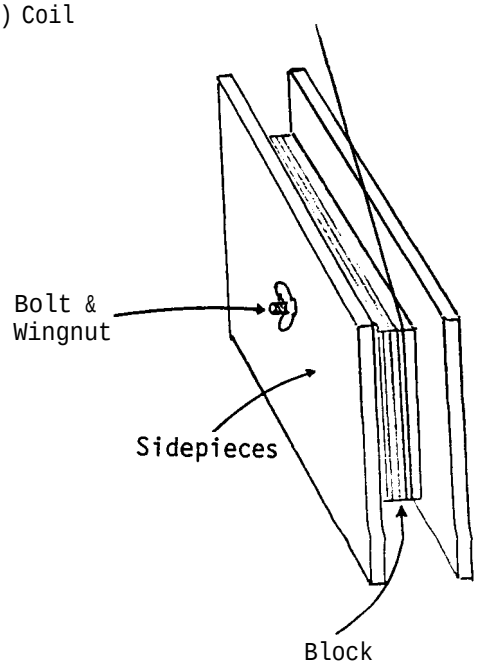


Make a four-sided wooden support from the wooden base (A), wooden sides (B) and platform (C). Fasten the base and sides together with small screws (D) and wood cement, but do not put the platform in position yet.

Drill an inset (2.5 cm diameter, 0.2 cm deep) into the middle of the platform, and two holes (1 cm diameter) right through the platform to take the coil. Cut the platform into two equal halves, fastening one half only in position with small screws and wood cement.

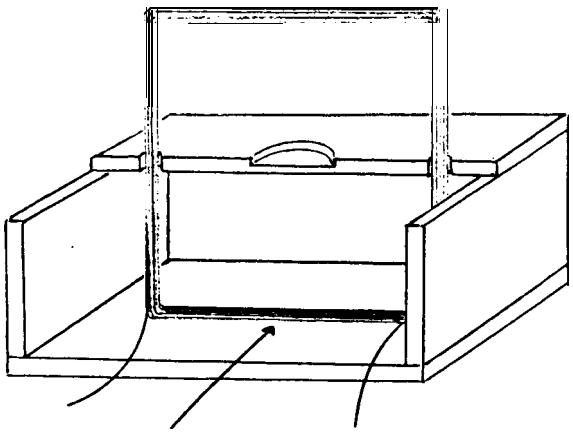


(2) Coil



To make the coil a simple winding device is desirable. This may be made from a block of wood (5 cm x 5 cm x 1 cm) and two cardboard sides (8 cm x 8 cm x 0.5 cm). Drill a hole through the middle of the block and sides and hold the parts together with a bolt and wing nut.

Wind 100 turns of magnet wire (E) onto the block, layer by layer, adding a coat of varnish (F) to each layer to hold the turns together. Make sure that about 20 cm of both ends of the



wire are left free to make appropriate connections.

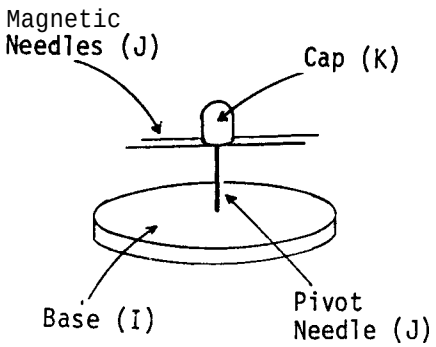
When the varnish is dry remove the coil from the block (simply by releasing the sides) and sit the coil vertically in the support.

Attach the second half of the platform with small wood screws and wood cement.

(3) Terminals

Use bolts (G) and nuts (H) to make two terminals as described under VIII/A2, Component (4). Fix one on either side of the support, and attach the two wires from the coil to the terminals. Don't forget to clean the ends of the wire with sandpaper.

(4) Compass

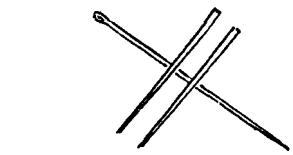


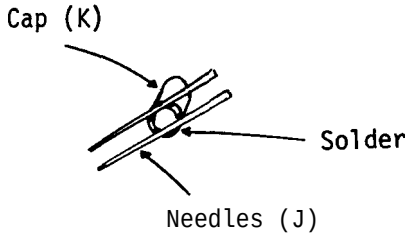
Use the wood disc (I) as the base of the compass. Alternatively, a cork disc would serve equally well, although less durable.

Cut a 1 cm length off the pointed end of a needle (J). Drill a small hole (0.1 cm diameter) in the middle of the base and set the needle in the hole with epoxy resin so that it stands vertically, pointed end uppermost.

Holding rod (K) firmly in a clamp, drill a hole (0.3 cm diameter) 0.3 cm deep along the axis. You now have a suitable cap to sit on the pivot.

Cut 2 cm lengths off the two remaining needles (J). Determine the center of gravity of each by balancing the needles over another needle. Mark in the position of the center of gravity of each of the two needles.





Hold the needles parallel to one another and drop some solder on the base of the cap. Innnediately attach the needles (at their centers of gravity) to the cap by placing them in the still molten solder.

Finally, place the cap and needles inside a magnetizing coil (IX/A2) to magnetize them, and then place them on top of the pivot.

Note the ends of the needles which point to the North, and mark these (e.g., with paint).

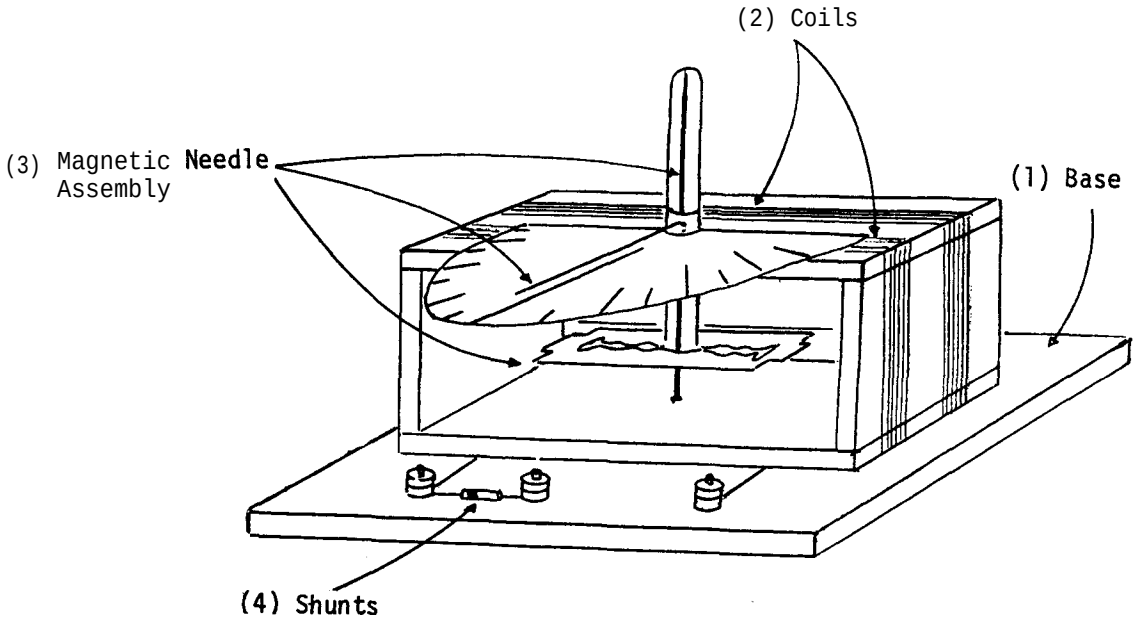
C. Notes

(i) The galvanometer should be set so that the plane of its coil is in a North-South direction, as indicated by the compass needle. A current passing through the coil will cause the needle to be deflected out of this plane, the angle of deflection depending on the strength of the current.

(ii) It is important that magnets and iron should be kept well away from the galvanometer during use to avoid influencing the compass needle.

(iii) The galvanometer will readily detect the differences in magnitude of currents produced by the various combination of plates and electrolytes in the Chemical Cell (VIII/Al).

B2. Tangent Galvanometer with Shunts *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	10 cm x 10 cm x 1 cm
	2	Bolts (B)	0.3 cm diameter, 2.5 cm long
	4	Nuts (C)	0.3 cm internal diameter
(2) Coils	2	Wood (D)	8 cm x 5 cm x 0.5 cm
	2	Wood (E)	3 cm x 5 cm x 0.5 cm
	1	Magnet Wire (F)	#26 (diameter 0.05 cm), length approximately 16 meters
	--	Masking Tape (G)	--

*Adapted from Fr. George Schwarz, A Don Bosco Laboratory Manual, (Philippines: Unpublished Papers).

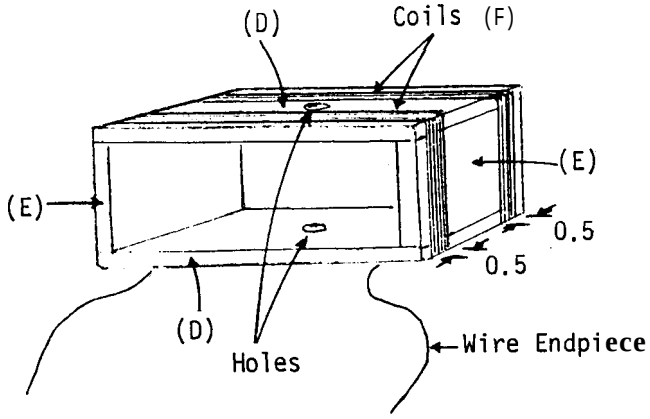
(3) Magnetic Needle Assembly	1	Needle (H)	10 cm long, 0.1 cm diameter
	1	Razor Blade with Double Edges (I)	--
	1	Glass Tube (J)	6 cm long, 0.5 cm external diameter
	2	Screws (K)	1.5 cm long
	1	Cardboard Sheet (L)	2.5 cm x 2.0 cm
	1	Pin (M)	2.5 cm long, approximately
	3	Cardboard Sheets (N)	B cm x 4 cm
(4) Shunts	1	Nichrome Wire (0)	#24, 0.17 ohms (approximately 5 cm long)
	1	Resistor (P)	1,000 ohms (from radio shop)
	1	Bolt (Q)	0.3 cm diameter, 2.5 cm long
	1	Nut (R)	0.3 cm internal diameter

b. Construction

(1) Base

Drill two holes (diameter 0.3 cm) in Wood (A) about 3 cm apart and close to one edge to take the terminals. Use bolts (B) and nuts (C) to make two terminals as described under VIII/A2, Component (4), and fit them through the holes in the base. The boltheads should be countersunk into the bottom of the base so that the latter sits flat on any horizontal surface.

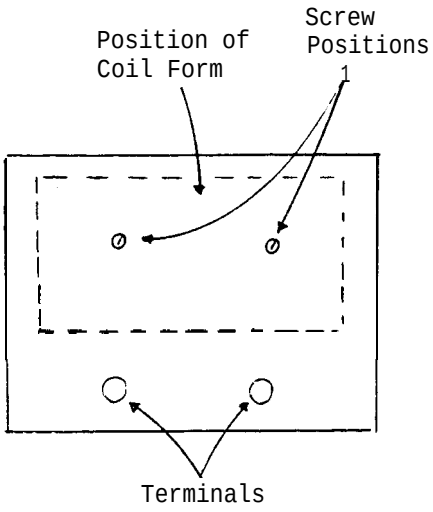
(2) Coils



Make a wooden form using wood (D) for the top and base and wood (E) for the side pieces. Glue the pieces together.

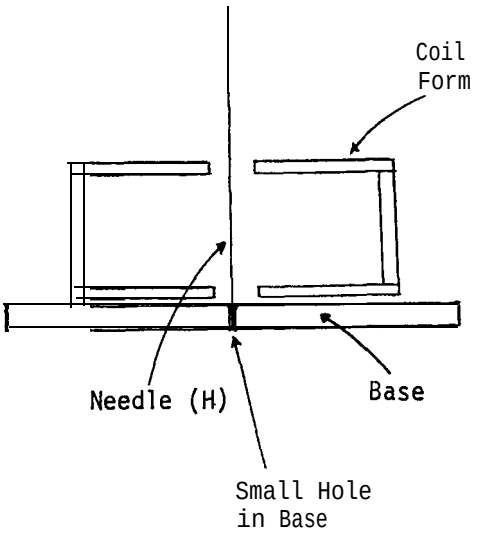
Drill a hole (1.0 cm diameter) in the middle of the top, and an identical hole (1.0 cm diameter) directly beneath in the middle of the base of the form.

Wind magnet wire (F) around the form to make two coils which are connected in series to one another, and which are wound in the same direction around the form. Wind 20 turns of wire into each coil, and locate these close to the opposite edges of the form. Make sure that about 10 cm of each end of the wire is left free. After winding the coils, cover the final layer of turns with a layer of masking tape (G) to hold the coils in position.

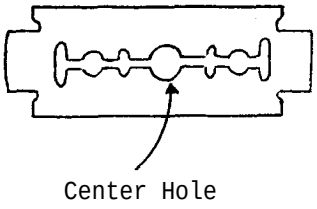


Drill two appropriate holes through the base in order to attach the coil form to the base with screws, but do not screw the form on to the base yet.

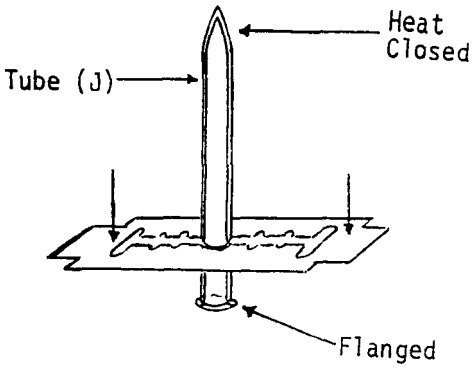
(3) Magnetic Needle Assembly

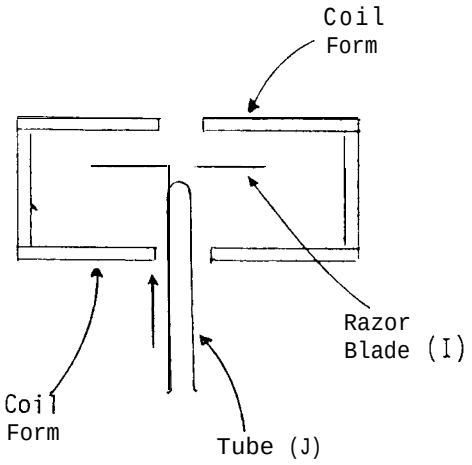


Drill a hole (0.1 cm diameter) in the base in the position that corresponds to center of the larger hole in the base of the coil form. Cut the end (containing the eye) off needle (H) to make it 8 cm long, and set the blunt end of the needle firmly in the hole in the base, so that it stands vertically with the point upwards. A little epoxy resin may be required to hold the needle firmly in the hole.

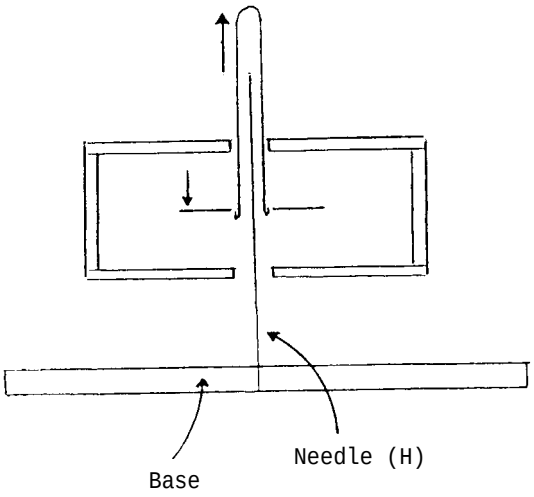


Take a double-edged razor blade (I) which contains a center hole, and magnetize it with the help of a magnetizing coil (IX/Al). Measure the size of the center hole (probably about 0.5 cm diameter), and take a glass tube (J) with the same external diameter as that of the center hole. Heat close (CHEM/I/D5) one end of the tube and create flanges (CHEM/I/D7) at the open end. The flanges on the tube will prevent the razor blade from slipping off the tube, so long as the latter is held in a vertical position.

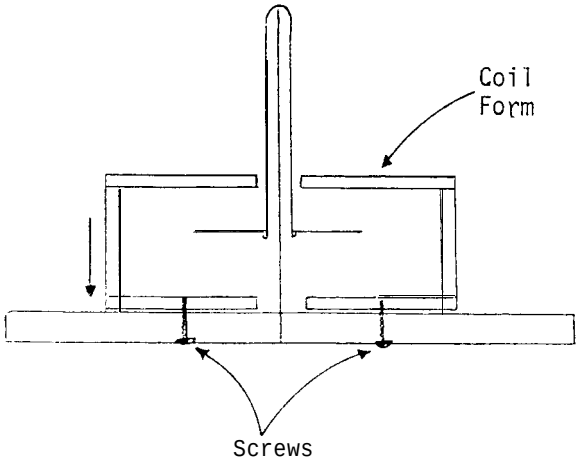




To put the magnetic needle assembly together, hold the razor blade horizontally inside the coil form. Insert the glass tube through the base hole in the form, and then through the hole in the blade.

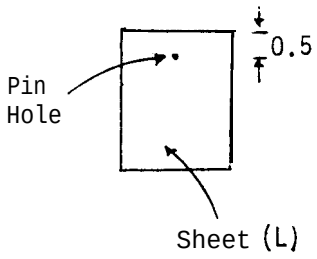


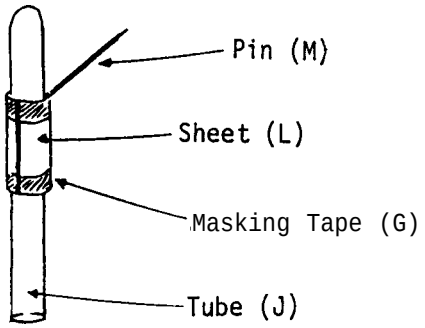
Lower the blade onto the flanges of the glass tube, and raise the tube partially through the upper hole in the form.



Lower the coil form and tube together onto the needle projecting vertically from the base. Take two screws (K) and firmly attach the base and coil form together.

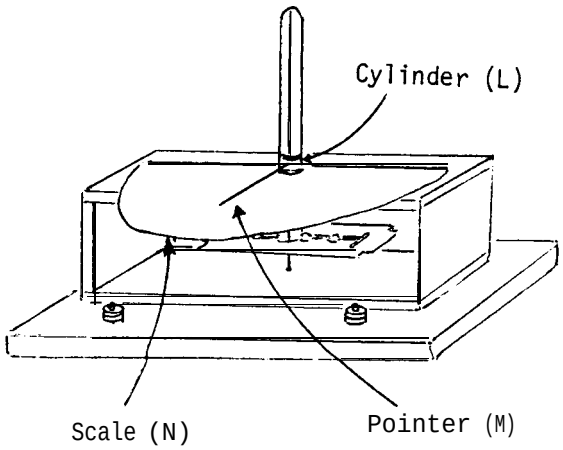
Connect the loose wires from the coils to the terminals, making sure that all enamel has been removed from the wire ends.





Take the thin sheet of cardboard (L), and thrust pin (M) through the sheet at about 0.5 cm from the middle of the top edge. Bend the cardboard around the glass tube (J) to form a tight cylinder from which the full length of the pin will protrude. Fasten the free ends of the cardboard sheet together with masking tape wrapped around the cylindrical sheet.

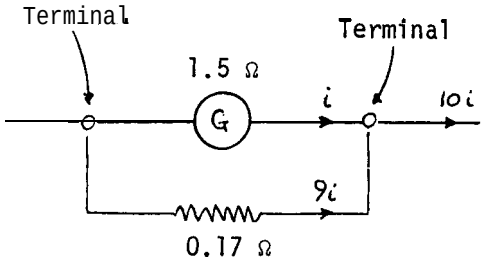
Lower the cardboard cylinder onto the tube until it touches the razor blade. The pin should clear the top of the form by about 0.5 cm, and will serve as a pointer to record the motion of the magnetized needle below.

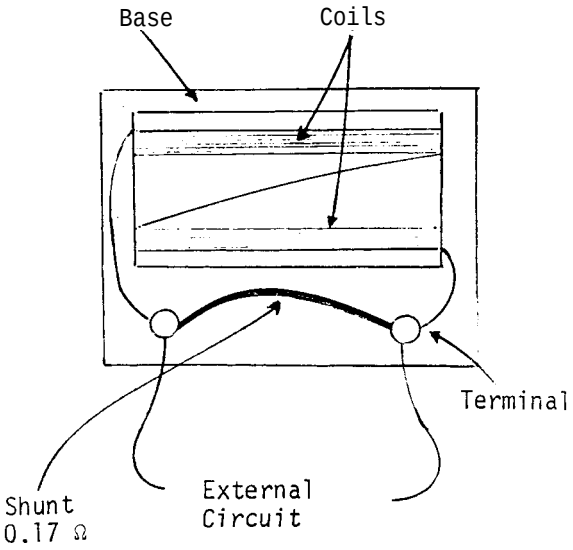


Cut a semicircular disc (diameter B cm) out of the cardboard sheet (N), and set it on top of the coil form to serve as a scale. Mark the position of the cardboard on top of the form, SO that the cardboard scale may be replaced in exactly the same position whenever it is removed.

(4) Shunts

Set the plane of the galvanometer coils in a North-South direction so that the longitudinal, horizontal axis of the magnetized razor blade is in the same plane as that of the coils. The direction of the pointer should be set at 90° to this plane. Now calibrate the galvanometer by placing it in series with a milliamneter (0-100 milliamps), a voltage supply (dry cells, battery, etc.) and a variable resistance. The resultant scale will swing from the center zero position of the pointer through about 90°. If the direction of the current through the coil is reversed, a deflection (and hence scale) in the opposite direction will be obtained.

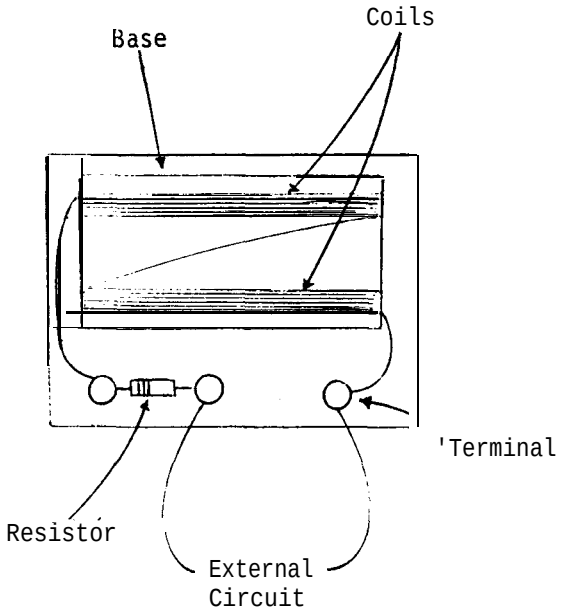




Top View

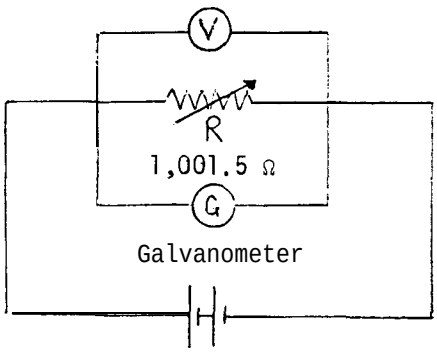
Take a suitable length of nichrome wire (0) and connect it across the galvanometer terminals. In this case, since the resistance of the galvanometer is 1.5 ohms a wire of resistance 0.17 ohms (5 cm of #24, U.S. Standard Plate guage, nichrome wire, 20% chrome, 80% nickel) would result in 1000 milliamps (1 amp) producing a full scale deflection instead of 100 milliamps doing this.

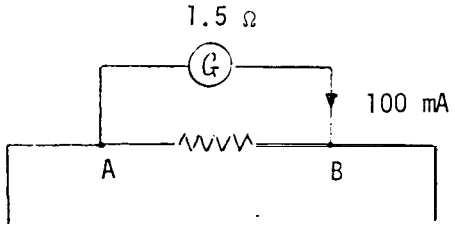
With the resistance wire across the terminals recalibrate the galvanometer in the usual way with a fresh cardboard sheet for a new scale.



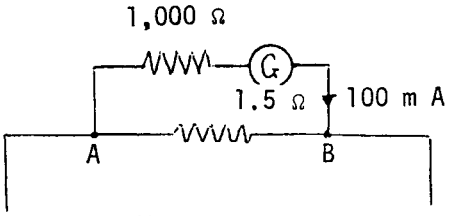
To convert the galvanometer to a voltmeter; add a 1,000 ohm resistor (P) in series to the galvanometer. To do this use bolt (Q) and nut (R) to make a terminal as described under VIII/A2, Component (4), and add it to the base between the existing terminals. Then connect the resistor (obtained from a radio shop) across two adjacent terminals as illustrated. Recalibrate the modified galvanometer by placing it in parallel across a variable resistance, and comparing the potential at any moment with a commercial voltmeter, also placed in parallel with the variable resistance.

Voltmeter





V_{AB} = 0.15 volts

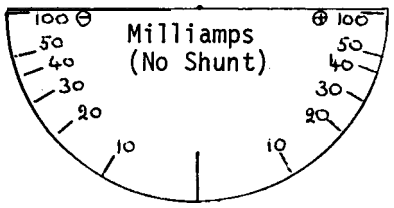


V_{AB} = 100 volts

Without a resistance in series, the full-scale deflection of the galvanometer would only measure 0.15 volts across the terminals. With the 1,000 ohm resistance in series, the full-scale deflection of the galvanometer would measure 100 volts across the terminals, More important, the current taken through the galvanometer, compared with that in the circuit being measured, would be negligible.

c. Notes

(i) The resultant scales will be nonuniform, sensitivity falling off with increasing voltage as indicated. The scale will indicate the direction of the current through the galvanometer.

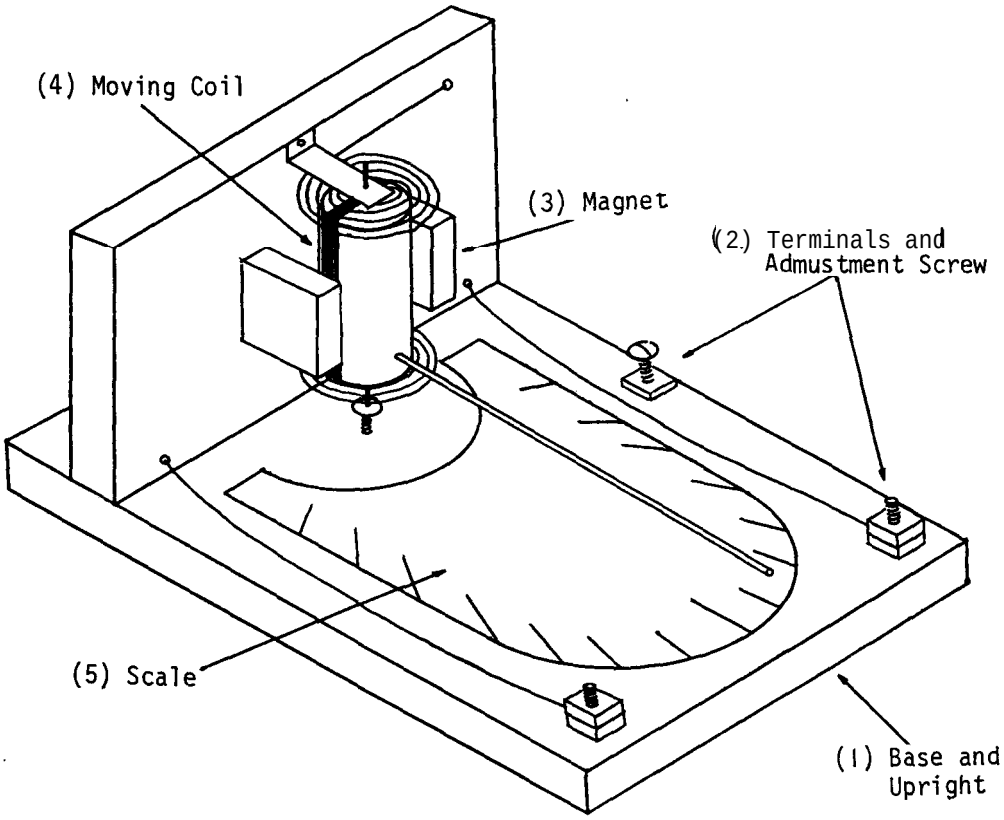


(ii) The galvanometer cannot measure AC current.

(iii) This galvanometer is relatively simple to make, it is surprisingly sensitive, and in combination with the shunts may be used for a wide range of measurements of amperage and voltage.

C. FUNCTIONAL MOVING COIL GALVANOMETERS

C1. Moving Coil Galvanometer©



a. Materials Required

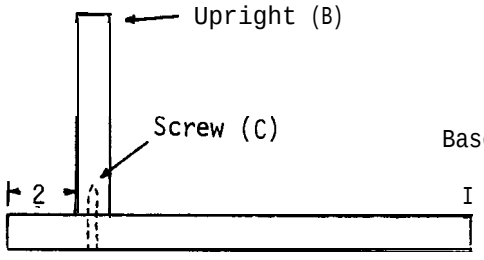
Components	Qu	Items Required	Dimensions
(1) Base with Upright	1	Wood (A)	14 cm x 11 cm x 1 cm
	1	Wood (B)	6 cm x 11 cm x 1 cm
	2	Wood Screws (C)	2 cm long

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for ~~Educational Development Overseas, 1972), pp 153-158.~~

(2) Terminals and Adjustment Screw	2	Brass Bolts (D)	0.3 cm diameter, 2.0 cm long
	4	Nuts (E)	0.3 cm internal diameter
	1	Bolt (F)	0.2 cm diameter, 2 cm long
	1	Nut (G)	0.2 cm internal diameter
	2	Thumbtacks (H)	--
(3) Magnet	1	Horseshoe Magnet (I)	Separation of poles between 3.0 cm and 3.5 cm
(4) Moving Coil	1	Wooden Dowel (J)	2 cm diameter, 3 cm long
	1	Galvanized Wire (K)	7.5 cm long, 0.1 cm diameter
	1	Needle (L)	0.1 cm diameter, 5 cm long
	1	Box of Nails (M)	2 cm long, diameter as small as possible
	1	Roll of Magnet Wire (N)	#22
	2	Pieces of Magnet Wire (O)	#30, 50 cm long
	1	Wood Screw (P)	0.8 cm long
	1	Brass Strip (Q)	3.5 cm x 1.0 cm x 0.05 cm
	1	Wood Screw (R)	0.8 cm long
(5) Scale	1	White Paper (S)	10 cm x 10 cm

b. Construction

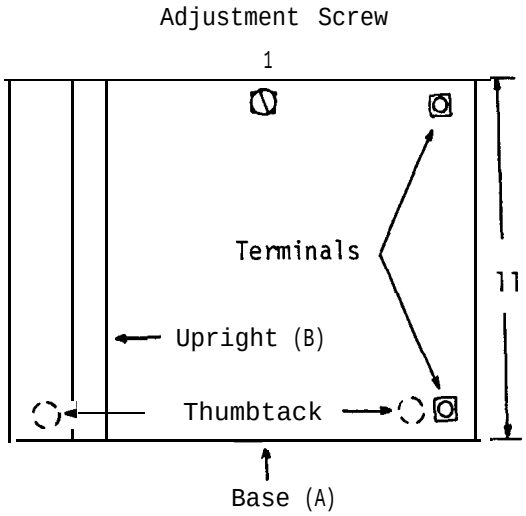
(1) Base with Upright



Side View

Attach the wooden upright (B) to the base (A) with two screws (C) from beneath the base and with wood cement to make a firm joint. Leave approximately 2 cm behind the upright.

(2) Terminals and Adjustment Screw

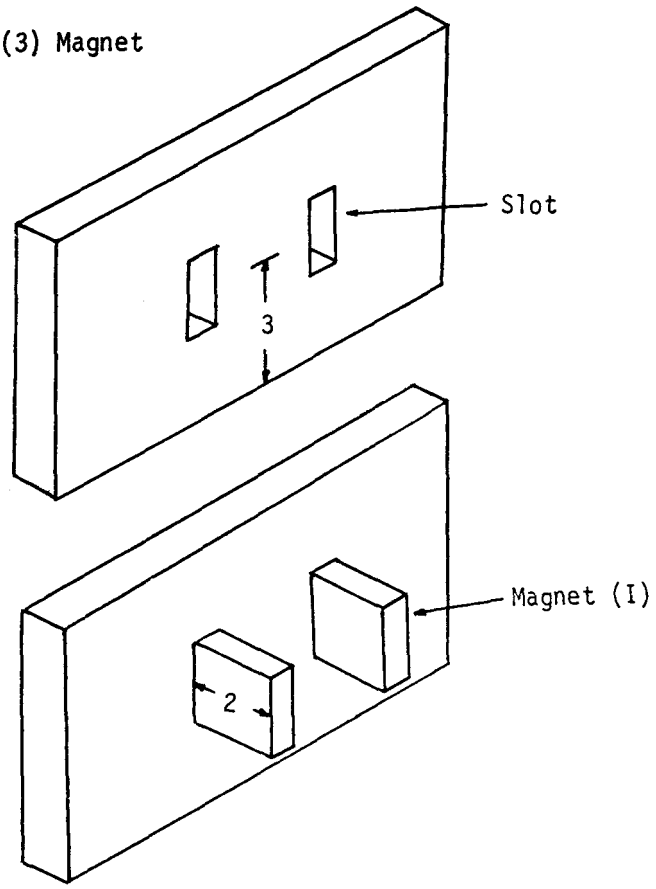


Top View

Make two terminals in the front of the base from the brass bolts (D) and nuts (E) [See VIII/A2, Component (4)].

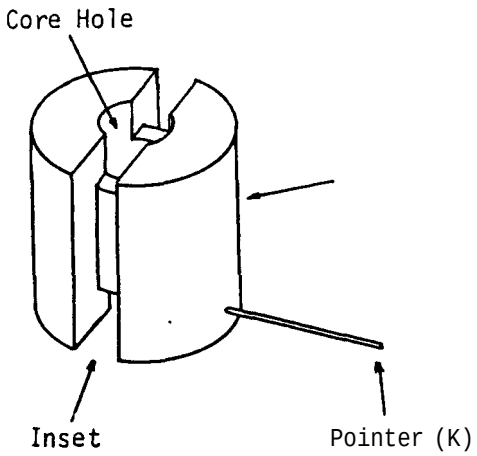
Make an adjustment screw [as described under IX/A3, Component (l)] from the bolt (F) and nut (G) to fit in one side of the base. At opposite corners of the other side of the base, insert two thumbtacks (H) to the bottom so that the base is rested on three points, the adjustment screw and thumbtacks.

(3) Magnet



Obtain a strong horseshoe magnet (I) in which the separation of the two sides of the horseshoe is approximately 3 cm (or a little more). Make slots in the upright (B) as illustrated to allow the magnet to be pushed through the upright so as to protrude a distance of 2 cm. Once the moving coil (below) has been fixed finally in position, fix the magnet firmly in the upright with epoxy resin. The slots are most easily made before the upright has been screwed to the base.

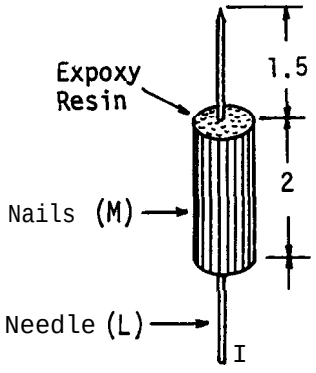
(4) Moving Coil



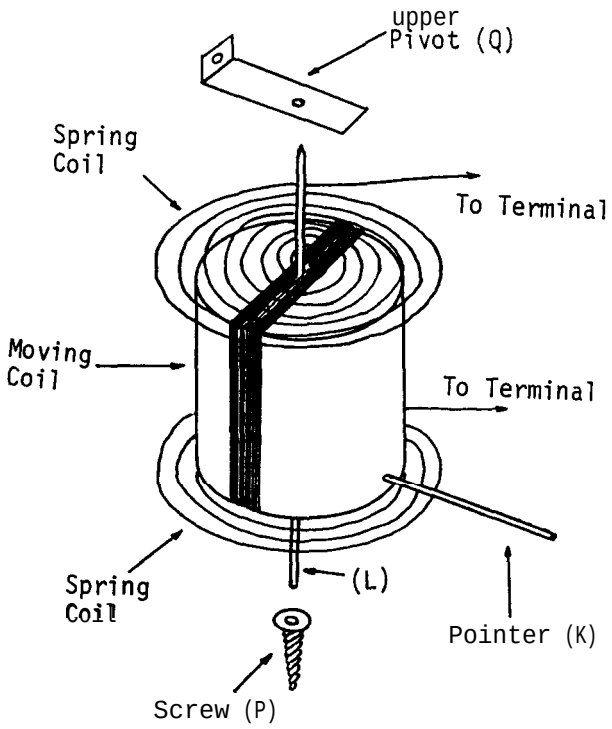
Make an inset (0.5 cm wide, 0.5 cm deep) around the wooden dowel (J) specifically to hold a coil. Drill a hole (0.8 cm diameter) along the axis to take the pivot and soft iron core.

Bore a hole (0.5 cm deep, 0.1 cm diameter) horizontally into the bottom of the core at right angles to the plane of the inset (and coil)

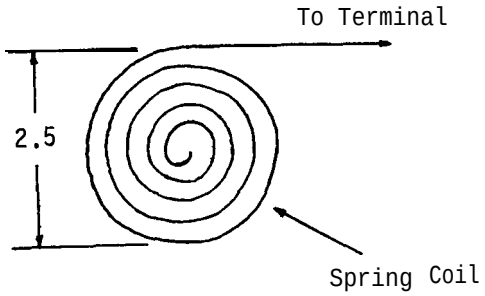
Then, fit the galvanized wire (K) into the hole with epoxy resin to serve as a pointer.



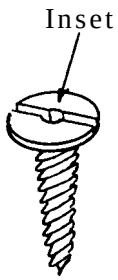
The needle (L) will serve as a pivot. Cut off the heads of the nails (M), and make the length 2 cm. Pack the nails into the hole through the middle of the wooden core (J), placing the needle (L) in the very center of the hole, so as to protrude an equal distance from either end of the core. Bind the newly created core and pivot firmly in position with a liberal coating of epoxy resin over the nail ends and around the needle.



Wind 40 turns of magnet wire (N) around the inset of the core, making sure that both ends are left free. Clean the ends of the wire with sandpaper and solder each end on to another length of very fine magnet wire (0) from which fine spring coils may be made around the top and bottom portions of the pivot.

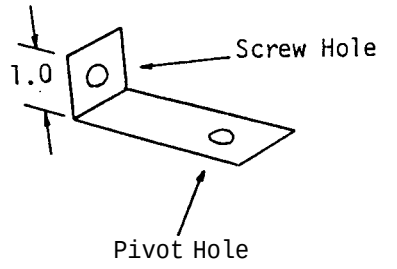


The sensitivity of the spring increases as the number of turns wound into the spring increases, and as the diameter of the spring increases. Once each spring has been wound, avoid subsequent damage during construction by holding it between two pieces of cardboard which may be taped to the wooden core.

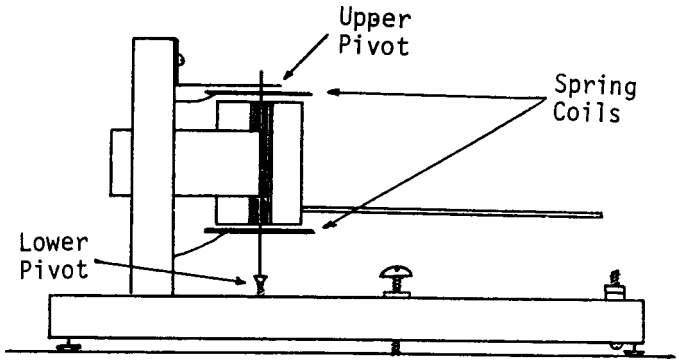


Screw (P)

Insert the wood screw (P) into the base at a point 2 cm from the front of the upright and centered. Drill an inset (0.2 cm deep) into the head of the screw so that it will serve as a lower pivot for the coil.



Bend the strip of brass (Q) to form an "L" shape. Drill a screw hole (diameter 0.3 cm) in the short end and a pivot hole (diameter 0.2 cm) at a distance of 0.5 cm from the other end. Slide the strip over the pivot needle, and screw the strip to the upright, with the screw (R).



Side View

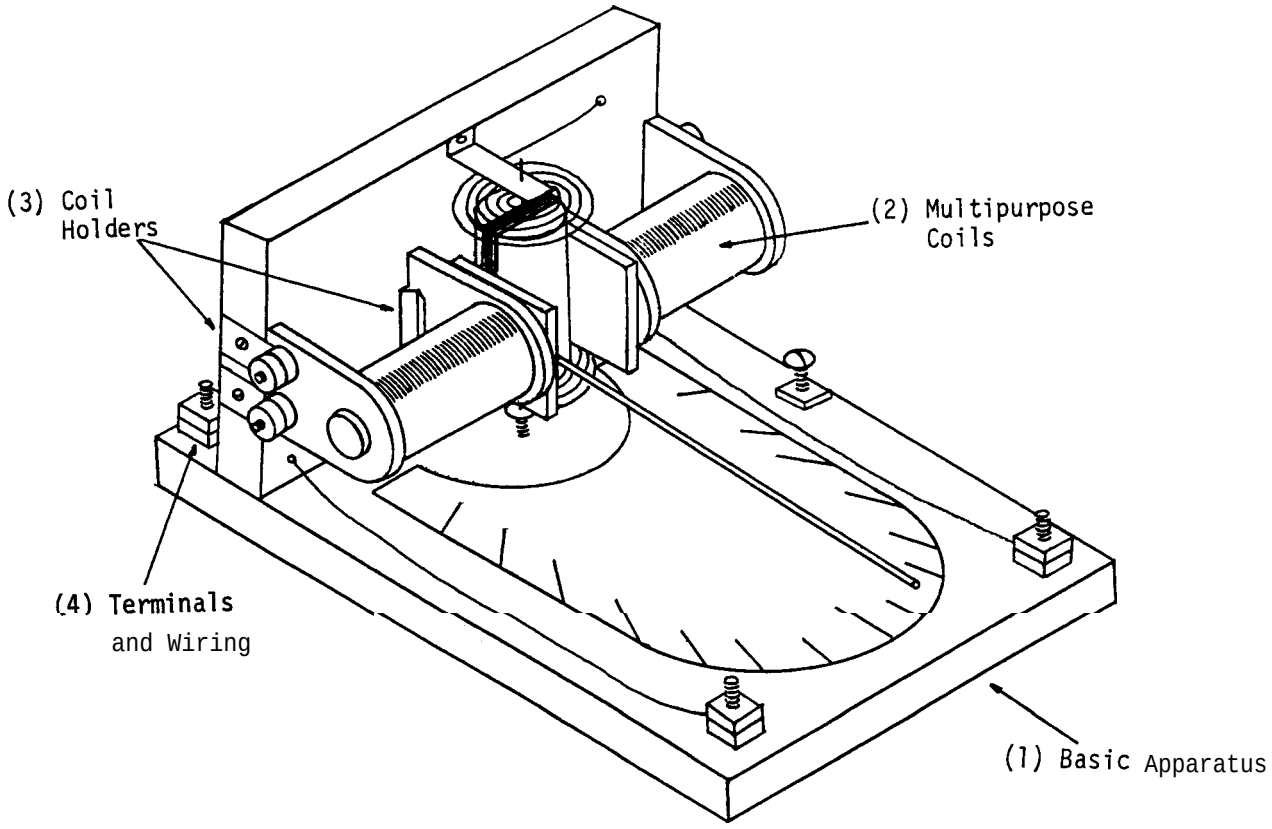
Connect the wire from the two ends of the springs to the two terminals, One of the best ways of doing this is to drill small holes in the upright (opposite the springs) threading the wire through the holes. If two more holes are drilled through the upright near the bottom (one on either side) the wire may be threaded back through the upright to the terminals.

(5) Scale — Cut a sheet of paper (S) and paste it on the base. Taking the lower pivot as the center point, mark off a scale to indicate every 10° movement of the pointer. The scale may later be recalibrated in amps or volts as desired.

C. Notes

(i) Should there be any difficulty in obtaining a suitable, strong horseshoe magnet, then multipurpose coils may be used as described in the next item.

C2. Moving Coil Galvanometer with Multipurpose Coils ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basic Apparatus	1	Moving Coil	X/Cl, all components except component (3)
(2) Multipurpose Coils	2	Multipurpose Coil with Cores (B)	IX/A2
(3) Coil Holders	4	Brass Sheets (C)	3.0 cm x 0.8 cm x 0.05 cm
	4	Screws (D)	0.8 cm long
	2	Brass Sheets (E)	2 cm x 2 cm x 0.02 cm
	4	Screws (F)	0.8 cm long

© From Reginald F Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 19/2), pp 159-161.

(4) Terminals and Wiring	2	Brass Bolts (G)	0.3 cm diameter, 2 cm long
	4	Nuts (H)	0.3 cm internal diameter
	1	Roll of Magnet Wire (I)	#24

b, Construction

(1) Basic Apparatus

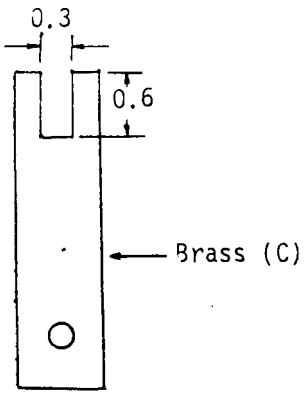
Make the moving coil galvanometer as described under X/Cl, but do not make component (3) of the item or the holes in the upright to take a magnet. The finished product will in fact be the basic apparatus (A).

The subsequent making of the coil holders and addition of further terminals to the basic apparatus is likely to damage the moving coil springs unless these are carefully protected. It is therefore suggested that the springs be held between cardboard sheets taped to the wooden core while further modifications are made,

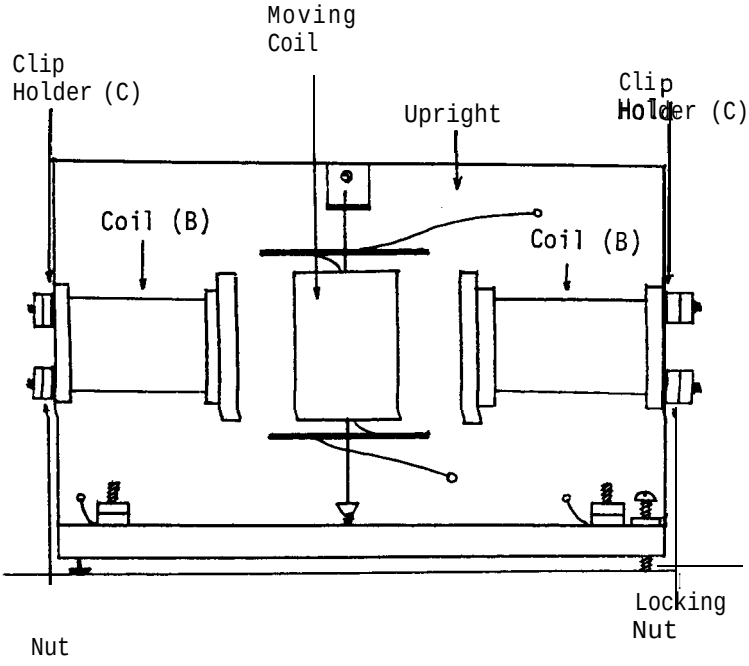
(2) Multipurpose Coils

Make two multipurpose coils (B) complete with soft iron cores and pole heads as described under IX/A2.

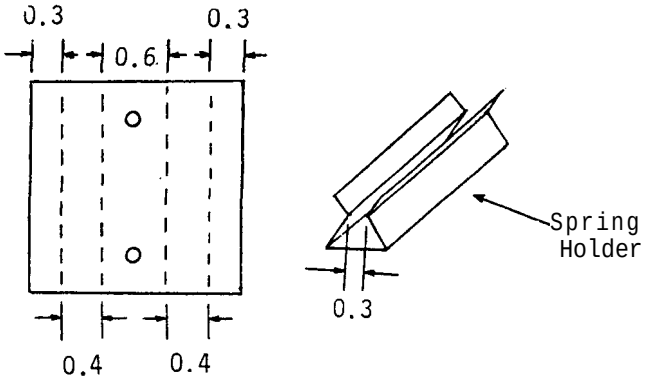
(3) Coil Holders



Cut four clip holders from the four brass sheets (C), making a screw hole at one end and a small slit at the other. Fit the four slits in the holders under the locking nuts of the four terminals of the multipurpose coils (B). Then position each coil in turn on the upright so that the pole head is at exactly the same height above the base as the moving coil core. In this position screw the clips firmly onto the edge of the upright with the screws (D).



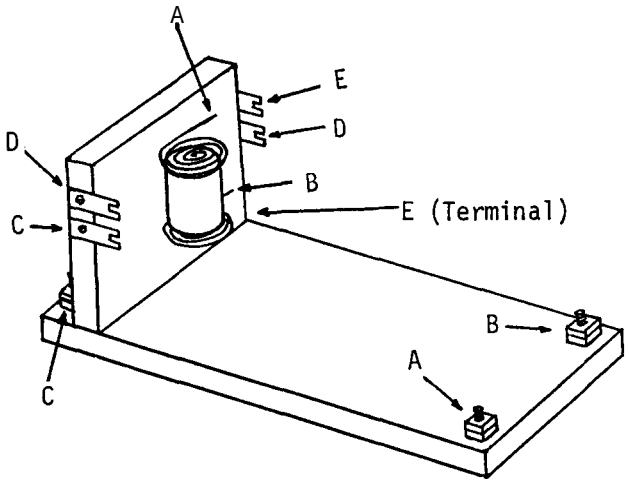
Front View



Make two spring holders from the two brass sheets (E) and slip these on the free ends of the multipurpose coils to determine where they should be attached to the upright. Having marked in the position, screw the

holders onto the upright with the remaining screws (F).

(4) Terminals and Wiring



Use the bolts (G) and nuts (H) to make two additional terminals as described under item VIII/A2, component (4). Attach them to the base, just behind the upright, and then connect the clips and terminals with magnet wire (I) so that electrical connections exist between points A to A, B to B, C to C, D to D and E to E, thus insuring that once the additional terminals are connected to a circuit, the resultant current will flow through the two coils in the same direction.

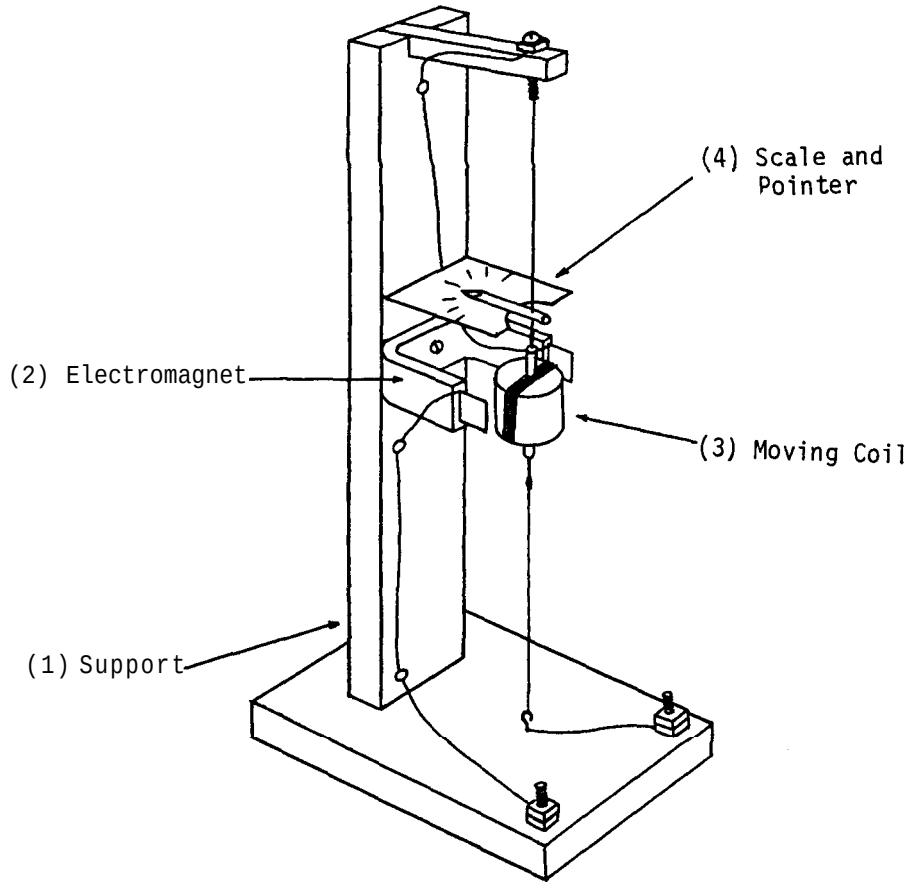
C. Notes

(i) Changing the direction of the current through the moving coil will change the direction of the deflection, so long as the current through the multipurpose coils remains in the same direction. The resultant scale is thus a center zero scale, with the deflection indicating the direction of the current. So long as the current through the moving coil and the multipurpose coils are independent of one another, this galvanometer cannot measure AC current.

(ii) The galvanometer may be calibrated in the usual way by placing it in series with an ammeter (0 → 2 amps), a voltage supple (cells, battery, etc.) and a variable resistance.

(iii) With a current of 0.25 amps flowing through the multipurpose coils, the galvanometer constructed had a range of 0 to ± 1.5 amps. When the current through the multipurpose coils was doubled to 0.50 amps the galvanometer was much more sensitive, and the same deflections produced a range of 0 to ± 0.85 amps.

C3. Moving Coil Galvanometer with Shunts *



a. Materials Required

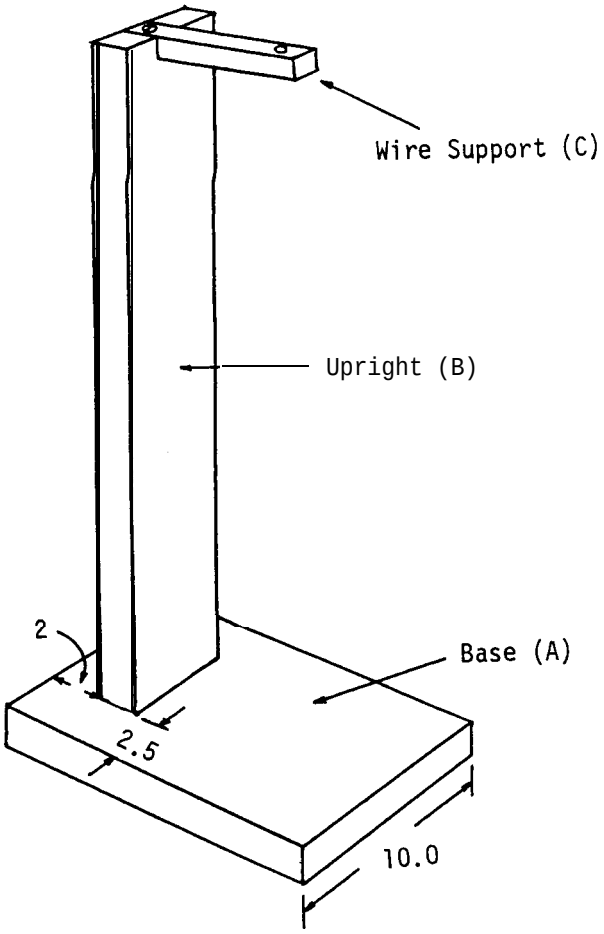
Components	Qu	Items Required	Dimensions
(1)Support	1	Wood (A)	1 cm x 10 cm x 2 cm
	1	Wood (B)	38 cm x 5 cm x 2 cm
	1	Wood (C)	10 cm x 1 cm x 1 cm
	1	Screw (D)	2.0 cm long

*Adapted from Fr. George Schwarz, A Don Bosco Laboratory Manual, (Philippines: Unpublished Papers).

(2) Electromagnet	1	Soft Iron Bar (E)	18 cm x 2.5 cm x 0.3 cm
	--	Masking Tape (F)	--
	1	Bolt (G)	0.3 cm diameter, 4 cm long
	1	Nut (H)	0.3 cm internal diameter
	1	Wing Nut (I)	0.3 cm internal diameter
	1	Magnet Wire (J)	#26 (0.05 cm diameter), 150 g
	1	Bolt (K)	0.4 cm diameter, 3 cm long
	2	Nuts (L)	0.4 cm diameter
	2	Bolts (M)	0.3 cm diameter, 3.5 cm long
	4	Nuts (N)	0.3 cm internal diameter
	4	Thumbtacks (0)	--
(3) Moving Coil	--	Washers (P)	0.6 cm internal diameter, 1.2 cm external diameter
	1	Wooden Dowel (Q)	0.6 cm diameter, 5.5 cm long
	2	Needles (R)	0.1 cm diameter
	1	Wooden Dowel (S)	3.0 cm diameter, 3.5 cm long
	1	Magnet Wire (T)	#26, 800 cm long
	2	Magnet Wire (U)	#30, 16 cm long
	1	Eye Screw (V)	--
	1	Magnet Wire (W)	#26, 7 cm long
(4) Pointer and Scale	1	Soca Straw (X)	5 cm length
	1	Cardboard Sheet (Y)	6 cm x 5 cm

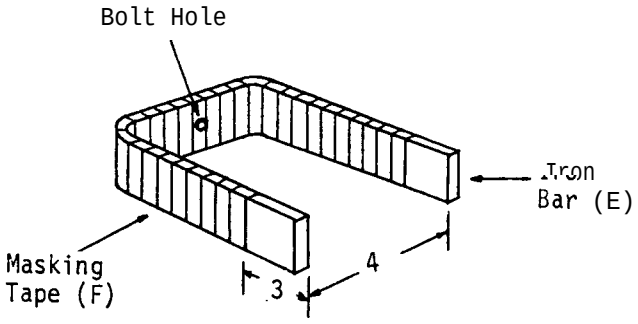
b. Construction

(1)Support



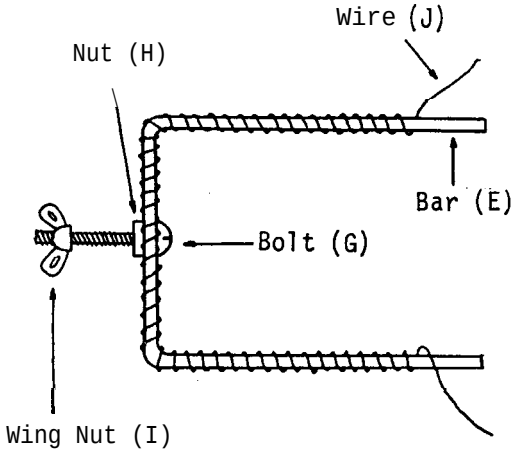
Use wood (A) for the base. Drill two screw holes in the base and attach a wooden upright (B), as indicated, with the help of screws and glue. Make a slot 1 cm wide, and 1 cm deep, in the top of the upright to hold wood (C), the wire support. Drill a hole (0.2 cm diameter) at one end of the support, so that the latter may be attached to the upright by means of a screw, and drill another hole (0.4 cm diameter) at the other end of the support to take a bolt. Attach the wire support to the upright with the help of the screw (D) and glue.

(2) Electromagnet

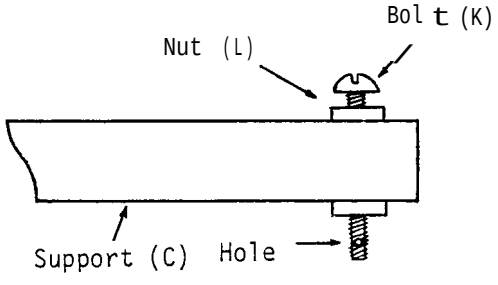


Bend the soft iron bar (E) into a "U" shape with the parallel sides 4 cm apart.

Wrap a layer of masking tape (F) around the bent bar, leaving the ends (3 cm lengths) clear. The tape will prevent the subsequent magnet wire from being scraped and bared on any sharp edges. Bore a hole (0.3 cm diameter) in the middle of the base of the U-shaped bar. Insert the bolt (G) through the hole, and attach it firmly to the bar with the nut (H). Wrap about 150 g of magnet wire (J) around the covered portion of the bar to make an electromagnet coil. Leave about 40 cm of free wire at either end of the coil. Cover the final layer of magnet wire with masking tape (F) to hold it firmly in position.

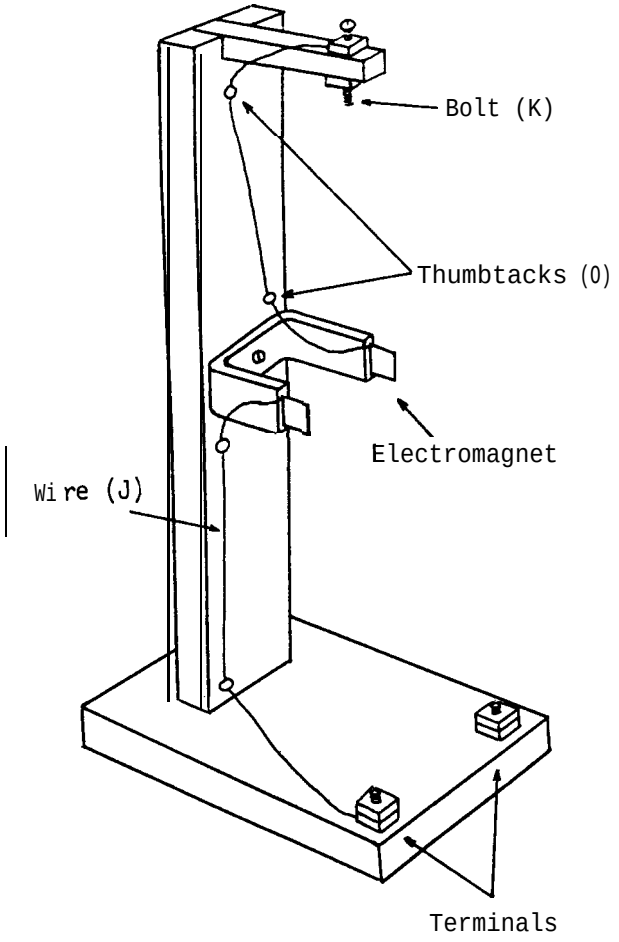


Drill a hole (0.3 cm diameter) through the middle of the upright, and attach the newly made electromagnet to the upright with the help of the protruding bolt and wing nut (I).



Side View

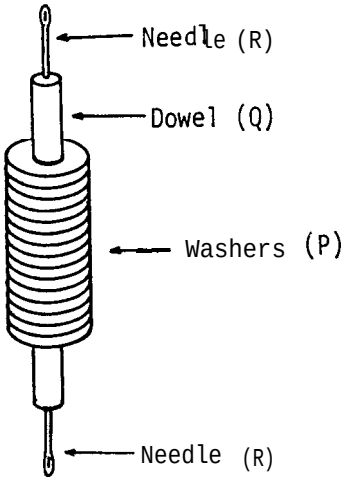
Drill a small hole (0.2 cm diameter) through the end of the bolt (K) furthest from the head. Insert the bolt through the hole in the end of the wire support, and hold it in position with two nuts (L) as illustrated.



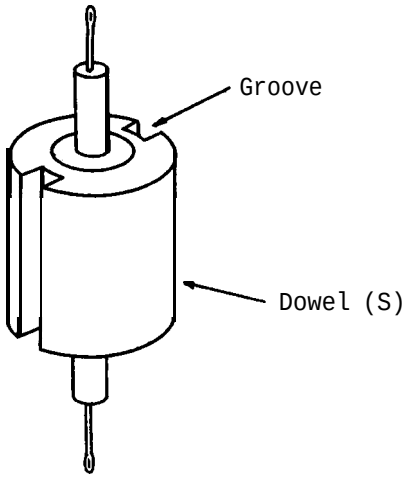
Drill two holes (0.3 cm diameter) into the front of the base. Make two terminals from the nuts (N) and bolts (M) as described under item VIII/A2, component (4). Set the terminals into the holes, making sure they are inset into the bottom of the base, thus leaving the bottom perfectly smooth.

Fasten one of the wires from the electromagnet to a terminal on the base, and the other wire from the electromagnet to the bolt (K) on the wire support. Make sure the enamel has been removed from the wire ends prior to connection. Use thumbtacks (0) to hold the wires in position on the upright.

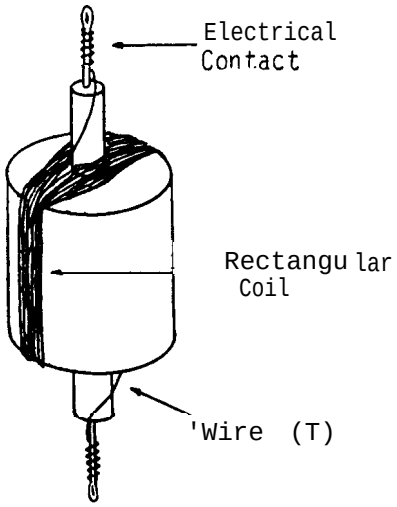
(3) Moving Coil



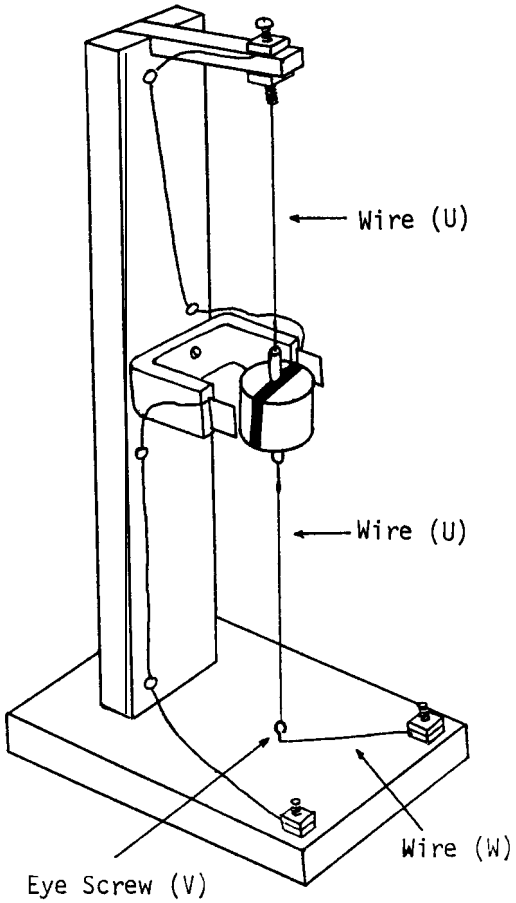
Slide the washers (P) onto the middle of the wooden dowel (Q). Add the washers until they make a stack 3.5 cm long on the middle of the dowel. Use epoxy resin to fix the washers in position. Drill a hole (0.1 cm diameter, 1 cm deep) into either end of the dowel. Cut two 2 cm lengths off the eye ends of the two needles (R), and insert these into the newly drilled holes (needle eyes projecting). Fix them firmly in position with the help of epoxy resin.



Cut a groove (0.5 cm deep, 1 cm wide) around the wooden dowel (S) to hold the subsequent magnet wire coil in position. Drill a hole (1.2 cm diameter) along the axis of the spool, and insert the newly made stack of washers on the dowel (Q). Use epoxy resin to hold this firmly in position within the dowel.



Take the magnet wire (T) and wind it around the dowel (S) to make a rectangular coil contained within the groove which was cut for this purpose. Bare the ends of the wire, and wrap them around the stem of the top and bottom needles (R) respectively, insuring good electrical contact between magnet wire and needle.

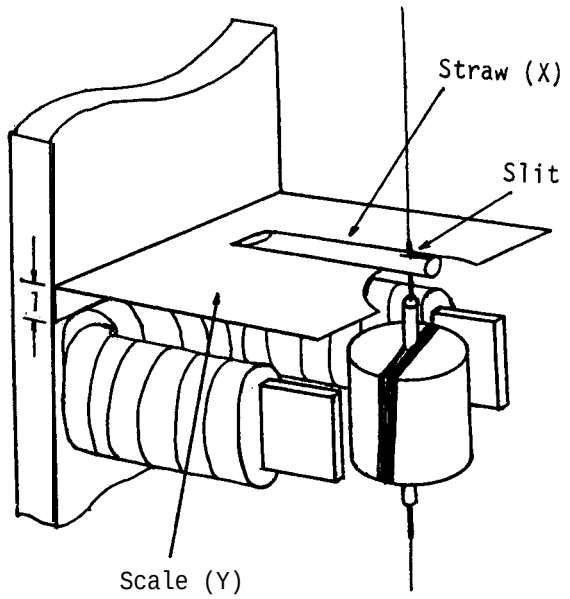


Bare one of the ends of the magnet wire (U) and wrap it around the eye of the needle in the top end of the dowel (S). Suspend the dowel and coil by the wire, so that the dowel hangs between the pole ends of the electromagnet. With the dowel in this position, fasten the other end of the magnet wire to the hole in the bolt in the wire support (after cleaning the end of the magnet wire).

Take the second length of magnet wire (U) and attach one end (after cleaning) to the eye of th needle in the bottom of the dowel (S). Insert an eye screw (V) in the base, directly beneath the dowel, and connect the other end of the magnet wire (bared) to the screw. The slack should be taken out of this bottom magnet wire.

Connect the eye screw to the unused terminal in the base by means of the remaining length of magnet wire (W).

(4) Pointer and Scale



A pointer for the galvanometer may be made from a soda straw (X). Make a small slit in the end, and fit it around the eye of the needle at the top of the dowel (S). A little glue will hold it firmly in position.

To make the scale, bend the 5 cm end of cardboard (Y) at 90° to make a 1 cm flap, and a flat surface 5 cm x 5 cm. Attach the cardboard to the upright (immediately beneath the pointer) with glue placed between the cardboard flap and the upright.

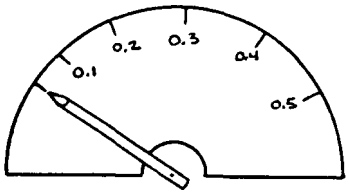
C. Notes

(i) The galvanometer may be calibrated by placing it in series with an ammeter (0 - 1 amp), a voltage supply (dry cells, battery, etc.) and a variable resistance. The resultant scale will not be uniform.

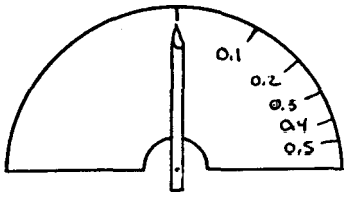
(ii) Changing the direction of the current through the moving coil changes the direction of the current through the electromagnet. As a result, the deflection of the pointer is always in the same direction, regardless of the direction of the current. The galvanometer thus measures AC and DC current equally well. (This would not be the case if a permanent magnet was used instead of the electromagnet.)

(iii) Strictly speaking, the earth's magnetic field should be taken into consideration in using this galvanometer. For most purposes in the

secondary school, this confounding factor may be ignored. Hence, in calibrating the galvanometer it is useful to set the zero position of the coil at an angle to the line between the pole heads of the electromagnet, thus making full use of the scale.

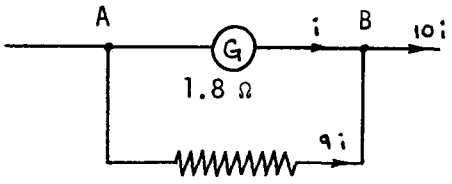


DC Amps

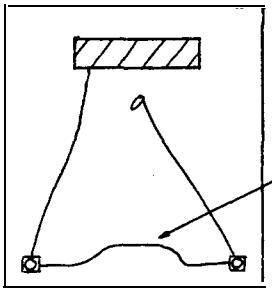


DC Amps

(iv) The resistance of the galvanometer is 1.8 ohms. Hence, if a shunt of 0.2 ohms is placed in parallel with the galvanometer, the scale of the latter will be multiplied by 10. The full scale deflection will thus correspond to 5 amp instead of 0.5 amp. Such a shunt may be made from a length of nichrome wire (approximately 5 cm of #24 nichrome, 20% chrome and 80% nickel) connected between the terminals of the galvanometer.

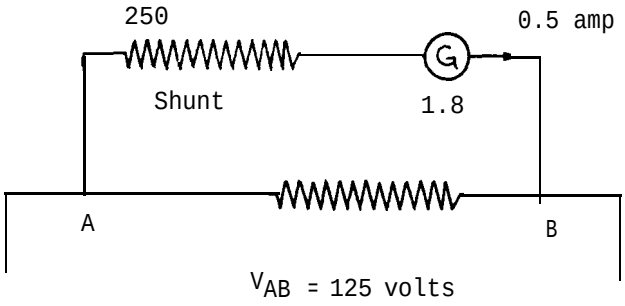


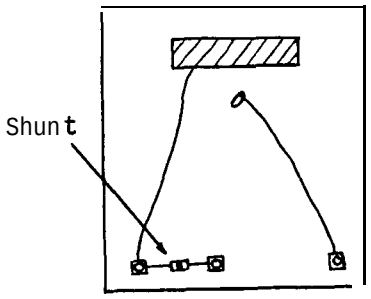
0.2
Shunt



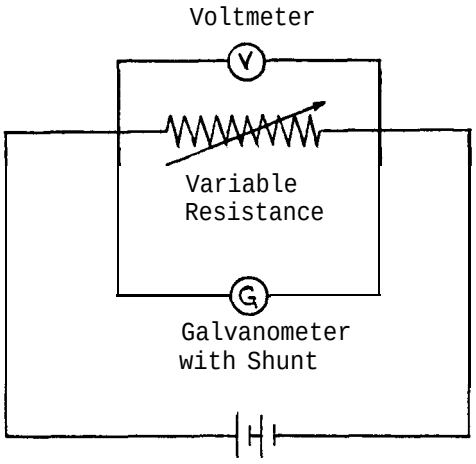
Top View
(Cross-section)

(v) If a 250 ohm shunt is added in series to the galvanometer, it may be used as a voltmeter, the full-scale deflection corresponding to 125 volts (DC). One way of conveniently doing this is to add a third terminal [see VIII/A2, component (4)] to the front of the galvanometer base, simply placing the shunt (obtained from a radio shop) across two adjacent terminals.





Top View
(Cross-section)



The modified galvanometer may then be calibrated by placing it in parallel across a variable resistance, and comparing the potential at any moment with that indicated by a commercial voltmeter, also placed in parallel across the variable resistance.