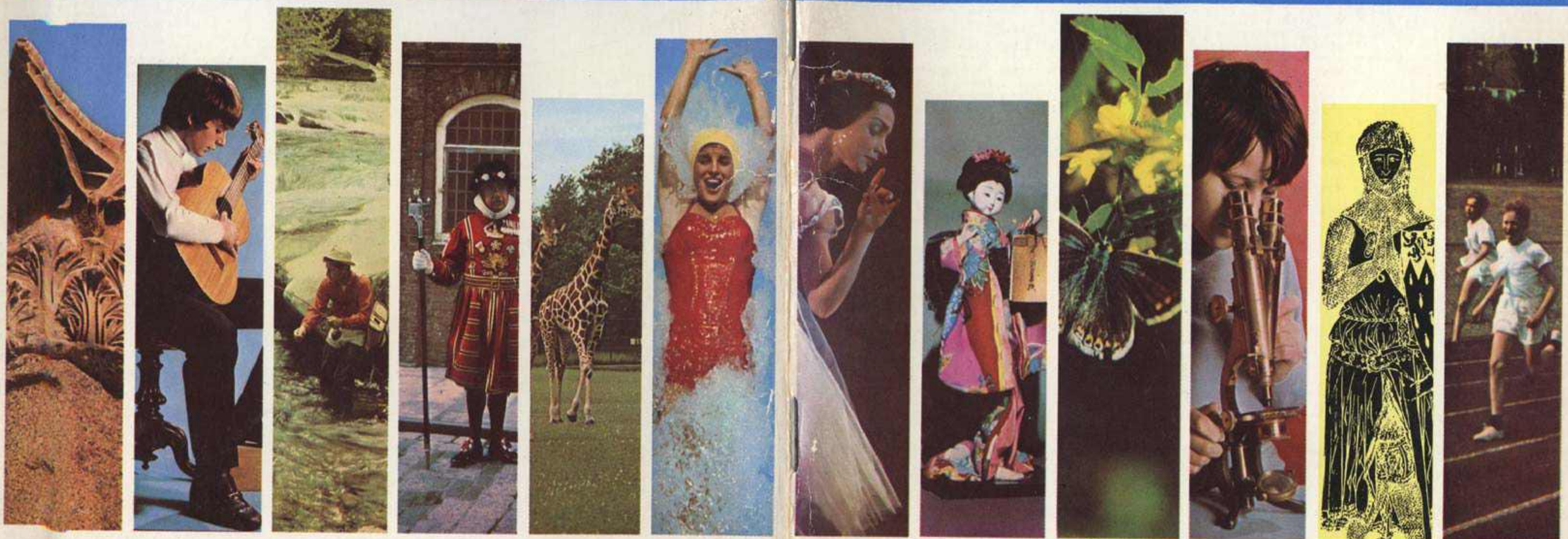
THE PROJECT CLUB

Build your own Crystal Set

PROJECT BOOK 147



RADIO

200 PROJECT BOOKS

continued on P. 64

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THE PROJECT CLUB

Build your own Crystal Set

PROJECT BOOK 147

By R. H. Warring

Illustrated by Peter Loates

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FOR THE DAIRY INDUSTRY

For many years the Dairy Industry has been helping young bodies to grow healthy and strong on milk—one of the most natural and valuable foods we have. With The Project Club it is branching out: young minds will be stimulated by this series of books, each written by an expert in his field. Project Club members not only learn useful techniques and facts, they build up a reserve of information which will be useful to them in later life—whatever they decide to do. Just as a daily 'pinta' is an unbeatable way of feeding your body, and laying the foundations for a healthy life in the future, so the Club provides projects for members which can be the basis for a career or a lifelong interest.

CONTENTS

The fact that you have joined The Project Club means that you already have a responsible attitude towards your everyday activities, and that you will read and carry out the project instructions carefully. This will enable you to get the most out of this book and ensure the safety of yourself and others.

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PART ONE

How a radio set works

The simplest way of sending a message is to speak. Anyone near enough to you can then hear what you are saying. If you try to speak to someone who is too far away, he will find it difficult to hear you unless you raise your voice or shout.

Speech is simply vibrations sent out through the air. The louder the speech the stronger the vibrations, and the farther they will travel before they die away. You can check that speech —or any other noise—is air vibration, or *sound waves*, by holding your hand in front of your mouth and speaking loudly. You can feel the sound waves hitting your hand. You can feel sound waves very much better by touching the front of a radio when it is playing music. Turn the volume control up and feel how the vibrations get stronger as the volume is increased.

PROJECT

Sending sound over longer distances

Collect two tin cans of the same size and pierce a small hole in the bottom of each. Tie the two cans together with a piece of thin string about 30 ft. long (*fig. 1*). Hold one can and get a friend to take the other and walk away until the string is quite

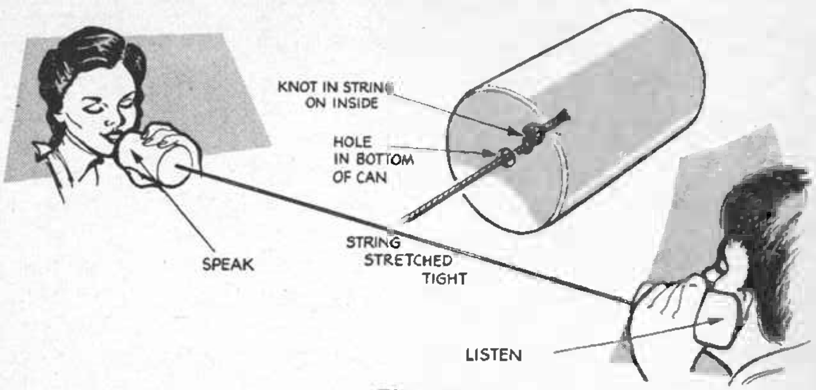

Fig. 1

taut. If you speak into your can, and your friend holds the other can to his ear, he will be able to hear what you are saying.

You have made, in fact, a simple telephone system for sending sound waves over longer distances than they would be heard with normal speaking. See how long you can make the string and still be able to hear what is said over the 'tin can telephone'.

The 'electric' telephone

A real telephone works in a slightly different way. Instead of sending the sound waves along a connecting line, it changes these sound waves into electrical waves, which are carried by wires. The energy for these electrical waves is supplied by a battery at the telephone exchange. To send sound over any distance by telephone, therefore, the caller and the person being called must be connected directly by wires. This is what the telephone system does automatically when you dial a number. Selecting the right number is a very complicated business and is done by special switching circuits in the telephone exchange.

Wireless sending

Some time after the telephone had been invented, a man named Marconi had an even better idea. The telephone showed that sound waves could be turned into electrical waves. Marconi worked on the idea of sending electrical waves through the air *without* wires, and after years of experimenting he was eventually successful. The electrical waves were a different type of wave, known as *radio waves*, and because he used no wires to carry them, but simply sent them through the air, the system was called *wireless*. The names wireless and wireless set were used for many years, though nowadays we usually call it radio (and radio set) after the type of electrical waves used. Do you know anyone who still talks of 'wireless sets'?

PROJECT

Picking up radio waves

Every broadcasting station sends out radio waves which travel through the air in all directions. These waves can travel for very long distances without losing their strength—that is why an ordinary radio receiver can tune in to many foreign stations a thousand or more miles away.

These waves travel at the speed of light, or 186,000 miles per second. So, if you tune in to a European station which is 1,000 miles away you will hear the sound in your set only 1/186th of a second after it has been spoken or played into the microphone in that distant studio. A radio signal sent by the astronauts on the moon takes only $1\frac{1}{3}$ seconds to reach the earth.

Try working out for yourself how long radio waves take to travel between two distant points—from New York to London, for example.

The Radio Receiver

Sending waves by radio is very simple, apart for one thing. A special *radio receiver* is needed both to pick up the radio waves and then turn them back into sound again. Also this radio receiver must be made so that it can be *tuned in* to each broadcast station, otherwise all we would get would be a jumble of sound.

A simple radio receiver, therefore, consists of three parts:

1 One part capable of picking up the radio signals which are in the air, and tuning in to a particular signal. This is called a *tuned circuit*.

2 Another part which takes this radio signal and turns it back into sound wave signals. This is called a *detector*.

3 A final part which enables the sound wave signals to be heard. This is a *loudspeaker* or an *earphone*.

Can you see how this is different from a telephone system? A telephone has sound wave signals carried to it by wires, and so only needs part **3**.

PART TWO

Making a tuned circuit

Whatever the type and size of a radio receiver—and however cheap or expensive it may be—a *tuned circuit* has two components. One is a *coil*, and the other a *capacitor*. A coil and a capacitor connected together will pick up a radio signal or a particular *wavelength* or *frequency*, depending on the size of the coil and the value of the capacitor.

Each station broadcasts on its own wavelength or frequency. When you tune in an ordinary radio set you are simply altering the frequency of its tuned circuit to pick up the signal from the station you want. If the coil is fixed in size, as it usually is, then the only way to vary the tuned circuit is to alter the value of the capacitor in the circuit. In other words, a *variable capacitor* is used, rather than one with a fixed value.

This variable capacitor is adjusted by the tuning knob on the outside of the set. Turning this alters the value of the capacitor connected to the coil in the tuned circuit. At the same time it may drive a pointer over a scale (*fig. 2*) showing the setting of the tuned circuit, or the stations to which it is tuned.

You will have to buy a variable capacitor as a standard radio component. For a simple crystal set the cost is only a shilling or so. The coil we can make ourselves.

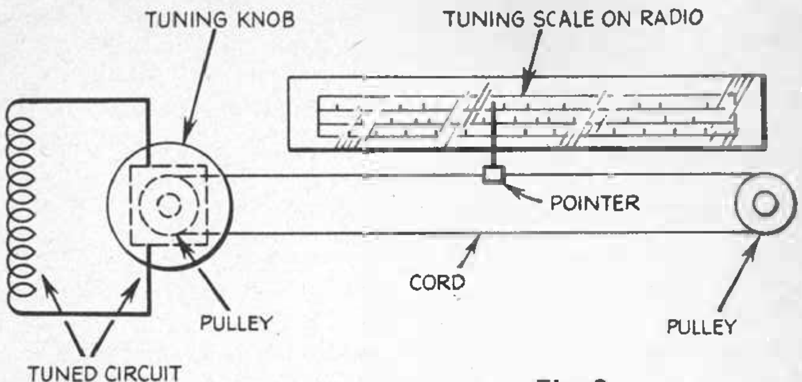

Fig. 2

PROJECT

Making the coil

You will need some 38 gauge enamelled copper wire, or better still 38 gauge enamelled and double silk covered wire. This can be bought from any radio supply shop (or by mail order. You will also need a good stiff cardboard tube 1 in. in diameter, such as a mailing tube. If you cannot get hold of one easily, a length of 1 in. diameter balsa dowel will do, or even a piece cut off a broom handle. It only needs to be about 2 in. long.

On this short length of tube wind 32 turns of the wire, laying each turn closely against the one before it (*fig. 3*). Now make a loop in the wire and wind on another 68 turns. Secure the two ends of the wire with a dab of sealing wax or 'Bostik' adhesive. Your coil should then look like the second diagram in *fig. 3*—a 100-turn coil with a loop or *tapping point* at 32 turns.

This coil will be suitable for receiving broadcast stations in the medium wave band. To make a coil suitable for the long wave band, start as before by winding on 32 turns and make a loop. Then carry on for another 200 turns, making 232 turns in all (*fig. 4*).

We will use both coils with the crystal set.

The variable capacitor

To match either of these coils you need a 500 picofarad variable capacitor. These come in various shapes and sizes, but it does not really matter which you use as long as it is the right value. You can choose a larger capacitor with vanes, adjustable by a knob; or a small *trimmer capacitor* which is adjusted by turning a screw at the centre. This is much cheaper than the vane type, but not so easy to adjust.

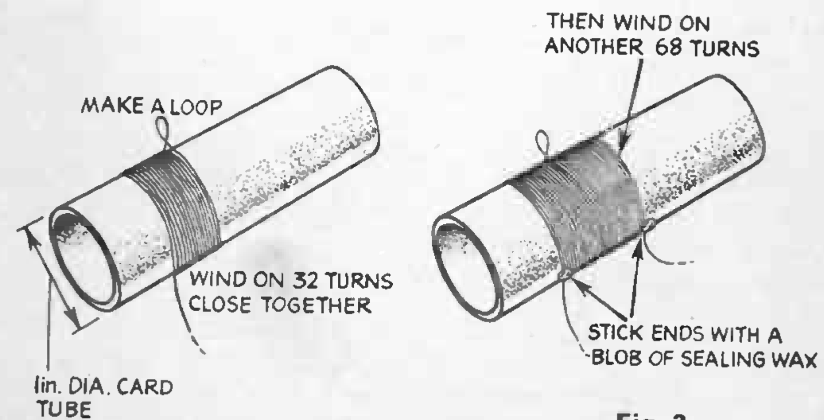

Fig. 3

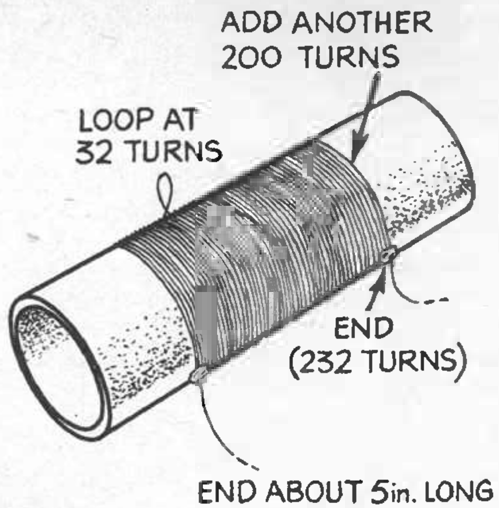

Fig. 4

PROJECT

A baseboard for the receiver

For this project we will use a very simple method of assembly and use balsa as a baseboard. Choose a really hard piece of 3 in. × $\frac{1}{4}$ in. balsa sheet and cut off a 6 in. length. Secure the coil to the baseboard, near one edge, using balsa cement (*fig. 5*), and stick down the variable capacitor close to the coil, this time using a glue such as Bostik.

PROJECT

Connecting up the tuned circuit

Scrape off the insulation on each end of the wire on the coil with a penknife, until you have exposed a length of bright copper

wire about 1 in. long at each end. Take one wire through each of the connecting tags on the variable capacitor, double back and twist round to hold in place (*fig. 5*). To make sure that the connection is good, squeeze tightly with a small pair of pliers.

If you can already use a soldering iron, all connections should be soldered, not twisted, together. If you have not used a soldering iron before, you can start with twisted connections. Soldered joints will be described in Part 4.

The connections you have made between the coil and the variable capacitor complete the tuned circuit.

All components for building crystal sets should be bought from shops which specialise in radio supplies—not radio shops which merely sell radio sets.

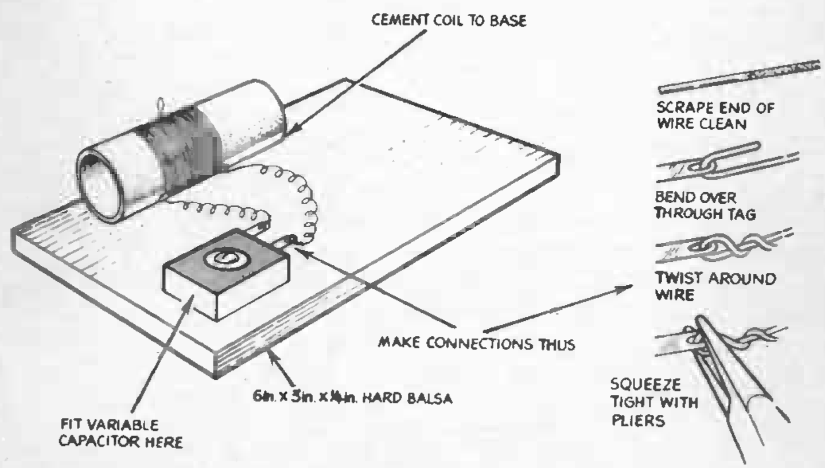

Fig. 5

PART THREE

Completing the crystal set

For the detector you need a component known as a *crystal diode*. This is a tiny cigar-shaped object made of glass, with a special crystal inside and connecting wires emerging from each end. It costs about 10p (2s.). You should ask for (or order) a diode by type number. Any of the following types will be suitable: GEC GEX34; BTH CG IOE; or Mullard OA70 or OA71.

The other components you need are: A capacitor of value .001 microfarad; and a pair of high impedance earphones, or a high impedance deaf-aid earpiece. If you decide on an earpiece instead of headphones, you will need a socket to go with it. The earpiece will already be connected to a plug and using a socket to match this plug makes it much easier to connect to the circuit. Remember, whether you buy earphones or an earpiece, either must be of *high impedance* type.

PROJECT

Connecting up the circuit

Bore or pierce two holes in the balsa panel (*fig. 6*). Screw a 1 in. long 6BA brass bolt into each hole from the bottom side of the panel and tighten in place with a nut.

Scrape the loop of wire on the coil with a penknife until it is free of insulation. Now make the following connections.

1 Connect the capacitor between bolts B and C, bending the ends of the leads around the bolts.

2 Connect one side of the variable capacitor to bolt B with a length of 15 amp fuse wire. Add a nut and tighten to hold these connections in place.

3 Connect one of the diode leads to bolt C, bending into a loop around the bolt. Secure this connection with a nut.

4 Connect the other diode lead to the loop in the coil by bending it into a hook and then using another brass bolt (bolt A) to clamp coil loop and diode lead together.

5 Connect the earphone leads to bolts B and C, adding another nut on each to hold in place.

If you are using an earpiece, connect the earpiece socket to bolts B and C with fuse wire and secure with nuts.

The circuit is now complete, but unless you are close to a broadcast station it will not work without an *aerial* and an *earth*.

PROJECT

The aerial

You can use any sort of wire for the aerial (wire left over from winding the coil will do, but slightly thicker bell wire will probably be better). The longer the aerial the better, so you will have to work out where you can run it. Here are two methods you can try (you can probably think of others).

1 Run a length of aerial wire along the length of the loft, then down through the hatch into your bedroom.

2 To use the set in a downstairs room, run the aerial wire right around the room on the picture rail, or trail it up the stairs.

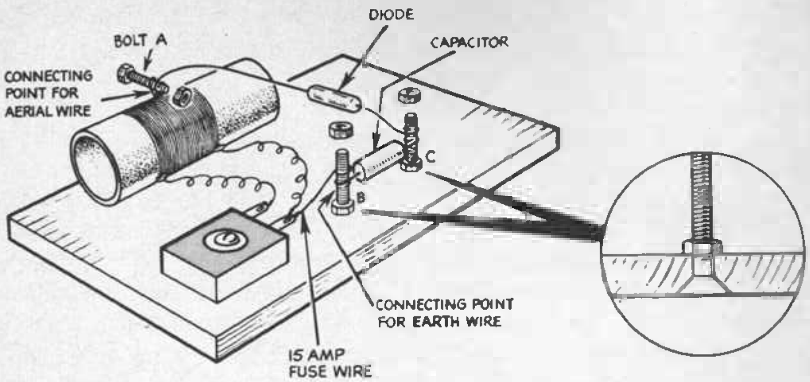

Fig. 6

The earth

The best 'earth' connection you will find in a house is a water pipe, or a pipe running to a radiator. To make a good connection to this pipe, it must be scraped clean until bright metal shows. The end of the earth wire is also cleaned and bound tightly around the pipe. Hold in place with a binding of cellulose tape, or insulating tape.

PROJECT

Connecting up the aerial and earth

The connecting points are shown in *fig. 6*. Connect the aerial wire to bolt A (i.e. to the loop on the coil), and connect the earth to bolt B.

You should now be able to hear a very faint noise in the ear-phones or earplug. Adjust the variable capacitor, either by turning the knob or using an *insulated* screwdriver on the

screw, and you should be able to tune in to one or more broadcast stations.

PROJECT

Getting the set to work properly

You may be lucky and find that you can tune in to several stations without any trouble, although they will all be quite faint. After all, the set is working without any batteries. It is using only the energy in the radio signals themselves. You also need a quiet room for good listening. Earphones are better than an earpiece because they shut off outside sounds.

If the set does not work at all, then the trouble is probably a wrong connection, or a connection not tight enough. This is a common fault. It could also be a faulty component, although that is less likely. If you think this is the problem, try changing the diode and the capacitor.

You must remember that the number of stations you can pick up, and loudness, will depend on where you live. Some places are very poor for radio reception, others are very good. The reception you get will also depend on the time of day, and the weather. Try to find out what is the best time for listening in, and which weather gives you the best reception.

PROJECT

Improving the set's performance

There are several ways in which you may be able to improve the performance of your crystal set. For example:

1 Try a longer aerial if you can, stringing it up as high as possible. Sometimes you can get a considerable improvement by connecting the aerial wire to a bed spring.

2 Try changing over the aerial and earth connections. Sometimes this produces much better results. Also see if you can find a better earth connection if reception is poor.

3 Try the effect of unwinding turns from each end of the coil (remove the same number of turns from each end). This will 'shift' the position of the stations when you adjust the variable capacitor. This shift may bring in more stations.

4 Replace the medium wave coil with the long wave coil. This will not give you as many stations, but the few you can get on the long wave may be louder. Also you can tune in to them more easily—you do not need such an exact adjustment of the variable capacitor.

PROJECT

Experiments with the aerial

1 Connect it directly to the variable capacitor (the earth connection being made to the other tag), instead of to the tapping point on the coil.

2 Connect a 220 picofarad capacitor to the end of the aerial wire, and then connect the other lead of this capacitor either to the tapping point of the coil, or directly to the variable capacitor.

Make a note of the results of all these experiments, so that you can finally get the best possible arrangement. If you alter *two* things at the same time, though, you may not get quite the results you expected from the experiments.

PROJECT

Making a two waveband set

Having tried the set with both coils—and adjusted the number of turns on these coils to get the maximum number of

stations, you can now make up a single coil which will cover both wavebands. This is a 232-turn coil of 38 gauge wire on a 1 in. diameter tube, or *former*, with tapping points at 32 turns and 100 turns (*fig. 7*). If you have found that less turns work better, then adjust the number of turns accordingly. For example, if you found that the medium wave coil worked best with 5 turns taken from each end, your two-wave coil would be 232 minus 10, or 222 turns, with tapping points at 32 minus 5, or 27 turns, and 100 minus 10, or 90 turns.

The second tapping point, and the far end of the new coil should both be bent into a loop, with the wire scraped clean.

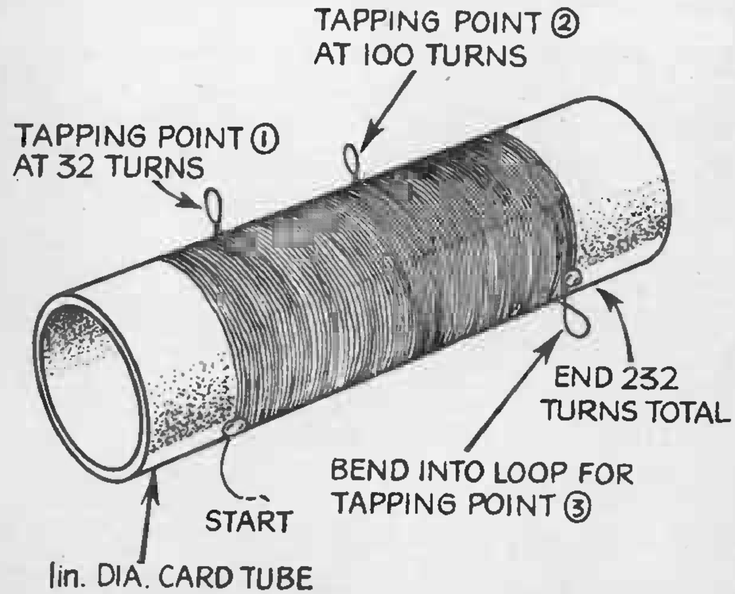

Fig. 7

Use a 6BA brass bolt and nut to connect a length of insulated wire to one side of the variable capacitor from tapping point 2 for medium wave; and from tapping point 3 for long wave. Tapping point 1, of course, connects to the diode and aerial.

Can you see how a switch could be used to change from medium wave to long wave, rather than swapping connections? *Fig. 8* shows how this can be done. Your crystal set is then like any other radio receiver with a *wavechange switch*.

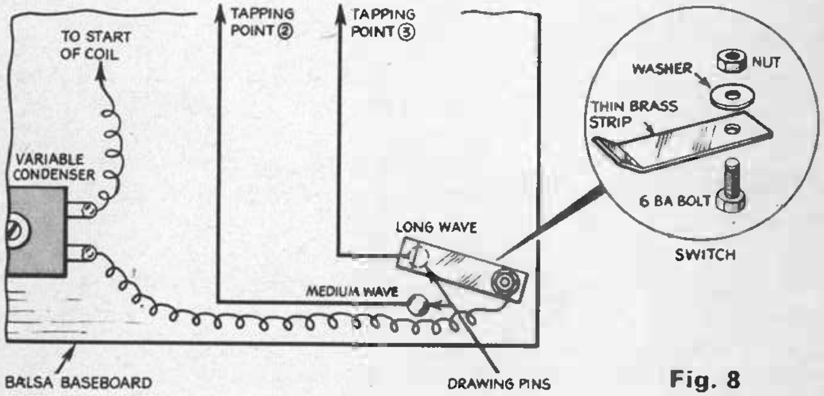

Fig. 8

PART FOUR

How to solder

Before we can improve our crystal set still further, we need to learn how to solder. Good soldering joints are essential for proper electrical connections.

For soldering you need an electric soldering iron, with a $\frac{3}{16}$ in. diameter bit and a rating of about 50 watts. You must use resin cored solder, which looks like soft wire, but has a centre core of flux.

The rules for good soldering are as follows.

1 The iron must be hot enough. That means it must be left for a sufficient time after switching on to heat up fully. This can be checked by touching the tip of the iron with solder. If it is hot enough, the solder will melt immediately and run over the tip of the iron.

2 The tip of the iron must be clean and bright. If it is dull and dirty, clean it with emery paper.

3 The parts to be soldered must be bright and clean. Clean any connecting points with emery paper. Wire leads can be cleaned by scraping with a penknife.

Fig. 9 shows the stages in successful soldering. In this example a lead is being soldered to a connecting tag. The same steps apply to any soldered joint in an electrical circuit.

First make sure that the two parts to be joined are bright and clean. Connect the wire to the tag by bending it so that it will keep in place.

When the iron is hot enough, put it on one side of the joint. Then put the solder on the *other* side of the joint. It should melt immediately and run smoothly over the joint. If it does not, then either the iron is not hot enough (the solder does not melt properly); or the joint is dirty (the solder does not spread out over the joint).

That's really all there is to it. Using the correct method, a joint should be completed in a matter of two or three seconds, after which the iron is taken away and you can blow on the joint to help cool it. Leaving the iron in place for too long may cause damage to components through heat being conducted along the leads. So, if you cannot make a proper joint in about two to three seconds, then either the iron is not hot enough, or the iron is too small for the job.

Now you can solder up all the twisted connections on the crystal set made in Part 3, and you will not have to worry about poor connections, or connections working loose.

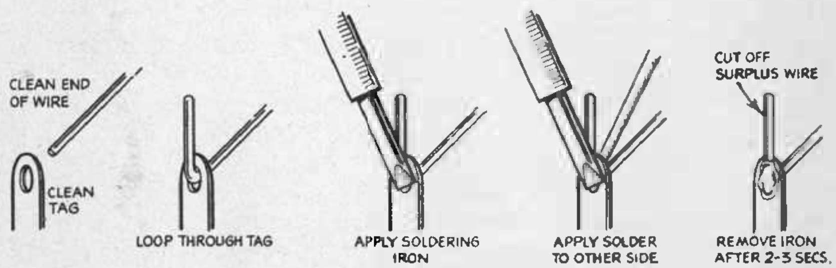

Fig. 9

PART FIVE

Improving the tuned circuit

You will have discovered from the experiments in Part 3 how important the aerial is for good reception with a crystal set. In fact, the more efficient the aerial can be made the more stations the set will pick up, and the louder they will be heard.

The simple coil we used in the tuned circuit is not very efficient. Its performance can be greatly improved by winding it on a material which has good magnetic properties. Such a material is Ferrite, made specially in the form of rods and slabs for winding tuning coils.

PROJECT

Winding an improved coil

Ferrite rods are made in various sizes. A rod 4 in. long by $\frac{5}{16}$ in. diameter is a good, compact size. The coil is not wound directly on to this rod, but on a paper sleeve which fits over the rod. You can make a suitable sleeve from gumstrip. Cut a 1 in. length of gumstrip and wrap round the rod, gum side uppermost. Now wind on further gumstrip, gummed side down, to build up a sleeve of about three or four layers (*fig. 10*). Make sure that the sleeve is a tight fit, but free enough to be slid up and down the rod.

The coil winding is made from 38 gauge enamelled wire, as before, but this time only 50 turns are needed, with a tapping point at 16 turns. Hold the ends of the wire in place with a dab of sealing wax (*fig. 11*).

PROJECT

Adjusting the improved coil

Replace the original coil with the improved one, which matches the original variable capacitor and the other components. The results should be much better. You can experiment with aerial and earth connections, as before, to adjust for best

Fig. 10

results, but this time do not remove any turns from the coil. There is a much easier method of shifting the tuning of the circuit with this new coil. Simply slide the coil up and down the Ferrite rod until you find the position which enables you to tune in to the maximum number of stations over the adjustable range of the variable capacitor. When you have found this position, fix the paper sleeve to the ferrite rod with a dab of sealing wax.

There is another way you can set up the coil position on the rod. Screw down the variable capacitor until it is fully closed

and then back off about half a turn. (If you are using a vane type variable capacitor, turn so that the vanes are fully closed, and then turn back until they are slightly open again).

Now slide the coil up and down the ferrite rod until you can hear BBC Radio 3. A look at the published programme will help you to identify the station properly. Fix the coil in this position with wax. This should then give you a full tuning range from the variable capacitor, with Radio 2 at about the middle of the variable capacitor movement, and Radio 1 at the other end.

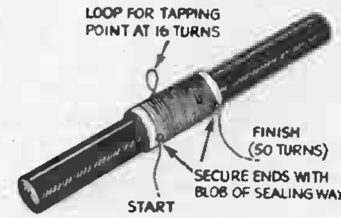

Fig. 11

PART SIX

A better receiver

This time we will use the same circuit as before, with the improved coil, but built in a more professional way. Instead of plywood, we will use a Paxolin base—a material you can buy from radio supply shops in the form of sheets. You will also need some solder tags of the type shown in *fig. 12*.

Cut a piece of Paxolin sheet 5 in. × 3 in., using a small hacksaw. Mark the positions of holes A, B, C and D (*fig. 12*) and drill these with a $\frac{5}{64}$ in. drill. Using short 8BA bolts and nuts, fix a solder tag at each hole position as shown. Cut two small pieces about $\frac{1}{2}$ in. × $\frac{1}{4}$ in. from the spare Paxolin sheet and stick to the large Paxolin base to form mounting pads for the ferrite rod carrying the coil. Use glue such as Bostik or Araldite.

PROJECT

Assembling the receiver

The complete receiver is assembled on the Paxolin sheet. Fit and connect the components in the following order and solder all connections.

1 Glue the ferrite rod down on its mounting pads.

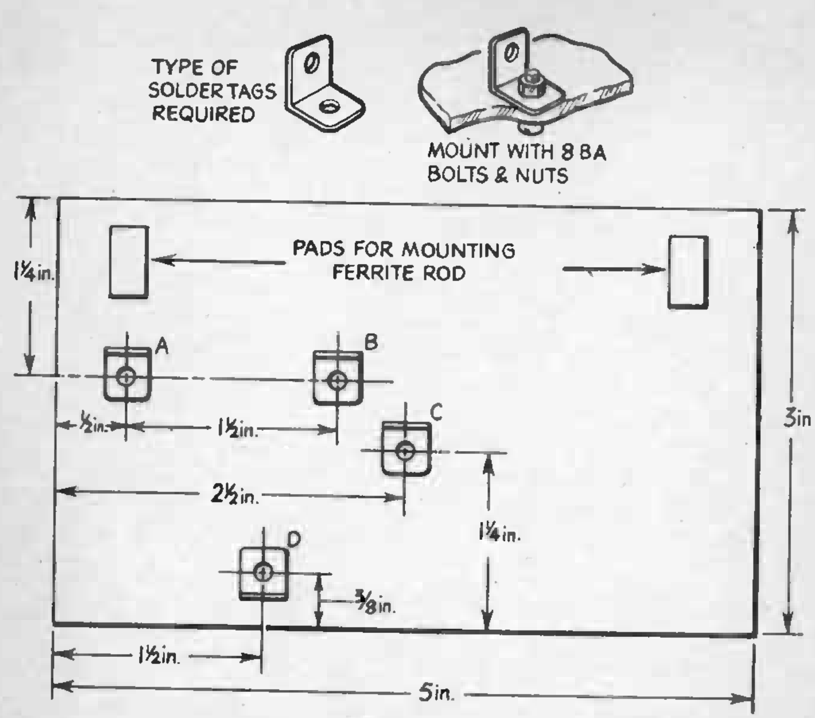

Fig. 12

2 If the variable capacitor is a trimmer type, glue it to the Paxolin panel in a similar way. For the vane type, drill a hole in the Paxolin so that the capacitor can be mounted on the top of the panel with the spindle coming out on the other side.

3 Connect one wire of the coil to one of the tags of the variable capacitor, and the other coil wire to the other tag of the variable capacitor. Connect this side (2) to tag D with a length of 15 amp fuse wire.

4 Connect the tapping point of the coil to tag B.

5 Connect the .001 microfarad capacitor between tags C and D.

6 Connect the diode between tags B and C.

7 Connect the tag on the variable capacitor to which the coil wire nearest the tapping point is already connected to tag D.

8 Connect a 220 picofarad capacitor between tags A and B.

The complete assembly should then look like *fig. 13*. Check over all the connections. The headphones are then connected to tags C and D, and the aerial wire to tag A. The earth wire

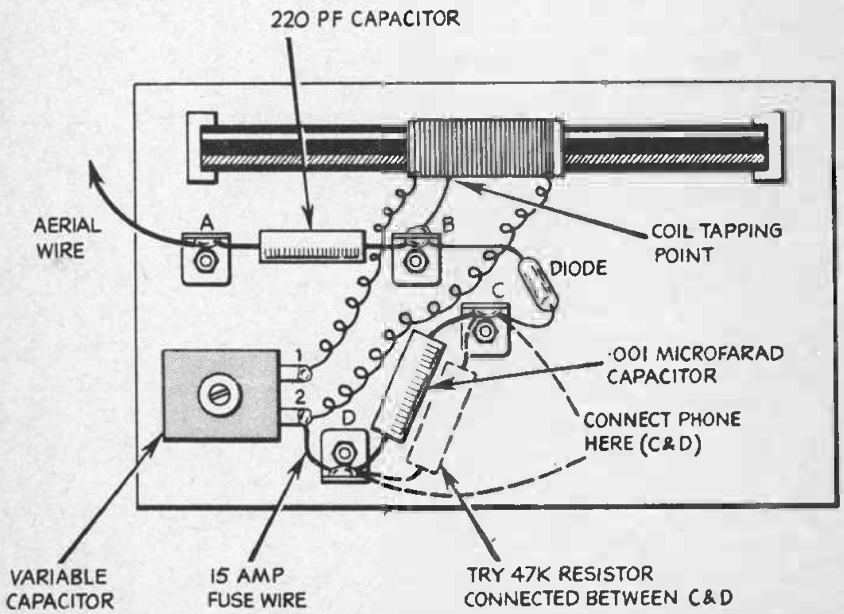

Fig. 13

connects to tag D. Adjust the set for best performance as described in Part 3.

PROJECT

Making adjustments

The main adjustments to try are:

1 Slide the coil up and down the ferrite rod to find the best position.

2 Try attaching the aerial wire to tag B, or to tag 1 on the variable capacitor. Find out which of these three alternative positions for the aerial wire is best.

3 Try connecting a 47 kilohm (47K) *resistor* between tags C and D. This may or may not improve the performance. If it does, try other near values of resistors to see if you can get even better results.

PART SEVEN

Circuit drawings

Rather than planning a circuit showing all the components in positions as in *fig. 13*, the usual way of drawing a plan of a radio circuit is to use symbols for the components. This makes it much easier to understand, once you know what the symbols mean (*fig. 14*).

Letters can also be added to the symbols—C for capacitor, R for resistor, D for diode—and if there are more than one of a type, a number—e.g. C1, C2, and so on. This makes it easy to refer to any particular component on the plan.

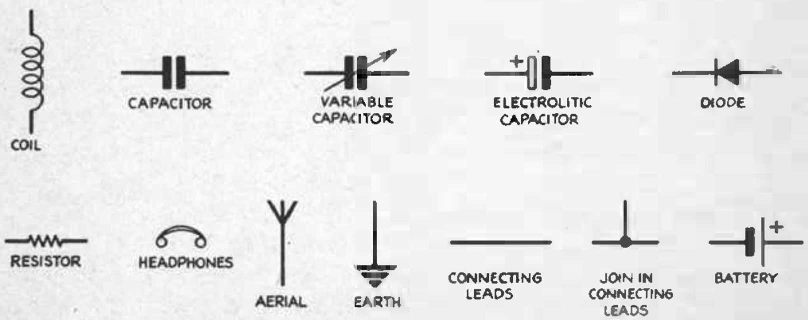

Fig. 14

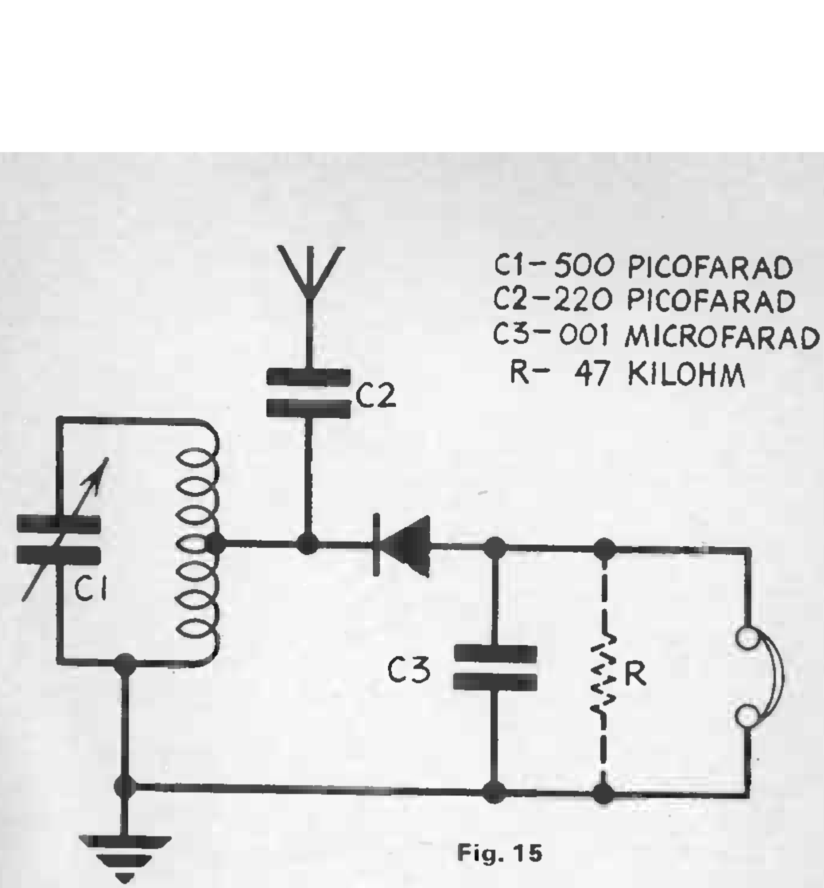

Fig. 15

The circuit we have used in Parts 3 and 6 is shown drawn in symbol form in *fig. 15*. This is the way the plan of any radio set is normally given. It is called a *theoretical* circuit, which shows all the components and how they are connected. But it is not a wiring up diagram, for the components will almost certainly have to be laid out differently on a base panel. Compare this figure with *fig. 13*, for example, which is a wiring diagram. A theoretical circuit gives all the information you need to build that particular design, but you still have to work out a suitable wiring diagram.

More about resistors

Capacitors have their value marked on them, so it is easy to find the right ones to use. Resistors, though, all look alike and have no figures marked on them, only coloured rings. These form a *colour code* which tells what the value of that resistor is.

The body of the resistor is marked with three coloured rings near one end (*fig. 16*). These are read in the order shown (1, 2, 3) according to the following code:

Colour	1 (gives first figure of resistance value)	2 (gives second figure of resistance value)	3 (gives number of noughts to put after first two values)
Black	0	0	none
Brown	1	1	0
Red	2	2	00
Orange	3	3	000
Yellow	4	4	0000
Green	5	5	00000
Blue	6	6	000000
Violet	7	7	0000000
Grey	8	8	00000000
White	9	9	000000000

For example, suppose the rings were brown, green, orange:

brown	green	orange
1	5	000

the value would be 15,000 ohms.

A thousand ohms is 1 kilohm, and so, instead of 15,000 ohms, this would be called 15 kilohms, or 15K. This simply saves writing a lot of noughts. Similarly, if you have a resistor value of so many million ohms this would be so many Megohms.

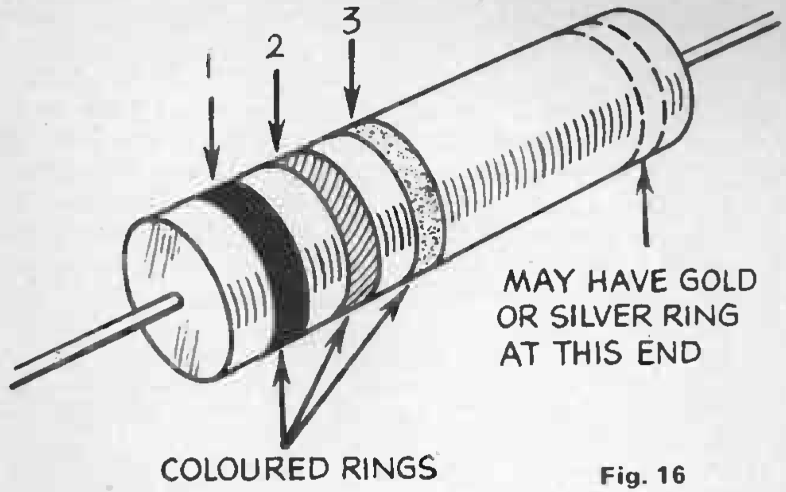

Fig. 16

PROJECT

Some calculations

Try working out other examples. What value would orange, orange, green be? If you wanted a value of 4.7K (4.7 kilohms), what colour code would you look for?

You may also find another single colour band marked on resistors, at the other end of the body. This will either be silver or gold. This is not read as part of the colour code but merely shows that the resistor is made to a close tolerance.

Transistors

We shall be using transistors in the further circuits to be described and there are a few things to note about them first (*fig. 17*). A transistor has three leads, connecting to the base b, collector c and emitter e. The circuit diagram for a transistor (*fig. 17*) gives no clue about the position of the leads—merely where b, c and e are to be connected *to*. It is very important, therefore, to be able to know how to identify the b, c and e leads on an actual transistor. If these are connected up wrongly, not only will the circuit not work, but the transistor may be ruined.

The three leads emerge from the bottom of a transistor either in the form of a triangle, or in a straight line (*fig. 17*). The collector, c, is always marked with a white or coloured spot on the body of the transistor, near the lead. Having identified this lead, the position of the other two can be worked out from *fig. 17*. If the leads are in line there is also a further clue. Base and emitter leads are always closer together than the base and collector, and the base lead is the *inside* one.

One further thing about transistors. They are quite sensitive to heat, and are easily damaged by overheating. To prevent this when soldering into a circuit, the leads should be kept quite

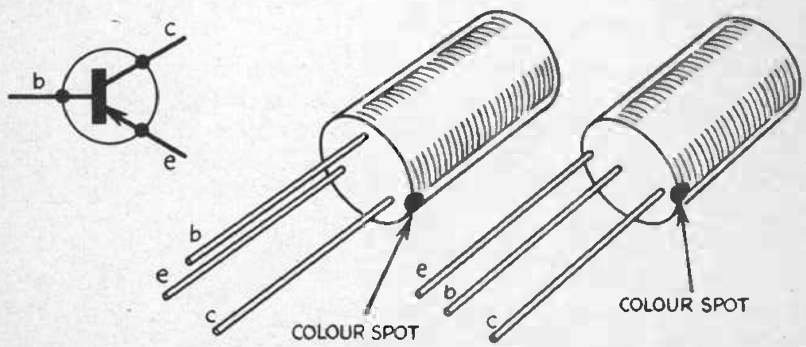

Fig. 17

long—at least 1 in. Also, the iron must not be held in contact with the joint for more than *five seconds at the most*.

It helps if you hold the transistor lead being soldered with a pair of flat nosed pliers, as these will conduct some of the heat away from the transistor. But you need not bother about this if you can solder properly.

PART EIGHT

Crystal set with amplifier

A transistor is a very good amplifier. That is, it can be used to increase the sound level in a receiver circuit. One of the main faults of a crystal set is that the sound is seldom very loud, so the addition of an amplifier can improve its performance considerably, especially for listening to weaker stations.

Fig. 18 shows a theoretical circuit for the crystal set with an amplifier stage added. This is the same as *fig. 15* with the addition of some new components:

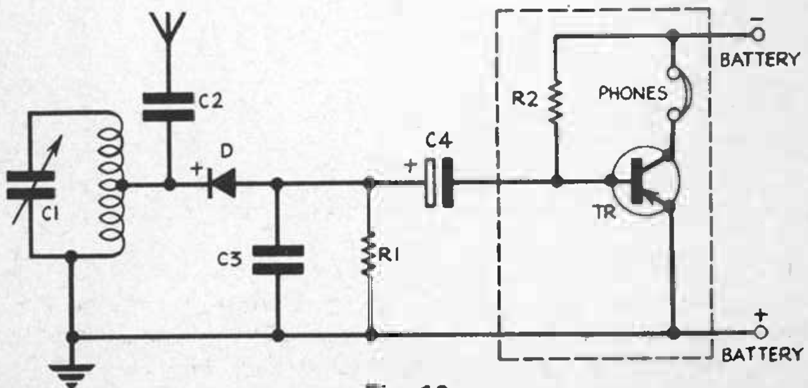

Fig. 18

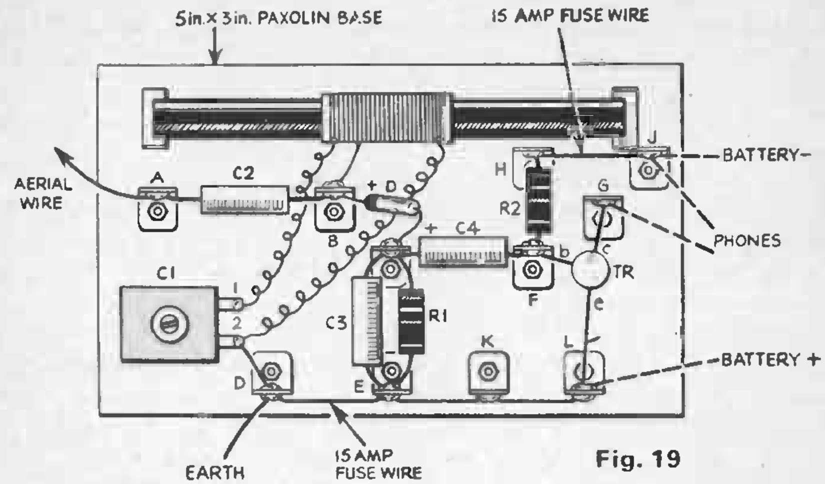

Fig. 19

C4—8 microfarad capacitor. This is an *electrolytic* type, marked with a plus sign on one end, and must be connected the correct way round.

R2—1 megohm resistor.

TR—Mullard OC71 transistor (or equivalent).

PROJECT

Assembling the amplified set

This time, the circuit will also need a battery to work the amplifier, connected between the plus and minus terminals, as shown.

Fig. 19 shows the same circuit drawn as a wiring diagram, with the position of all the components and their connections. The Paxolin panel is the same size as before, but is drilled and fitted with seven additional solder tags—E, F, G, H, J, K and L, positioned as shown.

Follow the same assembly instructions as for *fig. 13*, then connect up the additional components. C4 is connected between tags C and F. R2 is connected between tags F and H. Then connect tag H to J with a length of 15 amp fuse wire, and connect tags D, E, K and L together with a length of 15 amp fuse wire.

Connect the transistor like this: b lead to tag F; c lead to tag G; and e lead to tag L. The headphones connect to tags G and J.

The battery negative (minus) connects to tag J, and the battery positive (plus) to tag L. You can try 3 volt, 4.5 volt, 6 volt and 9 volt batteries to see which gives the best results.

PROJECT

Further experiments with the circuit

Try the three alternative positions for the aerial wire—tag A, tag B, or connecting tag 1 on C1—and use the one which gives the best results. See if leaving out R1 makes any difference. Remove C4 and replace with a length of 15 amp fuse wire soldered between tags C and F. See if the set is better or worse. Try different values for R2.

In areas of good radio reception this circuit should work particularly well, and you should be able to pick up as many as a dozen stations on the medium wave band, some quite loudly.

PROJECT

Additional stages of amplification

We can, if we like, go on adding further stages of amplification to this circuit, each stage boosting the sound even more.

The actual *amplifier stage* is enclosed by the dotted 'box' (*fig. 18*). To add a second stage of amplification:

1 Replace the headphones in the first amplifier stage with a 4.7 kilohm resistor.

2 Build another complete amplifier stage, with headphones included this time, just like that in the dotted box outline.

3 Connect the collector lead (c) of the transistor in the first amplifier stage to one side of a 8 microfarad capacitor and the other side of the capacitor to the base (b) of the second transistor (in the second amplifier stage). This couples the two stages together. You may find that it will work satisfactorily by connecting the collector of the first transistor directly to the base of the second transistor, without using a capacitor.

You can go on adding two, three, four or even more stages of amplification in this way, but the results will not be satisfactory. You will find that in addition to increasing the volume of the sound you are also getting *distortion* and a lot of unwanted sounds as well. One stage of amplification (*fig. 18*, for example) is very worthwhile. Two stages of amplification (one further stage added to *fig. 18*) may be worthwhile, but you will almost certainly get some distortion of the sound and loss of quality. Any further number of stages may increase the volume, but the quality of reception will be poor.

You cannot, in fact, get enough power out of a crystal set, even with several stages of amplification, to operate a loudspeaker and give good listening. That is why earphones are used with crystal sets.

PART NINE

A circuit for weaker signals

This circuit is really the same as *fig. 18*, except that a different value for resistor R2 is used, and the phones are connected to the emitter side of the transistor rather than the collector side. It will work better where signals are very weak, and perhaps pick up stations that *fig. 18* would not.

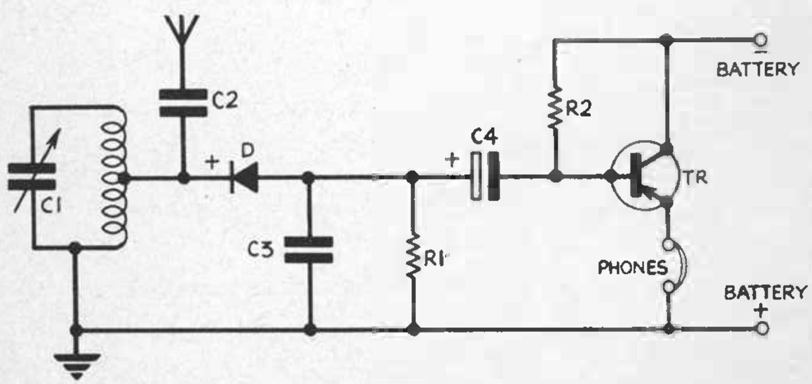

Fig. 20

The circuit diagram is shown in *fig. 20* and a full list of components is given below, to save you looking back.

C1—500 picofarad variable capacitor.
Coil—wound on ferrite rod, as described in Part 5.
D—diode (Mullard OA70 WOA71).
C2—220 picofarad capacitor.
C3—.001 microfarad capacitor.
C4—8 microfarad electrolytic capacitor.
R2—470 kilohm resistor.
TR—Mullard OC71 transistor.

PROJECT

Wiring up the circuit

The wiring diagram for this circuit (*fig. 21*) is the same as *fig. 19*, except that one additional solder tag is required—M.

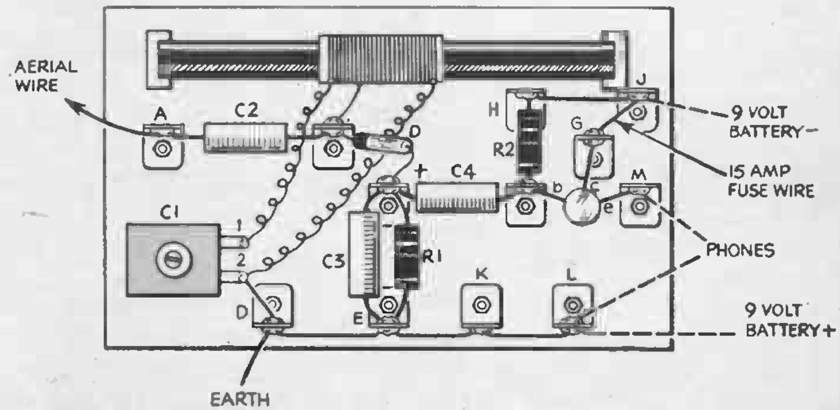

Fig. 21

The emitter lead (e) of the transistor is connected to this tag, and to one lead of the phones. The other lead of the phones goes to tag L. Tags G and J are connected with a short length of 15 amp fuse wire.

PROJECT

Further experiments with this circuit

Try connecting the aerial wire to tag B.
Try connecting the aerial wire to tag 1 on C1.
Try leaving out R1.
Try replacing C4 with a length of fuse wire between tags C and F.
Try different values for R2.
Remember that you should use a 9 volt battery with this circuit (PP3 or equivalent).

PART TEN

A stabilised circuit

The circuit we developed in *fig. 18*, with one stage of amplification, is a very good one. But it can be improved on. The performance of a transistor tends to vary with changing current passing through it—as it does when amplifying the sound signals. To overcome this we need to add some more components to *stabilise* the transistor.

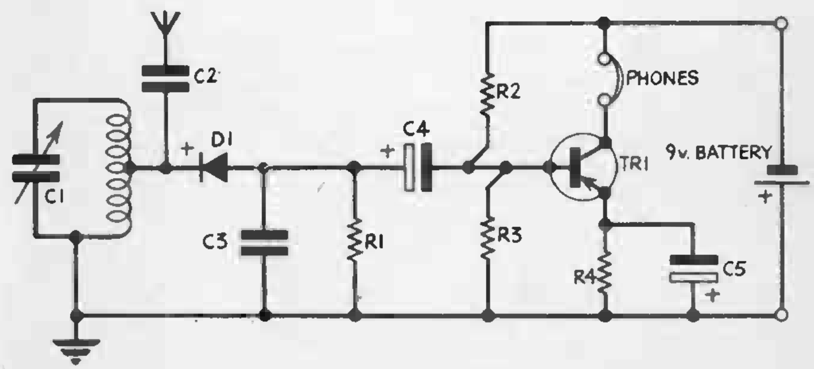

Fig. 22

This involves two additional resistors and one additional capacitor. A theoretical diagram of this circuit (*fig. 22*) uses the following components:

Coil—wound on Ferrite rod (described in Part 5).
C1—500 picofarad variable capacitor.
C2—220 picofarad capacitor.
C3—.001 microfarad capacitor.
C4—8 microfarad electrolytic capacitor.
C5—8 microfarad electrolytic capacitor.
R1—47 kilohm resistor.
R2—22 kilohm resistor.
R3—10 kilohm resistor.
R4—4.7 kilohm resistor.
D—diode (Mullard OA70 or OA71).
TR—Mullard OC71.

PROJECT

Making the stabilised set

The component layout and a wiring diagram (*fig. 23*) has the same placing of solder tags as *fig. 21* except for the addition of one more tag (N). You should have no difficulty in completing this circuit and getting it to work properly.

PROJECT

Further experiments with this circuit

Try different positions for connecting the aerial wire—tag A, tag B and tag 1 on the variable capacitor.

Try leaving out R1.

Try different values for R1.

Try replacing C4 with a fuse wire connection between tags C and F.

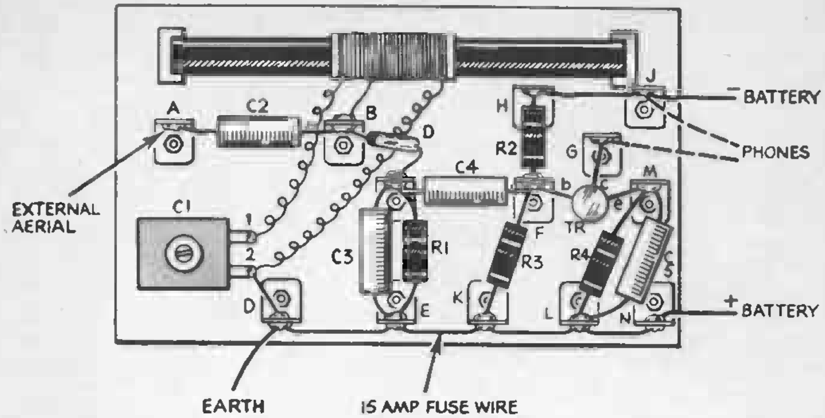

Fig. 23

PART ELEVEN

More circuits to try

There are a number of other simple circuits you may like to try, although none can be expected to give better results than those which can be obtained by the designs in Parts 8, 9 and 10. They are really 'trick' circuits, which are interesting to experiment with.

PROJECT

An all-transistor crystal set

This circuit uses a transistor instead of a diode, the only other component needed being a normal tuned circuit (see Part R), headphones and a battery (circuit diagram, *fig. 24*).

You can use almost any type of transistor, but a Mullard OC71 or equivalent is preferred. Any battery voltage between 1.6 and 6 volts should work the set.

Remember that the emitter (e) of the transistor is connected to the tapping point on the coil; the collector (c) to the phones, and the base (b) to the earth side of the circuit (and positive battery connection).

If you cannot get this circuit to work, try modifying it (*fig. 24*). R1 is a 10 kilohm resistor, and C1 is a 1 microfarad capacitor.

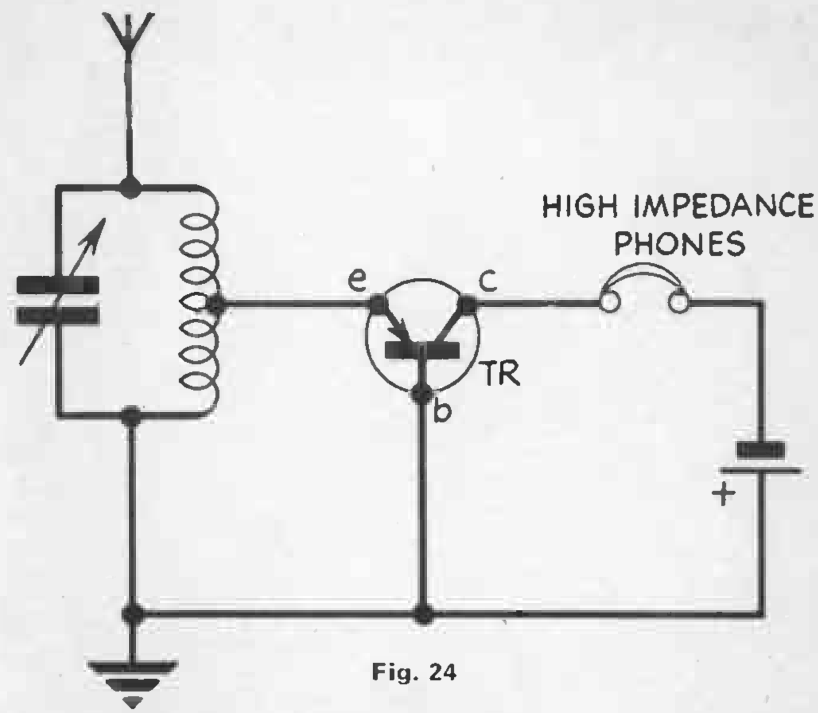

Fig. 24

PROJECT

Transistor set without a battery

If you live in an area which is near to a local broadcast station and you can get strong reception on an ordinary crystal set, you may be able to get a transistor set to work without a battery. This is the same circuit as *fig. 25*, but without a battery (*fig. 26*).

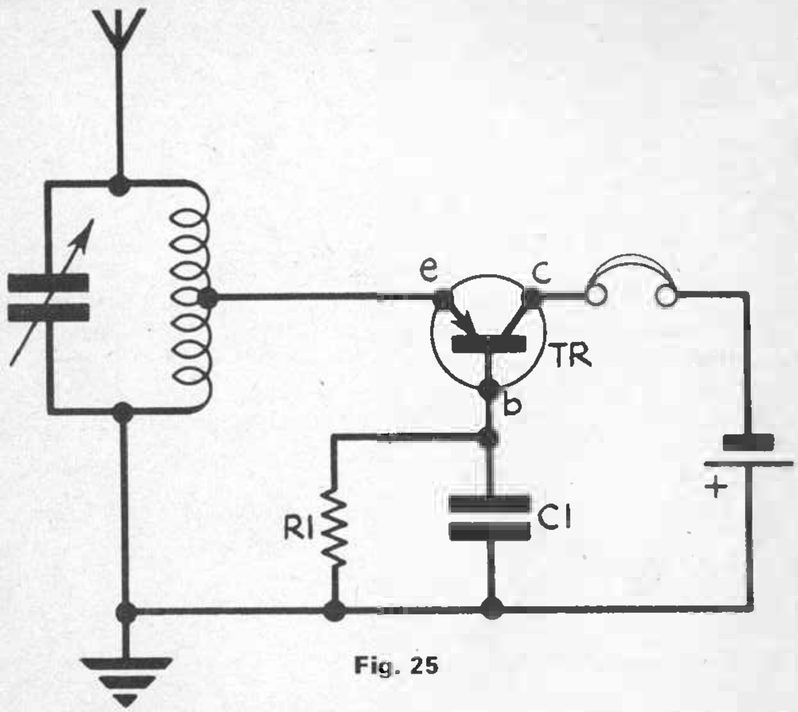

Fig. 25

If you can get this set to work, but the signals are too weak to be heard properly, you may be able to improve the performance by:

1 Trying another transistor.

2 Trying a different value for R1.

3 Reversing the aerial and earth connections on the tuned circuit.

You will need a good earth and a good length of aerial to get this set to work at all.

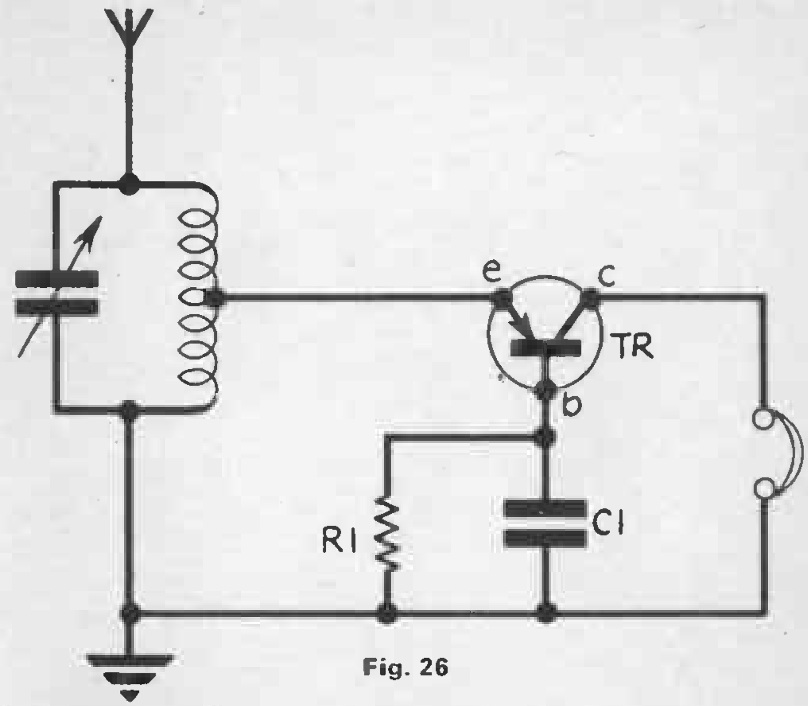

Fig. 26

PROJECTS

Crystal set and amplifier without battery

This is another simple circuit, using a minimum of components, which again is capable of working without a battery in areas of good reception. This time, however, we are using both a diode and a transistor, and it is the diode which supplies power to the transistor. Apart from the tuned circuit, the only other component needed is a 2 microfarad capacitor (C1) to couple

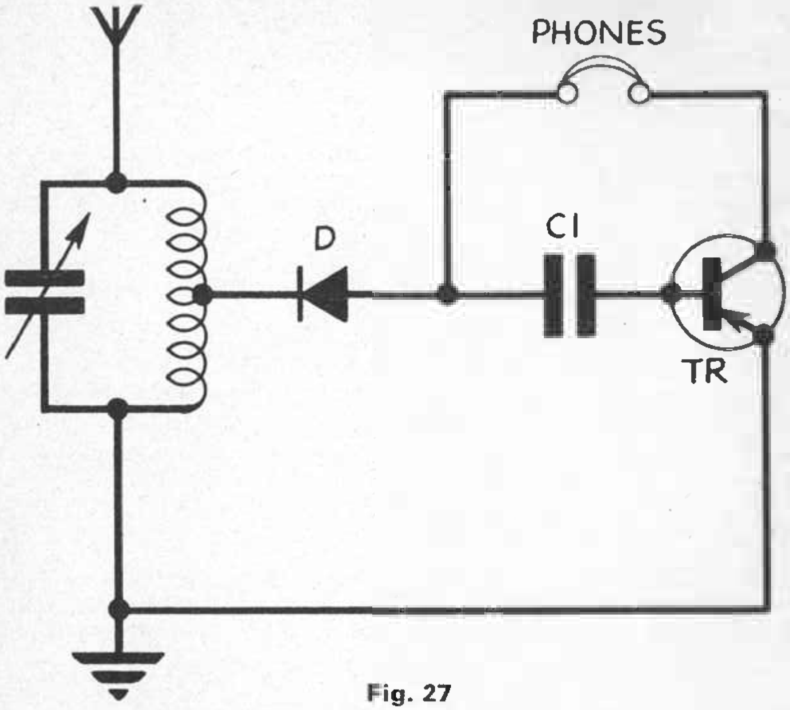

Fig. 27

the diode to the base of the transistor (*fig. 27*).

Use a Mullard OA70 or OA71 diode, and a Mullard OC70 or OC71 transistor.

PROJECT

Once you have learnt how to build crystal sets and get them to work you can try:

Making a pocket-size receiver

See how small you can make the receiver, using sub-miniature resistors and capacitors. The largest item will be the coil for the tuned circuit. Instead of using the coil described in Part 5, you can make a much smaller coil by using a 2 in. length of Ferrite rod and winding a 40 turn coil on this in 38 gauge enamelled wire. Take a tapping point out from the middle of this coil, that is at 20 turns.

Put the set in a cabinet

You can make up a cabinet in sheet balsa to hold the complete receiver, with a plug on the outside into which you can plug an earpiece for listening. If radio reception is good in your area, the set may work well by simply using the Ferrite rod aerial. If not, you will have to add two more plugs to connect in an aerial wire and earth connection.

Other simple circuits

You have discovered how a crystal set is built up from a tuned circuit connected to a diode detector, followed by an amplifier stage. See if you can design your own set on these lines.

PART TWELVE

Sensitivity and selectivity

One of the advantages of simple crystal sets is that they are very easy to make and get working. It is also easy to experiment with different values of components, to see if you can improve the performance. But you are limited by one thing. Although a crystal set gives very good reproduction, it is not very sensitive or selective.

Sensitivity is the ability to pick up several radio broadcast signals of different frequency. You will have found that the crystal sets you have made will pick up only a few stations. Signals from more distant stations will be too weak for the set to convert them into 'listening volume'.

Much depends on where you live. If you are fairly close to two or three powerful radio stations you will be able to receive them at good listening level, and perhaps get some other stations at a barely audible level.

If you can get good listening level on at least one station, you should be able to use the set without an external aerial. The set will now be very 'directional'—that is, the volume will increase and decrease as you turn the set round. This is because of the changing position of the ferrite rod aerial, relative to the direction of the broadcast station.

PROJECT

Improving the aerial

You can now increase the overall volume by buying an aerial coil, instead of using a home-made one. A bought coil will be much more efficient, used in the same circuit, and should double the volume. You will then have a set which can be made into a true pocket-size radio, with no external connections to be made other than plugging in the deaf-aid earpiece.

When you buy a ready-made aerial coil, make sure that it matches the capacity of your variable capacitor (tuning capacitor). If not, the set will not tune over the proper range. If you cannot get an aerial coil to match the value of the variable capacitor you are already using, then get a new tuning capacitor to match the new aerial coil.

Selectivity of the receiver

'Selectivity' means the ability of a radio receiver to separate the signals from two or more radio stations operating on nearby frequencies. If a set is not selective enough, you will hear stations on either side of the one you have tuned to.

Selectivity is very important on ordinary radio receivers, but not so important in the case of crystal sets. Can you see why? The crystal set is not very sensitive, so it does not readily pick up neighbouring frequency signals, and concentrates on the 'strong' signal at various points along the radio frequency band.

So, the lack of sensitivity in a crystal set is not wholly bad. It means that you will seldom have trouble with overlapping signals. That is one reason why the receiving quality of a crystal set is usually very good.

Increasing sensitivity

To make a crystal set more sensitive, use a more efficient aerial coil (a bought one rather than a home-made one), and use it with a good external aerial. That means you will have to use an extended aerial, taken up as high as possible, and in as straight a line as possible.

PROJECT

Test your aerial

If you have the space available, run a really long aerial wire from the house down to the end of the garden, and fasten it as high as possible at the garden end. This may make a considerable difference to the sensitivity of your set, and increase the number of stations you can pick up. But you cannot hope to pick up as many stations as on an ordinary domestic radio.

You may further improve the sensitivity of your set by using a 220 pF capacitor between the aerial wire and the aerial connection to your set. If this seems to work, try other values of capacitor to see if you can get even better results.

You might, in certain areas, improve the sensitivity so much that the set is no longer selective enough. You *are* hearing two stations together. The only thing to do then is make the set *less* sensitive again.

Make a cabinet

You may be lucky enough to live in an area where radio reception is normally good and, by trying out various designs and different adjustments, you may get a crystal set to work well without external aerial and earth connections. You then have a fully portable radio, which is worth putting into a small cabinet so that you can carry it about in your pocket.

Remember that once you have arranged the set as well as you can, there is only one adjustment you can make—turning the variable capacitor to tune in to different stations. This is going to be a little difficult if you put the set into a closed cabinet, unless you make provision to tune from the outside.

In the case of a postage stamp 'trimmer' capacitor, which is the usual type used with crystal sets (it is small, compact and cheap), tuning is done by turning the screw in the centre. This screw is almost always 6BA size, so the first thing to do is to unscrew the screw completely and replace it by a longer one with the same thread (6BA).

PROJECT

Make an external tuning knob

Cut a disc from stiff plastic sheet (thin ply or thin sheet wood will do) and stick it on top of the screw head (*fig. 28*). Use Araldite which will stick anything to metal. You now have a tuning 'dial' which can come outside the cabinet.

PROJECT

Making a cabinet

The best material to use for making a cabinet is sheet balsa.

Cut out the parts to build up a shallow box which will house the set completely. Simply measure how long and wide the set is, and from that work out the size of the box. Then measure the height of the set to get the height of the box (*fig. 29*). Assemble the sides and bottom of the box with glued joints, using balsa cement.

Only one component needs fitting to the box. That is a small plug to take a matching socket for the deaf-aid earpiece leads.

This can easily be mounted in one side of the box and connected to the appropriate parts of the radio circuit with thin insulated wires (*fig. 30*).

Put a few pieces of plastic foam in the bottom of the box, holding them in position with balsa cement. Then lay the set on top. Cut more pieces of plastic foam to support the set when the lid is in place, and prevent it from rattling (*fig. 31*).

The top can now be cemented in place, having first made a matching hole to go over the centre of the tuning capacitor. The screw, with its tuning dial, is removed from the capacitor while the lid is being cemented on.

Now replace the screw in the tuning capacitor so that the tuning dial domes just above the face of the top of the box. If the screw is too long, cut it off to the right length with a hacksaw and clean up the edges of the thread so that it will screw in place easily again.

If you are using a brass screw, run a *steel* nut on to the screw before you cut it to length. Then unscrew the steel nut and work it off and on the end of the screw several times. This will reform

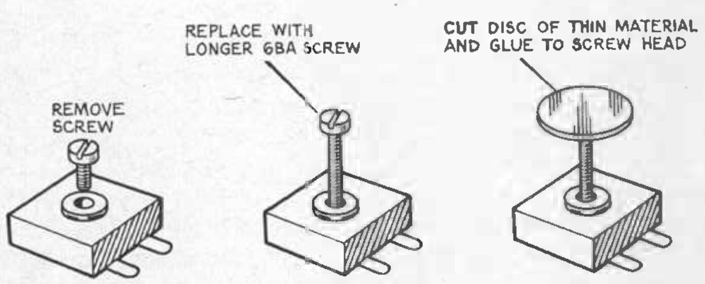

Fig. 28

the edge of the screw thread, which may have been damaged in cutting.

All that now remains to be done is to make a mark on the tuning dial to use as a 'pointer'. Then simply mark the position of the pointer on the top of the cabinet where it tunes in to various stations. You can write on the station names as in *fig. 32*.

PROJECT

Improving your set

1 Think of the various ways in which you can improve your cabinet. You can cover it with plastic material, or even wood veneer. Perhaps your father has some scraps of veneer left over from a do-it-yourself job. You can easily make a most professional looking cabinet this way.

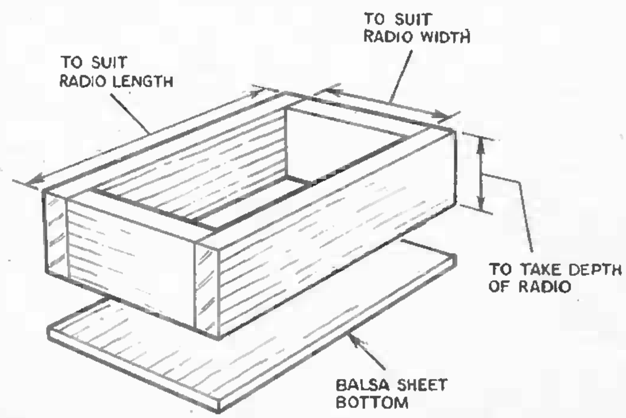

Fig. 29

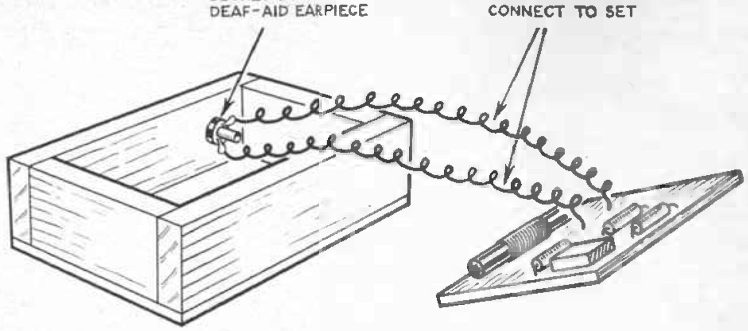

Fig. 30

2 If you have to use an external aerial and earth, add two further sockets to plug in the aerial and earth wires. Your set will look much neater in a proper cabinet, even if you do have to operate it under conditions where you can plug in the external aerial and earth wires.

3 See how *small* a crystal set you can make. Choose the smallest components you can find of the right values (sub-miniature components), and assemble them into the most compact circuit you can. Design a 'minimum size' cabinet around this, which can be made from balsa sheet again.

4 Build a set into a small, circular shaped cabinet, keeping the depth of the cabinet as small as possible. Fasten the back of the cabinet to a strap and you have a 'wrist watch' radio. You will have to cut the length of ferrite rod down to a minimum in this case, but this will not necessarily spoil the reception. Alternatively, you can mount the aerial separately—say in your top pocket—and connect it to the wristwatch radio with a single wire running down your sleeve.

5 Try building cabinet shapes that are different—like a cube or a cylinder, for example.

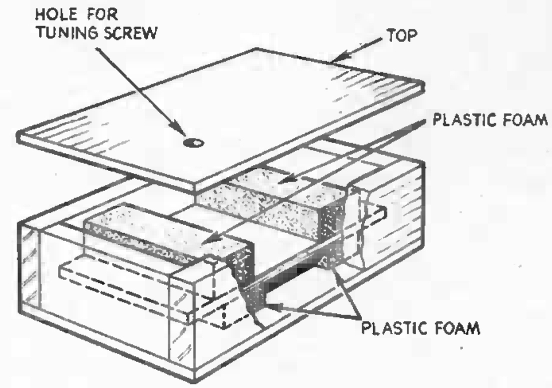

Fig. 31

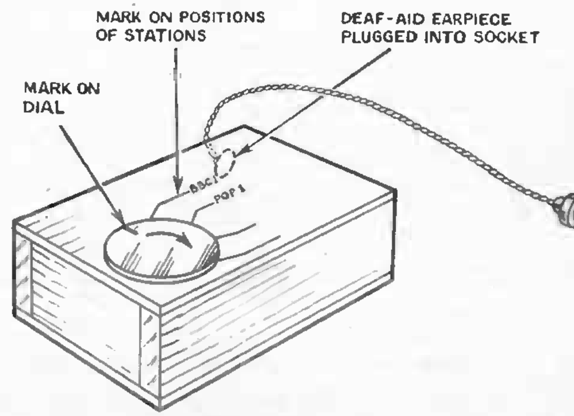

Fig. 32

FOR FURTHER READING

Amateur Radio Circuits Book, by G. R. Jessop. *Radio Society of Great Britain* (28 Little Russell St., London, W.C.1), 10*s.* 6*d.*

Amateur Radio Construction Projects, by C. Caringella. *Foulsham,* 20*s.*

Beginner's Guide to Radio. *Newnes* 8*s.* 6*d.* (100 diagrams and illustrations).

Boys' Book of Crystal Sets and Simple Circuits, by W. James May. *Bernards,* 2*s.* 6*d.*

Crystal Set Construction, by B. B. Babani. *Bernards,* 1*s.*

Fun With Radio, by G. Davey and Jack Cox. *Kaye and Ward,* 16*s.* **(Learning With Fun).**

Instructions to Radio Constructors, by R. H. Warring. *Museum Press,* 15*s.*

Radio, by D. Gibson. *Brockhampton Press,* 12*s.* 6*d.* (Illustrated **Teach Yourself** series).

Radio, by Geoffrey Middleton. *Bodley Head,* 9*s.* 6*d.* **(Study Books).**

Radio Controlled Transistor Circuits for Models, by H. Boys. *Barnards,* 7s. 6*d.*

Simple Radio Circuits, by A. T. Collins. *Newnes,* 3*s.* 6*d.*, and **More Simple Radio Circuits,** by A. T. Collins. *Newnes,* 3*s.* 6*d.* **(Key Books).**

Wireless for Beginners, by C. L. Boltz. *Harrap,* 18*s.*

(The prices shown were correct at the time of going to press, but are subject to alteration and are intended only as a guide.)

To buy any of the above books, first try your local bookseller. If he does not have it in stock, he will be pleased to order it for you. In case of difficulty, write to the publisher of the book in question.

POSSIBLE CAREERS

BROADCASTING (sound and television). There are opportunities with the B.B.C. for graduates in engineering, and for technical operators, who should have good 'O' levels, including English Language, mathematics and physics, as well as technical assistants, who need 'A'-level or equivalent mathematics or physics. There is avery little direct entry from school. The Independent Television Authority employs staff ranging from engineers-in-charge to technical assistants, who must be not less than 20 and have had practical telecommunications or electronics experience, with a Higher National Certificate or Technological Certificate.

Write to: The Engineering Recruitment Officer, B.B.C., Broadcasting House, London W.1; The Personnel Officer, Independent Television Authority, 70 Brompton Road, London S.W.3.

RADIO ENGINEERING. Entry to a career in radio and electronics engineering is at different levels. You can begin as a university graduate or professional engineer employed in research, development or production. Then there is the technician level, covering servicing, maintaining and repairing equipment, for which you need 'O' levels in English, mathematics and at least one science subject. Finally there are skilled craftsmen who train on a five-year apprenticeship and become toolmakers, electricians or radio mechanics.

Read: Careers in Radio and Electronics Engineering (from the Institution of Electronic and Radio Engineers, 9 Bedford Square, London W.C.1); **Electrical and Electronic Engineering—a professional career** (1*s.* 6*d.* from the Institution of Electrical Engineers, Savoy Place, London W.C.2); **Radio and Television Servicing,** Choice of Careers Booklet New Series No. 66 (from booksellers or Her Majesty's Stationery Office).

Write to: Education Officer, Institution of Electronic and Radio Engineers, 9 Bedford Square, London W.C.1, for a complete list of colleges offering suitable courses in radio and electronics.

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