

II. TIMING DEVICES

Timing devices have been divided into three groups according to the length of time intervals they would most conveniently measure. This categorization is somewhat arbitrary, and it follows that some devices could, under certain circumstances, exist in more than one category. The categories are defined as follows:

A. LONG INTERVAL TIMERS

The intervals to be measured may range from a day (month, year) down to an hour or minute.

B. MEDIUM INTERVAL TIMERS

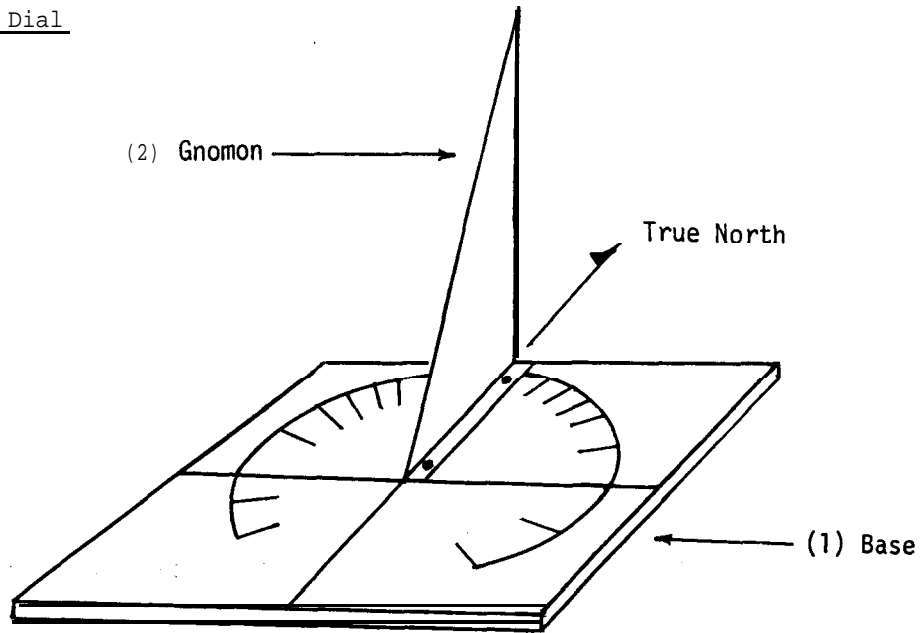
The intervals to be measured would range from minutes to seconds.

C. SHORT INTERVAL TIMERS

The intervals to be measured are subdivisions of a second.

A. LONG INTERVAL TIMERS

A1. Sun Dial

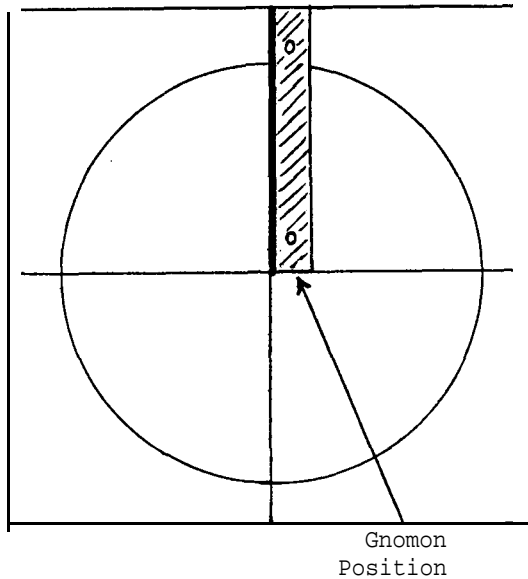


a. Materials Required

<u>Components</u>	<u>Qu</u>	<u>Items Required</u>	<u>Dimensions</u>
(1) Base	1	Wood (A)	16 cm x 16 cm x 2 cm
(2) Gnomon	1	Metal Sheet (B)	10 cm x 8 cm x 0.1 cm

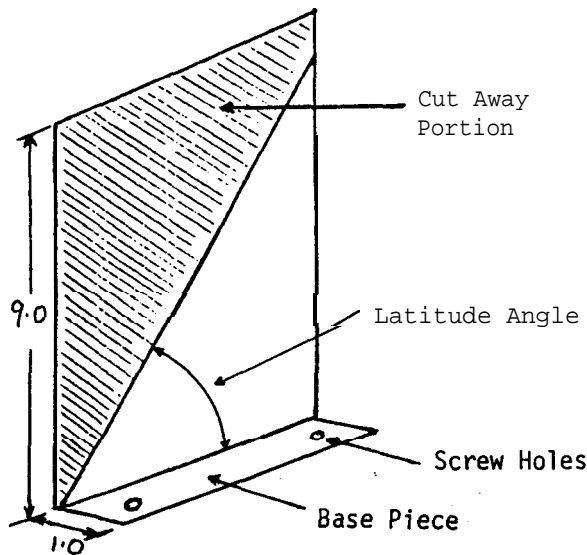
b. Construction

(1) Base



Cut the base from the wood (A). Use a felt pen to mark off the surface of the base into four equal portions. Draw a circle (diameter 7 cm) on the base with its center at the middle of the base.

(2) Gnomon



Make the gnomon from the metal sheet (B). Bend the end of the sheet at right angles to the sheet so as to form a base piece 1 cm wide. Drill two screw holes in the base piece. Note the latitude of your locality (e.g., 39° in Washington, D.C.) and mark out right-angled triangle on the vertical portion of the metal sheet such that the sloping side of the triangle is inclined to its base at an angle equal to the latitude angle. Cut off the sheet above the sloping side. You now have a metal gnomon. Attach the gnomon to the base with screws.

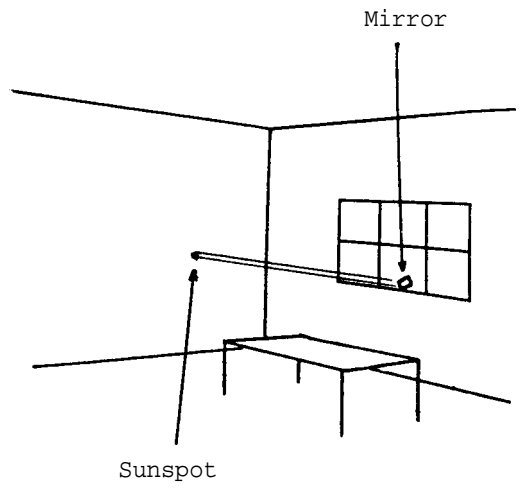
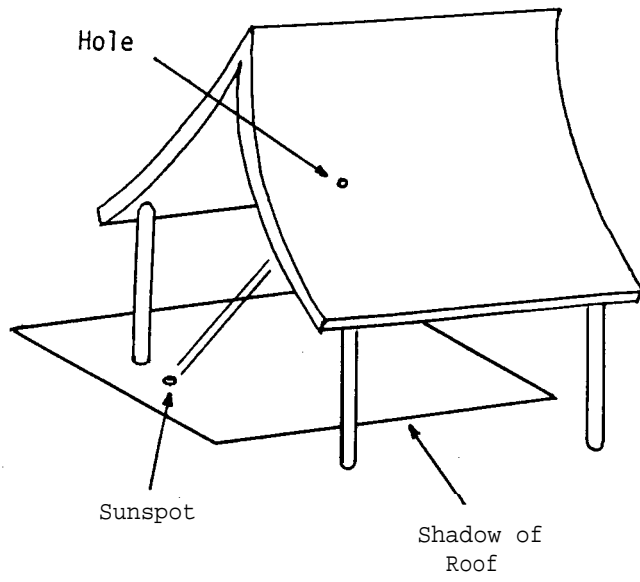
C. Notes

(i) The base of the apparatus should be placed on a horizontal surface with the plane of the gnomon in a true North-South plane, thus making the sloping side of the gnomon parallel to the Earth's axis. Calibrate the sun dial against a clock, marking in the positions of the shadow with a felt pen or paint.

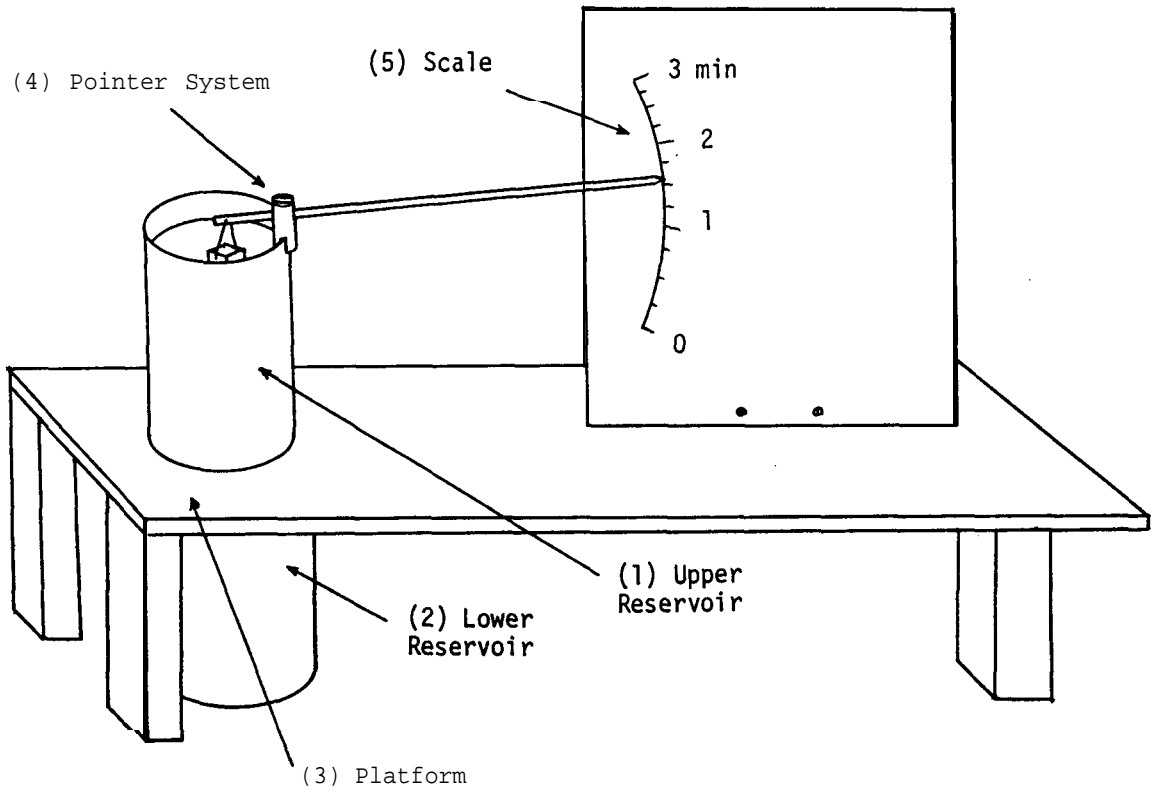
(ii) At the North and South Poles the shadow will move through 15° every hour. Elsewhere the angle rotated per hour will be greater than 15° in the early morning and late evening, and less than 15° towards midday.

(iii) Since the rotation of the Earth is not exactly 24 hours, the sun will not appear to be due North (or South, as the case may be) at noon, Greenwich Mean Time. Each month it will therefore be noted that the sun dial deviates further and further from the conventional time. From 5 to 30 minutes deviation will be noted over a period of one month, depending on the season.

(iv) The apparent motion of the sun may be used in even simpler (but cruder) ways to record the passage of time. It is thus possible to note the motion of a spot of sunlight due to a ray of light passing through a hole in a roof, or due to a ray of light reflected from a mirror placed by a window. The distance moved by the sunspot in successive intervals of time on the same day will be noted to be surprisingly regular. (See sketches on next page.)



A2. Water Clock



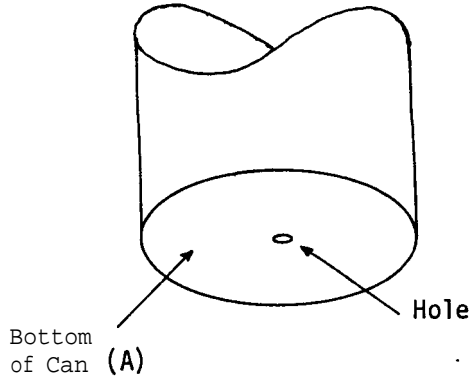
a. Materials Required

<u>Components</u>	<u>Qu</u>	<u>Items Required</u>	<u>Dimensions</u>
(1) Upper Reservoir	1	Can (A)	1 liter capacity
(2) Lower Reservoir	1	Can (B)	1 liter capacity
(3) Platform	1	Plywod (C)	50 cm x 15 cm x 1.0 cm
	3	Wood (D)	20 cm x 3 cm x 3 cm
(4) Pointer System	1	Wooden Dowel (E)	B cm long, 2.5 cm diameter
	1	Wood Strip (F)	35 cm x 0.6 cm x 0.4 cm
	1	Nail (G)	0.2 cm diameter, 4 cm long
	4	Washers (H)	--
	1	Wood (I)	4 cm x 4 cm x 1 cm
	1	Strign (J)	--
	1	Eye Screw (K)	--

(5) Scale	1	Plywod (L)	40 cm x 30 cm x 0.5 cm
	1	Wood (M)	30 cm x 3 cm x 3 cm
	1	White Paper (N)	30 cm x 40 cm

b. Construction

(1) Upper Reservoir



Take the tin can (A) and drill a small hole (0.1 cm diameter for example) in the middle of the base.

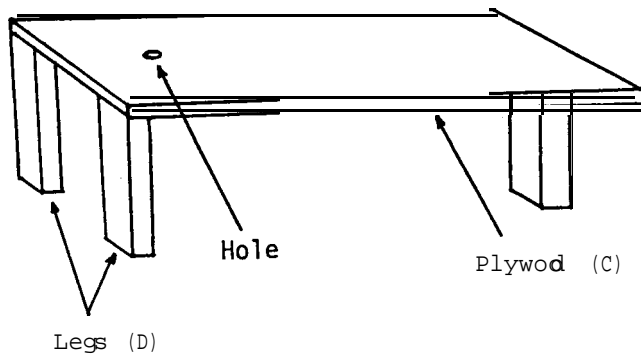
The bigger the can, and the smaller the hole, the greater will be the period of time for which the clock will run. This may be checked now by filling the can with water, and noting the time for it to drain.

If you wish to measure small intervals of time, you may increase the number of holes in the base of the can.

(2) Lower Reservoir

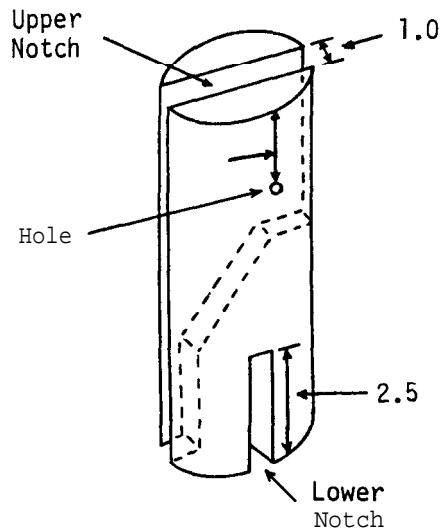
Use can (B) which should be of the same size as, or larger than, the can used for the upper reservoir.

(3) Platform

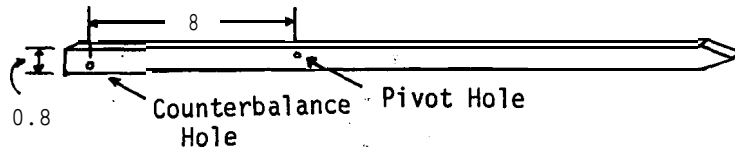


Take plywood (C) to make the platform, balancing this on the three legs (D) which should be sufficiently long to permit the lower reservoir to be moved under the platform without difficulty. Drill a hole (1 cm diameter) in one end of the platform. Place the upper reservoir over the hole in the platform and the lower reservoir underneath it so that water can run from the upper to lower reservoir.

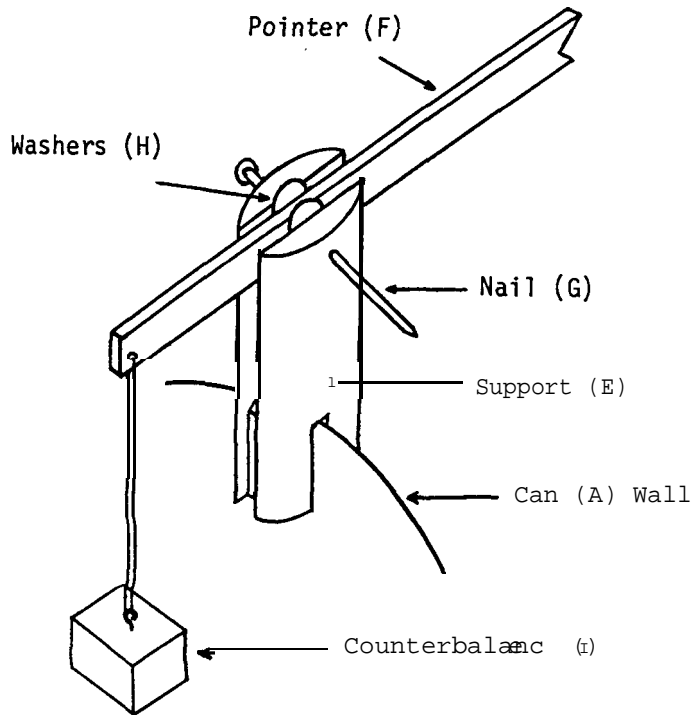
(4) Pointer System



Make a support from a wooden dowel (E) as indicated. Cut a lower notch in the support to enable it to sit on the side of the upper reservoir (A). Make an upper notch to permit the full movement of the pointer (E) to be attached. Drill a hole (0.2 cm diameter) horizontally through the upper part of the support to permit passage of the nail (G) to serve as the pivot for the lever.



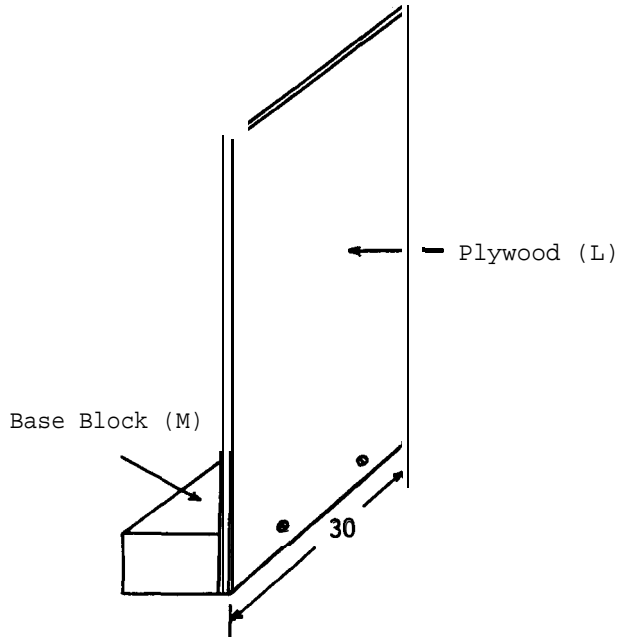
Make the pointer from a strip of wood, (F). Drill a small hole (0.3 cm diameter) at one end of the pointer to take the string (J) from the counterbalance, and 8 cm away from this hole drill a second hole (0.3 cm diameter), close to the top surface of the pointer, through which the nail (G) is to be put as a pivot.



Balance the pointer on the newly made support by inserting the nail (G) through the appropriate holes in the support and pointer. Washers (H) should be placed either side of the pointer to serve as spacers. These prevent unwanted motion of the pointer on the pivot. The pivot may be fixed permanently in position in the support with the help of epoxy resin, since the pointer can move about the fixed axle on its own pivot hole.

Take the small block of wood (I), and attach it to the pointer by means of the string (J) and a screw (K) attached to the top of the block.

(5) Scale



Attach a sheet of plywood (L) to the block of wood (M) intended to hold the plywood in a vertical position. Sit the newly made scale on the platform just behind the end of the pointer, sufficiently close to avoid parallax problems in recording the movement of the pointer. Screw the base block (M) of the scale onto the platform. Use a white sheet of paper (N) attached to the surface of the plywood with thumbtacks to actually record a time scale.

Adjust the length of string (J) on the counterbalance so that when the upper reservoir is full of water the pointer will be set towards the bottom edge of the scale.

C. Notes

(i) The counterbalance should be wet all over prior to use so that it does not tend to sink deeper into the water as it is used.

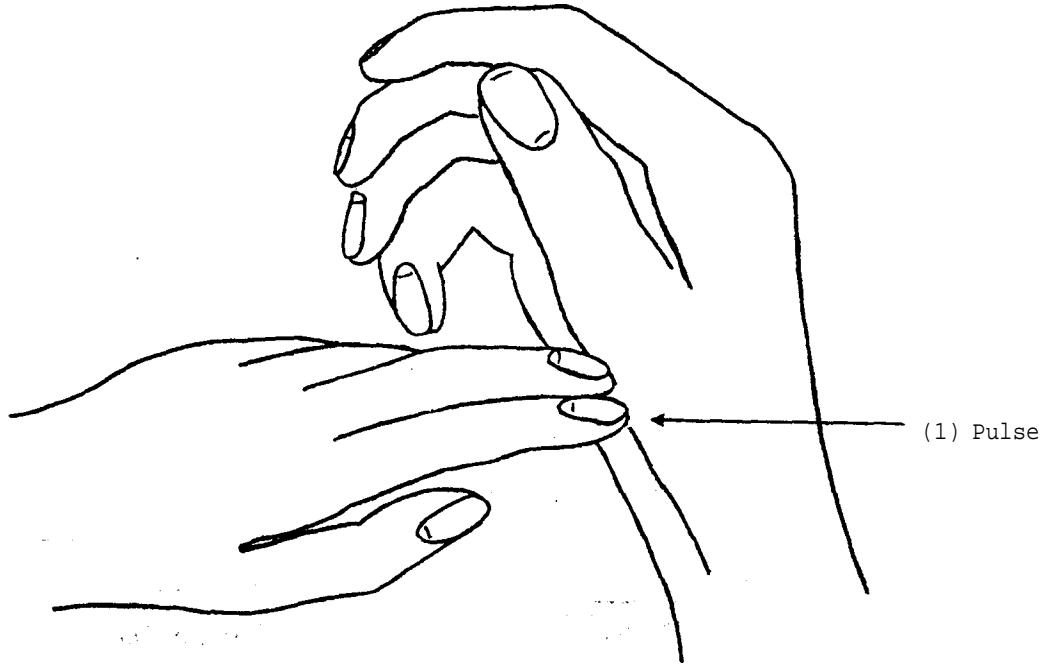
(ii) The water clock may be calibrated against a watch. The scale produced will not be linear since the water pressure over the hole in the base of the upper reservoir decreases as the water level drops. The initial rate of fall of water level is therefore greater than the final rate.

(iii) The clock will be found to be surprisingly reliable, observations being quite repeatable.

(iv) Using an upper reservoir of 1.3 liters, a depth of 19 cm and a base hole 0.15 cm diameter, a five-minute scale was very conveniently created. When the number of holes in the base was doubled the pointer traversed the scale in half the time (2 min 30 sec) and when the number of holes was increased to three the pointer traversed the scale in one third of the original time (i.e., in 1 min 40 sec).

B. MEDIUM INTERVAL TIMERS

B1. Pulse



a. Materials Required

Components

(1) Pulses

Qu Items Required

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Dimensions

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b. Construction

(1) Pulse

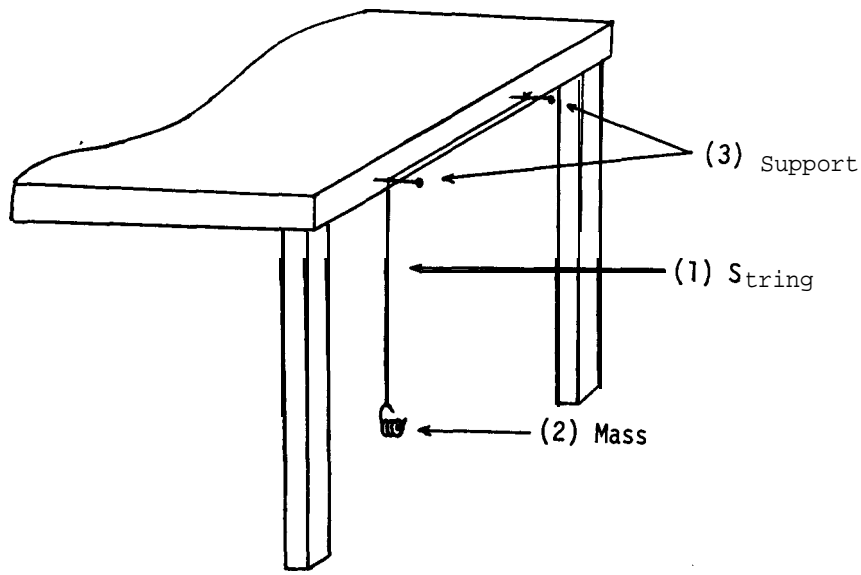
Place two fingers from the left hand over the pulse on the right wrist. The pulse beat can easily be detected.

c. Notes

(i) The pulse beat may be calibrated against that of other individuals and against other timing devices. Under normal conditions it remains surprisingly constant, but its rate varies according to the degree of exertion to which the individual is currently subjected.

(ii) It is useful to note that if the pulse in the neck, just below the angle of the jaw, is monitored with one hand, the other hand is left free for other functions.

B2.Simple Pendulum



a. Materials Required

<u>Components</u>	<u>Qu</u>	<u>Items Required</u>	<u>Dimensions</u>
(1) String	1	String (A)	1 meter long
	1	Paper Clip (B)	--
(2) Mass	10	Washers (C)	--
(3) Support	2	Nails (D)	3 cm long

b. Construction

(1) String

Take the length of string (A), and attach a hook [made from the paper clip (B)] to one end.

(2) Mass

Suspend washer (C) from the hook to serve as a variable mass.

(3) Support

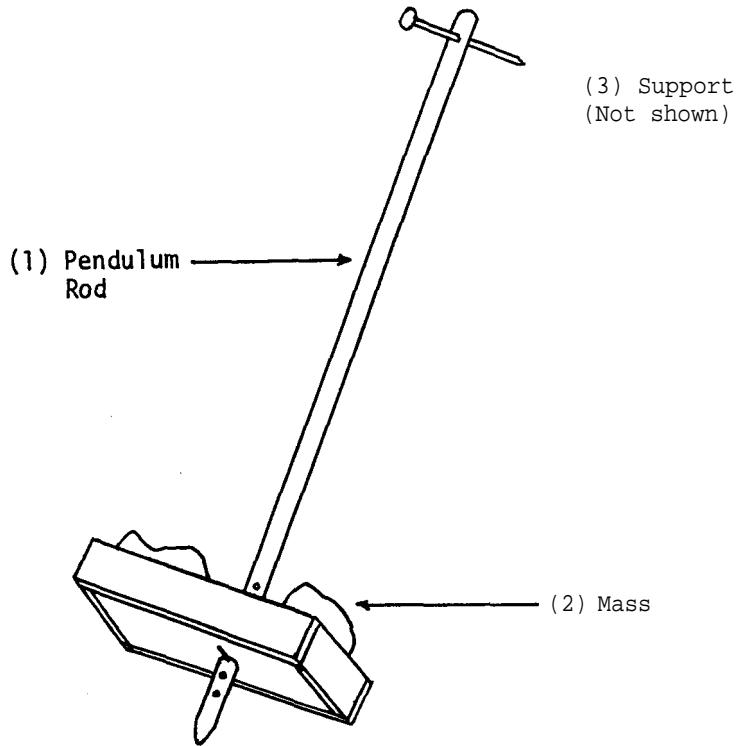
Drive two nails (D) into the side of a table, or into a wall, so that the nails are at the same height above the ground. Wrap the desired length of string two or three times around one nail, and fasten the spare length of string to the other nail. This should insure that

the string is pivoted rigidly
at the first nail.

C. Notes

(i) If the length of the pendulum, from the support to the center of gravity of of the mass, is adjusted to 25 cm (or more accurately to 24.8 cm) the pendulum will oscillate with a period of one second.

B3. Classroom Clock*



a. Materials Required

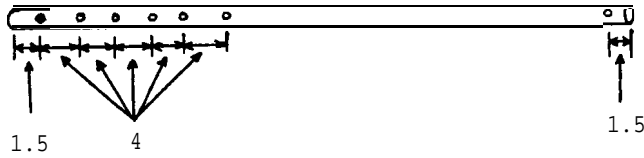
<u>Components</u>	<u>Qu</u>	<u>Items Required</u>	<u>Dimensions</u>
(1) Pendulum Rod	1	Broom Handle (A)	120 cm long, 2.5 cm diameter
	1	Metal Tube (B)	2.5 cm long, 1 cm external diameter; approximately 0.7 cm internal diameter
	1	Nail (C)	15 cm long, 0.5 cm diameter
(2) Mass	2	Wood (D)	22 cm x 6 cm x 0.5 cm
	2	Wood (E)	30 cm x 6 cm x 0.5 cm
	1	Wood (F)	31 cm x 22 cm x 0.5 cm
	1	Nail (G)	10 cm long, 0.5 cm diameter
	--	Bricks, Rocks, etc. (H)	--

*Adapted from Nuffield Foundation, Guide to Experiments I. Physics, (London: Longmans/Penguin, 1967), pp 79431.

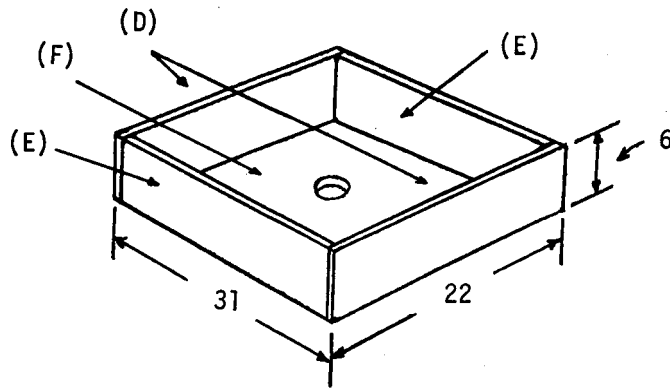
(3) Support	2	Tables (I)	--
	2	Stood (J)	--

b. Construction

(1) Pendulum Rod



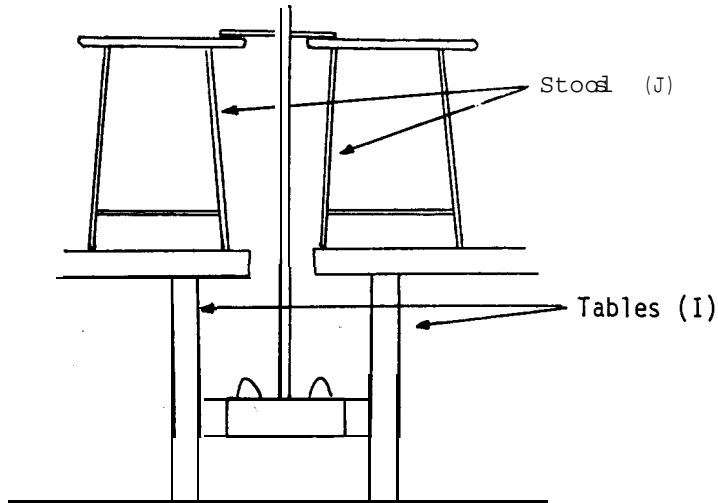
(2) Mass



Make the pendulum rod out of the broom handle (A). Drill six holes (0.6 cm diameter) in one end of the rod at 4 cm intervals. Drill another hole (1 cm diameter) 1.5 cm from the other end of the rod. Line this with a short length of metal tubing (B) to reduce friction at the pivot, and insert a long nail (C) through the tube.

Construct a wooden tray to hold the masses. Use one piece (F) for the base. Nail the four other pieces (D,E) to the base as shown. Drill a hole (2.7 cm diameter) in the middle of the tray base (F), and slide the tray onto the pendulum rod by way of this hole. Insert the strong nail (G) through one of the six holes in the end of the rod to hold the tray in position. The bricks or rock (H) may be placed in the tray to serve as appropriate masses.

(3) Support



Place two tables (I) fairly close together, and sit the stools (J) on top of both tables, sufficiently close to one another so that the pendulum may be supported by means of its pivot nail resting between the tops of the stools. The nail (G) must be held firmly in position on top of the stools hand, clamps, or any device which will hold it firmly.

C. Notes

(i) With the length (L) of the pendulum from pivot to tray bottom fixed at 103.5 cm the period (T) of the pendulum was noted to be two seconds.

Mass = 7,000 g

L (cm)	T (sec)
97.0	1.94
101.0	1.98
105.0	2.02
109.0	2.05
113.0	2.09
117.0	2.12

(ii) The initial displacement of the pendulum mass has negligible effect on the period. Keeping the length of the pendulum fixed at 105 cm and the mass constant at 7,000 g the following correlation of period (T) and initial displacement (D) was recorded.

D (cm)	T (sec)
5	1.99
10	2.01
15	2.00
20	2.00

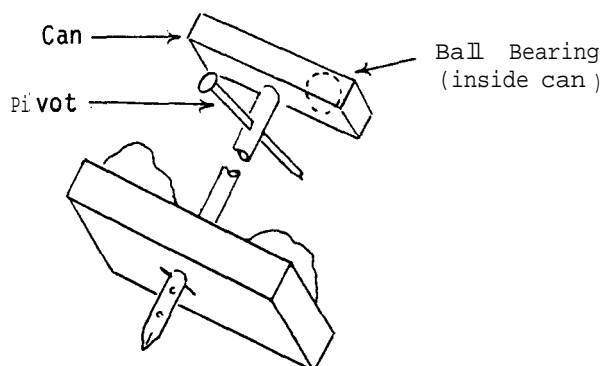
(iii) The period of the swing is virtually unaffected by variation of the mass. Hence, keeping the pendulum length constant at 105 cm, the mass (M) in the pendulum tray was varied by increasing the number of bricks. The following observations of the period (T) were recorded.

M (g)	T (sec)
1500	2.00
3250	2.00
5000	2.00
7000	2.01

(iv) The major effect of increasing the mass (M) of the bricks carried by the pendulum is to reduce the damping effect on the oscillations. With the length of the pendulum fixed at 105 cm, the pendulum mass was displaced a fixed distance (10 cm) and the number of oscillations (N) recorded as the displacement fell from 10 to 5 cm. The following results were obtained.

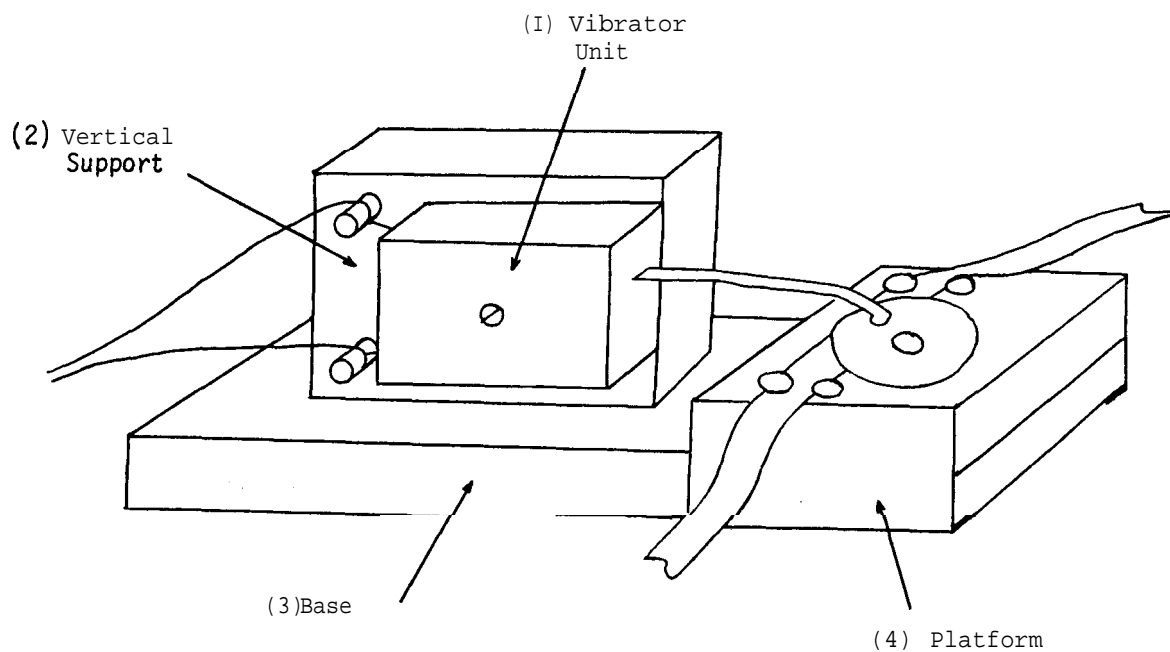
M (g)	N	Damping Effect
0	51.0	High
1500	95.5	Moderate
3250	97.8	Moderate
5000	98.2	Moderate
7000	131.6	Low

(v) If this timing device is to be used by a large class, it might be useful to modify it slightly to make the counting of oscillations possible without continuous visual observation. It is suggested that a metal container might be attached to the top of the pendulum rod, and a 2.5 cm ball bearing allowed to roll freely in the container, so that a click will occur twice per oscillation as the ball bearing hits the ends of the can.



C. SHOR T INTERVAL TIMERS

Cl. Ticker Tape Timer ©

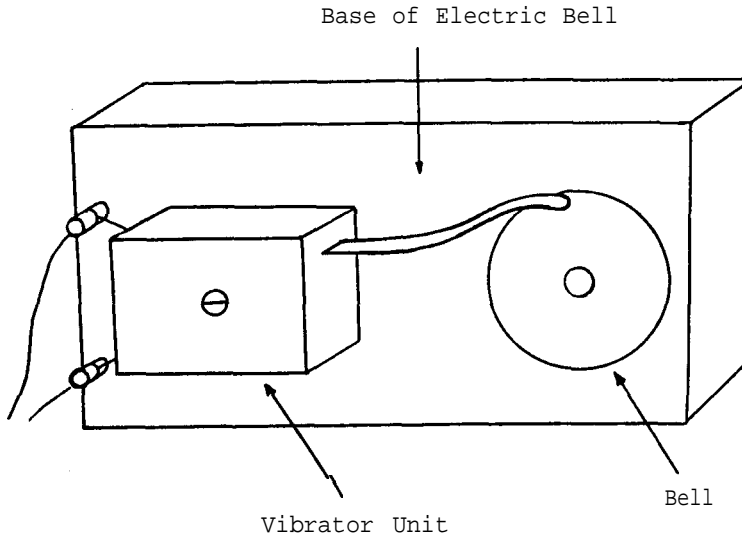


a. Materials Required

<u>Components</u>	<u>Qu</u>	<u>Items Required</u>	<u>Dimensions</u>
(1) Vibrator Unit	1	Household Electric Bell (A)	--
(2) Vertical Support	1	Wood (B)	7 c m x 5 c m x 2 c m
(3) Base	1	Wood (C)	1 6 c m x 6 c m x 2 c m
	2	Screws (D)	3 cm long
(4) Platform	1	Wood (E)	6 c m x 5 c m x 2 c m
	2	Aluminum Sheest (F)	6 cmx 5 cm x 0.05 cm
	1	Carbon Paper (G)	4 c m x 4 c m
	5	Thumbtacks (H)	--

b. Construction

(1) Vibrator Unit

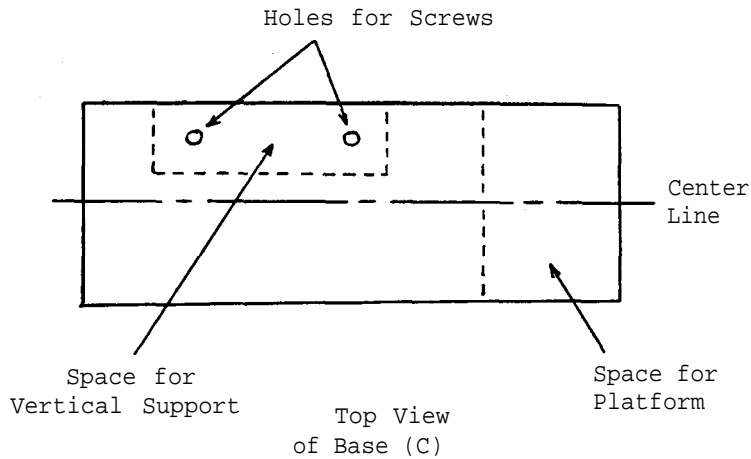


Take the household electric bell (A), and remove the vibrator unit. (The bell utilized in this instance was designed to operate normally at 10 volts.)

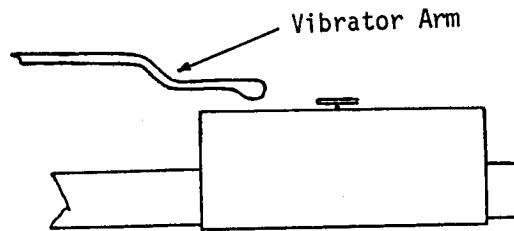
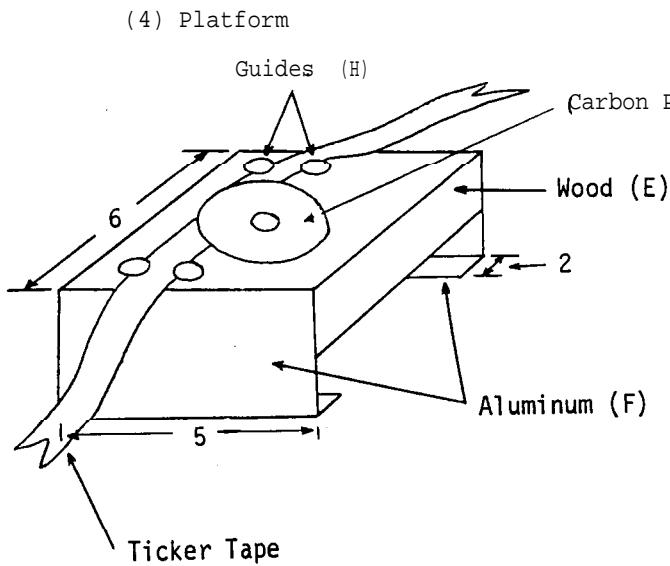
(2) Vertical Support

Use the piece of wood (B) to serve as the vertical support, and attach the vibrator unit to it with screws.

(3) Base



Use the wood piece (C) as the base. Place the vertical support on the base in such a position that the vibrator arm will be parallel to, and directly above, the line bisecting the length of the base. Mark in the position of the support, and then drill two appropriate holes in the base so as to facilitate the attachment of the support with the screws (D).



Side View

Attach the aluminum sidepieces (F) to wood (E) with nails to make a platform. Then with the platform in position on the base, bend the sidepieces at the bottom to hold the platform firmly in contact with the base. (A loosely fitting platform will result in a poor track being recorded on the ticker tape.)

Cut a circular disc out of the carbon paper (G) and pierce the center so that it may pivot freely about a thumbtack (H) in the center of the platform.

Pin four more thumbtacks (H) in the platform to serve as guides for the ticker tape, which must pass under the carbon disc. There must be negligible friction between the guides and ticker tape.

Bend the vibrator arm downwards so that the endpiece is within 0.3 or 0.4 cm of the platform surface.

C. Notes

(i) Two dry cells in series will generally operate the timer, even though the bell is designed for operation on a 10 volt supply.

(ii) If ticker tape is difficult to obtain, cashiers' paper rolls (for cash registers) are generally available, and may be cut into strips of suitable width, so long as care is taken to obtain smooth straight edges.

(iii) If the ticker tape from the vibrating timer is attached to a moving object, the motion of the object will be recorded on the ticker tape. It is thus possible to determine the distance moved by the object during specific time intervals. This is the basis of a wide range of experiments to determine the relationship between force and motion.