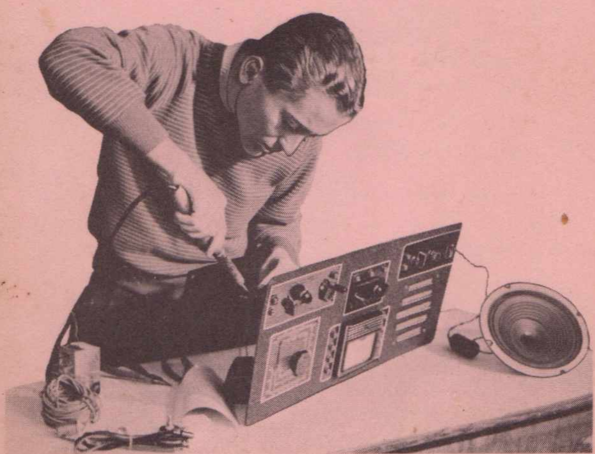
AUSTRALIAN RADIO & TELEVISION COLLEGE PTY. LTD.

PRACTICAL RADIO COURSE



of

HOME PRACTICAL INSTRUCTION

Lesson No. 3

THIS Radio Course of practical home instruction is the result of many years experience, and months of final experimental work by some of Australia's most competent Radio engineers. It is designed so that you acquire a thorough and most comprehensive practical Radio training by building up the kits which are supplied with these lessons. When the course is finished, and all the kits have been built up into the final unit, you will possess a complete professional outfit of Radio testing apparatus, which in itself is not only worth far more than the money you pay for it, but which will also enable you to earn many times its actual value from the Radio work you can perform with it.

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CONSTRUCTING A MULTIMETER

This lesson will show you how to:–

HOME PRACTICAL INSTRUCTION

LESSON No. 3

The materials contained in this kit will enable you to partially assemble the Multimeter in its final form.

In some of the Practical Instruction Kits you will receive later on, you will be supplied with the parts to make up a number of receiver, amplifier, oscillator and other interesting circuits. When you are experimenting with these units it will be necessary for you to make a number of tests of current, alternating and direct voltage and resistance. Consequently, it is desirable to build your multimeter into a more permanent form, which is easy to use, so that it is ready when you require it to make tests and measurements as you proceed.

You will receive in this third kit, the main panel upon which the multimeter is mounted, and also a number of parts which will enable you to extend its ranges to directly measure resistance and to measure values of direct voltage. In the next kit, you will receive the remaining material necessary to complete the multimeter and also a valve and other parts, so that you will be able to make a number of interesting tests with it, including the plotting of some of the valve's characteristic curves. In this way you will learn a lot about the behaviour of valves before you actually build them into receiver and other circuits.

As your principal practical instruction in connection with this particular kit will be in the construction of the multimeter, the greater part of this lesson will be devoted to building instructions and a description of the functions of the parts. Only, a small portion will be employed to describe experiments which you can make with the meter. On the other hand, the next lesson will cover only the final construction details and will be mostly devoted to a description of experiments to be undertaken. Contained in this third kit you will find the following materials:–

1 .25 megohm resistor accurate within ∓ 1%.
1 50,000 ohm resistor accurate within ∓ 1%.
1 1,000 ohm resistor accurate within ∓ 10%.
1 200 ohm resistor accurate within ∓ 2%.
1 1,000 ohm potentionmeter.
1 Front Panel.
5 Tipjack socket assemblies.
1 small pointer knob.
1 yd. nylex tubing.

1 pair test prods and leads with push-on clips.

ASSEMBLY.

The first step in assembly is to mount the tipjack sockets, and potentiometer on the main panel.

The positions in which the various parts are to be placed on the panel are clearly shown in Fig. 1. The two black moulded bushings are to be used on the large label, the three red bushings being for the voltage sockets on the narrow label at the right of the meter.

It is most important that the tipjack sockets are insulated from the panel and this is accomplished by means of the moulded insulating bushings provided. If the sockets are not carefully fixed in the centre of the holes in the panel, it is possible for the threaded part of a socket to touch the side of a hole and thus be connected to the panel. Should this occur, it will quite possibly result in damage to the meter when it

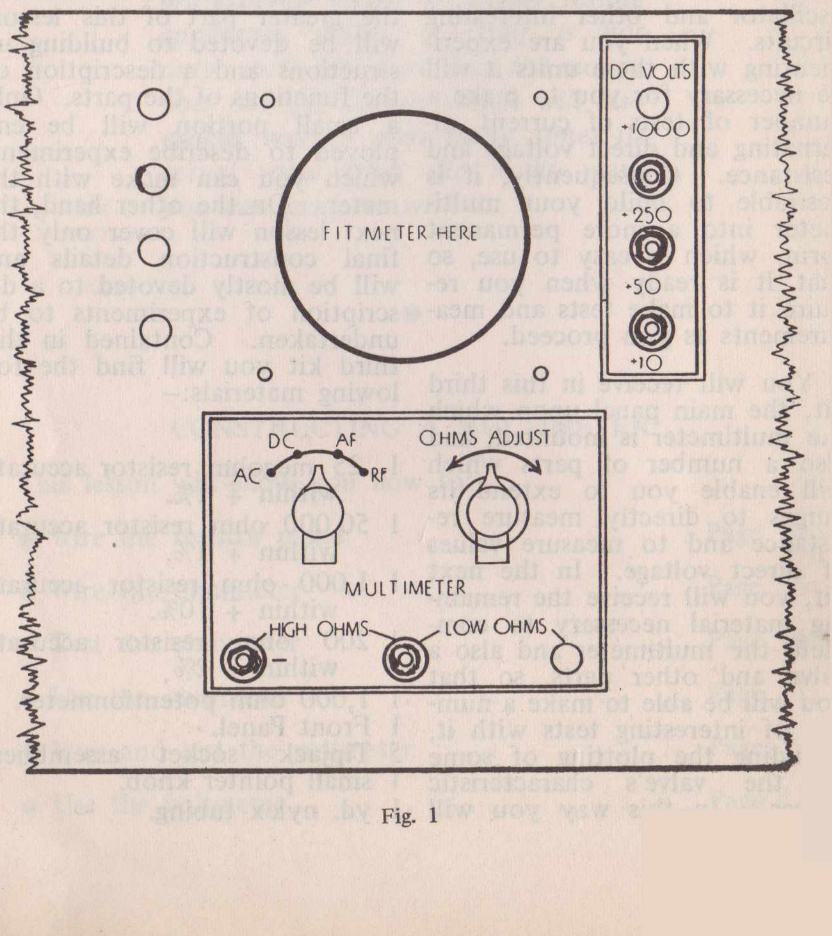

Fig. 1

is used for testing some of the units we will construct later. If you examine the bushings carefully, you will notice that a ridge about three-sixteenths of an inch high is provided on the underneath surface. This ridge is a little smaller in diameter than the holes provided in the panel and consequently, when this ridge is fitted down into the holes, it will prevent the threaded portion of the socket from touching the edges of the hole and thus assure satisfactory insulation. You must be careful, however, to see that this ridge passes through and fits into the hole in the main panel, before tightening up the nut on the socket.

The correct method of assembling the various components on the tipjack sockets is shown in Fig. 2. It will be seen that the long portion of the socket is passed firstly through the ridged bushing, then through the panel, plain

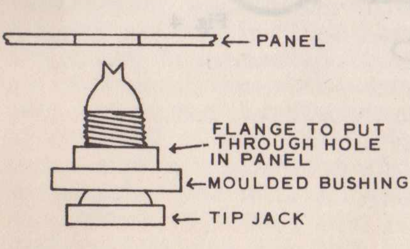

Fig. 2

bushings metal washer and solder lug, before the nut is finally screwed on. The nuts should be screwed on securely to prevent them from loosening when the instrument is in use.

To make sure that there is no accidental short circuit between the sockets and the panel, it is desirable to make a continuity test. Connect your meter, 10,000 ohm resistor and battery together as shown in Fig. 8 of Lesson No. 2. Scratch a small amount of the lacquer from the rear side of the large panel until you have a small shiny area of bare metal exposed. Connect one of the leads from the continuity tester to this bare spot on the main panel and touch the other lead in turn to each of the sockets. In no case should you obtain a reading on your meter. If the meter gives an indication then this shows that the sockets are not centred in their holes on the panel, and it will be necessary to loosen the nuts, reposition them and then tighten the nuts again. After this, make another test until you find that there is no reading obtained when testing to any of the sockets.

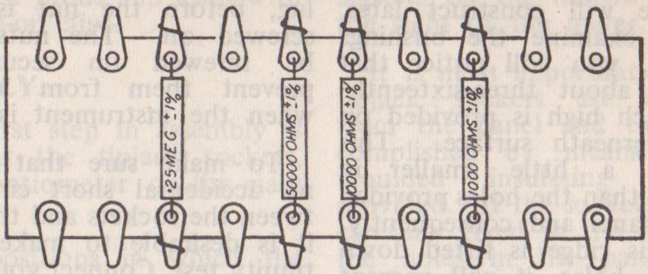

Fig. 3

RESISTOR PANEL.

The next step in the construction of the multimeter is to mount the various resistors on to the resistor panel (supplied in Kit 1) in exactly the positions indicated in Fig. 3. Count along from one end of the resistor panel and leave the number of spaces indicated on Fig. 3 before mounting the resistors in position. These vacant spaces will be used for some of the other resistors which will be supplied to you in your next kit.

To make certain that the resistors are mechanically secure before the soldering operation is carried out, pass the connecting wires from the resistors down through the eyelet holes, securing the various lugs in position, and then bring the connecting wires outward and around the solder lug. The correst method of attaching the resistors to the lugs is shown in Fig. 4. Now use your soldering iron to solder the ends of the wires to the solder lugs.

You may now mount your meter into position on the main panel by means of the four nuts supplied with it.

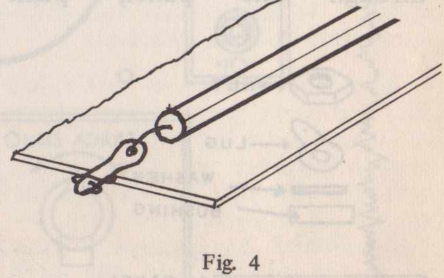

Fig. 4

Now solder the resistor panel to the two lugs attached to the meter as shown in Fig. 5. You will find, if you solder the fourth lug from the left-hand end of the resistor panel to the left-hand meter terminal that the seventh lug from the left-hand end of the resistor panel matches the soldering lug attached to the right-hand meter terminal.

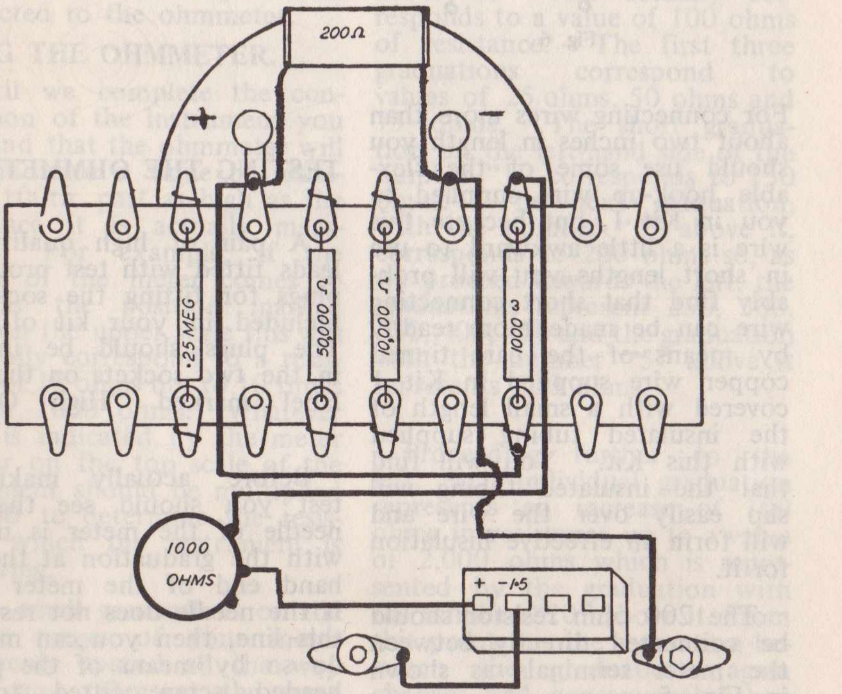

Fig. 5

WIRING THE OHMMETER.

The wiring necessary to complete the ohmmeter circuit is clearly indicated in Fig. 5 and the equivalent electrical circuit arrangement is shown in Fig. 6.

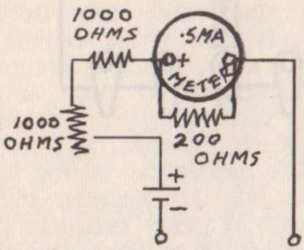

Fig. 6

For connecting wires more than about two inches in length you should use some of the flexable hook-up wire supplied to you in Kit 1, but because this wire is a little awkward to use in short lengths you will probably find that short connecting wire can be made more readily by means of the bare tinned copper wire supplied in Kit 1 covered with a small length of the insulated tubing supplied with this Kit. You will find that the insulated tubing will slip easily over the wire and will form an effective insulation for it.

The 200 ohm resistor should be connected directly between the meter terminals as shown in Fig. 5.

The wires from the centre lug of the potentiometer and from the centre socket in the large label should be left about eight or nine inches long so that they may be connected to the battery supplied to you in Kit No. 2. The wire from the potentiometer should connect to the positive terminal on this battery and the wire from the tipjack socket should connect to the battery terminal marked minus 1.5. Having completed our ohmmeter section we will proceed to test this before proceeding with the construction of the voltmeter.

TESTING THE OHMMETER.

A pair of high quality test leads fitted with test prods and plugs for fitting the sockets is included in your kit of parts. The plugs should be inserted in the two sockets on the large label marked "High Ohms".

Before actually making a test you should see that the needle of the meter is in line with the graduation at the left-hand end of the meter scale. If the needle does not rest over this line, then you can make it do so by means of the plastic headed screw fitted to the centre of the meter case just below the glass. Use a large screw-driver and turn this screw very slowly, one way or the other, until the needle is in line with the left-hand marking on the scale.

Next you should check the position which the needle reaches at the right-hand end of the scale when the two long test wires are touched together. When you touch them, you will find that the meter will move up the scale towards the right-hand end. You should use the knob supplied, fitted to the shaft of the potentiometer, to adjust the potentiometer until the needle just reaches the right-hand end of the scale. If you now separate the end of the test wires they are ready for measuring the resistance of any circuit connected to the ohmmeter.

USING THE OHMMETER.

Until we complete the construction of the instrument you will find that the ohmmeter will only indicate a value of resistance 100th part as high as the resistance it is actually measuring. For example, if the needle of the meter comes to rest at the position marked "10" on the upper scale this will not really correspond to a resistance of 10 ohms but to 10 times 100 or 1000 ohms. Whatever value is indicated by the meter pointer on the top scale of the instrument should be multiplied by 100 to determine the resistance which the instrument is measuring.

The small graduations on the voltage ranges of your meter are evenly spaced all the way across and represent the same value of voltage from one end of the scale to the other. This is not the case with the ohms graduations, however, and you will notice that they are not uniformly spaced and that the value represented by them varies from one end of the scale to the other. Make a careful examination of the graduations on the ohms scale, starting from the right-hand end and working towards the left-hand end. The graduation at the extreme right-hand end is marked zero because the needle should only reach this position when the test leads are directly joined to one another and when there is no external resistance present. Proceeding towards the left you will observe that the fourth graduation has the number "1" above it. This actually corresponds to a value of 100 ohms of resistance. The first three graduations correspond to values of 25 ohms, 50 ohms and 75 ohms. The short graduation on the left-hand side of the number "1" corresponds to 150 ohms. The next graduation, with the number "2" above it, corresponds to 200 ohms so, as we proceed towards the left, the graduations represent 250, 300, 350, 400, 450 and the graduation with the number "5" above it represents 500 ohms.

Proceeding further to the left, each individual graduation represents an increase of 100 ohms in resistance up to a value of 2,000 ohms which is represented by the graduation with the number "20" above it. From this point on, the separation between the graduations again changes and consequently they represent different values of resistance. The next short graduation represents 2,500 ohms, the longer one represents 3,000 ohms, then, in turn, 3,500 ohms, 4,000 ohms, 4,500 ohms and the graduation with the number "50" above it represents 5,000 ohms. The following unmarked graduations will represent 6,000, 7,000, 8,000 and 9,000 ohms and the graduation with the number "100" above it represents 10,000 ohms.

As we continue, the graduations will represent, in turn, 12,500, 15,000, 17,500, 20,000, 30,000, 40,000, 50,000 and the graduation with the number "1,000" will correspond to 100,000 ohms.

The last graduation, which is a symbol somewhat like a figure 8 turned on its side, represents "infinity" and means that there is an infinitely high resistance present between the ends of the test leads. The needle will normally rest on this graduation when the test leads are not connected to any conducting circuit.

To obtain some practice in using the instrument as an ohmmeter, we will proceed to measure the values of the resistors which you have not yet included in the wiring of the instrument.

Included amongst the materials supplied to you with your last kit was a 14.8 ohm resistor. If you touch the two test leads to the ends of this resistor the needle will move almost to the extreme right-hand end of the scale. The needle should take up a position approximately half-way between the end graduation marked "O" and the first graduation to the left which corresponds to 25 ohms. Next, carefully connect the two test leads to the ends of the 10,000 ohm resistor which you have now fitted near the middle of the resistor panel of your instrument. Be careful that the test leads do not touch any of the other solder lugs, especially the one attached to the right-hand meter terminal. When you touch the test leads to the ends of the 10,000 ohm resistor you will find that the needle will move a short distance across the scale and should come to rest somewhere near the graduation which has "100" above it. As previously pointed out, this number should be multiplied by a value of 100 times in order to obtain a correct indication and of course 100 multiplied by 100 represents 10,000, which is the correct value of the resistor.

Because of the wide range of resistance covered on the scale of an ohmmeter it is almost impossible to ever construct an ohmmeter which is absolutely accurate throughout the full length of its scale. For this reason, do not worry if the meter needle comes to rest a little to one side or the other of the graduation marked "100".

Next, you may check the value of the 50,000 ohm resistor by touching the two test leads to the ends of this resistor. Once again, be careful that the ends of the test leads do not touch any of the other solder lugs on the panel. When you have made the connection, you will observe that the meter needle will move only a very short distance up the scale and will come to rest somewhere near the graduation marked

"500". This value of course corresponds to 500 multiplied by 100 or 50,000 ohms.

You now connect the test leads to the two ends of the 250,000 ohm resistor. You will find that the needle will hardly move at all across the scale for the reason that this resistor is so high in value that it prevents any appreciable amount of current passing through the meter and the small amount flowing is hardly enough to move the pointer.

As mentioned earlier, it is impossible to make an ohmmeter which is absolutely accurate across the full length of its range. The degree of accuracy obtained on an ohmmeter will always be greatest near the centre portion of its scale and consequently the needle can be relied upon to come to rest within about 1-16 of an inch of the correct position when checking resistance values which cause the meter needle to come to rest anywhere between 1-3rd of the way across the scale and the right-hand end. The graduations become so crowded together near the left-hand end of the scale that, although the position of the needle may not vary by more than about 1-32nd of an inch from its normal position, this may actually cause it to indicate a value of resistance a little different from the true value of resistance being indicated. In most cases, for practical radio work, any slight error indicated in this fashion is not of sufficient importance to make any noticeable difference to the performance of a radio receiver and the ohmmeter may be regarded as a sufficiently accurate instrument for all radio servicing or constructional testing.

WIRING THE VOLTMETER RANGES.

The connections necessary to complete the wiring of the voltmeter are clearly indicated in Figure 7. The ohmmeter wiring has been omitted from this circuit diagram showing the wiring of the instrument embodying both the ohm and voltage ranges is shown in Figure 8.

When carrying out your wiring be careful to see that the solder, used for attaching the hook-up wire to the solder lugs mounted on the tipjack sockets, does not run underneath these lugs and form a bead which will connect the lugs to the front panel. To minimise the possibility of this occurring, it is a good idea to bend the ends of the soldering lugs upward away from the panel before you commence the soldering. After you have completed the soldered joint, examine the backs of the solder lugs and see that there is not sufficient solder to connect them to the panel.

You may now make some simple tests with the aid of the

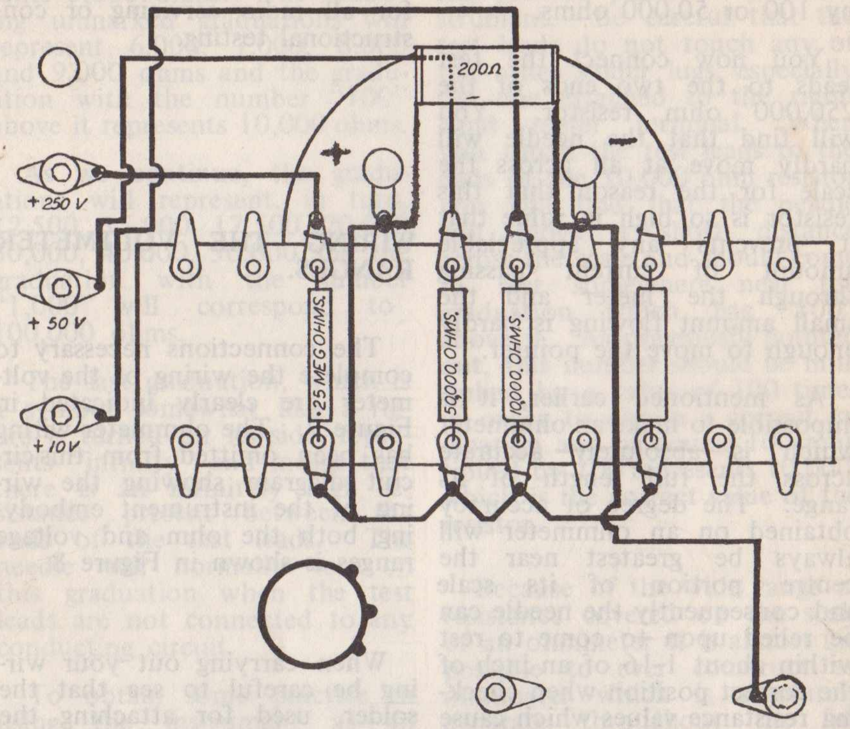

Fig. 7

ohmmeter battery to determine whether the voltmeter has been wired correctly. Insert one of the test leads in the socket mounted in the lower left-hand corner of the main label. This is the socket with the minus sign beside it. The second test lead should be plugged into the tipjack socket marked plus 10 volts. Disconnect the 4½ volt battery from the ohmmeter circuit and instead, connect the ends of the test leads to the two outside terminals on your battery. If your battery has not been extensively used, the meter needle should move almost half-way across the scale. When using the 10 volt range of the instrument, by plugging one of the test leads into the socket marked "+ 10 volts" you should observe the indication of the meter on the DC voltage

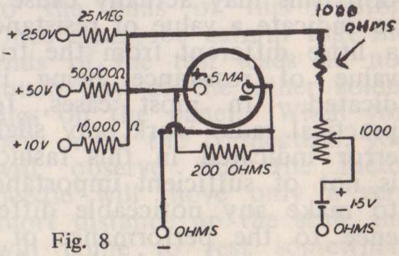

Fig. 8

scale terminating in the number 10 at the right-hand end. The value of 4½ volts from the battery should make the needle move a little less than half-way across the scale to a position about 2 or 3 small graduations beyond the number 4. On this range, each small graduation corresponds to a value of 0.2 volts so that if your battery has its full voltage of 4.5 volts, the needle should move about 2½ small graduations beyond the number "4". The first small graduation would correspond to 4.2 volts, the second to 4.4 volts and the third to 4.6 volts. If the needle does not register approximately 4.5 volts when testing the battery this may indicate either a fault in your instrument or that the battery is discharged. If the needle tends to move more than half-way across the scale this would suggest that the 200 ohm resistor has not been wired directly across the meter terminals; but on the other hand, if the needle does not come up as far as it should, this may indicate that the battery has been discharged or that you have mixed up the resistors and have not connected the 10,000 ohm resistor to the socket marked " + 10 volts".

The 50 volt range of your instrument may be tested by plugging the test lead, which was previously used in the socket marked "+ 10", into the socket marked "+ 50" instead. By touching the two test leads to the end terminals of the battery you will read its voltage on the 50 volt range of your meter. In this case, the needle will move only a short way across the scales. There are 50 separate graduations on the DC voltage scale of your meter so that each small graduation in this case will correspond to one volt and if your battery has its normal value of 4½ volts pressure, then the needle should move 4½ graduations across the scale.

In a similar fashion, we may obtain an indication as to whether the 250 volt range is correctly wired by plugging the test lead into the socket marked " + 250". In this case, the needle will hardly move at all across the scale as each small graduation will represent a value of 5 volts and consequently the needle should move not quite the width of one graduation across the scale from the zero position.

Once you have satisfied yourself that the 3 voltage scales are indicating correctly you may then connect a 1½ volt section of the 4½ volt battery to the ohmmeter circuit again and your instrument is ready to employ as a general purpose voltmeter or ohmmeter for testing radio receivers or electrical appliances. Even though your instrument is now capable of measuring voltages as high as 250 volts, when you employ the test lead in the socket marked "+ 250" you should fully realise that the voltmeter will only measure direct voltages and is not capable of measuring alternating voltages. In most districts, alternating voltage power mains are employed and consequently your meter will not be suitable for measuring the voltage of these power mains. If, however, you happen to live in a district where direct voltage power mains are in use, then you may use your voltmeter for checking the value of the actual voltage supplied by these mains. In many cases it will not be exactly 240 volts but your meter will enable you to determine just what voltage is available.

When measuring values of voltage exceeding 100 volts be very careful not to touch the two connections to the source of voltage simultaneously with your fingers or you may receive an unpleasant or even dangerous electric shock. You can quite safely handle voltages up to 50 volts without any fear whatsoever; you should be very careful in handling voltages from 50 volts up to 100 volts and you should be particularly cautious never to touch simultaneously the two sides of any circuit operating with a voltage in excess of 100 volts.

If you wish to use your instrument for checking the voltages present in an ordinary type radio receiver you will find that in most cases you can connect the test lead which is normally plugged into the socket marked "–" to the metal chassis of the receiver and then use only the other test lead, plugged into one of the voltage sockets, for measuring the voltage existing at the plate, grid, filament or other parts of the radio receiver.*

To prevent damage to your meter it is always advisable to start off with the highest voltage range provided, and obtain an approximate indication of the value of voltage before making use of one of the lower voltage scales. If you do not observe this precaution, you may perhaps be using your meter on the 10 volt range and accidently touch a point which is carrying a much higher voltage, say 200 or more volts. If you do this, the 200 volts applied to the meter on its 10 volt range would overload it and might possibly do some damage to it. If, however, you always start with the 250 volt range, you will immediately be given an approximate indication of the value of voltage present and you may, if you find it necessary to do so, safely employ one of the lower voltage ranges for measuring values of low voltage accurately. Do not attempt to measure voltages which may exceed 250 volts until you have wired up the 1000 volt range of your instrument as described in the next lesson.

The ohmmeter range will now enable you to measure directly the value of resistance of any radio parts or electrical device with a resistance between about 25 ohms and 100,000 ohms. In our next lesson we will see how to increase the usefulness of the ohmmeter for measuring very low values of resistance.

* See A.R.C. Service Engineering Course Lessons 7, 12, 20, 26, 44.

If you have a number of radio parts of electrical devices it is a good idea to gain practice in using the ohmmeter scale by measuring the resistance of these units. Do not forget to multiply the value indicated on the upper scale of your meter by 100.

Never attempt to measure the resistance of an electrical appliance or the circuits or a radio set with power applied. Always disconnect the appliance or radio set from the power mains before using your ohmmeter or, in the case of battery-operated sets, disconnect both A and B batteries.

In measuring the resistance of electrical appliances you may in some cases be puzzled by the fact that the resistance you measure appears different to the resistance which you may calculate. The reason for this is that the ohmmeter will measure the resistance of an electrical appliance such as a lamp, radiator, or other unit when the element is cold and the resistance of the element may increase appreciably when it is heated. For instance, the resistance of an electric lamp filament increases by about ten or more times when it is operating at its normal voltage. The resistance of an electric lamp filament when it is heated may be calculated by the formula $R = \frac{E^2}{W}$ This formula is derived from the better known formula

$$W = \frac{E^2}{R} *$$

If we use this formula for calculating the hot resistance of a 240 volt 60 watt lamp we have $R = \frac{240 \times 240}{60} = 960$ ohms. On the other hand, if you actually use your meter to measure the resistance of the 240 volt 60 watt lamp you will only obtain a measured value of about 70 or 80 ohms which is the actual resistance of the lamp filament when the lamp is cold. The lamp's resistance only increases up to 960 ohms when it is heated. This same effect applies to a somewhat lesser degree in the case of other electrical appliances which become quite hot during their operation, such as radiators, toasters, household irons, soldering irons, etc. When testing radio components, however, the parts do not normally become very hot during operation and consequently do not change their value of resistance appreciably, thus the meter will indicate the true value of resistance of radio parts with a fairly high degree of accuracy at all times.

If your instrument fails to perform as it should, carefully check over the wiring and see that it agrees exactly with the illustrations in this lesson.

* See A.R.C. Service Engineering Course Lesson 18A.

Lesson No. 3

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