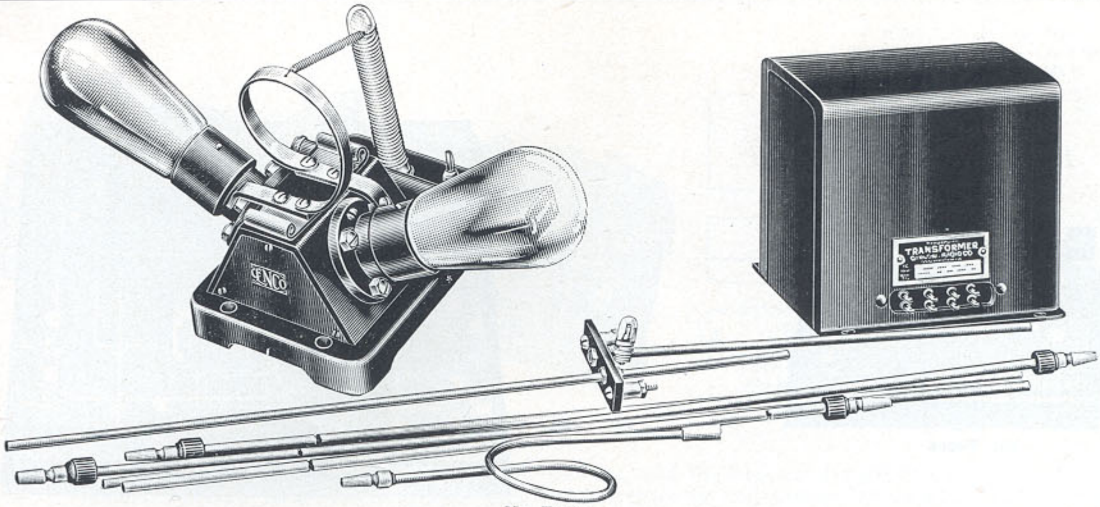


No. F4011
Shown with Accessories Furnished and with No. F4012A Tubes

F4011 SHORT WAVE RADIO DEMONSTRATION OUTFIT (Patent Applied For)

Prior to the publication of the present Cenco catalog, there has not been available for the teacher an apparatus with which clear-cut demonstrations not only of reception but also of transmission of electromagnetic (radio) waves could be made. To be sure, the antiquated coherer type of receivers have been listed for many years; but their effectiveness in teaching fundamentals of wireless was limited indeed. Ever since radio became popular, our technical staff has been studying the question of how to bring home to the student in a convincing way the manner in which radio waves are generated and transmitted, and how such waves can be received and detected. The development and perfection of the radio vacuum tube made possible the design of a demonstration outfit with which continuous waves of very high frequency, and with ample power to produce impressive results, could be produced. We have taken advantage of these possibilities, and are now offering for the first time an apparatus, at less than the price of an average broadcast receiving set, which provides the teacher with the means for one or several periods of experimental lecture that will instruct and fascinate the student, or give an evening's scientific entertainment to a lay audience. Those teachers to whom the apparatus has been shown have been enormously enthusiastic over its possibilities. Some of the demonstrations seem almost uncanny; to say the least, they are astonishing. Early in the development of this outfit, we adopted as a basic idea the principle that such an apparatus must be capable of showing the various phenomena of electromagnetic waves within the confines of the classroom. This meant that it must produce very short waves. The apparatus as designed produces waves about 3.2 meters long. Another test of its practicability was whether it would be so simple to operate that any teacher, by following directions, could make the demonstrations. This requirement is fully met. A third requirement was that it should send out radiations of sufficient power that reception, and conditions required for reception, could be convincingly shown, without delicate apparatus. This has also been accomplished.

The apparatus consists of three basic units: the high frequency electron tube oscillator with two sets of sending antennae; the power supply unit; and the tunable receiving antenna with indicating lamp. The **high frequency oscillator** comprises a simple circuit capable of generating oscillations of fixed frequency of about 100,000,000 cycles per second. Two power tubes of type UX210 are employed. These were chosen because they are standard and can be purchased from any good radio dealer, and because, of the common tubes, the UX210 is the best oscillator. Ample power is thus delivered into the oscillating circuit. The "sending" unit, consisting of tube sockets, condensers, inductive loop and accessory units, is mounted on a small bakelite base 11 cm by 16 cm. With tubes in place, its extreme width is 30 cm and height 13 cm. It is a most compact little unit. At the back is a multiple connector socket. The plug which fits this socket is connected to the **power supply unit**. To operate the "sending" unit, the power supply unit is connected to a 110-volt 60-cycle source, and the multiple connector plug to the "sending" unit. As soon as these connections are made, the "sending" unit is oscillating.

The **power supply unit** consists of a transformer with two secondary windings, made by General Radio Company. One of the windings is used for lighting the filaments of the two vacuum tubes, and the other for supplying the plate voltage. The latter is about 500 volts, and although caution in handling is advised, the circuits are so well insulated that, with ordinary care, there is no hazard whatever in the use of the apparatus.

With the "sending" apparatus we supply **two sets of radiating antennae**. One pair is attached directly to the terminals of the oscillator loop, and extend outward horizontally. The vertical antennae are connected to a coupling loop which may be variably coupled with the oscillator loop. Either pair of antennae may be used alone, or they may be used simultaneously, as described below.

The third unit of apparatus which is furnished as part of this outfit is **the receiver**. This is astonishingly simple. It consists of a tunable linear oscillator—a straight conductor of variable length—in the middle of which a small low-voltage incandescent lamp bulb is connected. Lighting of the filament is an indication of reception.

Included also in this group of apparatus is a **small neon glow lamp**, which is an excellent indicator of potential, and with which potentials existing at various points on the sending or receiving antennae may be explored.

The experimental procedure with this Cenco Short Wave Radio Demonstration Outfit is very simple. Using No. F4011 outfit as a nucleus, and the accessories listed below, the following interesting experiments, as well as others that will suggest themselves to the experimenter, can be performed.

1. **Starting the Oscillator.** Insert two No. F4012 Vacuum Tubes in the tube sockets. Connect the Sending Unit (Oscillator) to the Power Unit by the multiple connector plug. Then connect the Power Unit to the 110-volt 60-cycle supply. The Sending Unit should now be oscillating. To test whether it is oscillating, touch the exposed metal connected to the plate terminal of either tube with a piece of metal, or the graphite tip of a lead pencil, or the electrode of the neon test lamp. If the circuit is functioning, sparks appear at the contact, and the test lamp glows strongly. When the neon lamp is touched to the oscillator loop at the midpoint, where the plate supply voltage is led in, it will not glow at all, or only slightly. The reason is that this is a point of low potential in the oscillating circuit.

Note: It makes for great convenience and successful results in these demonstrations if the Sending Unit is supported on a wooden tripod stand like No. F283. The presence of large masses of metal near the set should be avoided.

2. **Measuring the Wave-Length.** When the oscillator is functioning, a quantity of electricity is surging back and forth at high frequency in the oscillator loop. The rate at which this surging takes place is determined by the inductance of the loop and the distributed capacitance of the conducting materials to which the ends of the loop are fixed. The oscillation of the charge in the loop constitutes a current of high frequency, associated with which there is an oscillating magnetic field which extends through the loop. At the instant the current reverses, the ends of the loop are at a large potential difference, and the current is zero. This condition gives rise to an electrostatic field across the ends of the loop. At the instant the current is maximum, the electrostatic field is zero. We may now trace

(Continued on Next Page)

Fig. 1

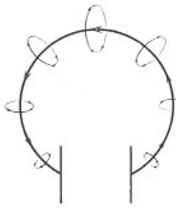


Fig. 2

Fig. 3

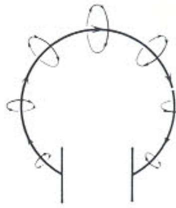


Fig. 4

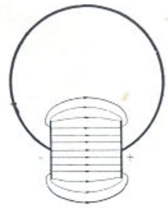


Fig. 5

(Continued from Preceding Page)

the complete cycle, referring for greater clearness to figs. 1 to 5 inclusive. We shall, in this process, not go into the details of functioning of the circuit, but take for granted that the vacuum tubes, supplied with power from the line, sustain the oscillations which we are examining more closely. In the figures the circular part represents the oscillator loop, which may be considered as having principally inductance; the parallel lines represent the capacitance associated with the loop.

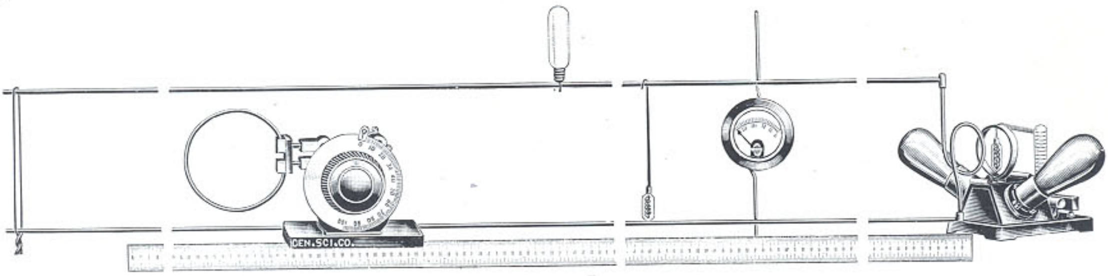
Fig. 1 represents conditions at some instant; let us consider it the beginning of a cycle. There is no current in the loop; but the charge (in terms of the usual convention) is at its maximum displacement, so that we have maximum potential difference across the capacitance. Consider the right-hand side positive, the left, negative. The electrostatic force is maximum, with its direction as shown. At the instant we are considering, current begins to flow, because of the large potential difference between two points connected by a conductor—in this case the loop.

In Fig. 2 the current has reached maximum value. With the current are associated magnetic lines of force which began to appear at the instant the current started to flow, and which have reached maximum value now. The lines are at right angles to the loop, coming out of the paper within the loop, passing into the paper outside the loop. During this time the magnetic lines are moving outward with the velocity of light; the electrostatic field has been disappearing, and at this instant is zero.

Because of inductance in the circuit, the current continues to flow in the same direction, which results in an increasing positive charge at the left, and negative on the right side of the condenser, as in fig. 3. A maximum is finally reached, depending on the characteristics of the circuit. The electrostatic field incidentally is not limited as shown by the lines in the figure, but becomes established theoretically to an infinite distance with the velocity of light. In fig. 3 the field is at maximum value in the direction shown. At this instant the potential difference between the condenser "plates" begins to flow clockwise, as shown in fig. 4.

Fig. 4 represents the current at its maximum value. The magnetic lines of force associated with it are now reversed in direction from those in fig. 2. The lines, which are at right angles to the electrostatic lines, move outward indefinitely with the velocity of light. When the current is maximum, the electrostatic field between the plates is zero.

Again, because of inductance, the current continues until the condition of maximum charge is reached, as in fig. 5, which is identical with fig. 1. We have now traced through a complete cycle of the oscillation, which is, in its simplest terms, an alternating current in the loop at exceedingly high frequency. Associated with this current are electrostatic and electromagnetic lines of force, mutually at right angles, travelling outward at the velocity of light. This travelling electromagnetic field constitutes a train of electromagnetic waves. One wave-length corresponds to a complete cycle of oscillation, represented in figs. 1 to 5, as explained. Since the waves travel with the velocity of light, or 300,000,000 meters in one second, the length of one wave is the distance the wave travels during the time of one oscillation. In the apparatus which we are describing, this wave-length is—as we shall directly determine by measurement—about 3.2 meters. Thus the time of one oscillation is 3.2/300,000,000 second, and the frequency is 300,000,000/3.2, or about 94,000,000 cycles (94,000 kilocycles) per second.



No. F4011

The motion of the electromagnetic field outward from the oscillating circuit represents a radiation of power, sustained by the power supply unit through the agency of the vacuum tubes. Such a loop is not a good radiating means, yet it is possible to detect the radiation, and to measure the wave-length.

To detect the radiation, we make use of the fact that if an electric circuit of proper inductance and capacitance is so placed relative to the oscillator that the electrostatic and magnetic lines which are radiated by the latter can induce a current in the former circuit, it will respond by having an oscillating current set up within it. The second circuit consists of a single loop, connected to a variable condenser of small capacitance. This condenser can be adjusted until the time of one oscillation in the circuit is the same as that in the oscillator. The combination of inductance and variable capacitance is called a wave-meter (F4012B). When the wave-meter is held with its loop parallel to and anywhere within 30 cm of the oscillator loop, and the condenser adjusted to the proper value, strong oscillations are set up in the wave-meter circuit. This adjustment is called tuning, and is **identical with the tuning of an ordinary radio receiver.** When the circuit is tuned it is said to be in resonance. To determine when the circuit is tuned we attach near one end of the loop the neon detector bulb (F4012E). The bulb glows at resonance. Another indicator is a small flashlight bulb (F4012C) clipped across a short section (about 3 cm) of the wave-meter loop. At resonance, the bulb lights brightly; in fact, unless one is careful, the bulb is easily burned out. The wave-meter has a 0-100 scale; a calibration chart supplied with the instrument converts scale readings to wave-length in meters.

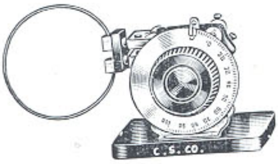
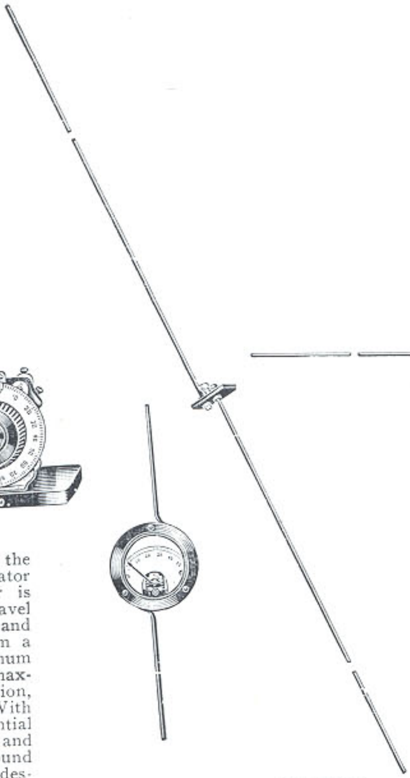
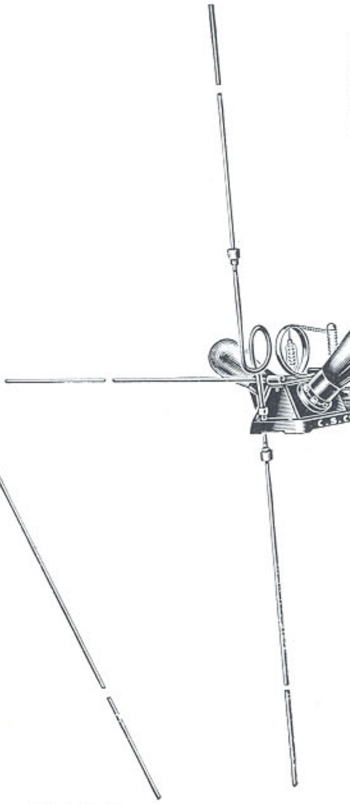
3. **Standing Waves on Wires.** Another method of measuring wave-length is by the Lecher wire method. Standing waves are generated on a pair of parallel wires by coupling the oscillator to the vertical antenna "coupling loop," to which the wires are connected. The loop is plugged into the sockets at the front of the oscillator, and two No. 24 bare copper wires are attached by twisting, one to each end of the loop. The wires are then stretched out parallel over any available distance, preferably greater than 5 meters, and supported at the opposite end by twisting them around a stick of dry wood, glass or other insulator, and clamping the latter on a rod, or otherwise holding it so that the wires are parallel and taut. The glow lamp (F4012E) is now so mounted in the oscillator loop that it will glow brightly when the power is turned on, thereby indicating that the circuit is oscillating. Standing waves of potential and current are established on the wires. These waves become especially pronounced if the parallel wire system is "in resonance," i.e., if the length of the wires bears a definite relation to the wave-length. In case the ends of the wires are "open", a reversal in phase on reflection takes place, as in an open organ pipe; the open ends become points of maximum potential variation. If the ends are "closed," or bridged by a conductor, the potential variation must become zero, and these points will then be potential nodes. A conducting wire bridging the parallel wires is, in fact, used to "tune" the system to resonance. This is moved from the open ends towards the oscillator until a glow lamp, connected across the wires about 80 cm away, glows most brightly. The condition of resonance is also indicated by the glow lamp connected to the oscillator coil; this shows sudden diminution in intensity when the nodal point is bridged. The other nodal points, at which zero values of potential exist between the wires can now be located by exploring the wires with a second glow lamp, its terminal touching one of the wires. The lamp remains dark in regions of small potential and bright in regions of high potential. The nodal points of potential can be even more accurately located by sliding another conducting bridge along the parallel wires. As each nodal point is passed, the glow lamp in the oscillator will suddenly "wink," or grow dimmer; possibly it may go out. This behavior of the glow lamp is due to the energy which is being abstracted from the oscillator, which is maximum at resonance. The distance between adjacent points of zero and maximum potential, respectively, is a half wave-length of the electromagnetic waves produced in the oscillator.

4. **Transmission and Reception of Radio Waves.** The electromagnetic waves which originate in this apparatus are found by

(Continued on next page)

F4011. SHORT WAVE RADIO DEMONSTRATION OUTFIT, Continued

measurement (see preceding sections) to be of the order of 3.2 meters in length. To increase the energy radiation from the oscillator, the latter is supplied with radiating antennae. These consist of two copper-plated brass tubes, one end of which is provided with a tapered plug for both mechanical support and electrical connection. As a first experiment, plug the antennae horizontally into the sockets at the lower terminals of the oscillator loop. When the oscillator is started, the electrical surges travel to the ends of the antennae, and there is set up in the system a "standing wave" with maximum potential at the ends and maximum current at the mid-section, which is the oscillator loop. With the neon test bulb the potential distribution can be explored; and the current distribution is found by means of the small incandescent bulb, "clipped" across a centimeter or two of the oscillator loop, or of the antennae. Several test bulbs may be used simultaneously.


No. F4011
Shown in Demonstration of Polarization Effects

With the wave-meter we find that connecting the antennae slightly increases the wave-length. Knowing this wave-length, we can construct a linear oscillator to resonate at the frequency corresponding to this wave-length. The length of the oscillator (in the middle of which the flashlight bulb is inserted) is roughly adjusted to one-half the wave-length. If properly tuned, this "receiver," held horizontally about a meter away, responds to the waves being radiated, and the bulb glows brightly; fine adjustment may be made to the setting at which the bulb is brightest. The length of the "receiver" is another check on wave-length. Under good conditions, the lamp glows at several meters from the transmitter.

Receiving Antennae (F4012G) are particularly effective in showing the current distribution in such an oscillator. A straight copper wire of the same length, on which several F4012E Neon Test Lamps are distributed, shows the voltage distribution.

5. **Demonstration of Polarization of the Waves.** Note that when the receiving antennae are parallel to the sending antennae, there is response; as the former are turned relative to the latter, the response weakens, and becomes zero at 90°. This shows polarization of the radio wave.

A vertically polarized wave of variable intensity can easily be produced. Plug the "coupling loop" into the socket in the base of the transmitter so that its single turn can be adjusted in position relative to the oscillator loop, by turning in the socket. Plug the one antenna into the upper end of the coupling loop, and the other into the socket from beneath. To do this, allow the base to protrude over the edge of the stand or table. With the receiving antennae arranged as before, it will be found that there is maximum response with the "receiver" vertical, and zero response when it is horizontal.

With the single bulb antenna held vertically in one hand, change the coupling by turning the coupling loop in the socket. When the two loops are far apart, i.e., when the coupling loop makes a large angle with the oscillator loop, response is weak; when the loops are parallel, response is strong. This shows that more energy is "fed into" the antennae, and radiated, with close coupling.

6. **Measurement of Electromagnetic Field Intensity.** Connect No. 4631 Weston Thermo-Galvanometer to the receiving antennae in place of the flashlight bulb. Deflection of the pointer is proportional to the square of the current, hence to the energy in the oscillator, which must be roughly proportional to the energy radiated to the point at which the receiver is located. It is instructive to take readings of the meter at different distances from the transmitter, with the receiving antennae parallel to the transmitting antennae, and to take readings, at a given distance, as the angles between receiving and transmitting antennae are changed.

Exploration of the electromagnetic field in the standing waves on the parallel wire system described in Section 3 may be simply and easily accomplished by moving the Thermo-Galvanometer along, but not touching the wires. In this manner the maximum and minimum points of electric force are quickly found and demonstrated.

7. **Composition of Two Plane Polarized Waves.** This experiment is a beautiful illustration of a polarized wave of great intensity, composed of two plane polarized waves at right angles to each other. To perform the experiment, both sets of antennae—horizontal and vertical—are used simultaneously. The oscillator is started. The receiver responds in either position parallel to one of the antennae. It responds with great intensity at 45°, in the position bisecting the angle between the antennae; but in the other 45° position, at right angles to the first, there is no response.

The reason is that in the one pair of quadrants the oscillations are in-phase, and strengthen each other; in the other they are out-of-phase, and annul each other.

Whether the flashlight lamp or the Thermo-Galvanometer is used as the detector, the experiment is very striking. With the Thermo-Galvanometer in the receiving oscillator at a given distance, relative values of the energy at different angles may be obtained.

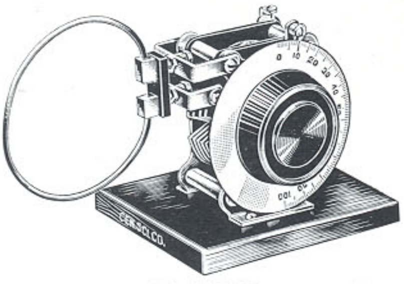
8. **Standing Waves in Space.** Using the sheet copper supplied under No. F4012K, prepare a large metal reflecting surface either on some convenient wall or in a frame mounted on casters. For best results the surface should be at least 1.6 meters (5.3 feet) square. A larger screen gives better results. Seams should be carefully soldered. With the oscillator and antennae (either set or both) at a distance equal to any odd number of quarter wave-lengths from this reflector, standing waves are set up in the region between oscillator and screen.

These can be detected with the linear resonator, in the usual way; with the thermo-galvanometer detector, it is instructive to plot the field as a function of location between oscillator and reflector. Another check on wave-length may be obtained in this manner.

9. **Transmission of Polarized Waves Through a Screen.** This experiment, though it requires the construction of an accessory, is eminently worth while. A screen is needed, which can be constructed by boys in the class. The screen consists of a frame which may be 1.6 meters (½ wave-length) square, made of wood. Parallel copper wires (No. 24 bare) are fastened vertically to the frame, individually secured to small brass or steel wire nails, spaced about 4 inches. Waves from the transmitter with horizontal antennae can be demonstrated to pass readily through the screen; waves from the vertical antennae are completely stopped. This is the exact analogy of polarized light and a polarizing plate, like tourmaline.

It is difficult, if not impossible, in limited space to give an adequate idea of, much less adequate instructions, for operating this unique outfit. The demonstrator after familiarizing himself with it will find unlimited opportunity for interesting experimentation. For example, he can try the "grounded" antenna on transmitter and receiver; he can try various hookups for making the received signals audible, as in a loudspeaker, and then transmitting "dots" and "dashes"; he can experiment with reflection from a plane surface at various angles; or explore the field in the vicinity of the transmitter with the wave-meter and either flashlight bulb or thermo-galvanometer detector; or light a flashlight bulb through his body by holding the screw base in his hand and touching the other terminal to the loop of the oscillator; or build a parabolic reflector of parallel wires or sheet metal and, with the vertical antenna in the focus, experiment with "beam" transmission.

Complete as described, including two pairs of transmitting antennae, vertical antenna coupler, tunable receiving antenna with flashlight bulb detector, and transformer, but **without vacuum tubes or other accessories listed under Nos. F4012 A to K......$40.00**



No. F4012B
Shown Mounted on Insulating Base

No. 4631

ACCESSORIES FOR USE WITH NO. F4011 SHORT WAVE DEMONSTRATION OUTFIT

F4012A. **Radiotron Tube,** No. UX210, for use in the oscillator of No. F4011. Two are required..**Each $9.00**

F4012B. **Wave-Meter, General Radio Company,** for use with No. F4011 in measuring the length of the short waves emitted. The condenser consists of four stationary plates and three movable plates of brass, soldered together, with metal end plates. The rotor is counterbalanced. The condenser is so well shielded by the metal end plates that the effect of hand capacity is negligible. The maximum capacitance is 50 mmf. The single turn coil is made of ⅛-inch copper tubing silver-plated for high conductance. The 4-inch dial is graduated over half its circumference with a scale of equal parts reading from 0 to 100. A calibration chart in a protecting frame with celluloid window is supplied from which the correct wave-length corresponding to any setting of the dial may be readily obtained. Screw holes in the base are intended for securing the Wave-Meter to a small board or other insulating base, by which it must be held when in use. The range of the meter in wave-lengths is from 3 to 5 meters (60,000 to 100,000 kilocycles) by 0.05 meters **12.00**

F4012C. **Mounting Clip,** for attaching a No. F4012H Flashlight Bulb to the loop of No. F4012B Wave-Meter, in order to determine when the wave-meter is properly tuned to the sending outfit.... **.75**

F4012D. **Lamp, Exploring, Mounted,** with conducting handle. This lamp consists of an incandescent bulb of suitable characteristics, to the central contact in the base of which is soldered a V-shaped wire guide; the bulb is mounted in a conducting handle. It is suitable for exploring conductors carrying high frequency. By touching such a conductor with the V-shaped piece, while the lamp is held by the handle, the presence of high frequency potential relative to the body is shown by the fact that the filament lights. It can be used, for example, with No. F4011 Radio Demonstration Outfit. By applying it, as mentioned, to the loop, away from the central point of the latter, the filament glows brightly as a result of current passing through the lamp and the body of the person holding it. If the lamp is moved along in contact with one of the Lecher wires (see description of No. F4011) it glows brightly at potential "loops" and is dark at potential "nodes." In this manner the standing waves are beautifully shown. It can also be used with No. F4051 Tesla Apparatus to demonstrate passage of high frequency current through the body. As described........ **1.50**

F4012E. **Neon Test Bulb,** for use with No. F4011 in determining whether the outfit is oscillating and in locating positions of maximum and minimum potentials **2.00**

F4012F. **Extra Receiving Antenna** with single lamp indicator. This may be used simultaneously with the one supplied with the outfit to show reception at various places at the same time........ **3.50**

F4012G. **Receiving Antenna,** consisting of an antenna to which are connected 7 of the flashlight bulbs. By means of this it is possible to show a class the positions of maximum and minimum current or the standing electromagnetic wave form in the antenna. Complete with 7 No. F4012H bulbs **7.50**

F4012H. **Flashlight Bulbs,** for use with Nos. F4012C and F4012G........**Each .25**

F4012K. **Roll of Sheet Copper,** No. 36, containing about 100 square feet or sufficient for the construction of a reflecting screen for standing wave demonstrations........ **20.00**

14422. **Copper Wire, Bare,** No. 24, for the Lecher wire experiment........**Per 4 oz. spool .35**

4631. **Thermo-Galvanometer, Weston Model 425,** for use in measuring the electromagnetic field intensity at various distances from the oscillator and in detecting the nodes and antinodes in the standing waves by reflection. A full scale deflection represents about 115 milliamperes. The safe current carrying capacity is 500 milliamperes........ **15.00**

F4012L. **Meter Terminals,** for use with No. 4631 Thermo-Galvanometer to provide for attaching adjustable antennae to the latter. These terminals are to be fastened to the Thermo-Galvanometer by means of hexagonal nuts provided on the back of the instrument. For antennae those supplied with the tunable receiving antenna of No. F4011 may be used.

In use Terminals No. F4012L are attached to the meter as shown in the figure on the opposite page. These terminals are designed to fit the telescoping tubes supplied with the receiving antenna which is part of F4011 Outfit. Adjustment in length of the antennae attached to the meter tunes the system to resonance, and this combination makes a very sensitive detector of the waves radiated from the transmitting unit ....**Per pair .80**