PHILIPS Compact Electronic Engineer

Instruction book | EE1050

POSSIBILITIES WITH EE 1050-1051-1052

CIRCUIT	DESCRIPTION	KITS
1	FLASHING LIGHT AND BURGLAR ALARM	1050
2	TRAFFIC BEACON WITH ADJUSTABLE FREQUENCY	1050
3	FLASHING LIGHT WITH ADJUSTABLE FREQUENCY	1050
4	GRAMOPHONE AMPLIFIER	1050
5	GRAMOPHONE AMPLIFIER WITH SINGLE ENDED PUSH-PULL	1050, 1051
6	GRAMOPHONE AMPLIFIER WITH FREQUENCY CORRECTION	1050, 1051
7	AUTOMATIC NIGHT LIGHT	1050
8	WETNESS INDICATOR	1050
9	TELL-TALE LIGHT	1050,
10	TELL-TALE LIGHT WITH SOUND	1050, 1051
11	ACOUSTIC RELAY	1050
12	ACOUSTIC AND LIGHT DEPENDENT RELAY	1050, 1051, 1052
13	MORSE CODE TRAINER	1050
14	MORSE CODE TRAINER WITH LOUDSPEAKER	1050, 1051
15	LIGHT DEPENDENT TONE GENERATOR	1050
16	VARIABLE AUDIO FREQUENCY GENERATOR	1050, 1052
17	GENERATOR FOR TWO-TONE KLAXON	1050, 1051
18	GENERATOR FOR TELEPHONE SIGNALS	1050, 1051
19	TELEPHONE AMPLIFIER	1050, 1052
20	TELEPHONE AMPLIFIER WITH LOUDSPEAKER	1050, 1051, 1052
21	LIGHTMETER	1050
22	TIME SWITCH	1050
23	TWO TRANSISTOR MW-RADIO	1050, 1052
24	MW-RADIO WITH LOUDSPEAKER	1050, 1051, 1052

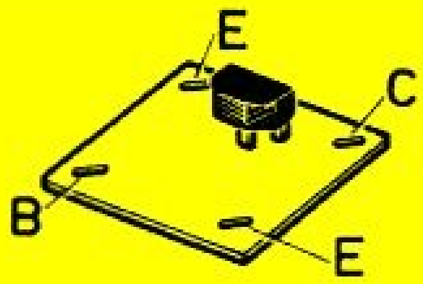
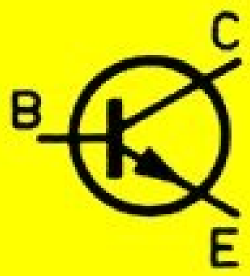
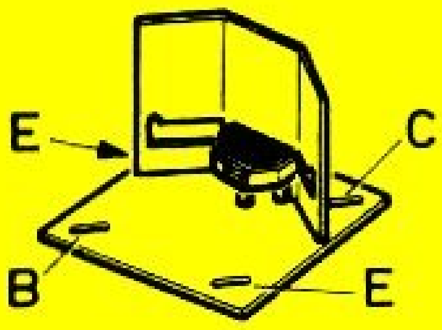
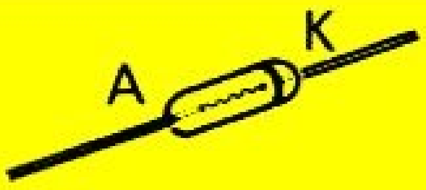
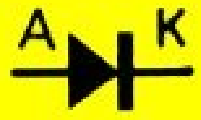
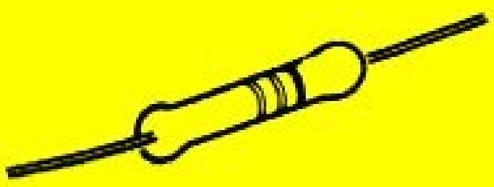
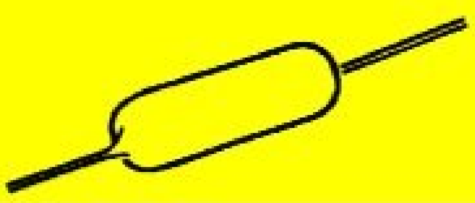
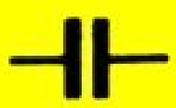
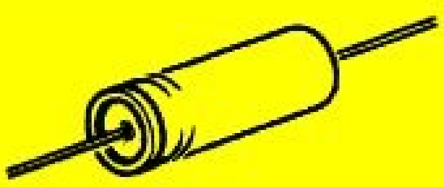
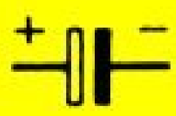
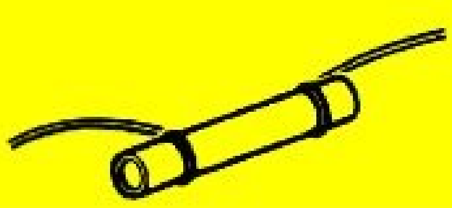
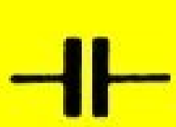
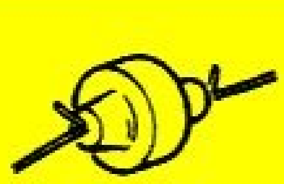
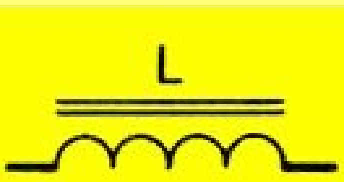
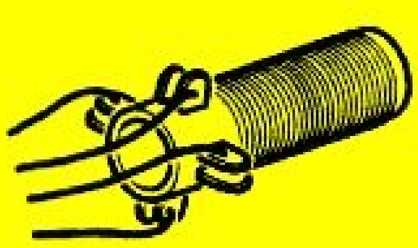
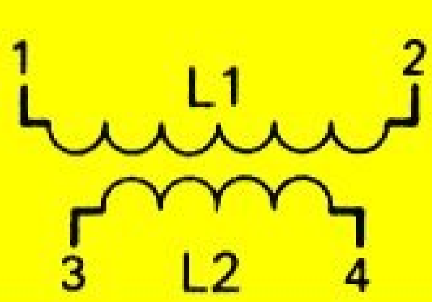
PHILIPS

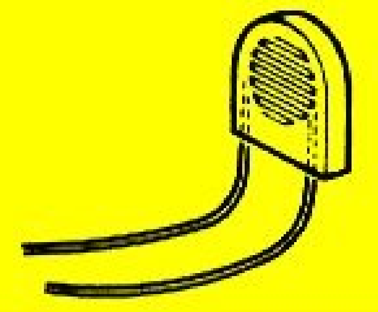
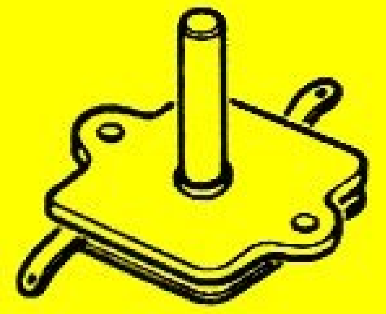
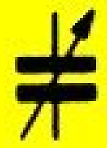
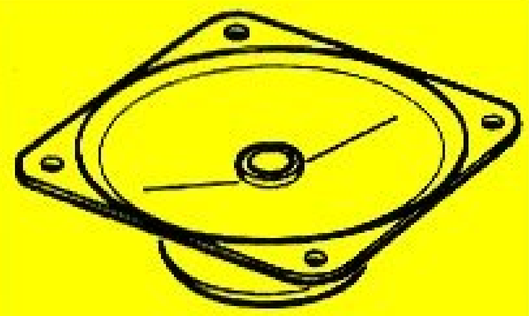
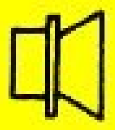
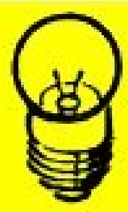
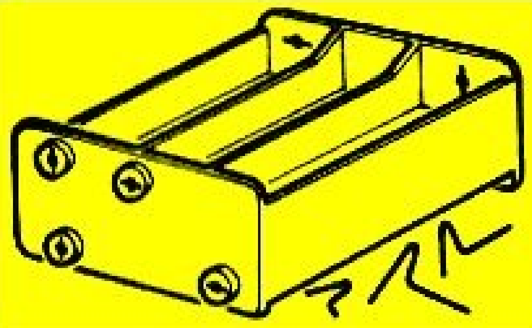
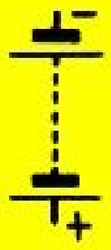
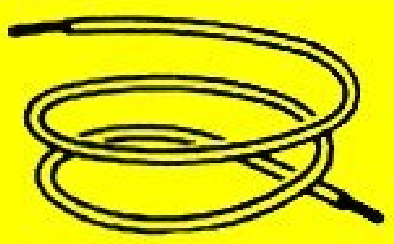
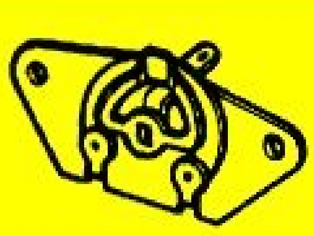
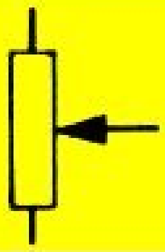
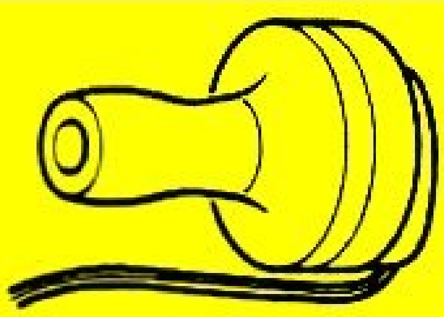
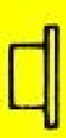
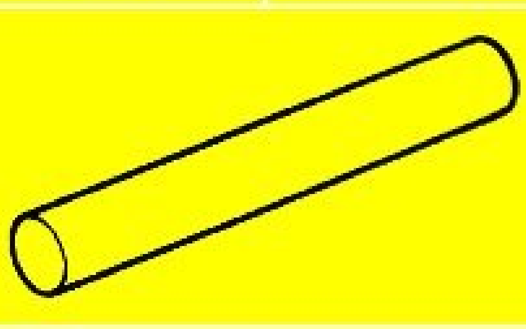
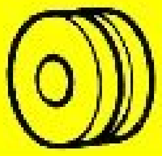
Compact Electronic Engineer

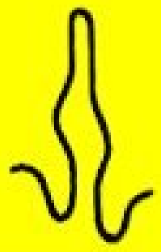
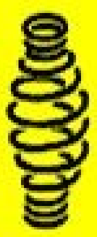
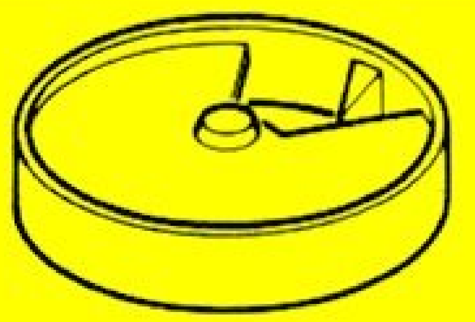
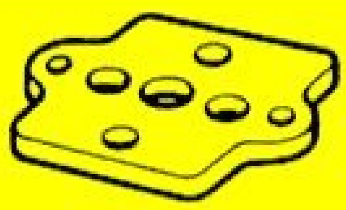
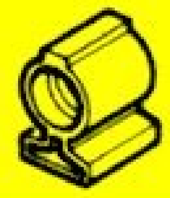
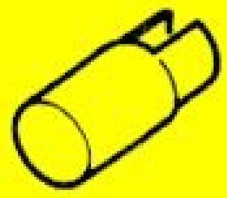
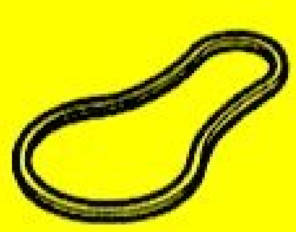
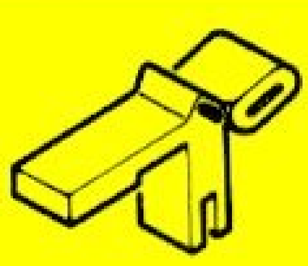
EE1050 EE1051 EE1052

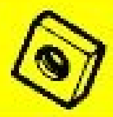
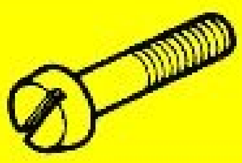
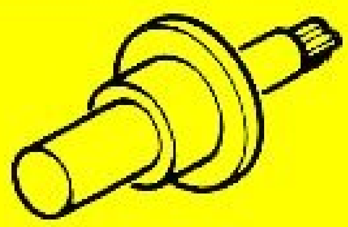
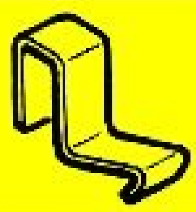
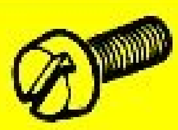
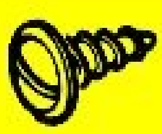
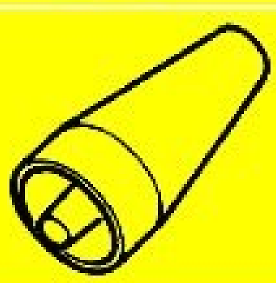
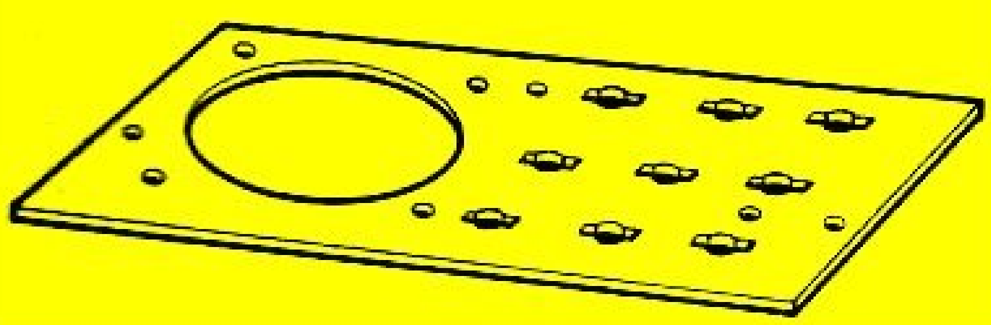
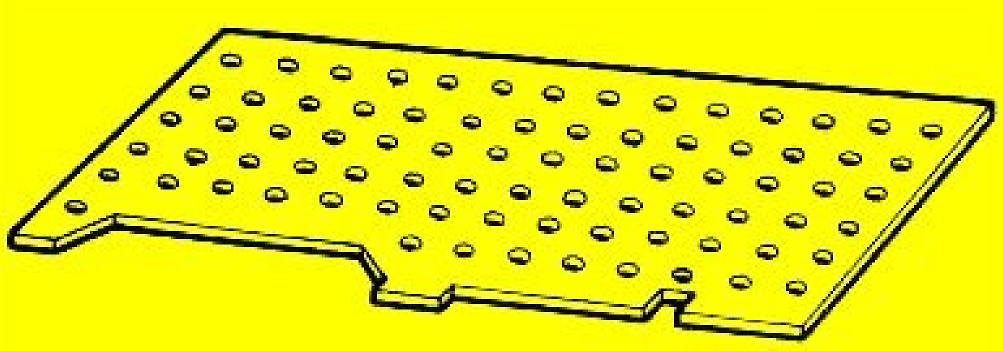
Instruction book

CONTENTS

COMPONENT AND SYMBOL		No	Quantity per kit → DESCRIPTION	1050	1051	1052
		1	**Transistor (T) BF194**	1	—	—
		2	**Transistor (T) BC148**	1	1	—
		3	**Diode (D) OA85**	—	—	1
		4	**Resistor (R)** EE 1050: 1 x 47 Ohm, 1 x 220 Ohm, 1 x 1,000 Ohm 1 x 2,200 Ohm, 1 x 3,300 Ohm, 1 x 4,700 Ohm, 1 x 10,000 Ohm, 1 x 47,000 Ohm, 1 x 220,000 Ohm, 1 x 470,000 Ohm. EE 1051: 1 x 10 Ohm, 1 x 100 Ohm, 1 x 470 Ohm, 1 x 1,500 Ohm, 1 x 4,700 Ohm, 1 x 10,000 Ohm, 1 x 15,000 Ohm, 2 x 22,000 Ohm, 1 x 47,000 Ohm, 1 x 100,000 Ohm. EE1052: 1 x 10,000 Ohm, 2 x 22,000 Ohm, 1 x 100,000 Ohm.	10	11	4
		5	**Polyester capacitor (C)** EE 1050: 2 x 0.1 uF, 1 x 47,000 pF. EE 1051: 1 x 22,000 pF. EE 1052: 1 x 0.22 uF, 1 x 22.000 pF.	3	1	2
		6	**Electrolytic capacitor (C)** EE 1050: 1 x 125 uF, 1 x 10 uF. EE 1051: 1 x 125 uF, 1 x 4 uF.	2	2	—
		7	**Ceramic capacitor (C)** EE 1052: 1 x 1000 pF.	—	—	1
		8	**Choke (L)**	—	—	1
		9	**Aerial coil (L)** **1 = red 3 = green** **2 = yellow 4 = grey**	—	—	1

		10	Light Dependent Resistor (LDR)	1	—	—
		12	Variable capacitor (C) 5-180pF	—	—	1
		13	Loudspeaker 150 Ohm	—	1	—
		14	Lamp 6 V, 50 mA	1	—	—
		15	Battery holder with springs for 6 penlite cells	1	—	—
		17	Insulated wire	5 m	5 m	5 m
		40	Potentiometer (R) 10,000 Ohms	1	—	—
		41	Earphone	1	—	—
		18	Ferroxcube rod	—	—	1
		19	Rubber grommet	—	—	2

	20	Hairpin spring	23	23	23
	21	Large coil spring	23	23	23
	22	Small coil spring	18	18	18
	23	Dial knob	—	—	1
	24	Plate for mounting variable capacitor	—	—	1
	25	Knob	1	—	—
	26	Lamp holder	1	—	—
	27	Window for lamp	1	—	—
	28	Rubber band	5	—	—
	29	Lever	2	—	—

	30	Contact spring for lever	2	—	—
	31	Bracket for lever	4	—	—
	32	Grub screw (3 mm)	1	—	1
	33	Square nut (3 mm)	3	—	3
	36	Screw (3 x 12 mm)	—	—	2
	42	Extension shaft for potentiometer	1	—	—
	43	Bronze spring	1	—	—
	44	Screw (3 x 8 mm)	2	—	—
	45	Screw for mounting chassis	2	—	—
	46	Bracket for mounting chassis	2	—	—
	47	Leg	2	—	—
	48	Frontpanel	1	—	—
	49	Mounting plate	1	—	—

SEQUENCE OF CONSTRUCTION

In this kit you will find a number of mounting cards, 1 to 24.
Some are for use in conjunction with the add-on kits EE 1051 and EE 1052. Each card shows which kit or kits has to be used. These mounting cards must be put on the mounting plate to show how the various components have to be connected to each other.
The components that are mounted on the front panel are indicated with a symbol on the mounting card.
In each kit you will also find a front card, that has to be put on the front panel. The front card which has to be used with each circuit is indicated below.
Frontcard from EE 1050 with circuits: 1, 2, 3, 4, 7, 8, 9, 11, 13, 15, 19, 21 and 22
Frontcard from EE 1051 with circuits: 5, 6, 10, 12, 14, 17, 18 and 20.
Frontcard from EE 1052 with circuits: 16, 23 and 24.
When you start experimenting first look up which mounting card and frontcard have to be used with the circuit concerned. Then put together the chassis, and the large components on the front-panel such as loudspeaker, potentiometer, lever, switch etc., where necessary. You can then start mounting the resistors, capacitors, transistors etc. The battery holder has to be mounted last.
Table 1 shows the position on the front-cards for the various large components.

Warning

Before you connect the batteries, or switch on the set always check for mistakes.

THE CHASSIS

Take the mounting plate (49) and the mounting card for the circuit which you want to build on it, with the symbols of the components to be mounted on the frontpanel toward the front panel (Fig. 1).
Now the hairpin springs (20) are pushed through the holes at the connecting points in an upward direction (Fig. 2). No springs must be put in the circled feed-through holes. Next put the mounting plate flat on the table and push the large coil springs (21) over the hairpin springs. Now fix two brackers (46) to the mounting plate with two screws (44) and two nuts (33). Finally screw the front card and front panel (48) to the mounting plate with two screws (45) (Fig. 3), and put the legs into the mounting plate.

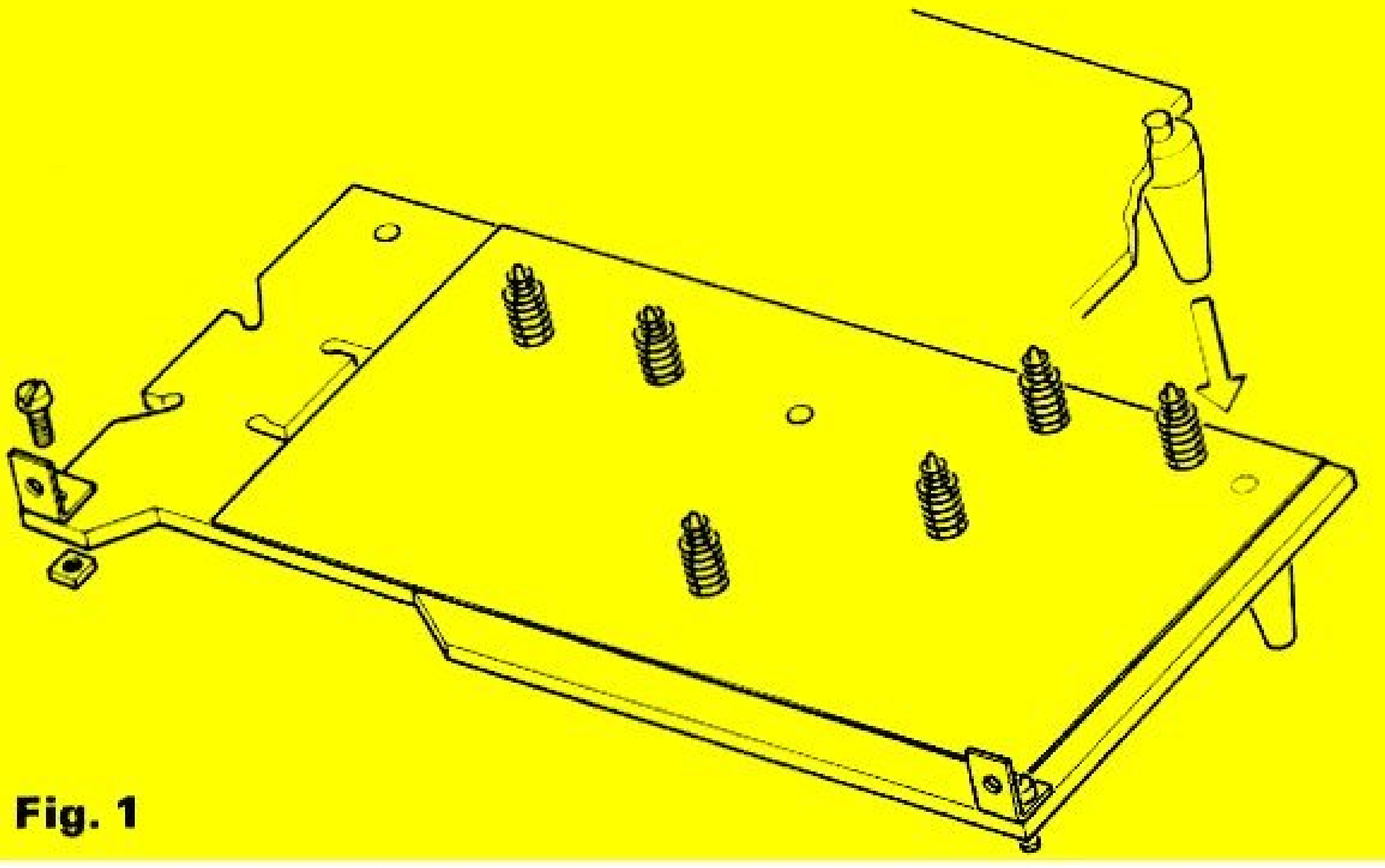


Fig. 1

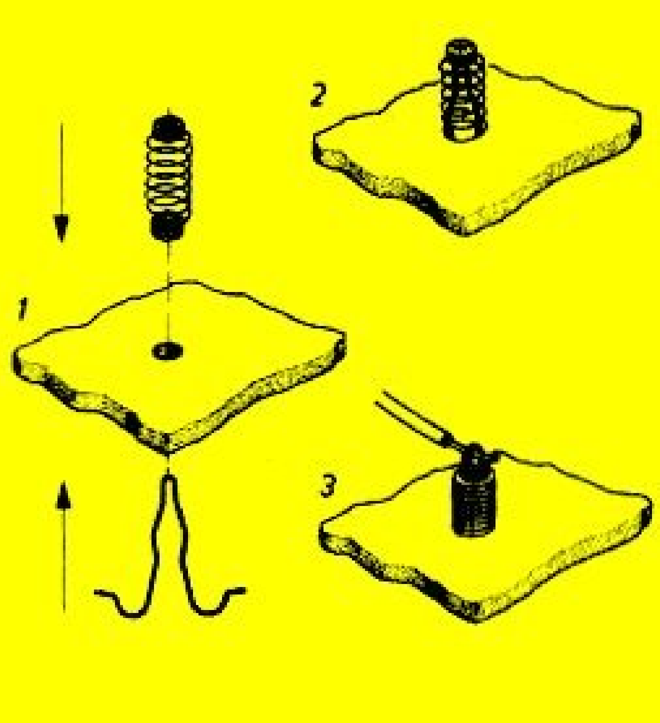


Fig. 2

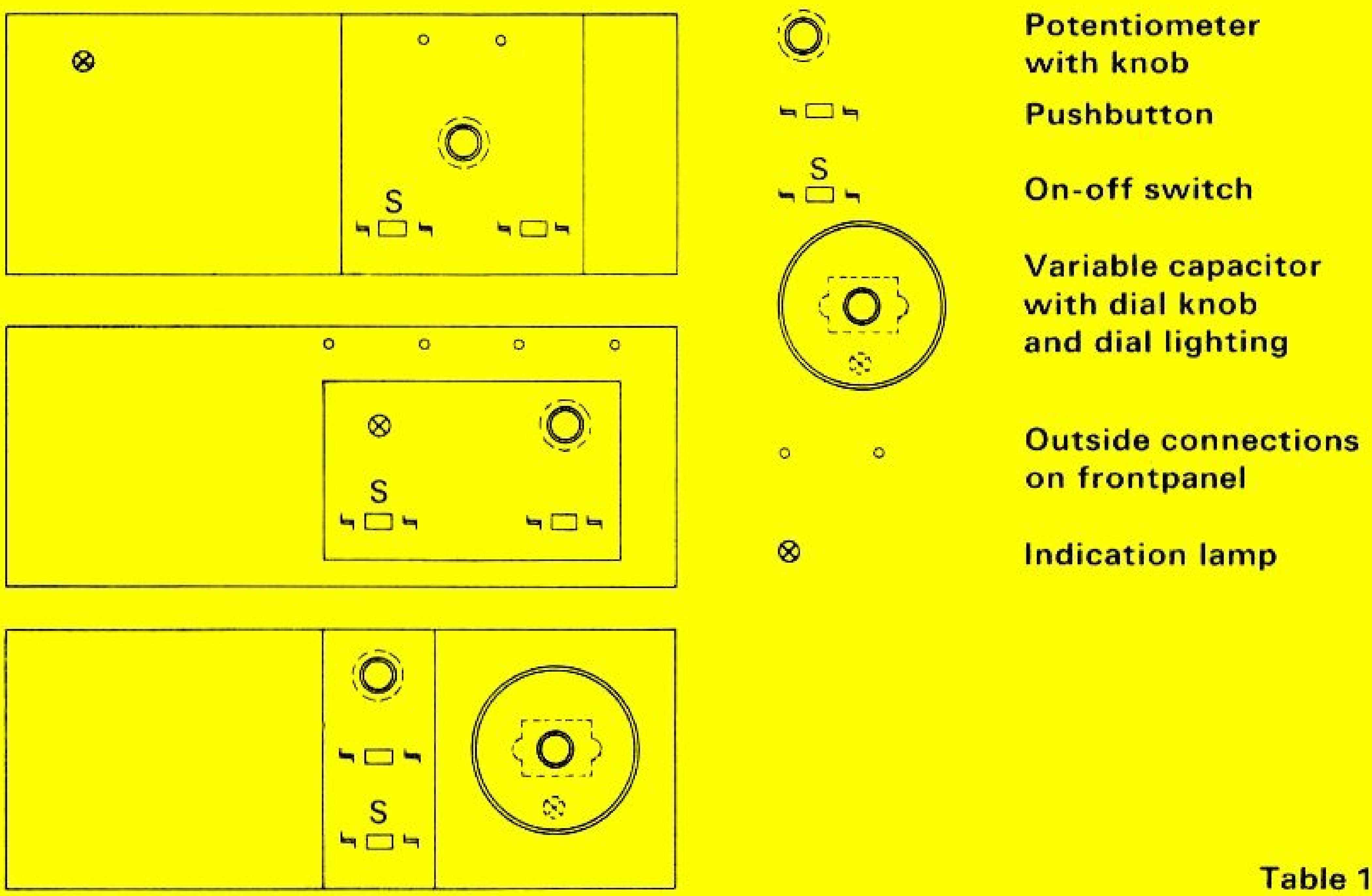

Potentiometer with knob
Pushbutton
On-off switch
Variable capacitor with dial knob and dial lighting
Outside connections on frontpanel
Indication lamp

Table 1

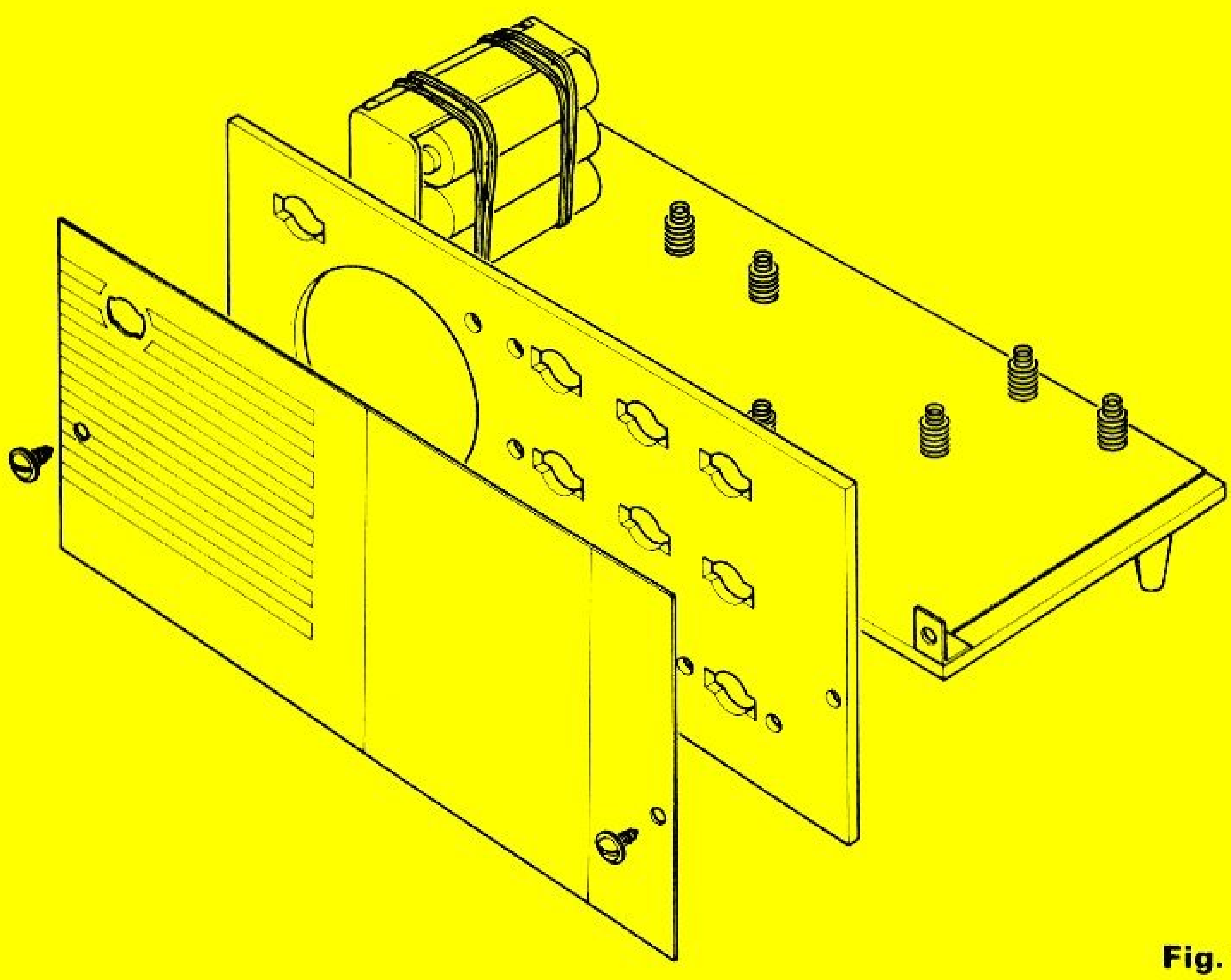


Fig. 3

FIXING THE VARIOUS PARTS

Loudspeaker fig. 4

Put four hairpin springs into the front panel from the outside. Put the mounting holes of the speaker over the springs. Push four large coil springs (21) over the hairpin springs.

Potentiometer fig. 5

Push two hairpin springs through the frontpanel from the outside and put large coil springs over them. Take the potentiometer (40) and put the extension shaft (42) on to it. Put the potentiometer with mounting holes over the two springs and fix it with two pieces of wire.

Variable capacitor fig. 6

Attach the capacitor (12) to the front panel with two screws (36) and two nuts (33). Do not forget to put the plate (24) in between them or the shaft will protude too far.

Pushbutton fig. 7

Push two hairpin-springs through the front-panel from the outside and push

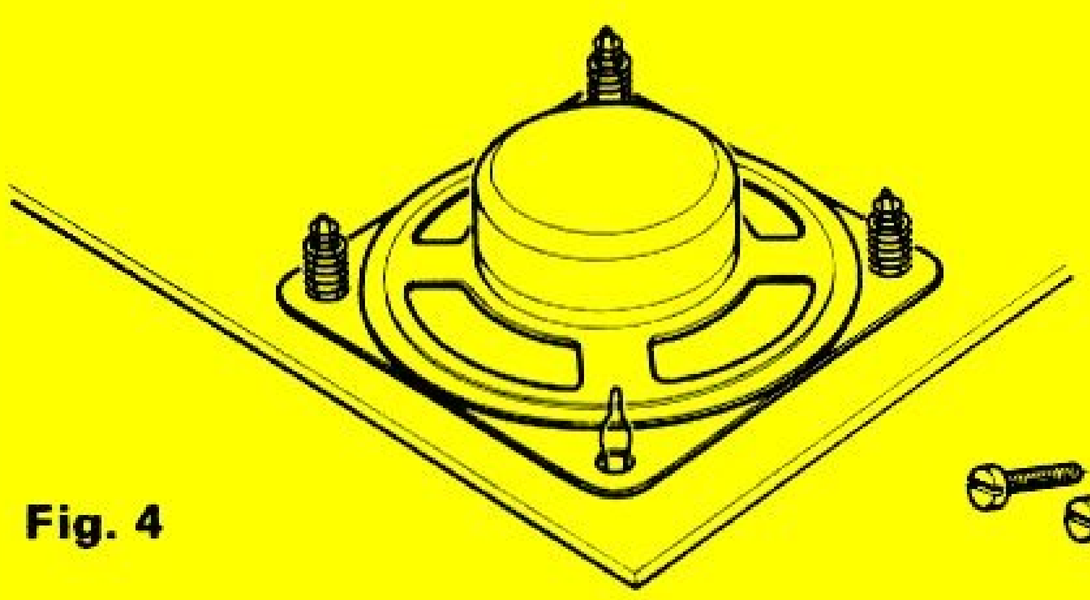


Fig. 4

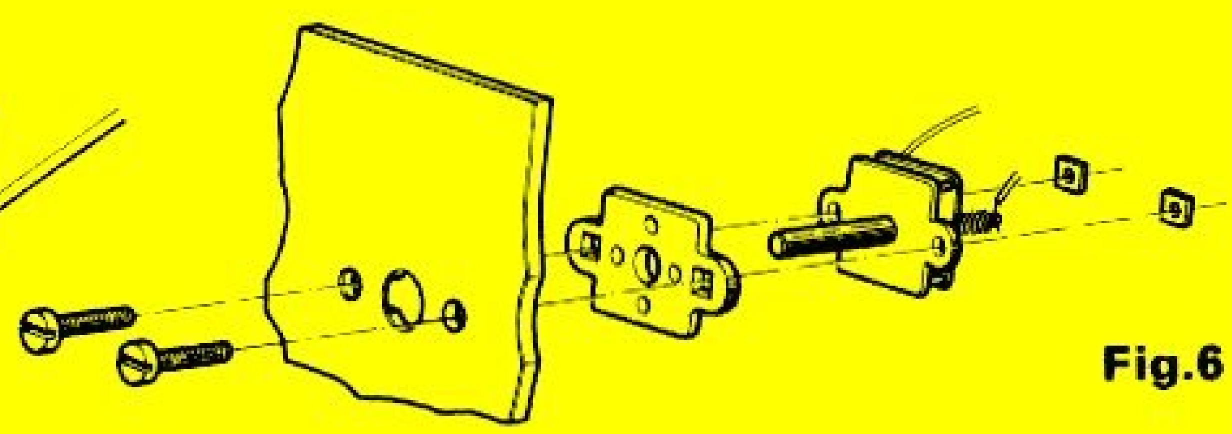


Fig.6

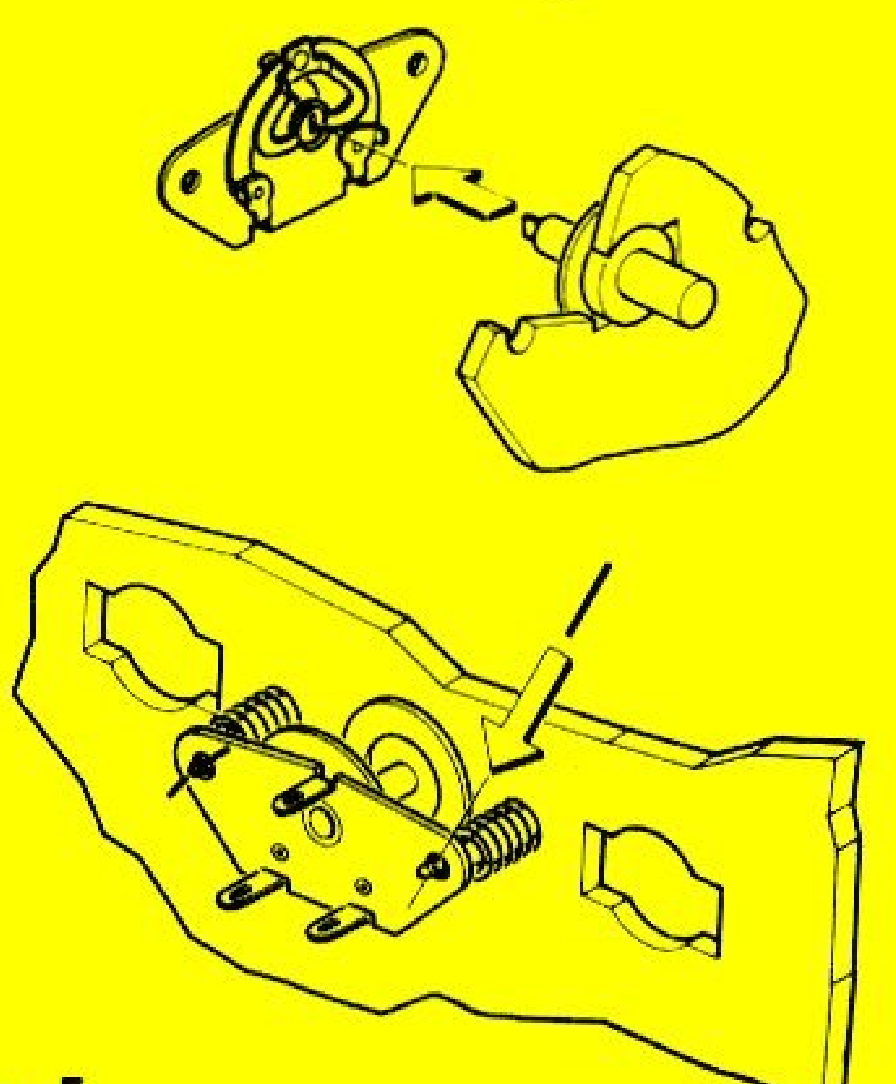


Fig. 5

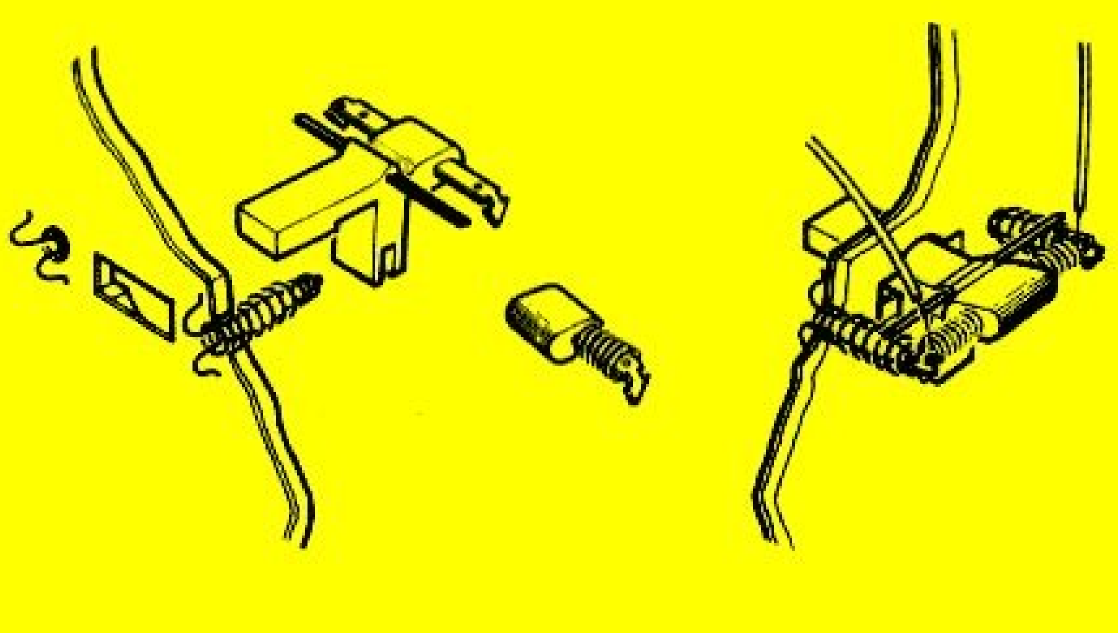


Fig. 7

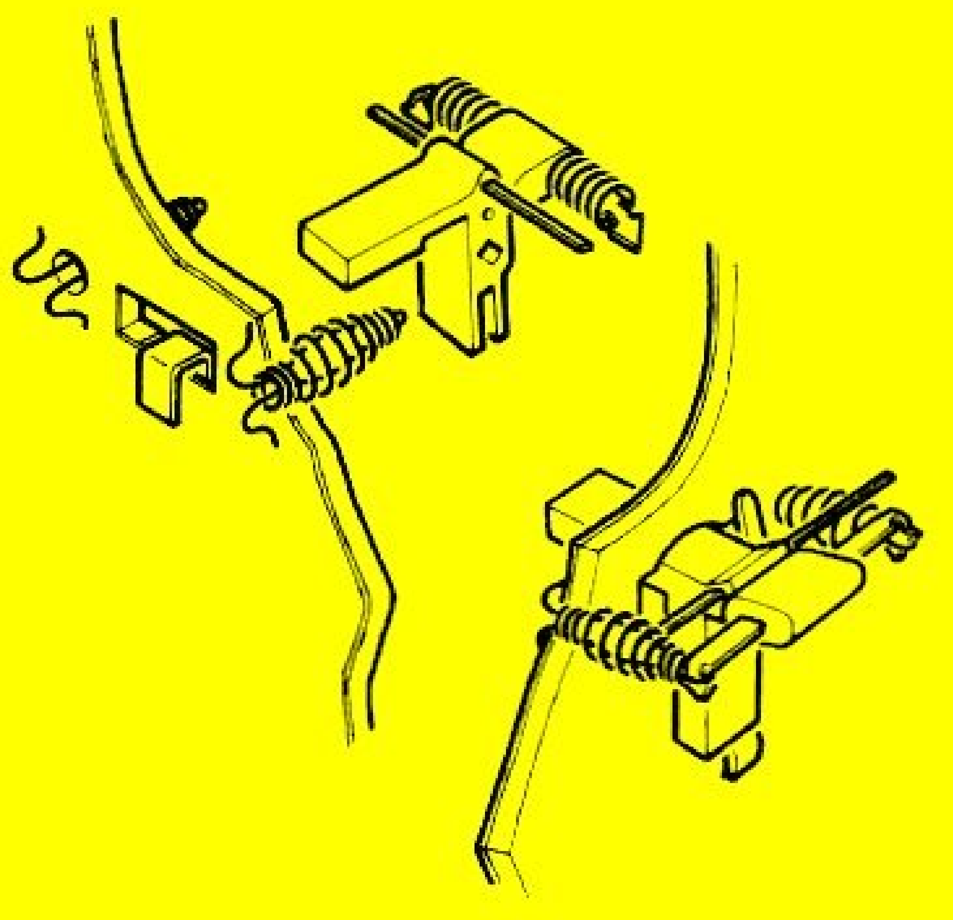


Fig. 8

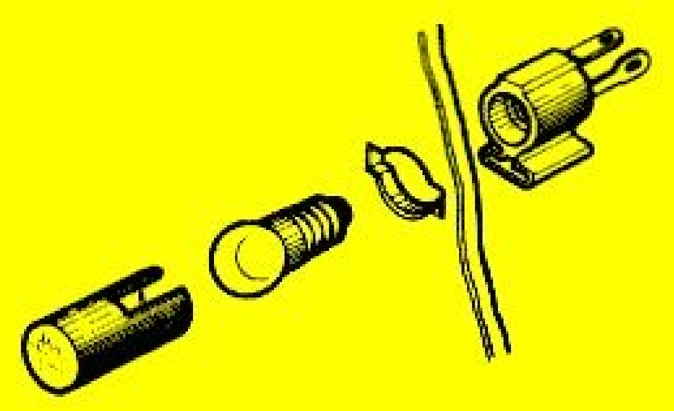


Fig. 9

Fig. 10

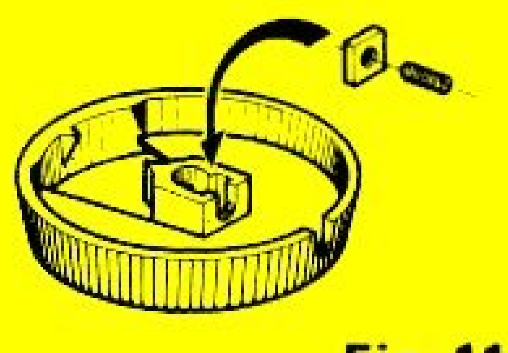


Fig. 11

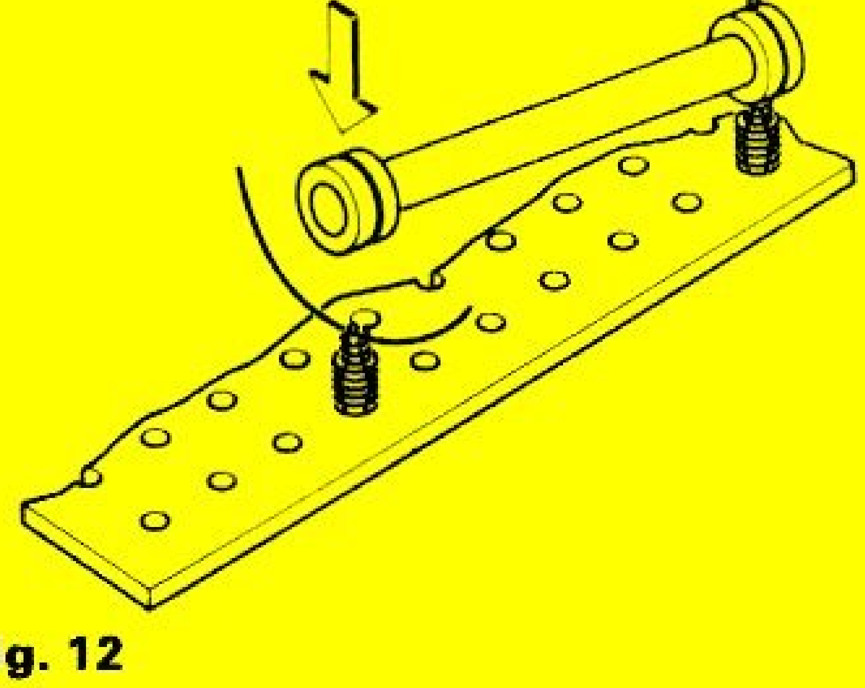


Fig. 12

large coil springs over them. Put the small brackets (31) into the lever from both sides. Push the small coil springs (22) over these brackets. Slide the contact spring (30) into the groove of the lever. Put the assembly with the points of the brackets into the hairpin-springs. The wires are connected by pushing the springs (22) against the lever and sticking the bared ends into the holes of the brackets.

Switch fig. 8

The mounting is practically the same as that of the pushbutton. However before it is connected to the contact springs, the bronze spring (43) has to be put into the hole through which the shaft comes.

Indication lamp fig. 9

Hold the lampholder (26) behind the hole and screw the bulb (14) into it through the hole.
Slide the red window (27) over the bulb with the tabs over the lampholder.

Knobs fig. 10 and 11

Put a grubscrew (32) into a square nut (33) for only a few turns. Put this assembly into the rectangular hole of the knob. Slide the knob on to the shaft and secure it with a small screwdriver. The dial knob has to be mounted so that the pointer indicates the P on the scale when turned to right.

Aerial rod fig. 12

Slide the aerial coil (9) over the ferroxcube rod (18). Put a rubber grommet (19) on both sides.
Take two pieces of wire (about 8 cm) and stick them through the hairpin-springs on which the rod must be mounted. Pull the wire through the slots of the grommets and twist the ends.
The copper core of the ends must not make contact.

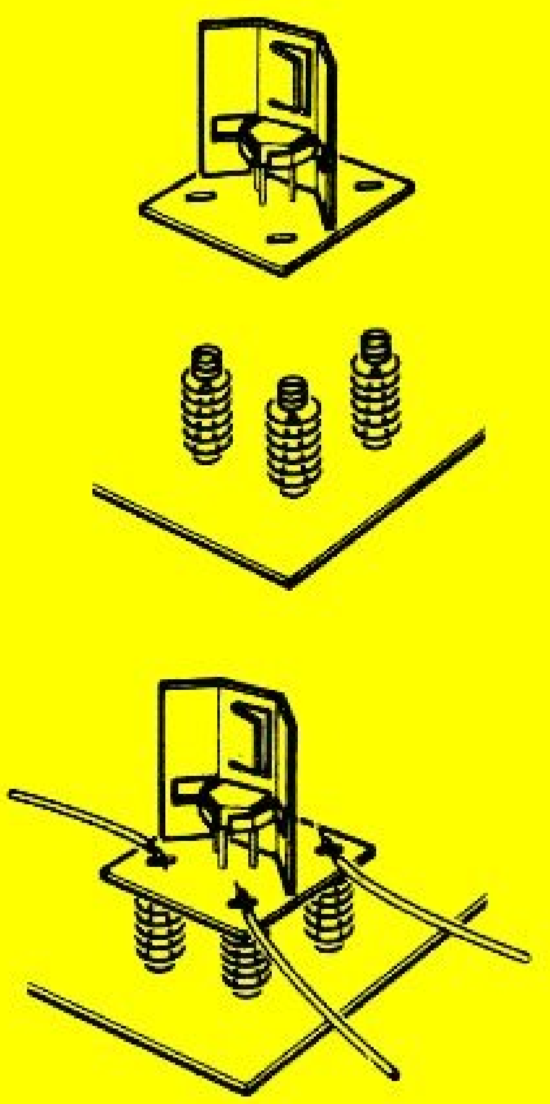


Fig. 13

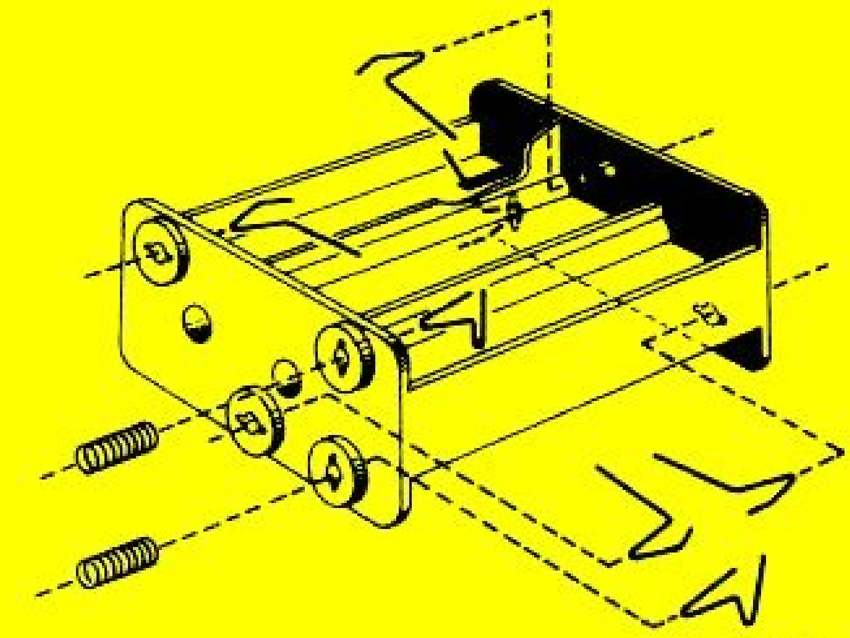


Fig. 14

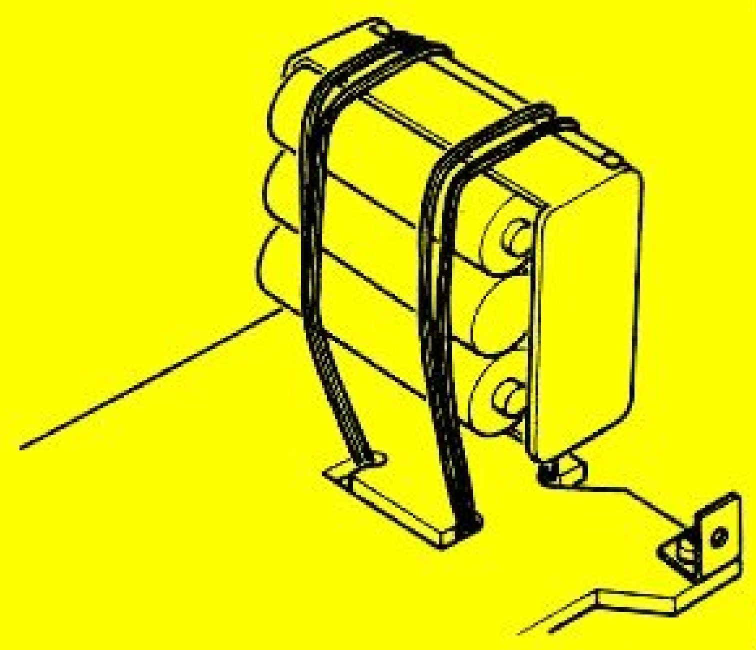


Fig. 15

Transistors fig. 13

Slide the slotted base plate over the three or four hairpin-springs. See that these springs are put in the right position. Push the plate down and push connecting wires through the springs.

Battery holder fig. 14 and 15

Put the springs into the battery holder in accordance with fig. 14 and put in the cells at the same time.
Put a rubber band around the battery holder, so that the cells cannot fall out. The correct position of the cells is indicated on the battery holder. Attach the assembly onto the mounting plate with the aid of two rubber bands. (fig. 15).

Attachment of wires to loudspeaker, potentiometer, lamp etc.

A small coil spring (22) is slid over the contact lugs of the part in question. Push back the springs, stick the bared end of the wire (about 7 mm) into the hole of the lug and release the spring.

Outside connections on the front-panel

A hairpin-spring is put into the hole from behind.
A bared wire end is also put through the hole and then a large coil spring is pushed over on the front side. Push the large coil spring firmly so that the wire is squeezed tightly between the spring and the panel and cannot be pulled out.

Circuit descriptions and data

More explanation and data about the working of the various circuits is given from page 11 to 20. In the chapter "How do electronics work" you will find technical details about the working of the various components.

HOW DO ELECTRONICS WORK

Engineers and technicians of our great laboratories have designed all the circuits of this electronic engineering kit. They have used all their skills to construct experiments, just as they do when they work on radio or radar, on electronic controls or television.
The field of applications of electronics is vast and for that reason the demand for designers and technicians is steadily growing. Perhaps the pleasure that you will derive from your Electronic Engineering Kits will encourage you to think of making technology your career.
At a later stage in your life, you will realise how many useful things you learn't when you were experimenting with your Kit. We wish you many hours of enjoyment.

ATOMS

Everything in nature is made up of atoms These atoms consist of a nucleus with a number of electrons round it. This can be compared with the solar system. In our solar system the sun is the nucleus and the planets revolve around it.
The tiniest piece of matter still detectable as such, consists of millions of atoms. In nature, substances differ one from another in regard to the composition of

ANDRE MARIE AMPERE (1775-1836)

ALESSANDRO VOLTA (1745-1827)

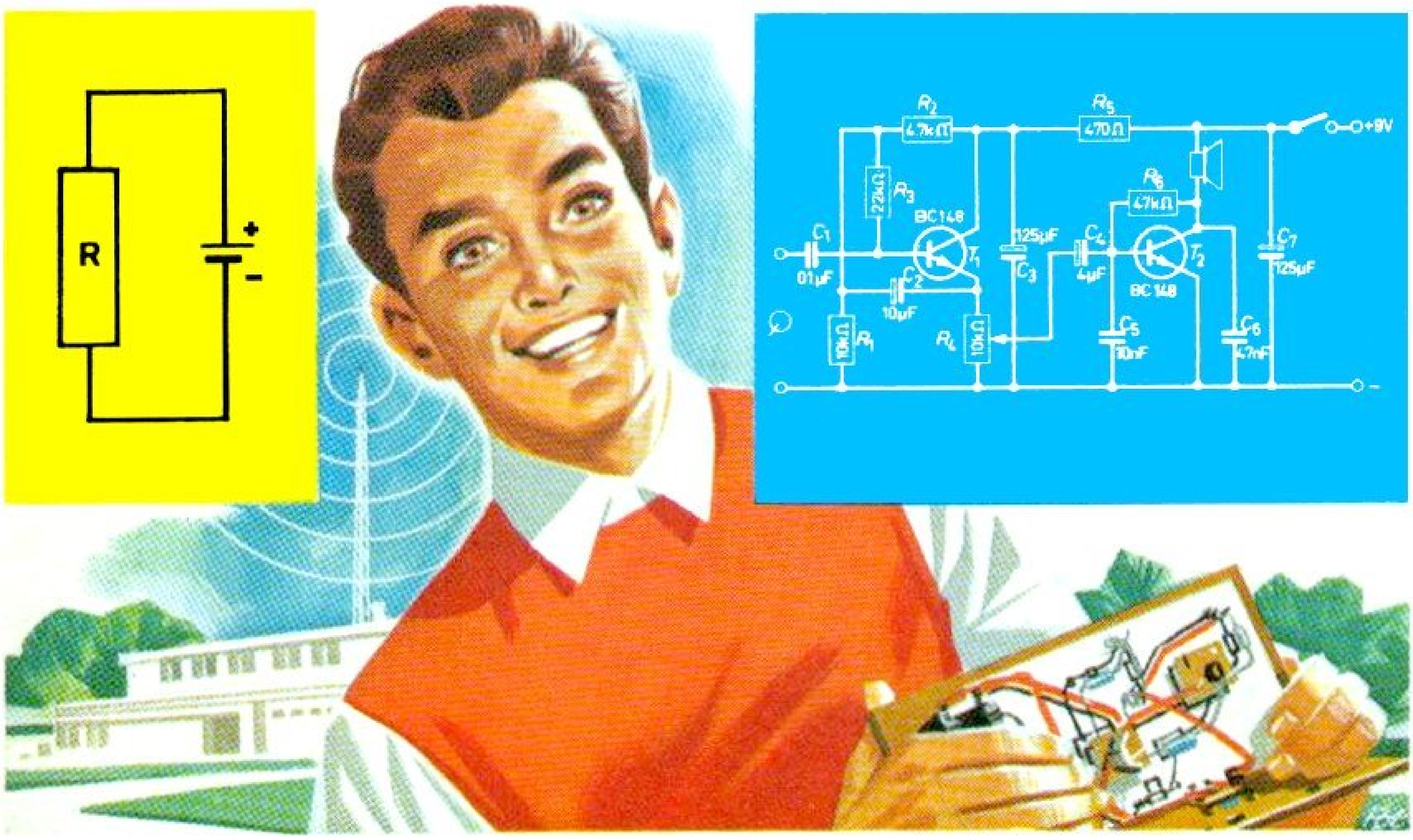
the nucleus and the number of electrons revolving around it.
Hydrogen is the substance with the simplest atom; only one electron revolves round the nucleus of the hydrogen atom. that of helium, has two electrons.
As for the copper atom, this has 29 revolving electrons, not all of which are at the same distance from the nucleus. The last of the 29 is far away from the nucleus, almost free from the others. The force that holds it in its solar system is not as strong as for the other electrons and so, it is able to slip from one copper atom to another. It is called a free electron. Since even a tiny bit of copper contains millions and millions of atoms, it also contains millions and millions of free electrons. Electrons carry a negative electric charge and a movement of electrons is called an electric current. Electrons can move easily through copper wire, and so copper is a good conductor

BIG AND LITTLE CURRENTS

When you turn on a tap, water begins to flow through a pipe. When you turn on the switch of an electric light, electrons stream through the wiring in enormous numbers, for when you switch on a large lamp, 6.3 million times a million times a million electrons flow through the lamp each second. It is very hard to work with

such a number and that is why a current of 6.3 million times a million times a million electrons per second is simply called a current of 1 ampere.
This can be written in an even shorter form as 1A. In electronics we are usually more sparing of electrons than in what we call the mains power supply. Here much smaller currents than 1 ampere (1A) are used, in fact 1000 or a million

In both cases a long supply system offers more resistance to the current than a short one and a narrow system offers more resistance than a broad one. In the case of water pipes, the sort of material of which they are made does not affect the flow. In electric wires it is more complicated, because if these are not made of a good conductor, like copper, then the current does not flow easily.



times smaller. In order to make it easier to talk about these little currents, the thousandth part of an ampere has been called a milli-ampere, shortened to mA and the millionth part of an ampere is called a micro-ampere shortened to µA.

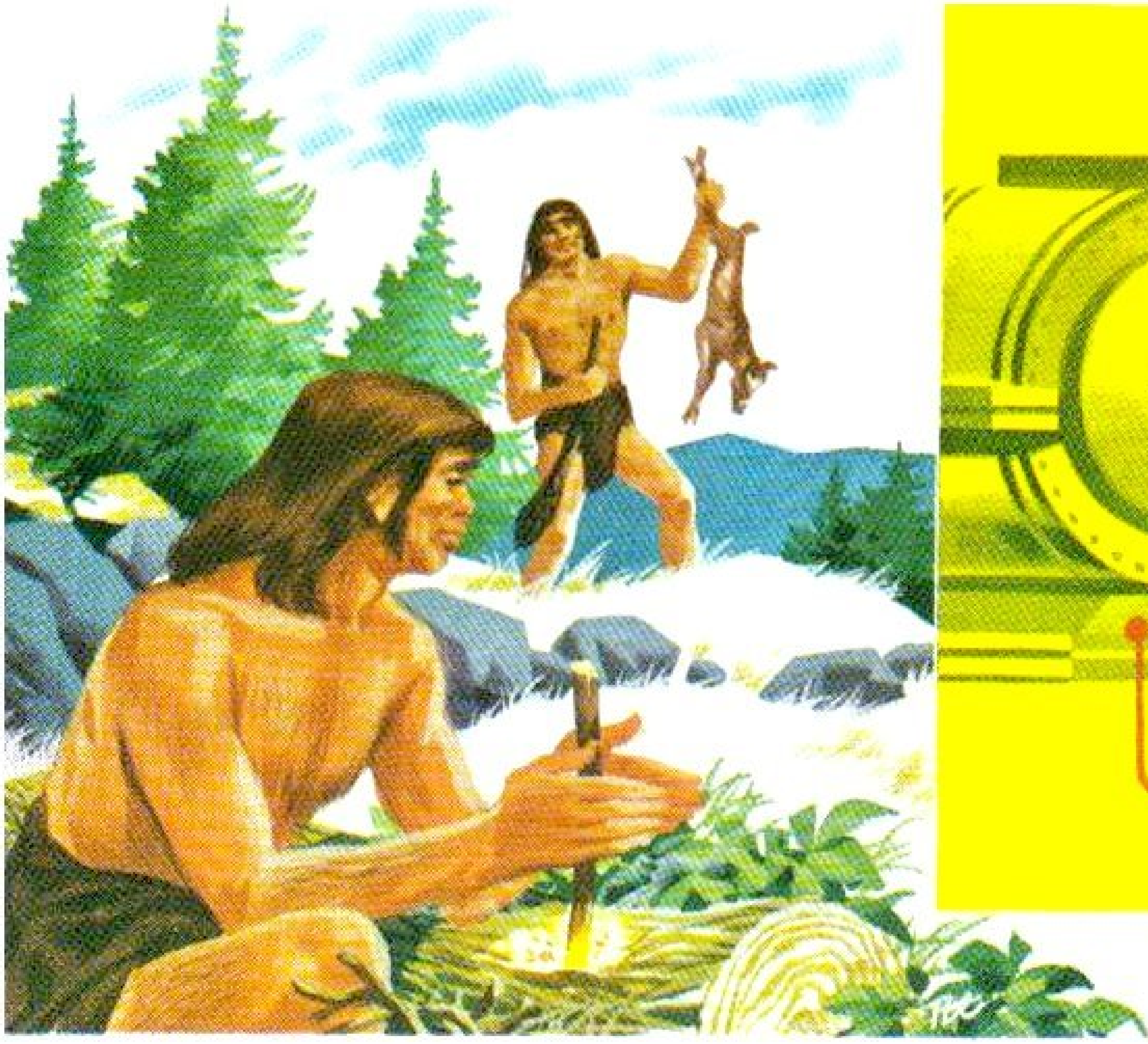
RESISTANCE

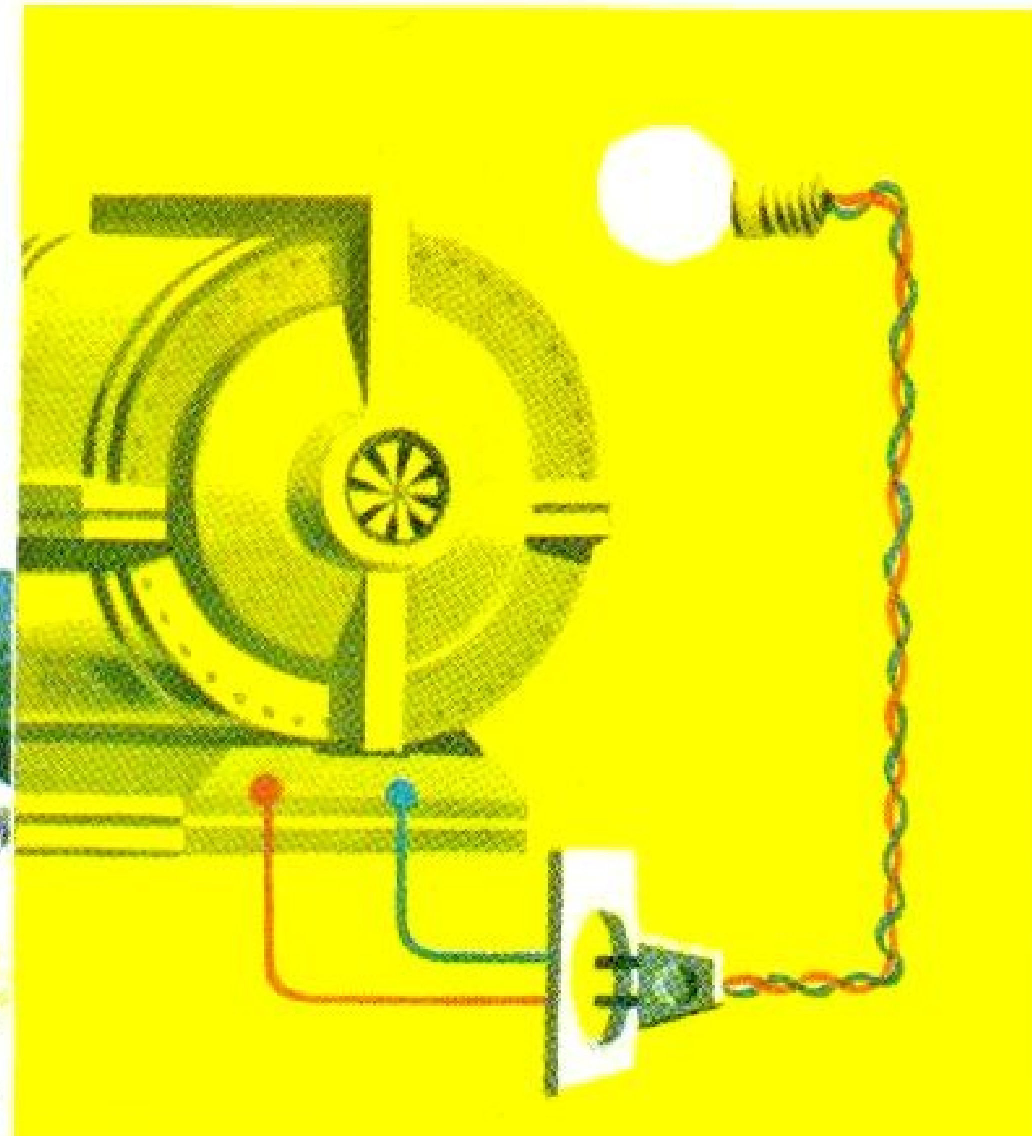
You know very well that water does not run through the pipes of the water system of its own accord. It has to be pumped through, because the water meets with resistance in its path through the pipes. Electric currents meet with resistance when they flow through the copper wires of a circuit, in just the same way.

For instance, iron has a greater electrical resistance than copper. The unit of electrical resistance is the ohm also written in symbol form as Ω.
A copper wire 200 yards in length and 1/12 inch in thicknes has a resistance of 1 ohm. A resistance of 1000 ohms is called 1 kilo ohm shortened to kΩ and one million ohm is called 1 megohm, shortened to MΩ. A resistance of 500,000 ohms can thus be called 500,000 ohms or 500 kΩ or 0.5 MΩ, whichever way is best for the purpose.

VOLTAGE

Water will not flow through pipes on its own. There always has to be a force to



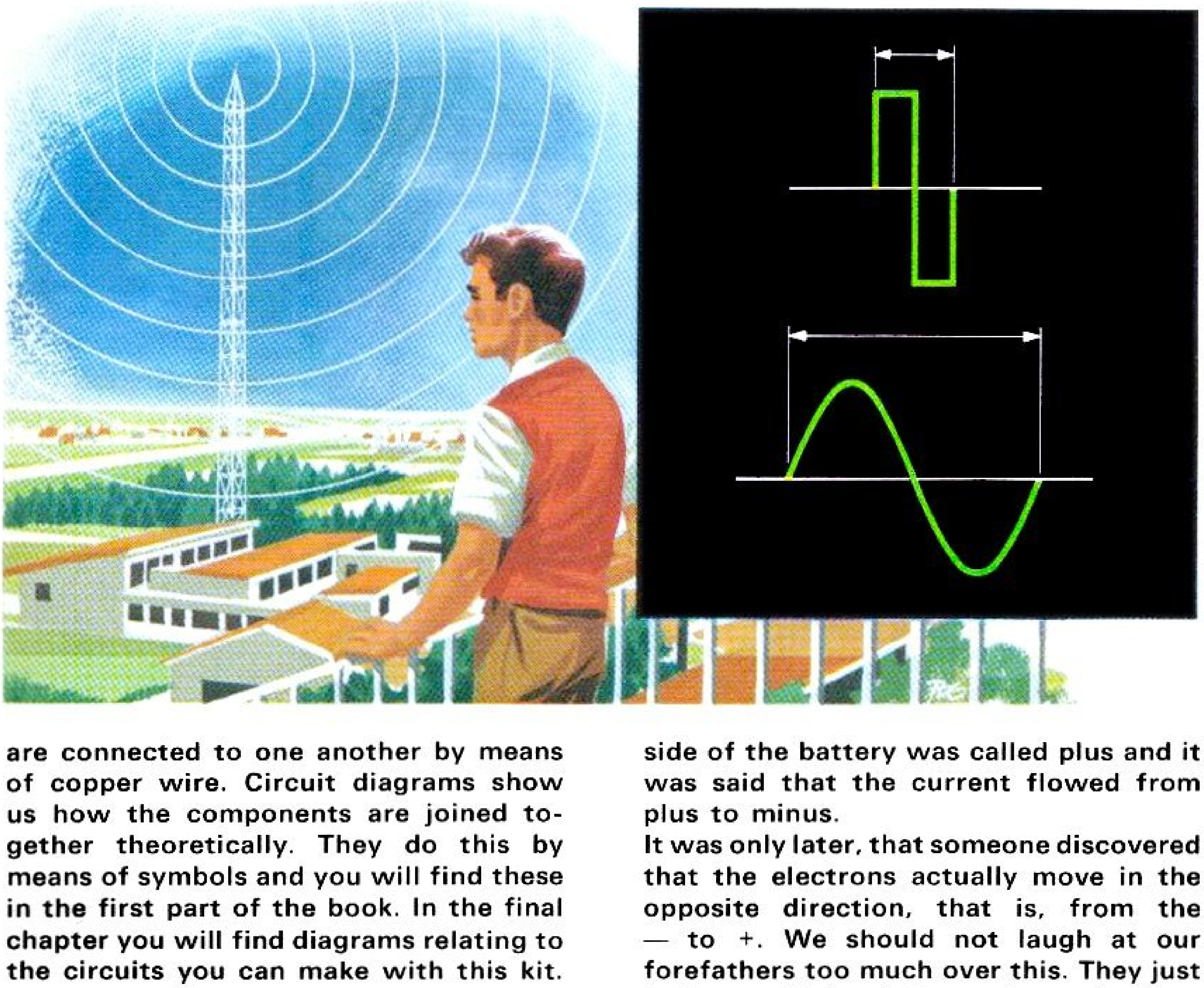


send it through the pipes. Similarly an electric current requires a force, a force which we call voltage. Voltage can be obtained from a battery and the unit of voltage is called a volt. If you have a wire with a resistance of 1 ohm and you connect it to a battery with a voltage of 1 volt, then a current of 1 ampere flows through the wire. In electronics we can have voltages far greater than one volt and also others which are much smaller. For instance, the picture tube of a television receiver works with 18,000 volts. In this case we can also speak of 18 kilo volts (kilo = 1000), shortened to 18 kV. But in a radio receiver we also come across voltages of 1/1000 volt and 1/1,000,000 volt. These are called millivolt, and microvolt, shortened to mV and μV respectively.

The batteries we use for our electronic experiments have a voltage of 1½ volts. However, if you put them in the batteryholder, they are connected as we say "in series". In that case the voltage from the batteryholder is 6 times 1½ volts giving 9 volts. Of course you can use any 9 V D.C. supply. The words ampere, ohm and volt are derived from the names of famous scientists.

SYMBOLS AND DIAGRAMS

In electronics, we use components which



are connected to one another by means of copper wire. Circuit diagrams show us how the components are joined together theoretically. They do this by means of symbols and you will find these in the first part of the book. In the final chapter you will find diagrams relating to the circuits you can make with this kit.

PLUS OR MINUS?

On the symbol for the battery you will see a plus sign and a minus sign. These show the direction in which the current flows. But pay attention now: The agreement to do this was made before we knew of the existence of electrons. One side of the battery was called plus and it was said that the current flowed from plus to minus.

It was only later, that someone discovered that the electrons actually move in the opposite direction, that is, from the — to +. We should not laugh at our forefathers too much over this. They just had not sufficient information at the time.

A battery is, as it were, a little box, in which there are an enormous number of electrons. The electrons flow from the minus side across the resistor along the connecting wire to the plus side of the battery.

When the chemicals in the battery which generate the voltage have lost their

strength, the battery is discharged, and must be replaced by a new one.
The number of hours you can use a battery depends on the size of the battery, the strength of the current that is taken from it, and the time that it is in use.

ALTERNATING CURRENT

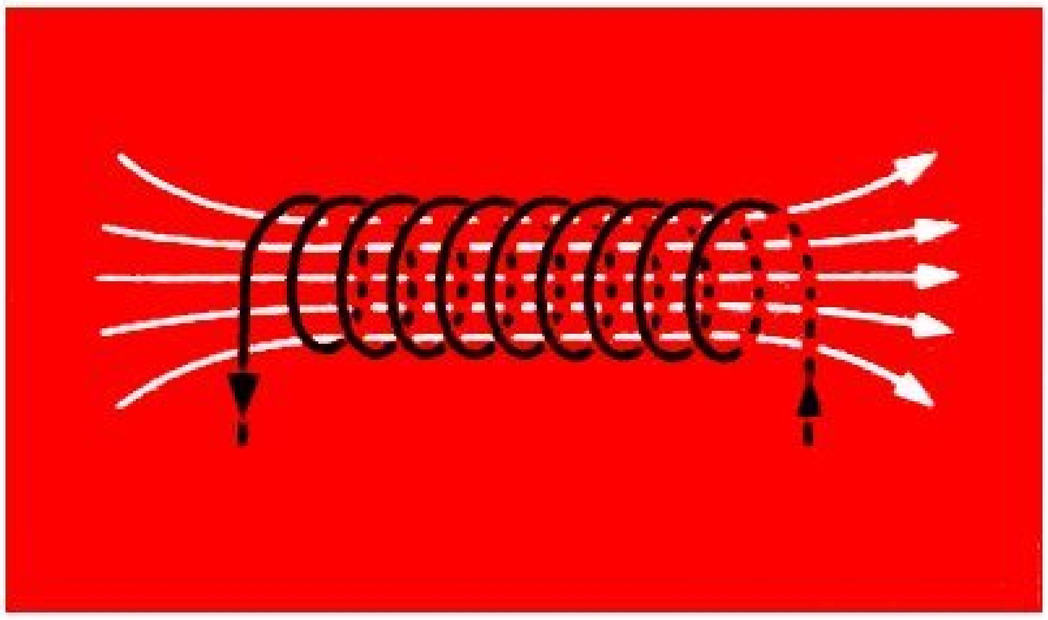
Until now we have considered only a current flowing in one direction. This is always the case in the water supply. In electricity it can be different. Here electrons can flow through the wire in one direction for a time, and then in the opposite direction and then once again in the first direction, and so on. If the water in the pipes behaved like that, very little would come out of the tap. However, electricity does not need to come out of the wiring, to be useful. In order to realise this let us learn from primitive man.
He could make fire, by rotating a stick very quickly in a block of wood. The friction caused heat and, if the heat was enough, the stick would start to smoulder. Friction means overcoming resistance.

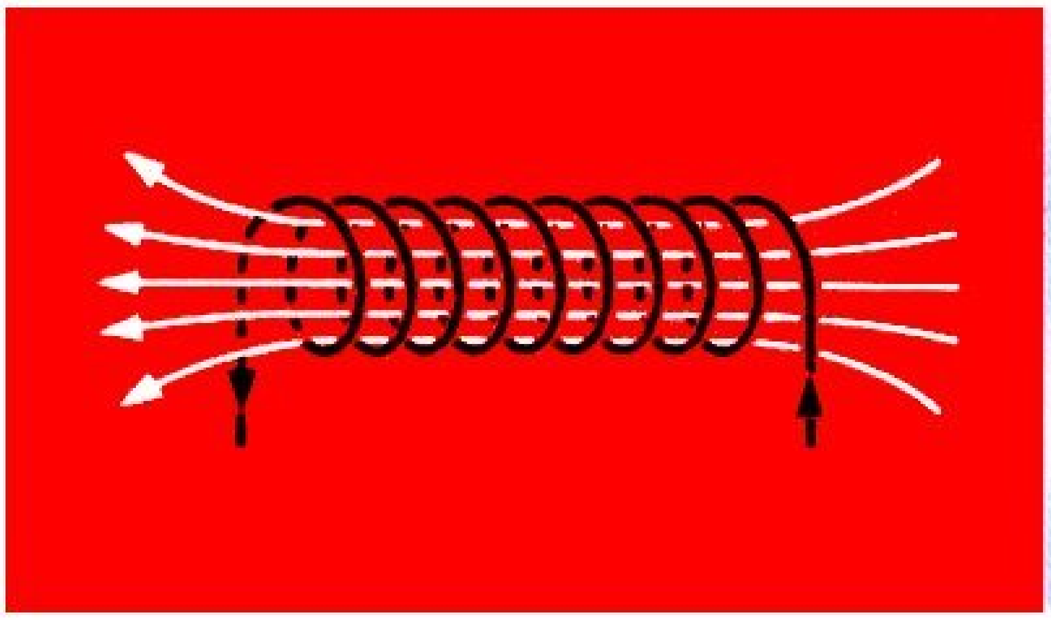
When you rub your hands, they get warm because one hand moves across the other and meets resistance. When an electric current flows through a wire, a resistance also has to be overcome. This makes the wire warm, regardless of whether the electrons move from left to right, from right to left, or to and fro. The strength of the current and the magnitude of the resistance determine how much heat is developed, irrespective of whether it is "direct current" (DC) or "alternating current" (AC). Examples of heat development by means of electric current are quite familiar to you e.g. the electric fire and the incandescent lamp.
Alternating current does, however, have other special advantages over direct current which we shall see in a moment.

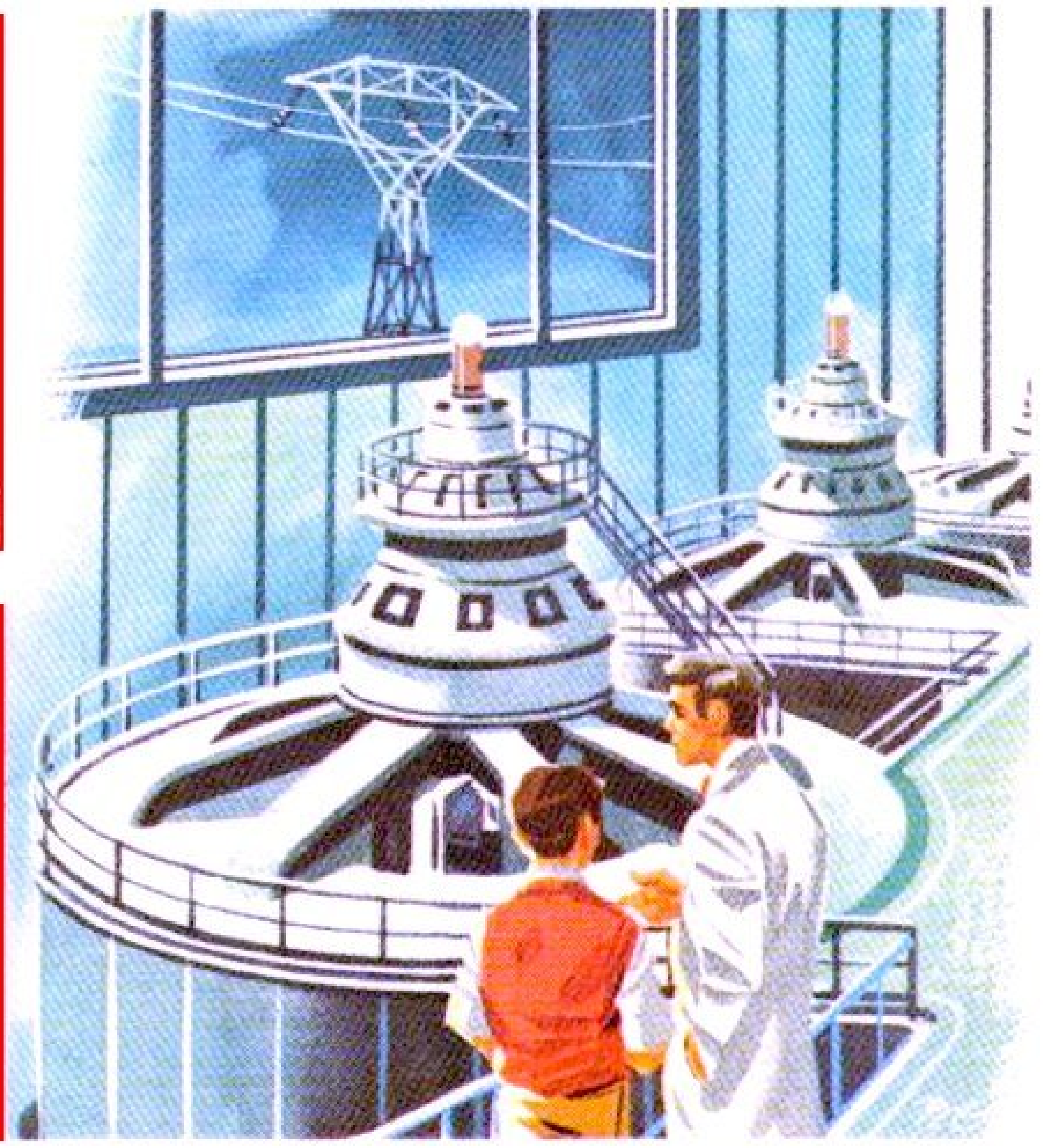
Alternating current is obtained from our mains sockets. Do not tamper with the mains as these voltages are more than enough to cause a fatal accident. The batteries we use give direct current, the voltage of which is enough to work the sets we are going to build, but fortunately much too small to be able to cause accidents.

FREQUENCY

We need to know a bit more about alternating current than the number of amps. For instance we have to know the speed at which the current moves to and fro. Just imagine that the current moves from







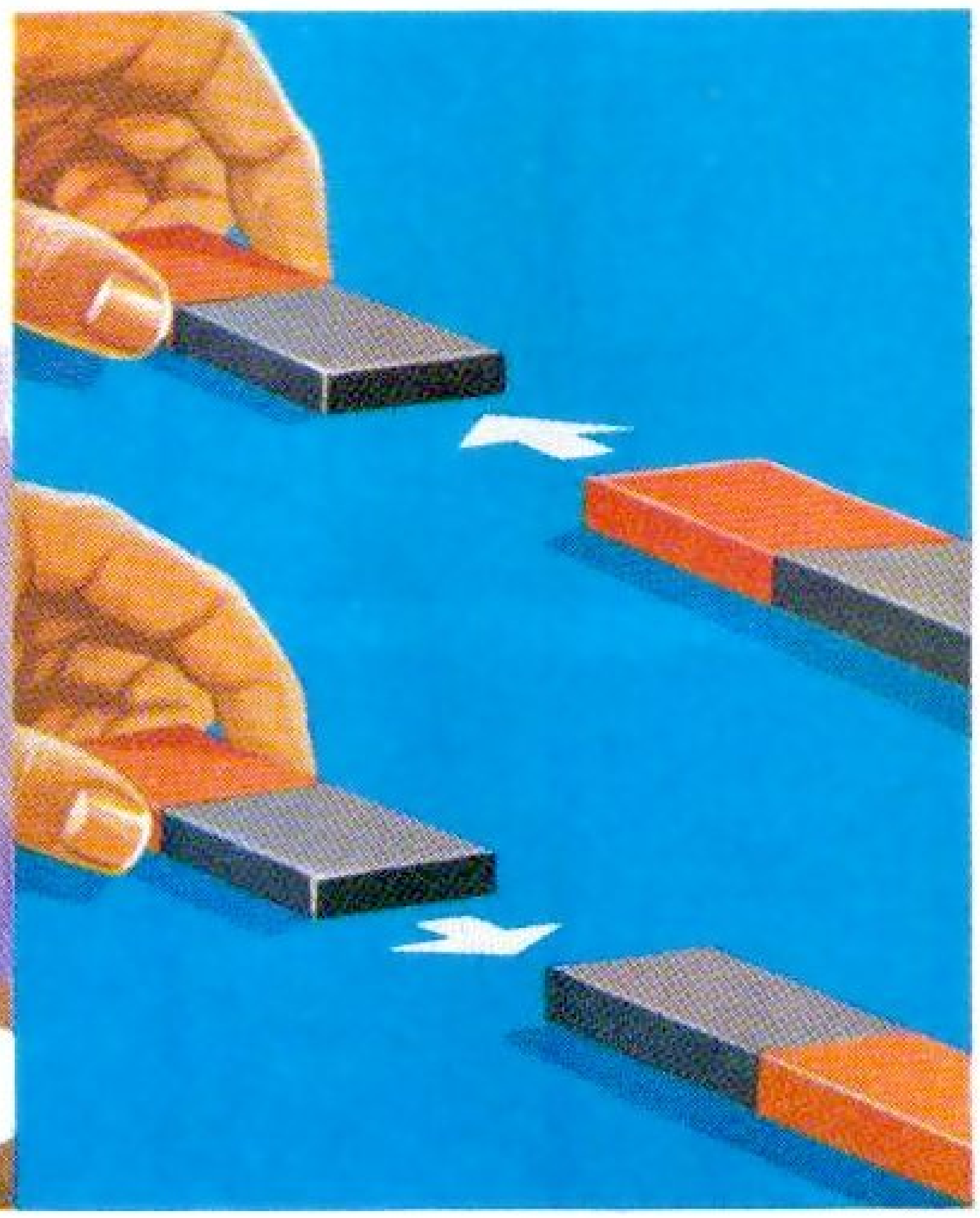
the top to the bottom for half a second and then for another 0.5 second from the bottom to the top. etc., that is, once up and down every second.
This once up and down or to and fro is called a "cycle" of the alternating current (and alternating voltage). The number of cycles per second is called the "frequency". In this example the frequency is thus 1 cycle per second. The voltage of the mains supply socket has a frequency of 50 or 60 cycles per second. Instead of writing cycles per second we can shorten it to c/s. or Hz (shortened from the name Hertz, also a scientist).
The power that our mains supply is able to deliver comes from giant rotating generators driven by steam or water turbines. The frequencies used in electronics are mostly much higher.
Many broadcasing stations work at frequencies of millions of c/s. For the sake of convenience, we speak of kilocycles per second (= 1000 c/s), shortened to kc/s (kHz) or megacycles per second (= 1,000,000 c/s) shortened to Mc/s (MHz). In reality an alternating current usually does not work by fits and starts but more gradually. It begins modestly in one direction, increases, and then decreases gradually, changes direction and so on. The horizontal line represents zero value. You can see that the current, or voltage, moves in two directions with respect to zero.

COILS

Alternating current goes through wires and resistors in just the same way as direct current. But when we wind a wire into a coil, we notice a difference. A coil offers more resistance to alternating current than it does to direct current.

The higher the frequency the greater the difficulty in flowing through a coil.
How does this come about? When a current passes through a coil a magnetic field is created similar to that around an ordinary bar magnet. A coil like this will therefore attract iron filings and a compass needle.
When a coil lies close to a bar magnet, no voltage is generated in it which can cause

coil. This AC will produce an alternating magnetic field which will in turn produce an alternating voltage. So far so good. But what next? Will this new voltage help the old one to send a current through the coil or oppose it? Fortunately the new voltage opposes the old one, for if it were the other way round the current woud get bigger and bigger and bigger. As it is, however, the so called induced



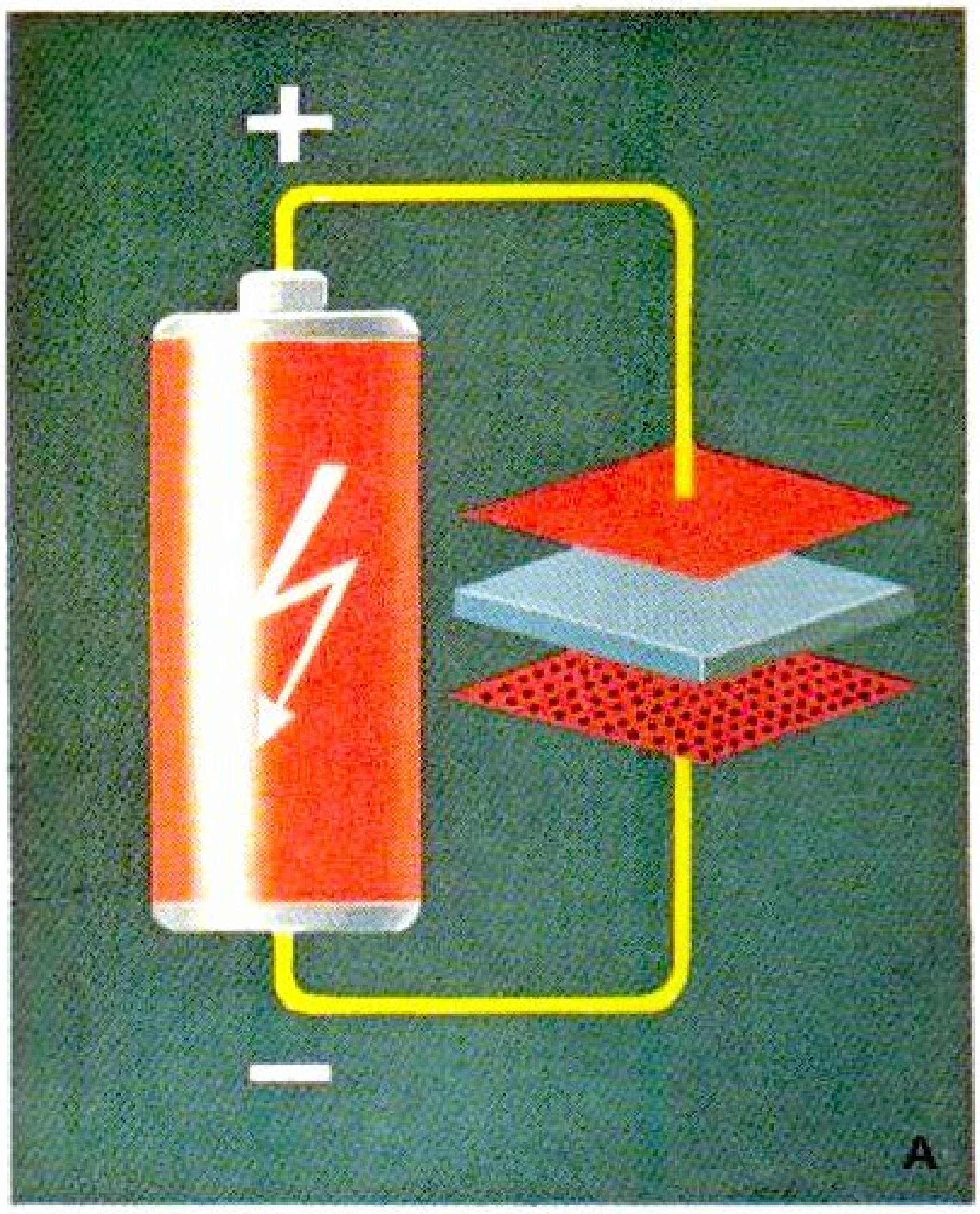
a current to flow, just as a stationary windmill will not generate wind. But this "no" is not final; which is just as well because otherwise radio, television and various other things would be impossible. What really is important, is that if we move the magnet, a voltage is in fact generated in the coil. A magnetic field moving along a coil generates voltage in the coil. When a current flows through a coil a magnetic field is generated. When the current is reversed in its direction, the magnetic field also changes direction. The magnetic field thus varies and generates a voltage in the coil. Now where does all this lead to? Let us pass an alternating current through the

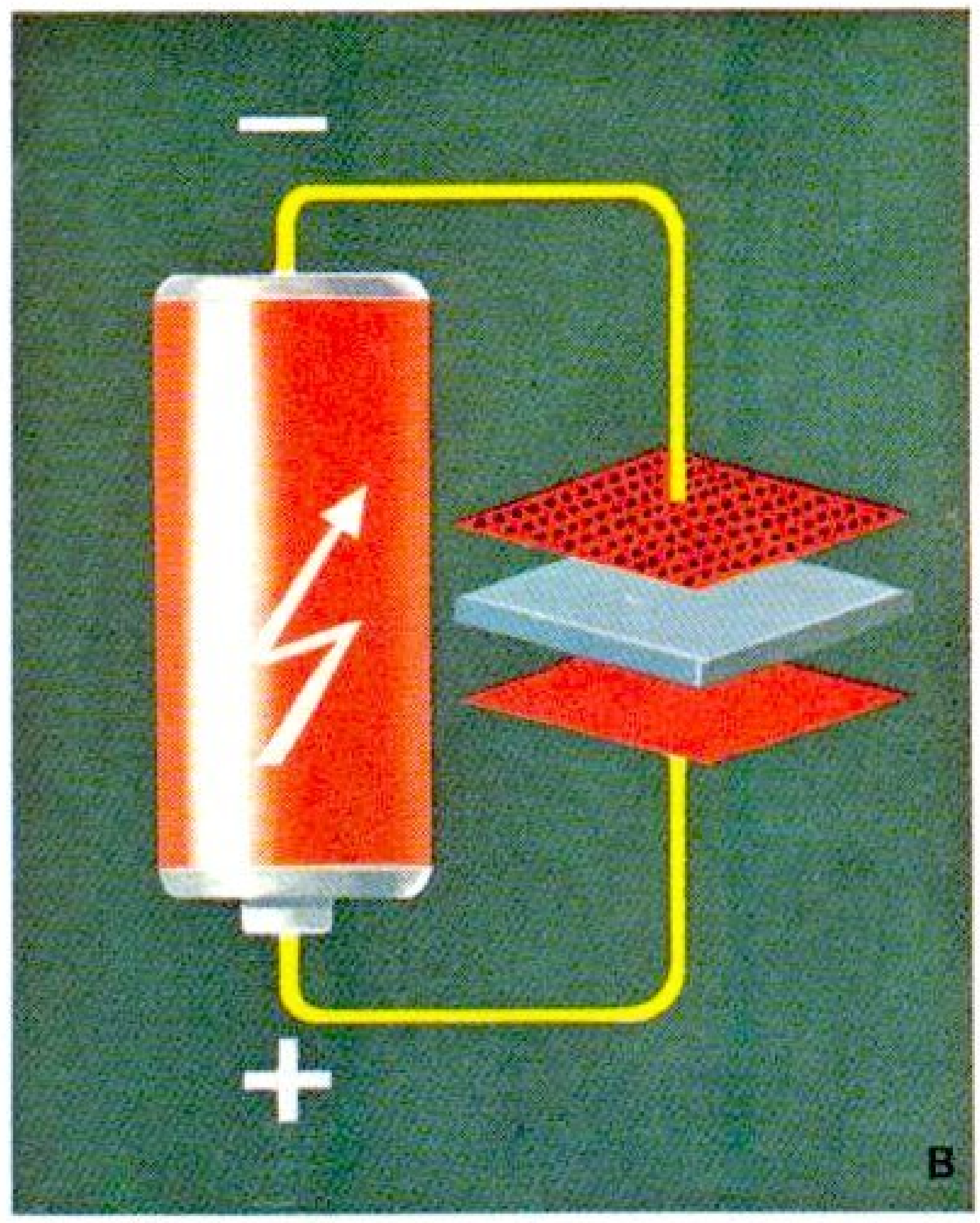
voltage works against the applied voltage and will thus cause the current to be smaller. It is the same as increasing the resistance.
Now the higher the frequency of the alternating current, the more rapidly the current changes its direction and the greater is the counter voltage. As a result the current decreases while the resistance of the coil increases. Of course, had we applied a steady DC source there would be no induced voltage once the current had begun to flow. The current is then only limited by the resistance of the coil wire, the important changing of voltage being missing.
Well, we have seen that direct current

can flow, more easily through such a coil than alternating current. The higher the frequency of the alternating current, the harder it is for this current to flow through the coil, The resistance a coil offers to the flow of alternating current of a certain frequency depends on its dimensions and its number of turns.

ELECTRIC FIELD

but also attracts or repels electrons. As far as repulsion is concerned just think what happens when two magnets are brought close together. The north pole of the one attracts the south pole of the other, but two north poles repel one another. Electrons are all negatively charged, so just as "like" magnetic poles repel one another, so also do electrons repel one another.





Magnetic fields are well known, thanks to the compass and the horseshoe magnet. However, there is also an electric field.

A magnetic field is generated when a current flows through a wire; an electric field is present around an object on which there is a voltage. You know that when you rub a glass rod or a gramophone record with a piece of dry wool or silk cloth, the rod or record can attract dust and small pieces of paper. This is due to the fact that, as a result of rubbing, these objects become electrically charged and electrons have crowded on to the surface. What you cannot see is that an electric field not only attracts particles of dust

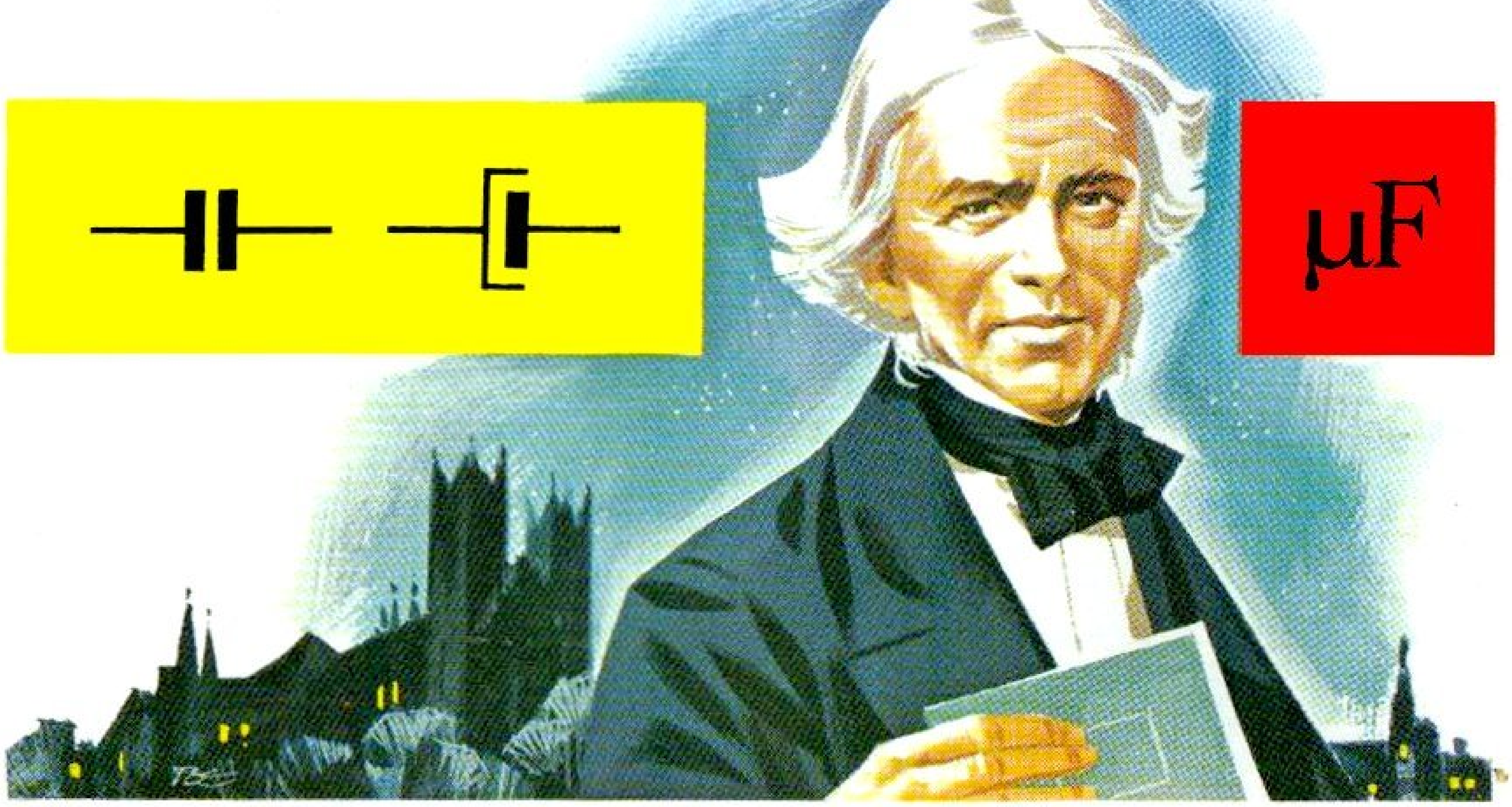
CAPACITORS

Let us now find out what happens when two metal plates set up as in the illustration are connected to a battery. Electrons flow from the negative pole to the lower metal plate. They have no alternative because there are lots and lots of electrons in the battery all trying to repel one another. The wire connection and the plate give them the chance of pushing a few thousand million electrons out of the battery along the wire and into the plate. Once they have got there they can go no further because the air space will not let the electrons through. Air is not a conductor it is an "insulator". But an electric charge generates an electric field which goes through the air and reaches the other plate. There are also electrons in this plate. As a matter of fact there are always electrons present in a conductor, even when the conductor is not connected to a battery. The electrons just happen to be present in the metal. They do not flow through it as there is no particular reason to, but they can be moved. As we have just said, electrons are unfriendly and impolite.

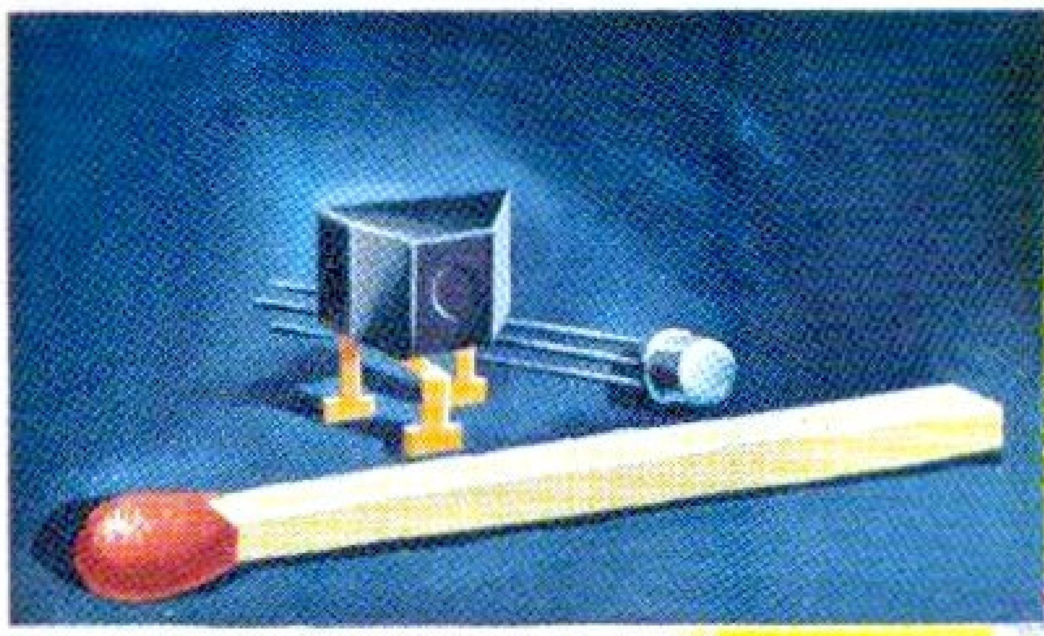
Impolite people boarding a train push their way in and use their elbows. Electrons are much worse than people. They are always impolite to one another and can even push at a distance, even when they cannot reach each other with their elbows. The electric field that is emitted from the lower plate therefore pushes electrons out of the top plate, along the wire to the "plus" of the battery. The higher the voltage the more electrons can be pushed away. What happened at the moment we connected the battery to the two metal plates? A current of electrons flowed from the minus pole of the battery to one of the plates and from the other plate to the plus pole of the battery. That is all. Once the "filling up" stops, the electrons on either side of the gap reach equilibrium. They stop moving and no more current flows. Now we quickly connect the battery the other way round to the two plates. Plus is now at the bottom and minus is at the top. The minus pole of the battery again sees its chance to rid itself of some electrons, this time to the upper plate which is, of course, "empty". Once the electrons have reached the plate they repel their brothers and sisters still present on the lower plate with such force that the latter end up in the battery, thus causing a current to flow again until the top plate is charged with electrons. Now compare the second drawing with the first one.

First of all the electrons flowed in the lower wire from left to right, then the other way round. If we keep reversing the poles of the battery an alternating current will flow through the wire. It will be clear to you that if reversing the poles is done very quickly the electrons will fly back-

MICHAEL FARADY (1791-1867)



ward and forward far more often than when the poles are reversed at a slow speed. Instead of reversing the poles of the battery we can apply an alternating voltage. In engineering, alternating voltages are produced in many ways, some of which will be discussed later on.
Two metal plates, parallel, but not touching another are known as a "capacitor". When the frequency of the alternating



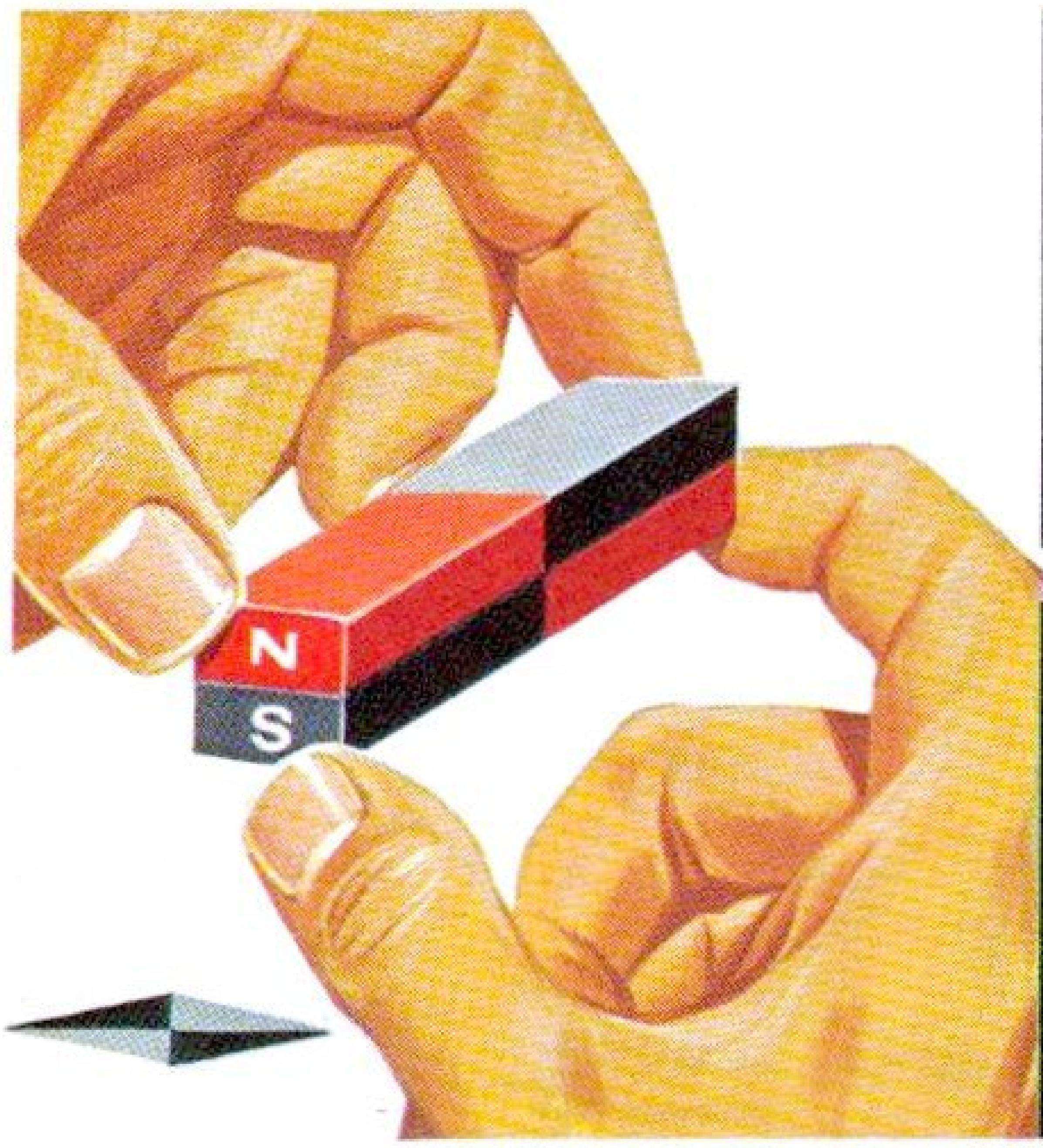
current becomes greater the current flows more easily through such a „capacitor" or "condenser" as it is sometimes called.
A capacitor is thus the exact opposite of the coil. It does not let any direct current through but permits alternating current to flow, particularly if it has a high frequency. The dimensions of the capacitor, that is to say the size of the plates and the distance between them, determine the „capacitance". The capacitance is the ability of the capacitor to hold an electric charge. The greater the capacitance, the easier the alternating current can flow through it. The capacitance is measured in farads, shortened to F.

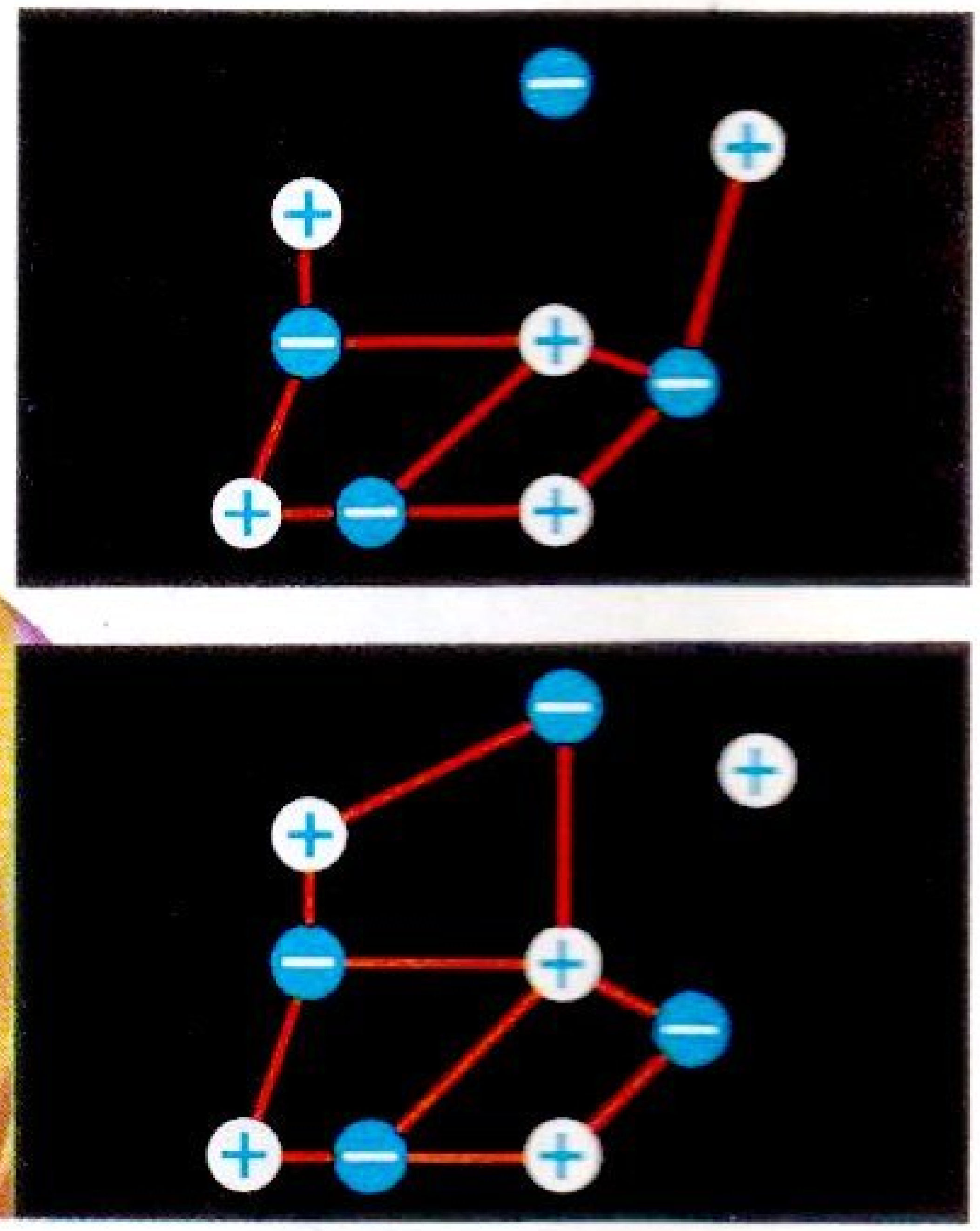
The farad is a very large value, therefore, we normally use the micro farad (μF), which is one million times smaller, and the micro micro farad ($\mu\mu$F), usually called pico farad (pF) which is a million times smaller still. Sometimes use is also made of the nano farad (nF), which is equal to one thousand pF. Thus:
1 F = 1,000,000 μF 1 F = 1,000,000,000 nF
1 F = 1,000,000,000,000 pf or $\mu\mu$F

SEMI CONDUCTORS

A loudspeaker needs quite a large current, which is, in fact, thousands of times higher than the currents that flow through your aerial as a result of the radio waves which it picks up. Therefore we need components that amplify the currents we pick up with the aerial. It is possible to amplify, that is, increase the strength of alternating currents and voltages by means of electron tubes (valves) or transistors. In our kits we make use of modern transistors.
The operation of a transistor is a rather complicated matter. In fact it is not only complicated, but rather mysterious. A

transistor has the appearance of a tiny metal or plastic envelope with three or four connections coming out of one end. The envelope however, is only a protection for the actual transistor. This transistor is made of rare, and therefore expensive, materials like germanium or silicon. These are precious and useful elements which are called metaloids.
The metaloids Germanium and Silicon have similar properties to those of metals like copper, iron, silver and gold. Most metals are good conductors of electricity, germanium and silicon however, are not. Substances like paper, rubber and mica are such poor conductors of electricity that they are called non-conductors or insulators. Germanium and silicon are not insulators either, since they do conduct to a certain extent. Therefore they are called semi-conductors. We might, however, also call them semi-insulators.
Germanium and silicon can only be used for transistors in an extremely pure form. If you were to count all the grains of sugar in a four-pound bag, you would find that there were about ten million.





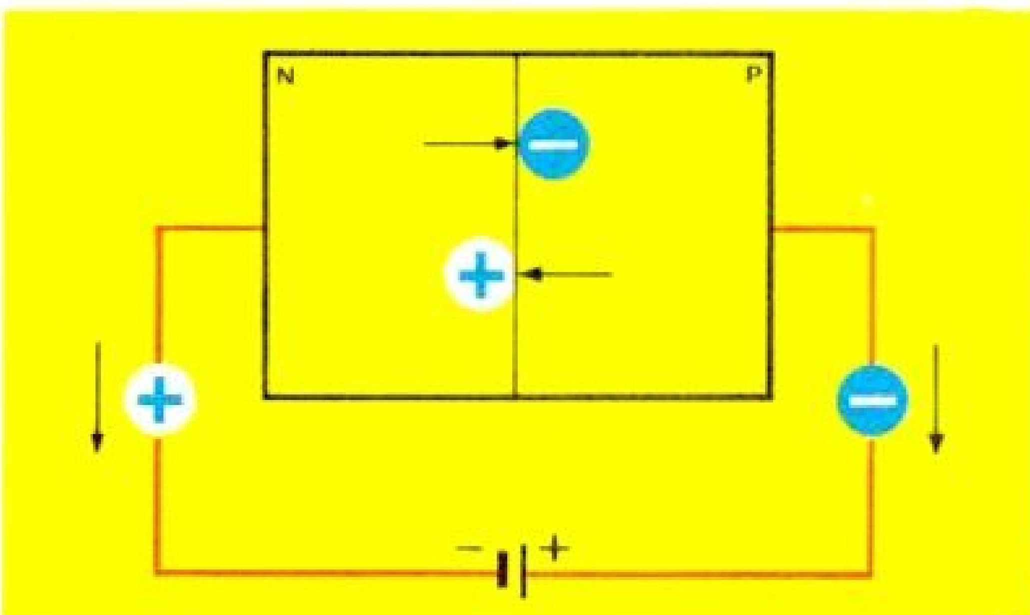
If one grain of sand was present in the four pounds of otherwise pure sugar, the sugar would be "contaminated" to the same extent as the germanium and silicon used for transistors. This should give you some idea of how pure these materials have to be.

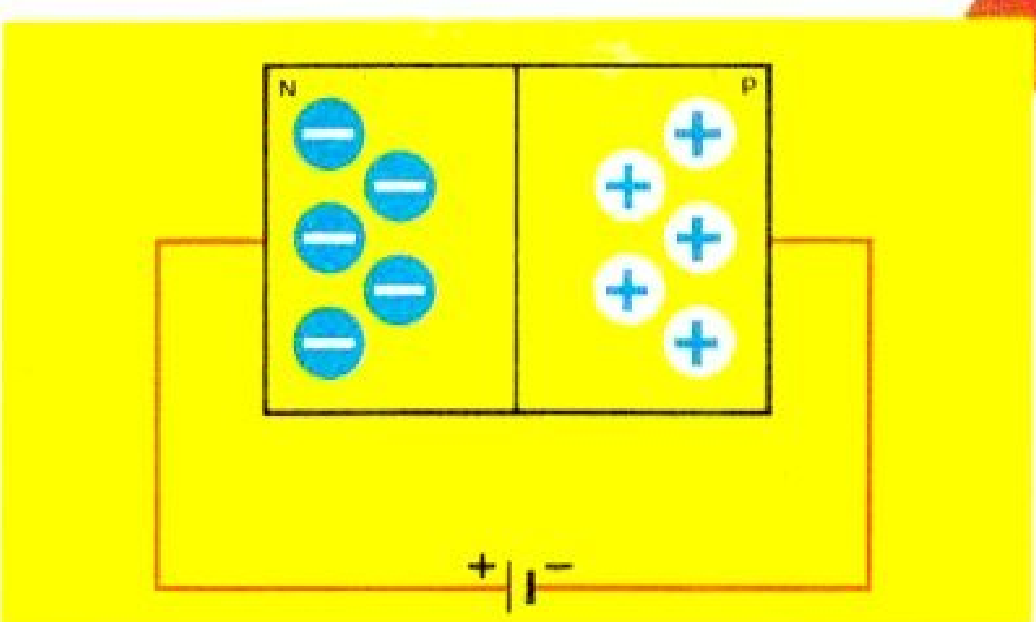
In the next chapter we will explain the working of a silicon transistor. The working of germanium transistors do not differ much in principle.

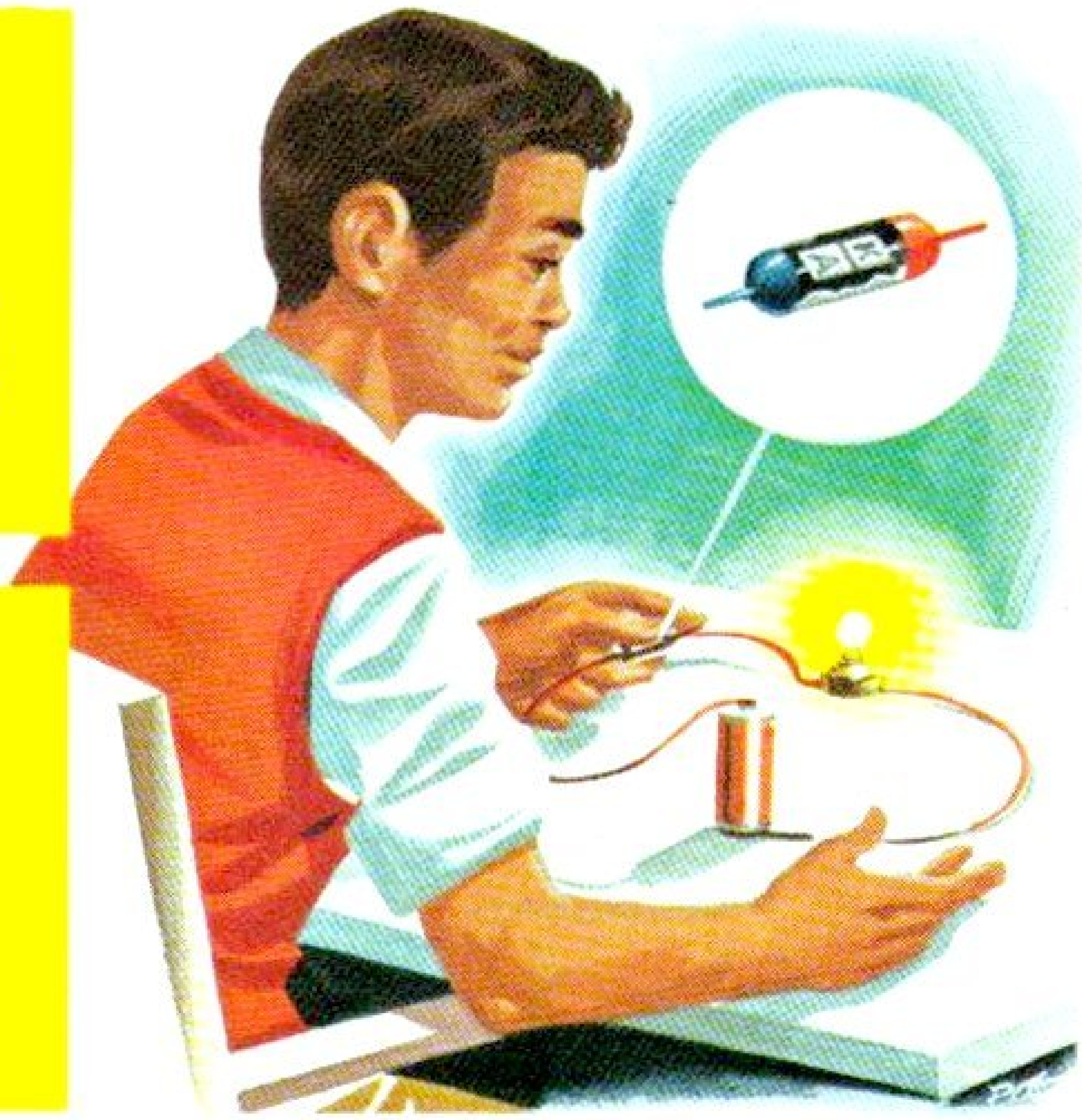
ELECTRONS AND HOLES

We already know that the smallest visible piece of metal contains millions of electrons. Electrons are minute particles possessing an electric charge. This charge is normally not noticable because there are also opposing charges in the metal which cancel it out. If you put identical magnets one on top of the other with the north pole of the one on the south pole of the other, you will see that iron objects are no longer attracted as strongly as before. The opposite magnetic charges

have cancelled each other out.
Like everything in nature, it all depends on balance. Electric charges are either negative or positive, just as magnetic poles are either north or south. Electrons are all negatively charged. If we take an electron (negative charge) out of the metal, there will be a "hole" left. The electric charge of this hole is the opposite of that of the electron. Therefore holes







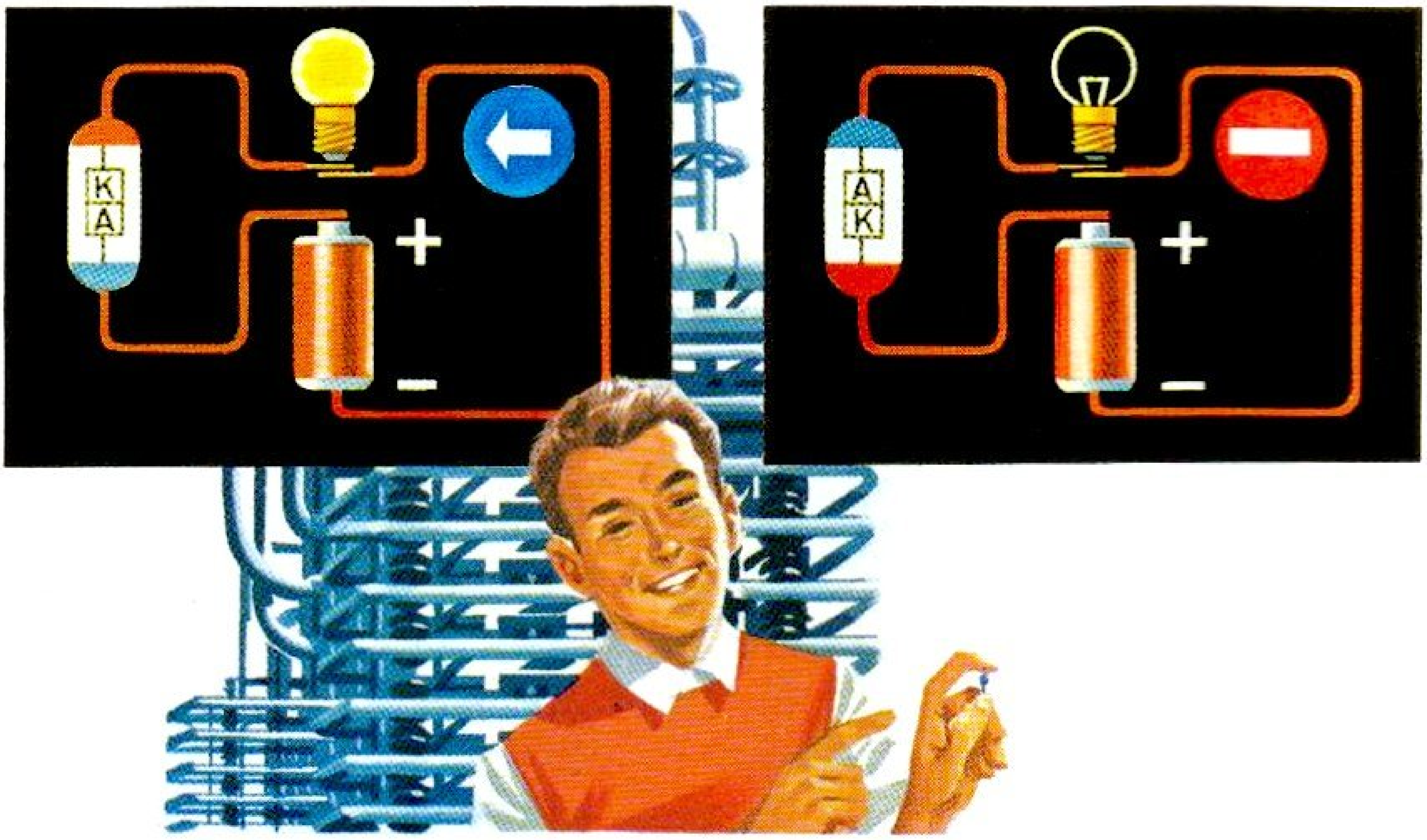
are positively charged. So the charges of the electrons no longer fully cancel out the opposing charges (of all the holes together) which are present.
Now what is the position in pure silicon? It is full of electrons and holes. These electrons and holes however are all firmly fixed in the material. This is why silicon is such a poor conductor. When some phophor is introduced into the silicon, it allows a number of electrons to be moved little more easily. If we put some borium into the silicon we find that some of the holes can be moved a bit more easily as well.
Silicon "doped" with a little bit of phosphor is called N-type Silicon because in this the negative electrons can move. Silicon doped with borium is called P-type Silicon as in this the positive charges can be moved about.

FRONTIER TRAFFIC

If you now place two small slices of pure silicon up against one another, nothing happens, not even if you connect a battery across the pair of them. If however, we put a slice of N-silicon and one of P-silicon together, we find that current flows easily through the pair of them when voltage is put across them. The plate of P-type silicon must then be connected to the plus and the N-type silicon to the minus. (The current generated by this voltage must be very low otherwise the small silicon slabs will be damaged). The ease of flow of the current can be explained as follows:
Opposite charges, like those of electrons and holes attract one another, the same as do opposite magnetic poles. The electrons in the N-silicon are attracted by the holes in the P-silicon. As the elec-

trons can move about within their own slice of silicon, the force of attraction will thus move them towards the junction between N- and P-silicon and some of the electrons may even cross this border. So likewise with the holes which are in the P-silicon.

The battery has been so connected that its minus pole tries to push the electrons in the N-silicon towards the P-silicon, minus pole does the same to the holes in the P-material. These forces are larger than the forces between the holes and the electrons within the P- and N-material respectively. Thus round the junction neither electrons nor holes are left. The battery has won, but at a price. Once the plus pole of the battery has drawn away all the electrons from near the junction, there are no more electrons to follow up



while the positive pole aids and abets by pulling at the electrons. Under the influence of all these forces some more electrons will cross the junction and even pass through the P-silicon. To make up for the loss, the battery supplies an equal number of electrons to the N-silicon which are again pushed and pulled towards the junction which they cross and so on. To the holes the same happens, but, of course, they move in the opposite direction. Next we connect the battery the other way round: plus pole to N-silicon, minus pole to P-silicon.

The plus pole attracts the electrons in the N-material away from the junction. The and hence, no current of electrons. It is the same with the holes.

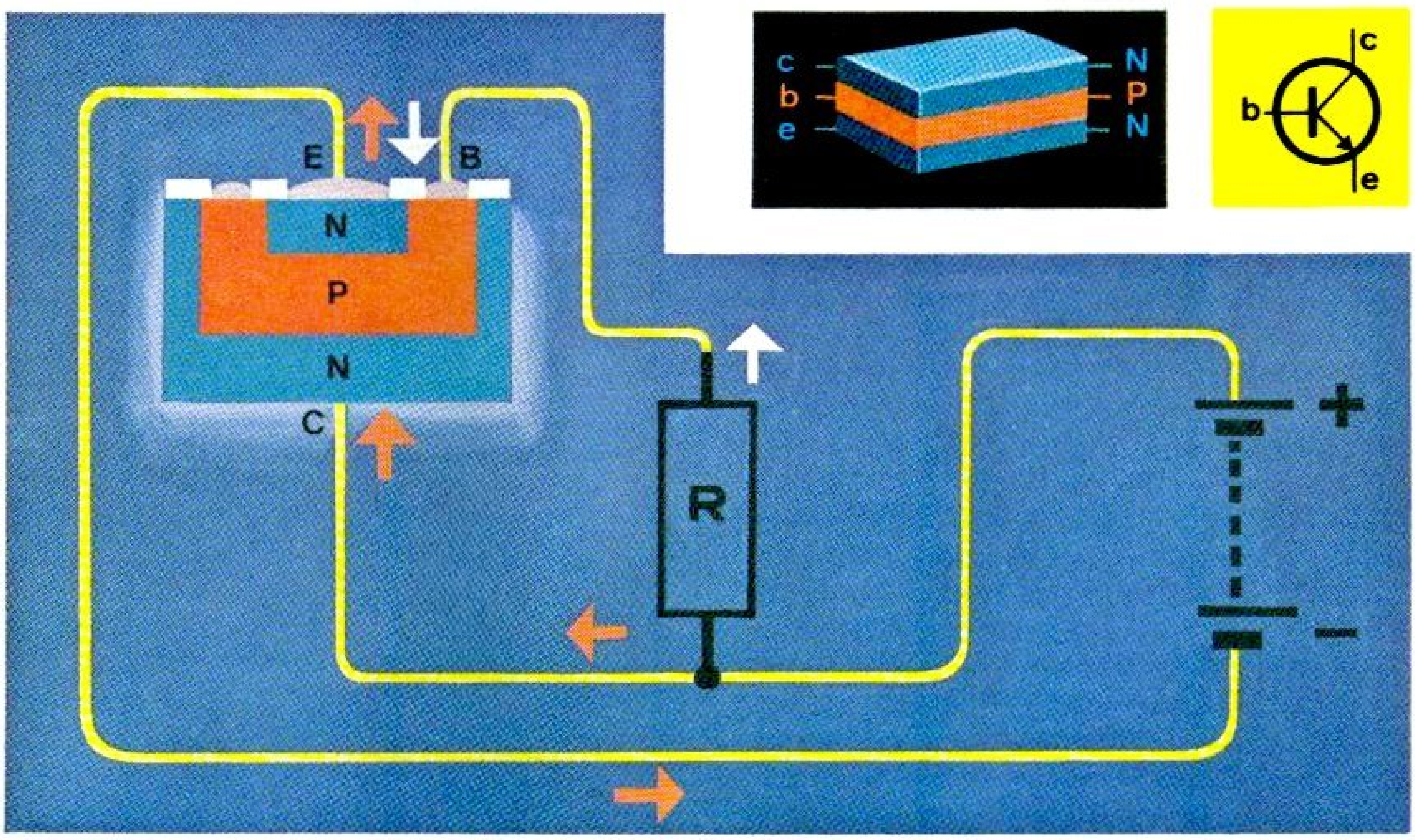
Such a combination of a slice of N- and a slice of P-material is called a diode- it lets the current pass in one direction only.

The diode converts an alternating current (AC) into a direct current (DC). It is not difficult to discover what happens when an alternating voltage is connected to a "diode" of this kind. During the half cycle, when the voltage on the P-material is positive and negative on the N-material, current flows. During the following half cycle, when the voltage is reversed, no current flows. The current through the diode will only flow in one direction and

is, therefore, direct current, even though it flows with interruptions. The alternating voltage has been "rectified". In our assembly kits, the diode is used in radio receivers and its function there is explained in the relevant chapter. Diode rectifiers are used for example in accumulator chargers.
Accumulators must be charged with direct current but the current we get from our mains is alternating. The accumulator charger therefore contains a rectifier which turns the AC into DC. The diode used in the kits is however not suitable for this purpose. (it is not strong enough).
There is no way of telling by just looking at the diode which of its two lead wires is connected to the N-type material and which the P-type. The diode is, therefore, always marked on the "cathode side". The other lead wire is said to be on the "anode side". You should always pay attention to this during assembly. In the symbol for the diode, the arrow shows the direction in which the holes go through the diode. The electrons thus move against the arrow. The mark put at one end of the diode indicates the negative side; that is, the side connected to the N-material.

TRANSISTORS AMPLIFY CURRENTS AND VOLTAGES

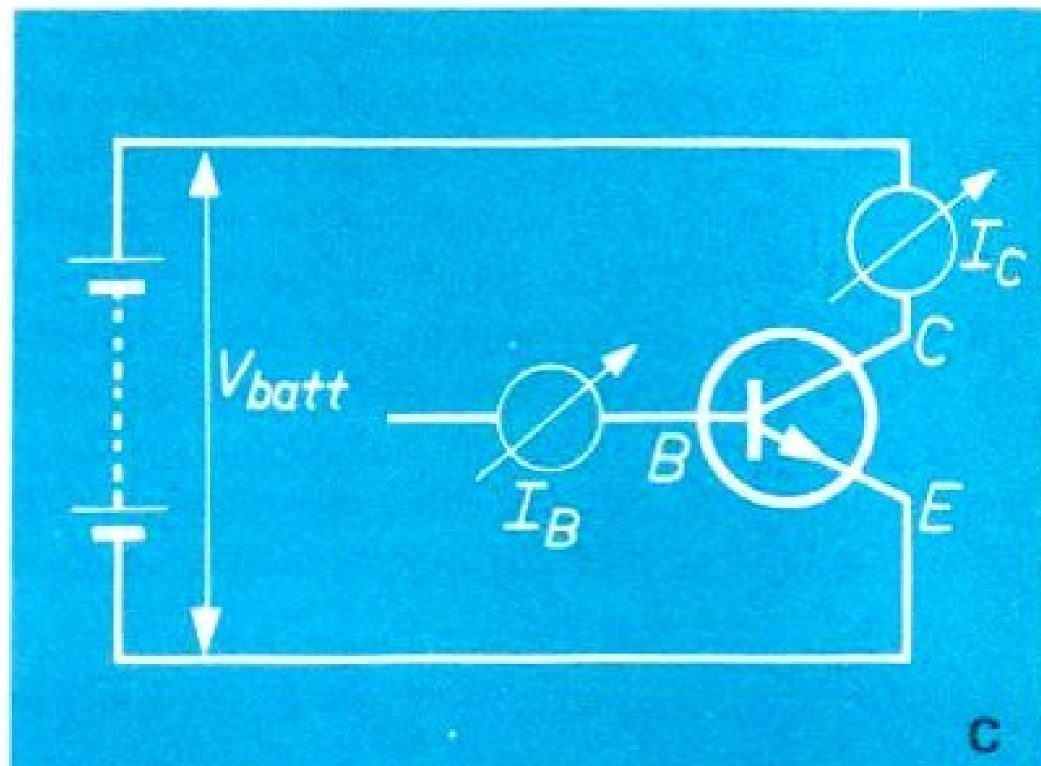
The transistors used in the assembly kits consist of three layers of silicon, namely one layer of P-type silicon with a layer of N-type on either side of it. The middle layer of silicon is called the base (B), one of the N-type layers is called the emitter (E) and the other the collector (C). Let us imagine that we put a voltage between the collector and the emitter of the transistor. (Fig. C).
Very little current will flow. Now we feed a current via R to the base of the transistor. (Fig. D). This resistor (R) is necessary to limit the base current otherwise the transistor will be damaged. When we now measure the various currents we will see that the collector current I_C is considerably higher thant the base current I_B. Let us suppose that the voltage V_{batt}



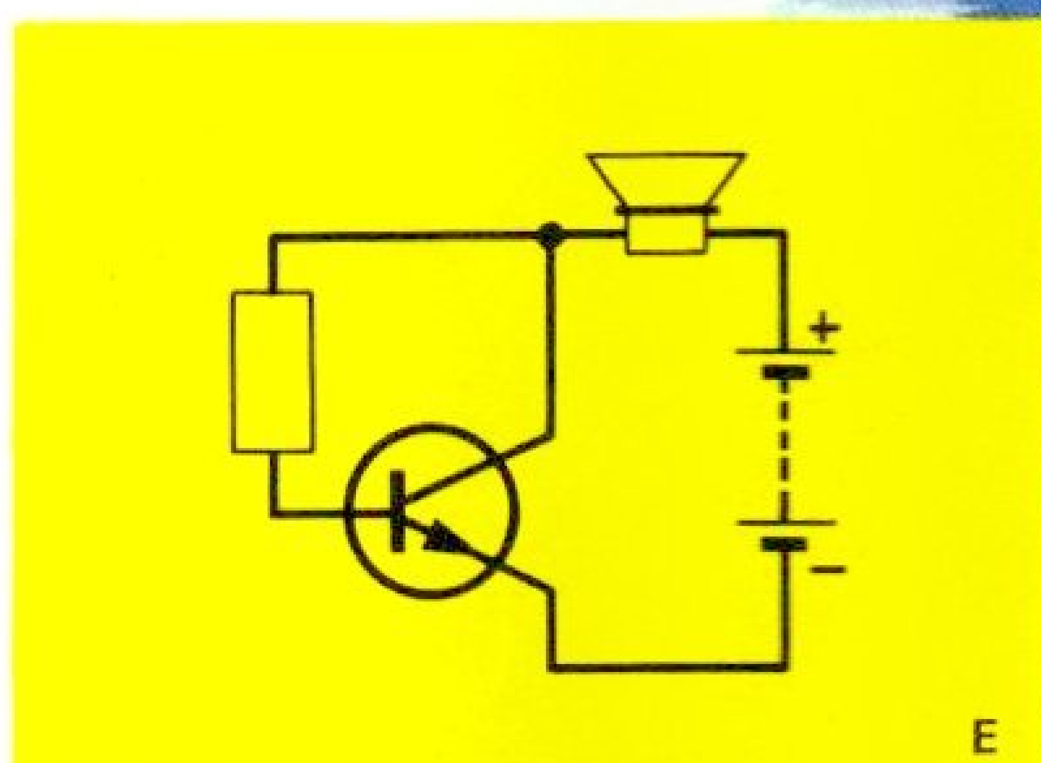
increases slightly. The base current will become slightly higher. The collector current however is also changing but the change of the collector current is much larger than the change of the base current. For example

V_{batt} = 4.5 V	V_{batt} = 9 V	V_{batt} = $4\frac{1}{2}$ V
Resistor R	Resistor R	Resistor $\frac{1}{2}$ R
I_B = 1 mA	I_B = 2 mA	I_B = 2 mA
I_E = 100 mA	I_E = 200 mA	I_E = 200 mA
I_C = 99 mA	I_C = 198 mA	I_C = 198 mA

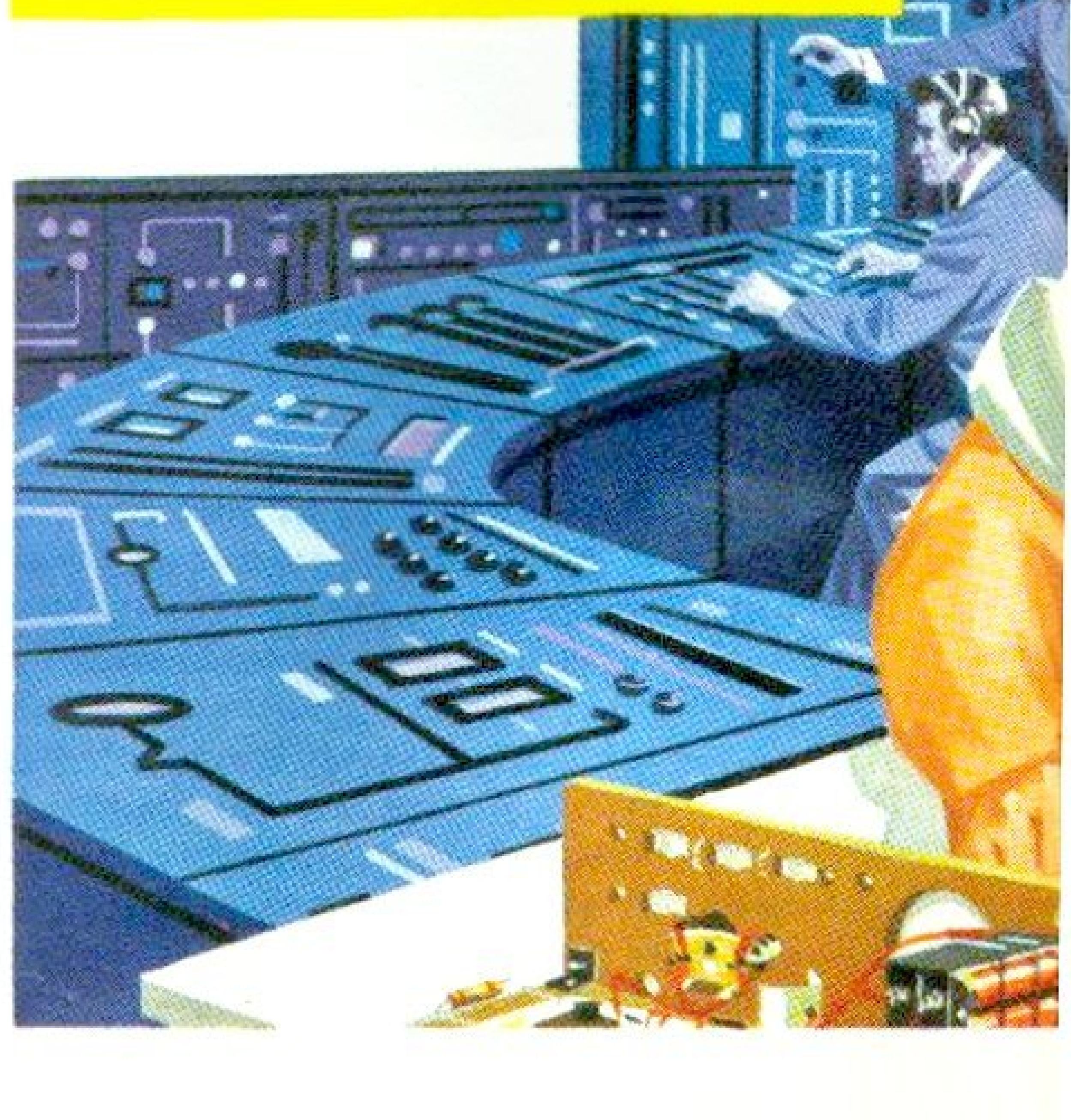
Change of the base current 2 — 1 = 1 mA. Thus, we see that whatever the voltage across R may be, the collector current is always 99 times as large as the base current. If we now look at the currents alone, we find that when the small base current is doubled the larger collector current is also doubled. If in a circuit the base current from the transistor is changed in one way or another, the collector current changes in proportion. We can also connect a source of alternating current, e.g. microphone, in series with R. We will then have not only direct current, but also alternating current flowing through the base of our transistor. Such a combination of direct current and alternating current can be regarded as direct current which periodically changes in strength. We will then have a current through the collector of the transistor which also becomes periodically stronger and weaker. These changes in the collector current may likewise be regarded as an alternating current super-imposed on the normal direct current through the collector. As we have just seen, this alternating current will be greater than that through the base; in our example it will be 99 times as large.
In other words, the transistor has amplified the alternating current 99 times. In practice, the amplification can be even greater, a few hundred times, for instance. Transistors are used to amplify the low voltages and currents coming from a pick-up, a microphone or an aerial so that they can operate an earphone or a loud-

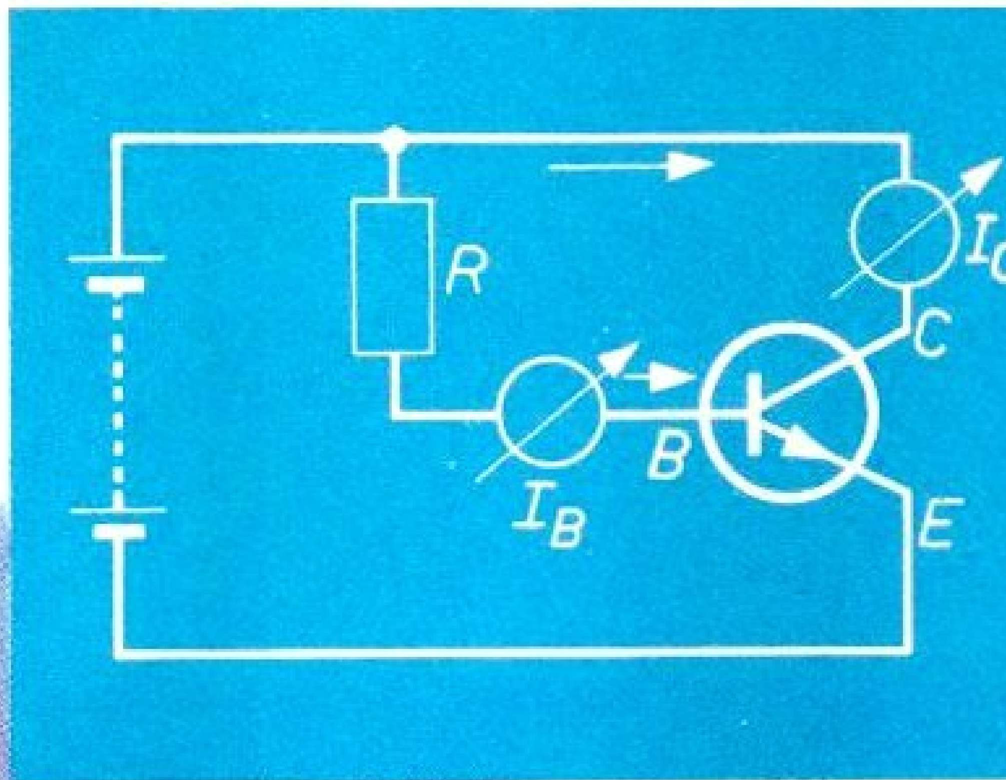


C



E





D

speaker. If one transistor does not give enough amplification, we can use two or even three, one after the other ("in cascade").

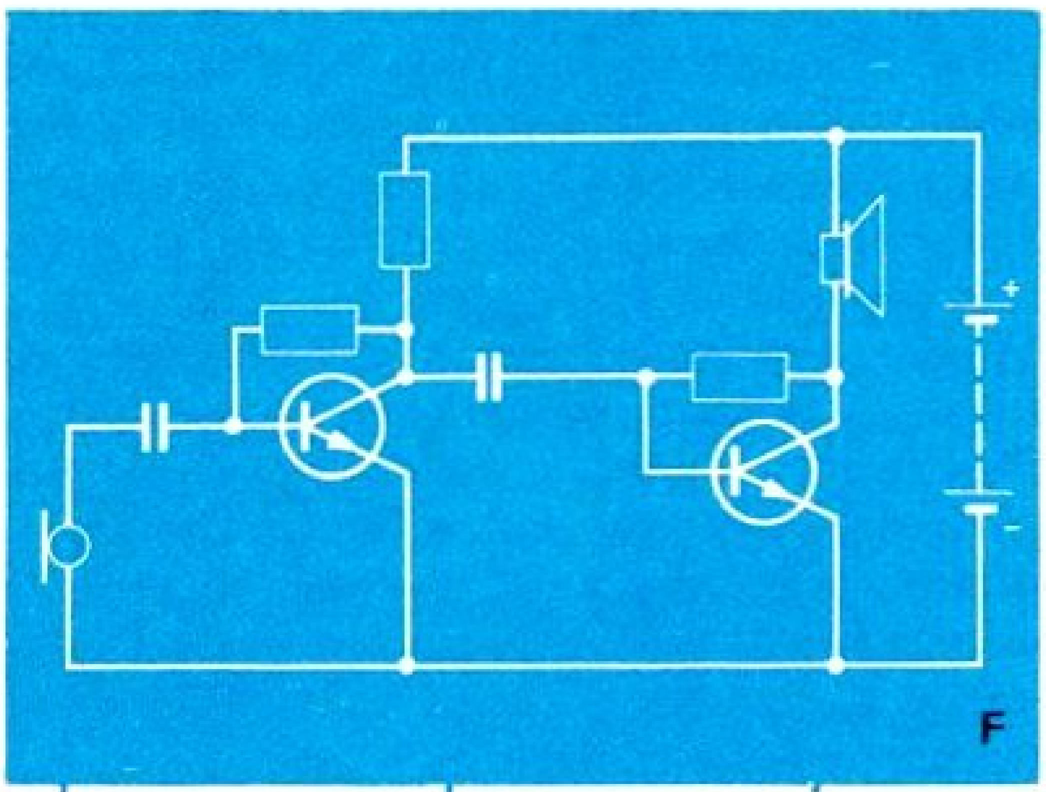
By giving the resistor the correct value, we can make sure that the base voltage will also have the right value. A transistor thus needs two kinds of voltages: DC voltage so that it can work at all and alternating voltages for it to amplify. It is of no use to let the collector current, which is in fact the amplified base current, flow through the battery only. What we really want to do with this current is for example to drive a loudspeaker. The loudspeaker is then connected in series with the collector (Fig. E).

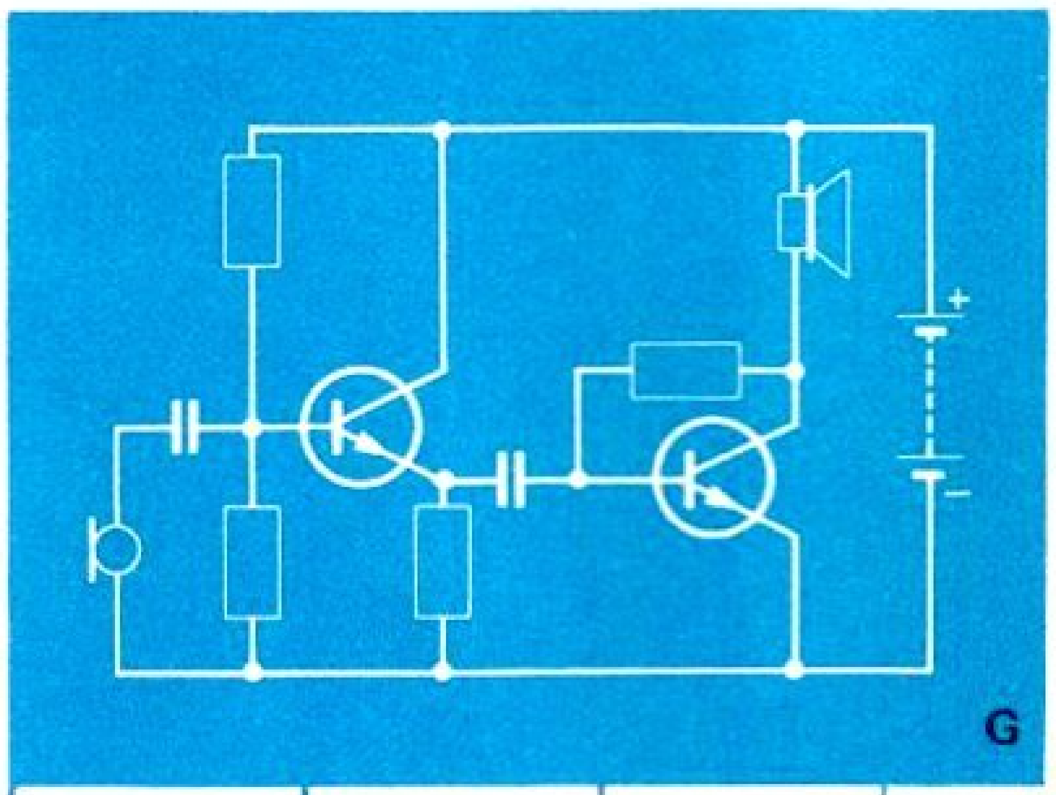
When one transistor is followed by another transistor, because more amplification is needed, a resistor is connected in series with the collector. If the transistor does not need to amplify sound waves but a carrier wave (in radio receivers) a coil or a tuned circuit is used instead of the resistor.

By using capacitors, which, as we have mentioned pass alternating current, but not direct current, we can arrange that the alternating current passes from one transistor to the next without the accompanying direct current. If we did not do this, the direct current accompanying the alternating current would upset the operation of the second transistor. The use of coupling capacitors prevents this trouble.

We call this set up a cascade amplifier; the second transistor is driven by the first one (Fig. F). The resistor that conducts a small direct current to the base is now connected to the collector instead of to the battery. This results in a direct current of the collector which remains more stable in case of temperature changes.

As the collector and emitter currents are practically the same, we can connect a resistor to the emitter instead of to the collector (Fig. G). In this case, the base is generally connected to the + and the — of the battery with two resistors. This circuit has other amplifying properties





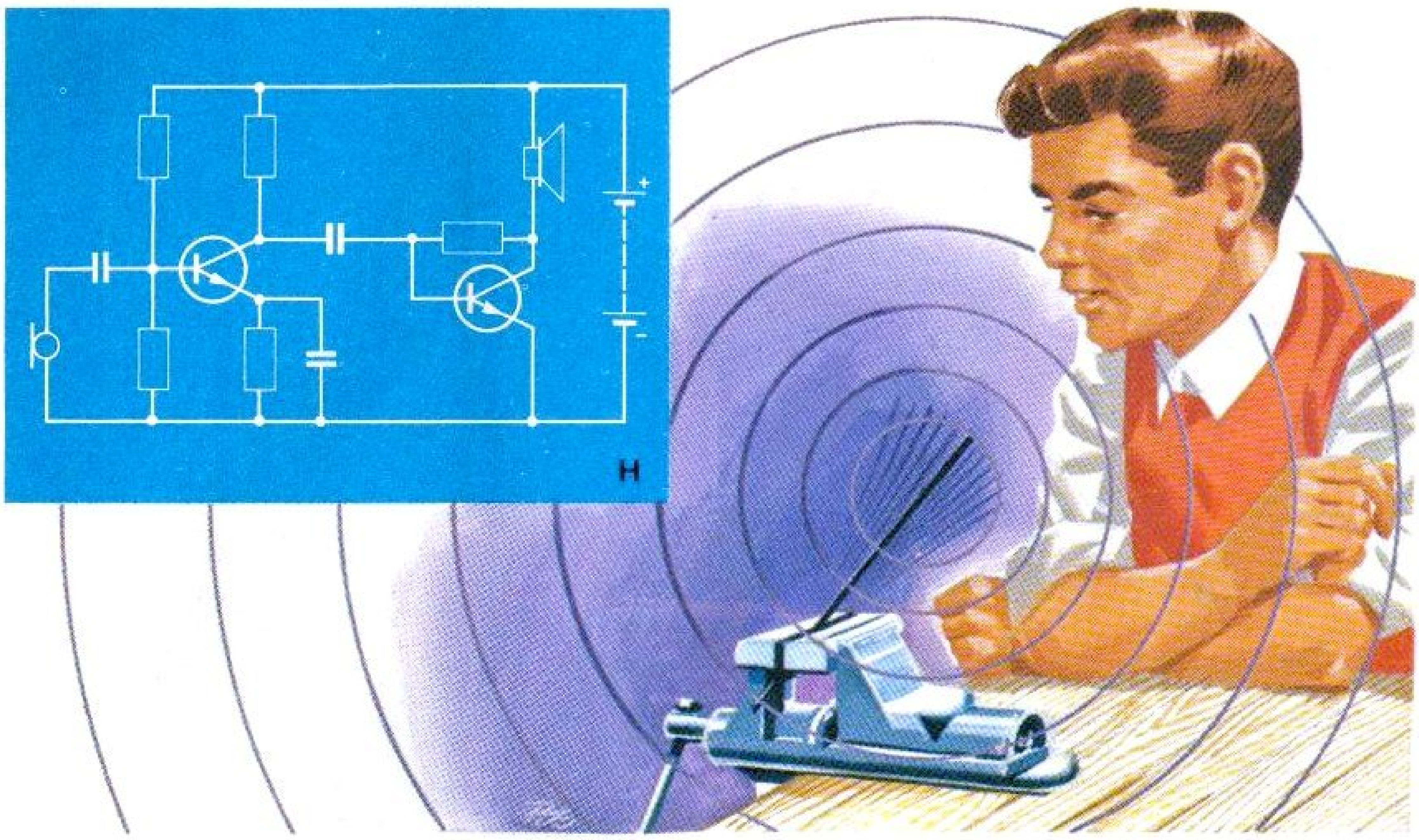
than the circuit of fig. F. Therefore it is also one of the experiments of this kit. A circuit with an emitter resistor and two resistors connected to the base can also be used if we have a resistor connected to the collector (Fig. H). In this case it is desirable to connect a capacitor across the emitter resistor. If the resistors have the correct value the stabilisation of the collector current is better than with one resistor between base and collector, although more components have to be used.

Transistors can also be used as a switching device. In this case the base and the collector currents are not varied by an AC voltage but are either zero or have a certain value. This is called a digital circuit in which the transistor is working as a switch or more correctly as a relay. By giving a small control current to the base, a large current in the collector circuit can be switched on. The application of this principle will be found in some of the experiments of the kit.

ELECTRO ACOUSTICS

Electro-acoustics is the fancy word for everything to do with picking up, amplifying and reproducing sound.

What is sound? Sound is what we call all audible vibrations of the air. When you throw a stone into the water you see the



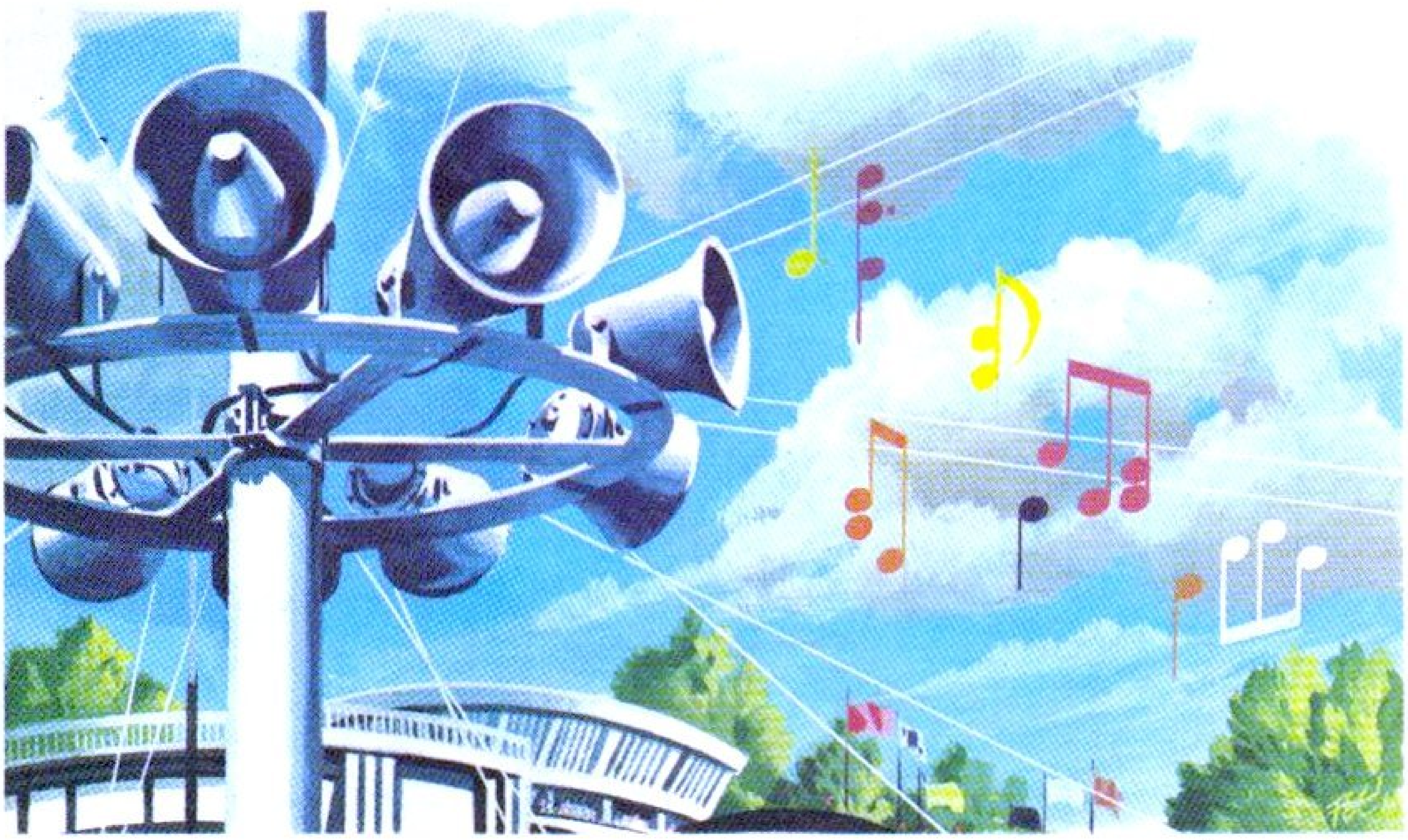
ripples on the surface. Circular waves spread outwards from the point where the stone fell into the water. When you clap your hands similar waves are generated in the air. You cannot see these waves but they are real nevertheless. You can hear them all right, for our ears are intended for the purpose of perceiving such air waves. The water waves go up and down, as you can see quite clearly, if, near the place where you have thrown the stone into the water, there is a little piece of wood. This is moved up and down by the waves but otherwise remains stationary. In the air, waves can travel like that too. Imagine a strip of metal locked in the jaws of a vice on a workbench. If you bend the free end of the strip and then release it, it will spring forward, going beyond its starting position, spring back again, then forward again and so on, each time passing its original position of rest. In fact the strip is vibrating. Such vibration makes the surrounding air vibrate too. Thus waves of air move from the vibrating strip in all directions, just as in our example of the stone thrown in water.

If such a wave catches your ear, you will hear a note. The more vibrations per second the strip makes, the higher the note is. The number of vibrations per second is called the frequency of the note. One vibration per second is called 1 Herz

(1 Hz) or 1 cycle per second (1 c/s). Our ear can perceive notes from about 50 Hz to about 20,000 Hz. A dog can hear higher notes; think of the silent dog whistle.

THE LOUDSPEAKER

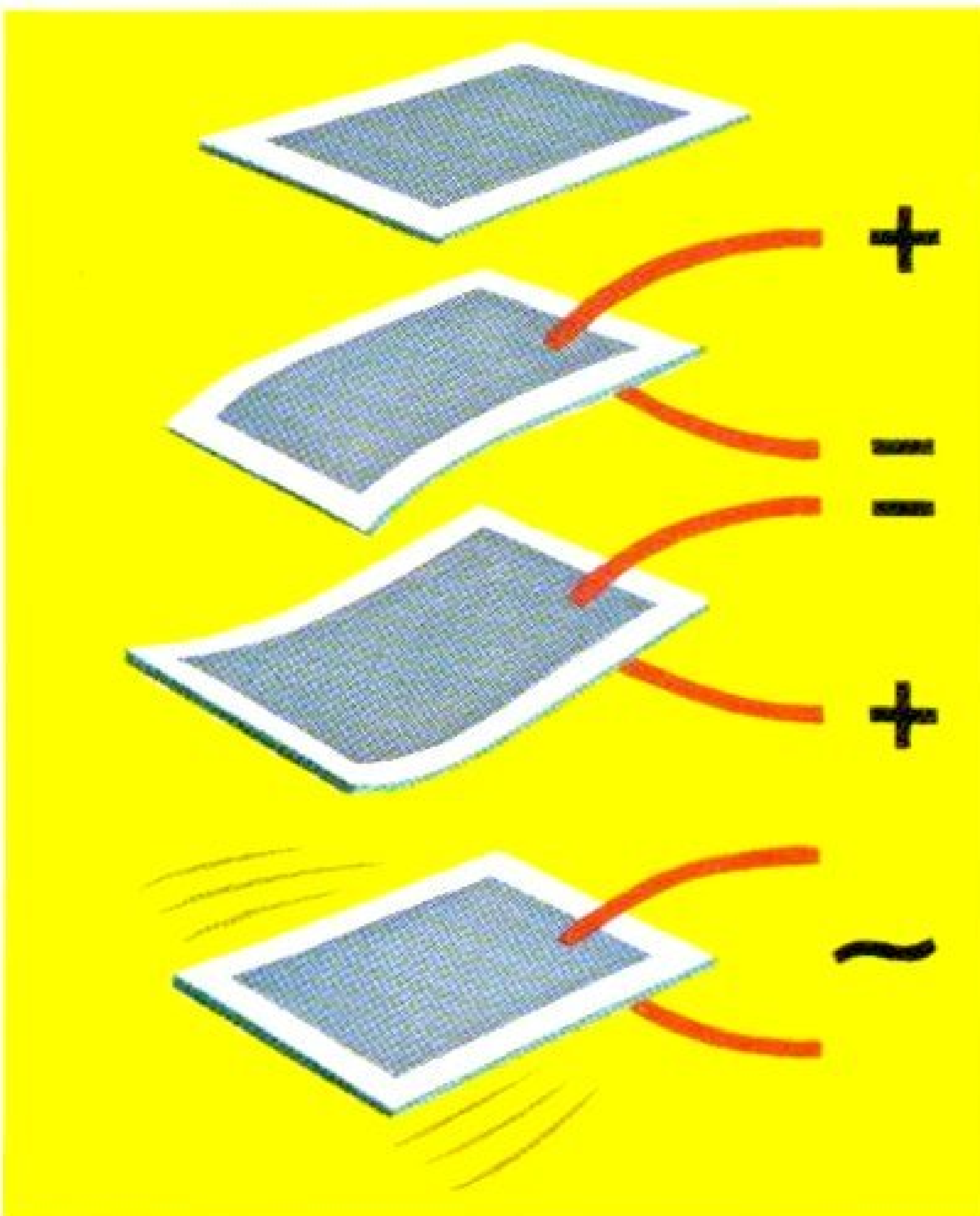
All musical instruments are based on the fact that the air is made to vibrate rapidly in one way or another. When we talk or sing, for instance, the air vibrates. The loudspeaker we use in our radio and gramophone amplifier is a device which causes the air to vibrate.
Just imagine you have a round disc which you move backwards and forwards a few hundred or a few thousand times a second. The vibrating disc will also cause the air to vibrate. This generates sound. The question is how do we get the disc to vibrate? To do this we fix a coil to the disc and place the coil near a magnet, for instance a horse shoe magnet with which you are familiar. Now we send an electric current through the coil. What happens next? The coil behaves just like a magnet with a north pole and a south pole. When the direction of the current is such that the north pole of the coil will repel the north pole of the magnet, the disc will move forward. If we now reverse the current we shall change the magnetic poles of the coil so that there is now a



south pole (at the end previously north) which is attracted to the north pole of the magnet. The disc will now be moved backward. What happens now if we send an alternating current through the coil? That is a current which keeps changing direction, lets say one thousand times a second (an alternating current with frequency of 1000 c/s). The coil will thus be attracted and repelled one thousand times per second by the magnet. The coil and the disc which is fixed to it will thus be vibrated one thousand times per second to and fro and we hear a clear tone. This is the principle of the loudspeaker. The real construction is somewhat different in order to ensure that a loudspeaker as powerful as possible is obtained with a magnet which is as small as possible.

MICROPHONE WITH MOVING COIL

We thus know how we can change an electric current into a sound vibration. But, how can we do it the other way round? How can we turn a sound vibration into an electric current? We do it with microphones. There are several sorts of these. One type, which is often used, works in the very same way as a loudspeaker does, but the other way round. Just imagine that there is a sound somewhere and that this sound strikes against the disc of the loudspeaker (the disc is called the loudspeaker diaphragm). This diaphragm then starts vibrating. When the diaphragm starts to vibrate, the coil does likewise. A little while back we said that when a coil is in a magnetic field and the magnetic field is changed, a voltage is generated in the coil. When the coil vibrates, its place in the magnetic field changes continuously. This is just



the same for the coil as if the magnetic field was changed. In the vibrating coil of a microphone, then, some small electric voltages are generated. These little voltages can be amplified in a way we told you about, and are then fed to a loudspeaker. The alternating currents now flow through the loudspeaker coil so that the loudspeaker diaphragm is made to vibrate and the original sound is heard again.

CRYSTAL MICROPHONES

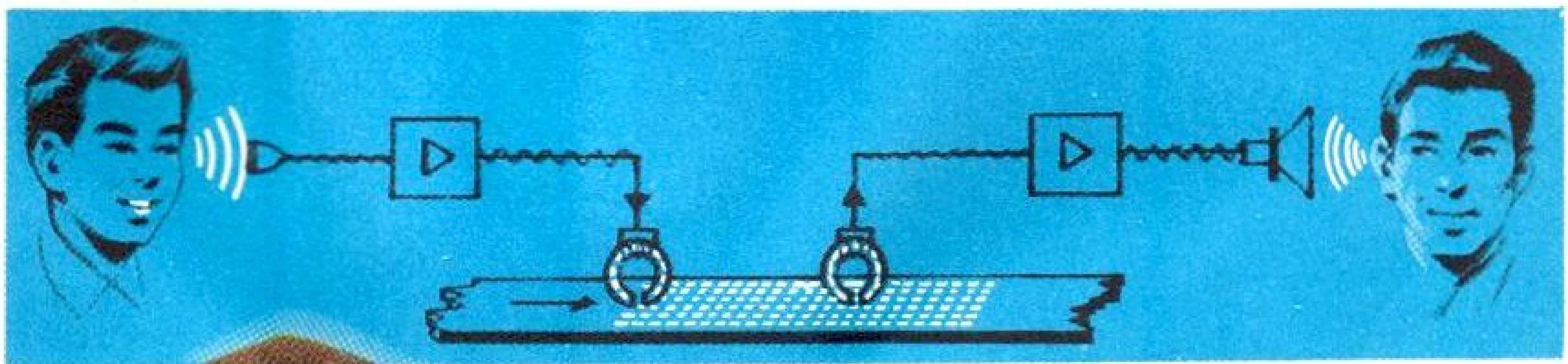
There is however another method of generating sound or picking it up, by using certain materials which have a very peculiar porperty. One such material is known as Rochelle salt. If you take a little slab of this, apply a conducting layer to each side and then connect a battery to the two conducting layers, something happens. The slab starts to bend to one side. If you then connect the battery the other way round the slab curves the other way. Do yo follow? When you connect an alternating current the slab it bends to

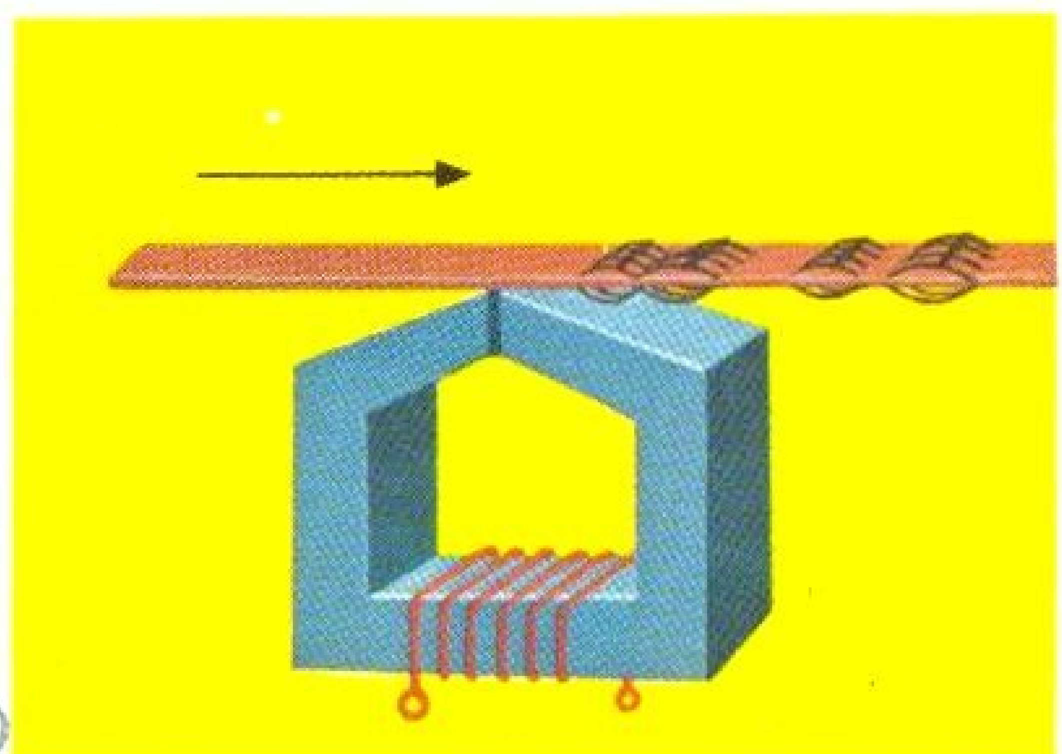
and fro. If you attach a diaphragm to this slab of Rochelle salt, the diaphragm will start to vibrate and you hear a tone. The opposite is possible too. When sound sets the diaphragm vibrating, the Rochelle salt slab is bent backward and forward and a voltage is generated between the two conducting layers on the slab. Used in this way it is called a crystal microphone.

CRYSTAL PICK-UP

In most pick-ups used in gramophones, Rochelle salt slabs are used. The vibrations come from the grooves in the gramophone record. When you examine

such a groove under a magnifying glass you will see that it is not just a spiral line but that the line wriggles to and fro a little. The wavy line of the groove corresponds with the air vibrations of the original sound.
The gramophone needle resting in the groove is also pushed to and fro by the groove. This needle is fixed to a slab of Rochelle salt, which is therefore also bent to follow the movements of the needle. Again as a result of being bent to and fro, an alternating voltage is generated between the conducting surfaces on the Rochelle salt. A pick-up is thus, as it were, a microphone with a needle on it, which is not vibrated directly by the air vibrations but by means of the needle in the groove of the record.





TAPE RECORDER

In addition to the gramophone you will also have heard of the taperecorder for the reproduction of sound. With the tape-recorder we can record the sound ourselves. The sound is picked up by means of a microphone and amplified electronically. This sound is passed to an electromagnet, the "recording head", in the form of current variations. A sound tape i.e. a tape with inumerable particles of magnetic iron oxide, is now passed at constant velocity along the recording head. The current fluctuations are then converted by the electromagnet into magnetic fluctuations.

The sound tape has the property of retaining the pattern of magnetic fluctuations. In this way the sound is recorded as a magnetic pattern on the sound tape. During play-back, the play-back head scans the magnetic track and thereby becomes energized. The play-back head converts the magnetic fluctuations into current fluctuations. These current fluctuations are amplified and passed to the loudspeaker, which reproduces them again as sound.
The magnetic pattern is retained on the tape until the tape is made magnetically neutral again with a special head, - the erasing head. The erasing head is also an electromagnet which in this case is

supplied with a strong alternating current of a very high frequency.

TELECOMMUNICATION

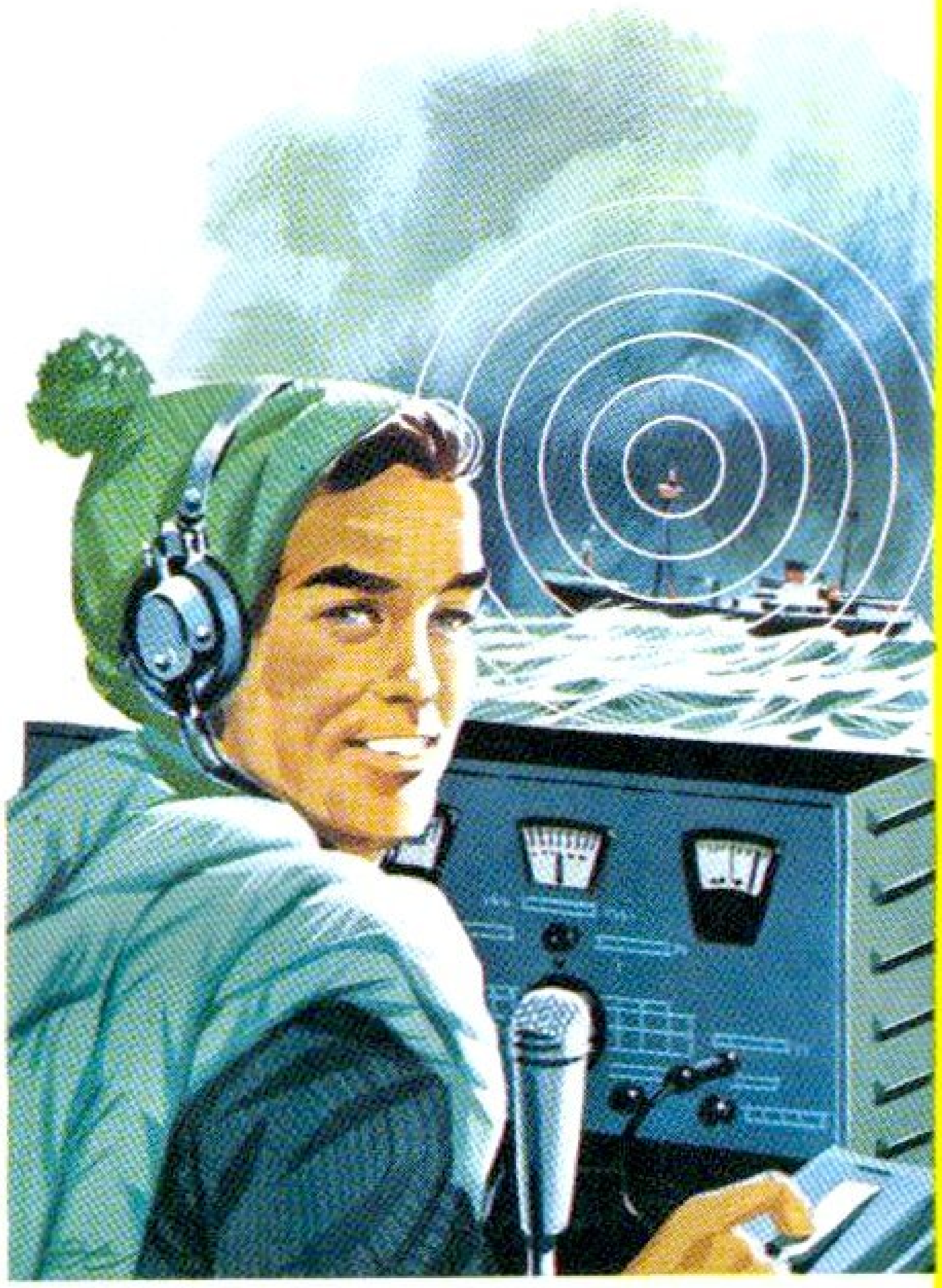
Telecommunication means something like "traffic at a distance". By traffic, however, you should not imagine motorcars, trains and aeroplanes, but the transfer of information. This can be by telegraphy, telephony, radio-telephony, picture-telegraphy or television. What is important here is that there is always a distance to be bridged. A house telephone or intercom is just as much a piece of telecommunication equipment as the installation which will eventually be used to send messages to the first people landing on the moon.

When you call out of the window to your friend who lives on the opposite side of the road, it is hardly telecommunication. Telecommunication is the transmission of messages over practically any distance you wish. You cannot do that by talking or even shouting. If your friend lives a mile away then you can yell as hard as you like, but he will not hear you. It is only by electronic means that it is possible to bridge any distance, and telecommunication is thus the electronic transmission of information. One of the oldest but still very important methods in telecommunication is telegraphy. Telegraphy is very well suited for the transmission of information over long distances.

One of the circuits in this kit is a telegraph; that is a set with which you can send morse signals. The morse code is fed from your morse key along wires to an earphone or loudspeaker and these wires can be very long. In this kit you will not get wire a mile long. In any case you are not allowed to fit wires over the street as you like - you have got to have the approval of the Town Council and of the Post Office authorities and we are afraid you would not get it. If your friend lives nearby and in the same block, it might be possible to fix up a connection between his and your room.

MORSE TELEGRAPHY

There is an international agreement that a dash should last three times as long as a dot. The rest interval between the parts



A	·—	P	·——·
B	—···	Q	——·—
C	—·—·	R	·—·
D	—··	S	···
E	·	T	—
F	··—·	U	··—
G	——·	V	···—
H	····	W	·——
I	··	X	—··—
J	·———	Y	—·——
K	—·—	Z	——··
L	·—··	Ä	·—·—
M	——	CH	————
N	—·	Ö	———·
O	———	Ü	··——
1	·————	6	—····
2	··———	7	——···
3	···——	8	———··
4	····—	9	————·
5	·····	0	—————

Call signal —·—·—

of the same letter lasts as long as 1 dot. The rest interval between two words should last as long as 5 dots. In between two letters of the same word is a space lasting 3 dots. You will note that you attain the correct speed with the least effort if for the dot you say quickly "de" and for the dash you take a bit longer and say "dah". Thus the "a" sounds as "de dah".

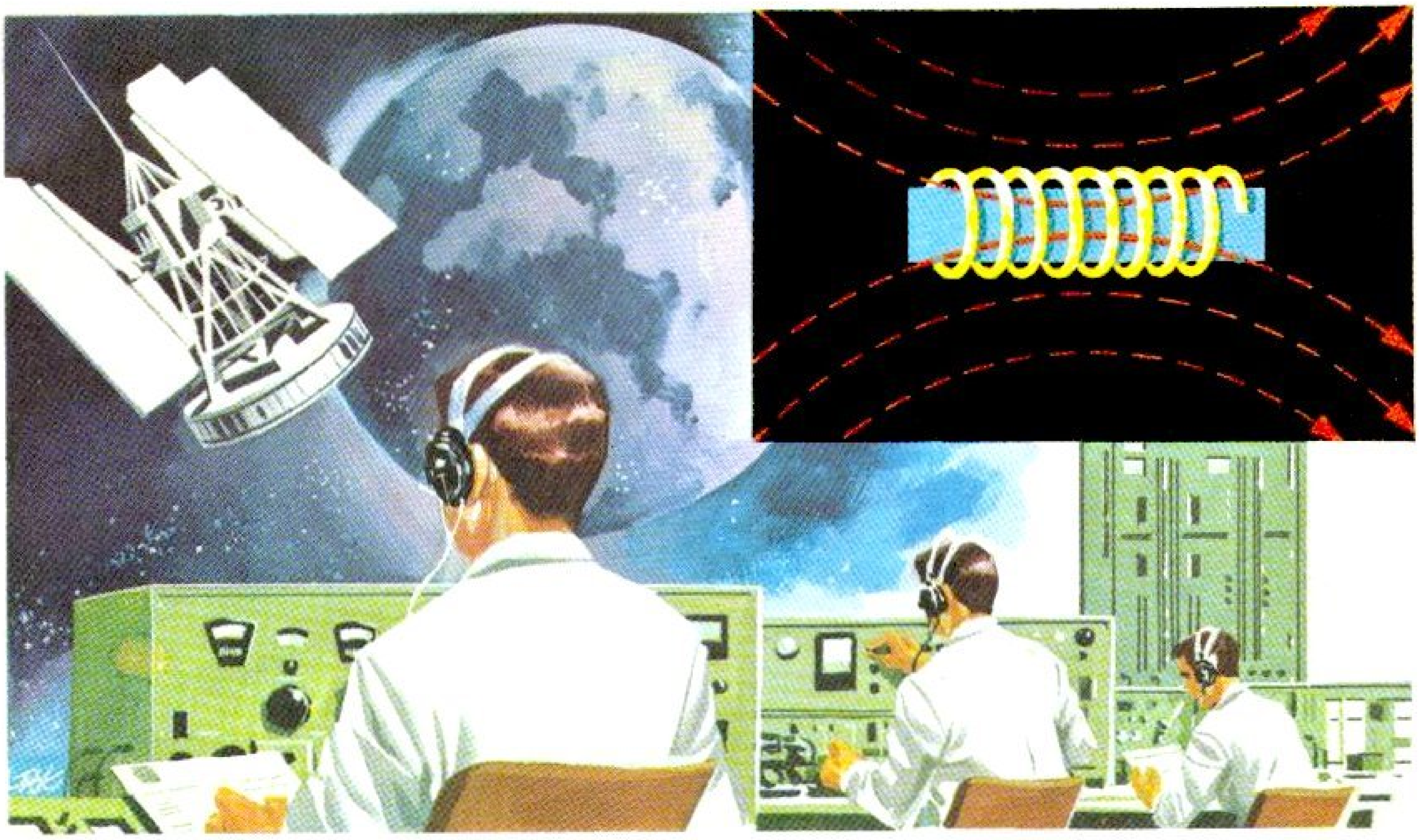
RADIO

You no doubt know what radio is but not how it works. A radio receiver resembles a gramophone amplifier halfway, but instead of a pick-up it has a section whose

working is probably new to you. Do you remember how the capacitor works? An alternating current can flow through two parallel metal plates, even when they do not touch one another. We shall now replace one of these plates by the earth. This is of course not of metal but it can conduct current. The other plate we replace by a long metal wire, stretched above the earth. This is again a kind of capacitor. If we now connect an alternating current to the metal wire - the aerial - and the earth, an alternating current can flow through this capacitor we have made. The higher the frequency of the alternating current, the greater the current which can flow through it.

Now we have already said that what we call an electric field is generated between the two plates of a capacitor. This happens here too. Between the aerial wire and the earth an electric field is generated, but that is not all. You know that a magnetic field is emitted from a coil when a current flows through the coil. This is also true of a straight wire, so that a magnetic field is generated about very high frequency that they behave in exactly the same way as light and do not pass the horizon.

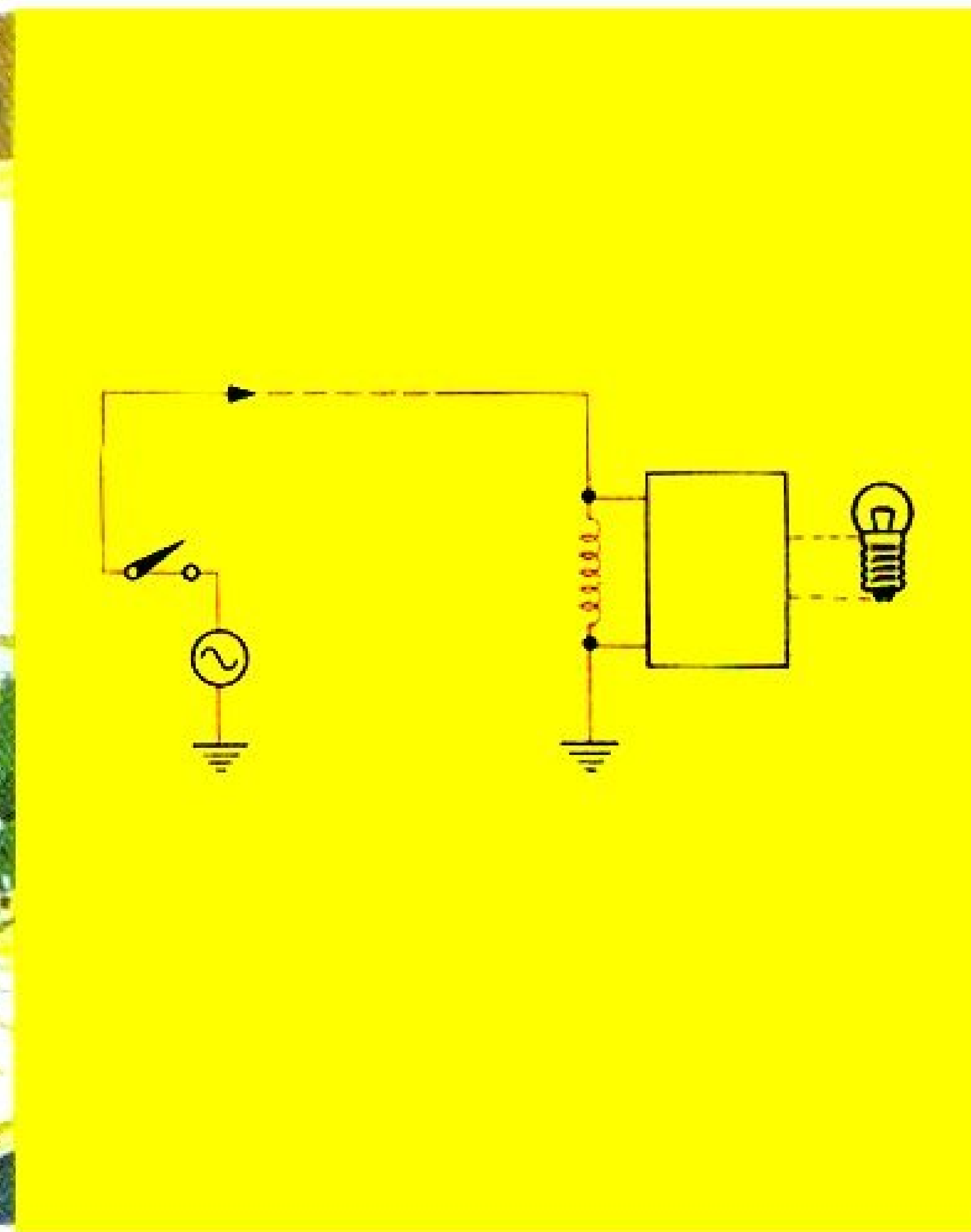
We have already said that an aerial must be compared to a capacitor. So long as the aerial is not particularly big the capacitance of this capacitor is relatively small. That is why only alternating current of very high frequencies can be sent successfully through such an aerial.



the aerial wire and the wire leading to it. What have we now? When we connect an alternating current between aerial and earth, an electric and magnetic field occur together, and simultaneously. A combined field of this nature is called an electromagnetic field. What happens now? An electromagnetic field like this propagates itself very far. It propagates itself through space, roughly in the same way as light does. In fact light is also an electromagnetic field. The radio electromagnetic field we are dealing with behaves in a somewhat different way, however. Light, as yo know, does not pass the horizon. Radio waves, except in special cases, do. It is only when the radio waves are of a The frequencies can be 100,000 c/s (100 kc/s) or even higher, for instance 1,000,000 c/s (1 Mc/s).

What happens now when the electromagnetic field strikes an aerial which is some distance away from the transmitting aerial? In this case the field generates a voltage between the wire of the receiving aerial and the earth. If we now connect a coil between the aerial and the earth, the result will be a current running through the coil. This is a very, very small current but with the help of transistors it can be further amplified. The field is however, electromagnetic and the magnetic part of this field will flow directly through what we call the

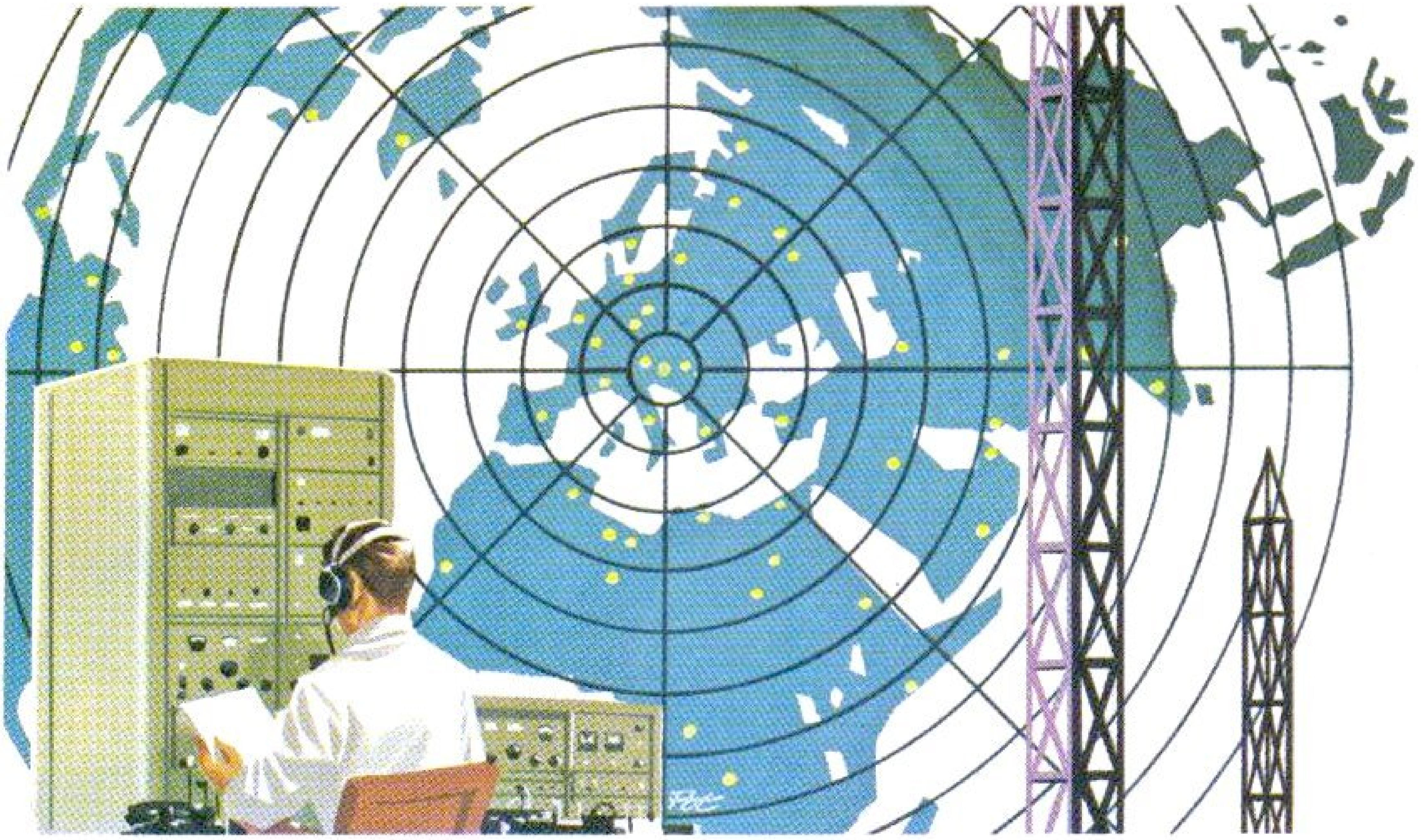
aerial coil. This magnetic part will itself generate a voltage in a coil as you may remember. We can therefore drop the aerial wire and use a coil as a receiver aerial.
However, you will realise that an ordinary coil can never capture as much of the electromagnetic field as an aerial which is perhaps ten or twenty yards above the ground and may be ten or twenty yards



long. A good out-side aerial has a far greater receiving capacity than any little coil.
What happens now if we put an iron core in such a coil? Iron has the property of attracting and concentrating a magnetic field. When a magnetic field is of a very high frequency, ordinary soft iron cannot follow the changes and other materials, such a ferroxcube are used. A ferroxcube core in a coil collects so much magnetic field, that the coil behaves like a far larger coil. Without the ferroxcube core the aerial coil in you radio receiver would have to be almost a yard in section instead of just $\frac{3}{8}$ inch in order to give the same results. Now when we send an alternating current with a frequency of 1 Mc/s through a transmitting aerial, an alternating voltage of the same frequency will occur in a receiving aerial, even hundreds of miles away, irrespective of whether this is just a wire on the roof or what is called a ferroceptor, that is, a coil with a ferroxcube core.
However, a vibration of 1 Mc/s cannot be heard and so we cannot listen to this wireless wave directly. We can however, use it to carry our music, speech or telegraphy signals. First an example of telegraph:.
Just imagine you can amplify the currents flowing through your aerial coil sufficiently to light a little lamp. When the transmitter broadcasts for a very short time the lamp lights up for a short time and when the transmitter broadcasts for a somewhat longer period, for instance, a half a second, the lamp will burn for half a second.
Now imagine you have a transmitting key connected in the transmitting aerial. Aerial current only flows when the transmitting key is pressed down. If you

let an operator do that, then dots and dashes are broadcast which, when put together, form letters, words and sentences.

When a second operator looks at the lamp in the receiver he sees the dots and dashes and knows what is being tapped out hundreds of miles away. When transmitting sound things are set about in rather a different way. Just assume that you now? The carrier wave becomes stronger and weaker one thousand times per second. This getting stronger and weaker is far too fast and the lamp cannot follow it. If we replace the lamp by a loudspeaker we hear . . . . nothing. The diaphragm of the loudspeaker would have to move back and forward one million times per second, a task it cannot perform as it is far too heavy.

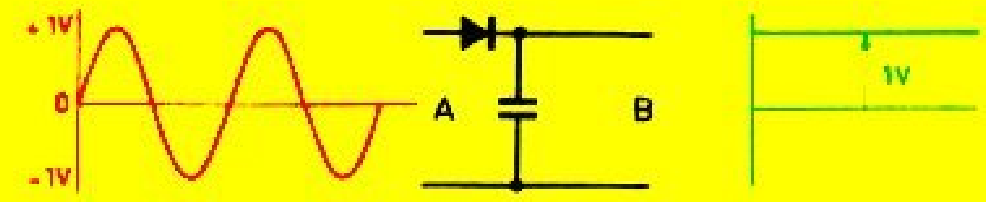


replace the morse key by a variable resistor. When the resistance is small a large amount of current goes through the transmitting aerial; when the resistance is great a small current will flow through the transmitting aerial. If somebody in the broadcasting station turns the resistor knob, the lamp in the receiver will burn either brighter or less brightly. Assuming he turns the knob back and forward three times per second then the little lamp in the receiver will also burn brighter or less brightly three times a second. Now let us assume that he does not do this three times a second but for instance a thousand times a second. What will the transmitted wave look like

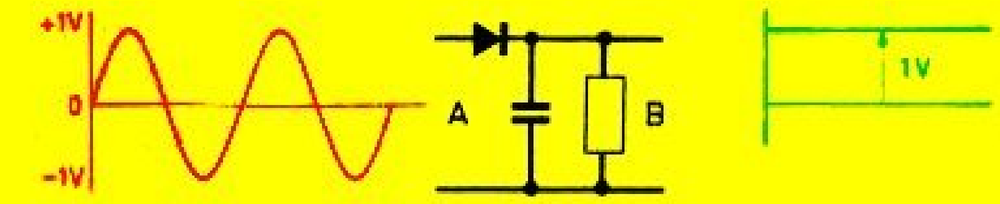
We want to reproduce the 1000 Hz again and therefore we rectify the carrier wave which has been modulated by it.

This rectifying process goes as follows: When we feed an AC voltage of 1 V. to the terminals A, we will measure a DC voltage of 1 V. at the terminals B (Fig. J). Only (he positive pulses of the voltage can pass the diode and charge the capacitor to 1 volt.

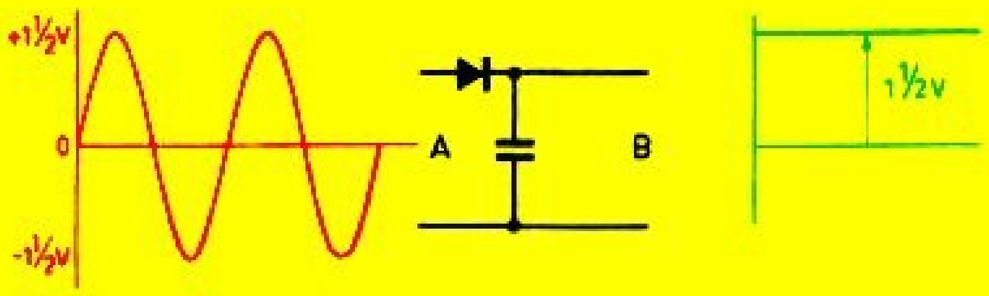
If we raise the AC voltage to $1\frac{1}{2}$ V. the DC voltage will also rise to $1\frac{1}{2}$ V. (Fig. K). If we lower the AC voltage to $\frac{1}{2}$ V. then the DC voltage will remain $1\frac{1}{2}$ volt, however, because the capacitor cannot discharge (Fig. L). We now switch a resistor in parallel with the capacitor, and then the



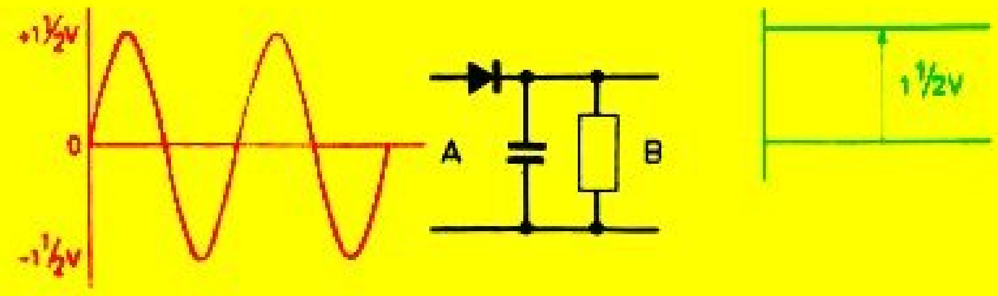
J



M



K



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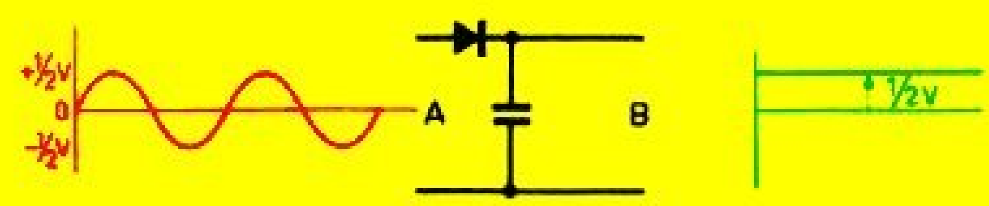
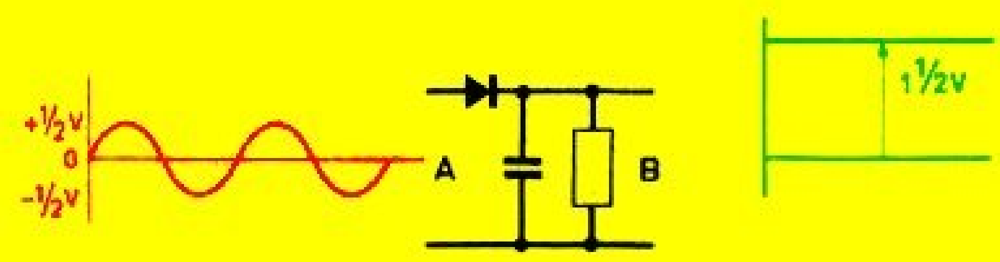


ERRATUM: The green graphs of figs. L and O should change places.

L



O

capacitor can discharge over the resistor and the DC voltage will follow the AC voltage in value (Fig. M, N, O). Now take the modulated carrier wave, which is in fact a varying AC voltage, and feed it to the terminals A. (Fig. P).

At the terminals B. we only get the DC voltage variation.

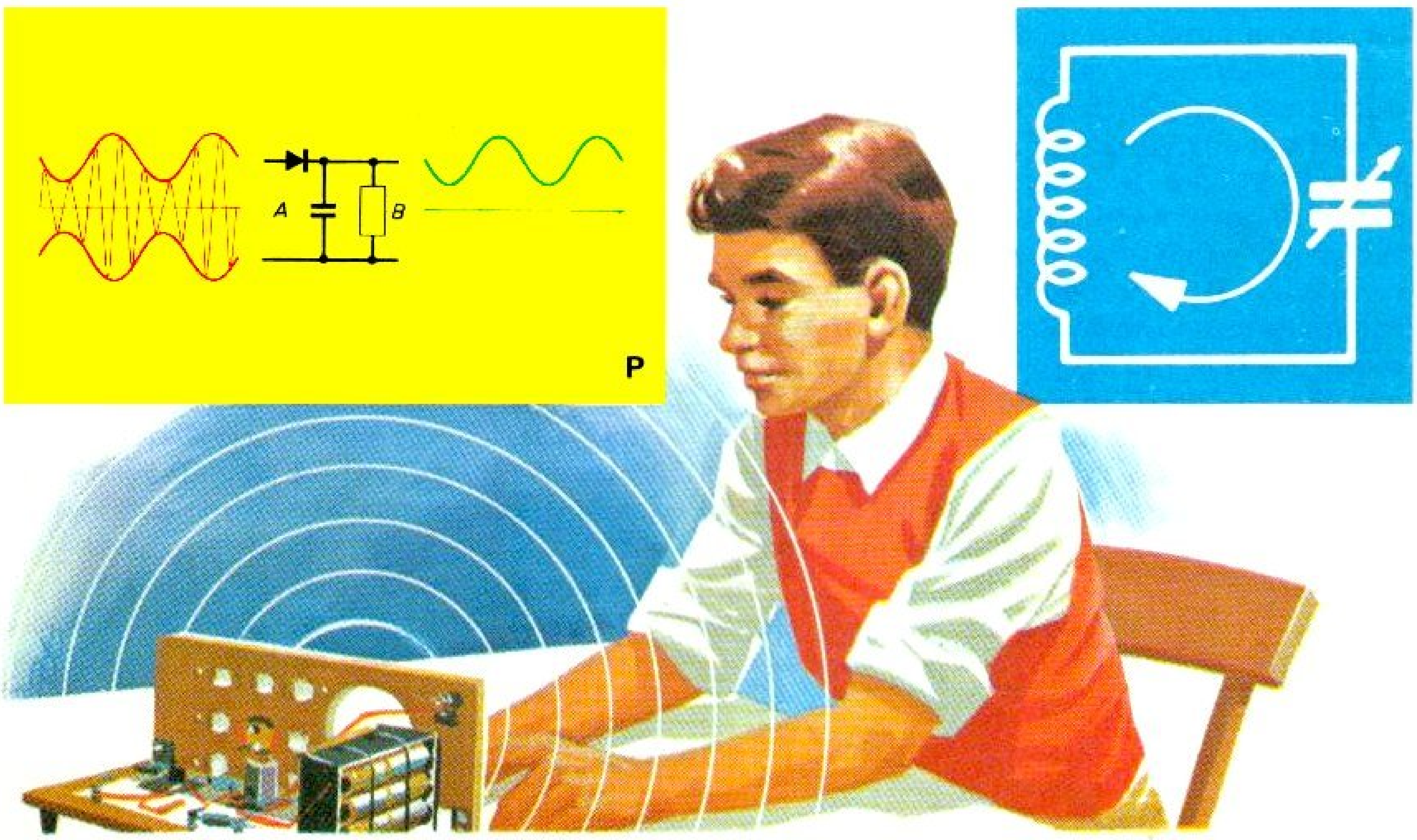
In reality the resistor is the loudspeaker. The DC variation activates the coil and the 1000 Hz is reproduced by the loudspeaker.

It is of course impossible to modulate the carrier wave with a knob, but we can e.g. use a microphone as a modulator instead. Then the carrier wave, will be modulated in accordance with the sound vibrations which have struck the microphone. If anyone sings a high note in front of a microphone then the carrier wave is modulated with a high note. If he sings a low note, the carrier wave is modulated with a low note. The receiver will thus reproduce these notes exactly.

TUNING

Of course you have known for ages how to tune a wireless receiver. It is a different thing however to know precisely what takes place. We have told you that the resistance to alternating currents of a capacitor drops as the frequency gets higher. On the other hand the resistance to the alternating current of a coil increases the higher the frequency gets. What happens now if we connect a coil to a capacitor? At one particular frequency the A.C. resistance of the coil will be exactly equal to the A.C. resistance of the capacitor. It depends entirely on the values of coil and capacitor at what frequency this takes place, and something very curious happens at this frequency.

If the capacitance of the capacitor is changed, then this phenomenon, known as resonance will occur at another frequency. All transmitters broadcast a carrier wave and the frequency of this carrier wave differs for each transmitter. At a given position of the tuning capacitor only one transmitter will bring about a powerful circular current. The circuit is therefore in resonance for that one



The currents which flow through coil and capacitor are, of course, identical. This is not quite so strange for, as you know, the same voltage and the same resistance means the same current.

What is odd, is that they chase each other in circles. The total current seems to flow in a circle through coil and capacitor and keeps going round and round as if it did not want to leave. It is so pleased that the A.C. resistances of capacitor and coil are the same that at the particular frequency, the current through the coil and capacitor becomes very high. At all other frequencies this current is much smaller.

transmitter, but not for any of the others. The other transmitters are therefore heard much less clearly, so that in most cases they are no longer audible. If we now turn the capacitor, the circuit can come into resonance with the carrier wave of another transmitter and we receive this one instead.

ELECTRONIC MEASURING AND SIGNALLING

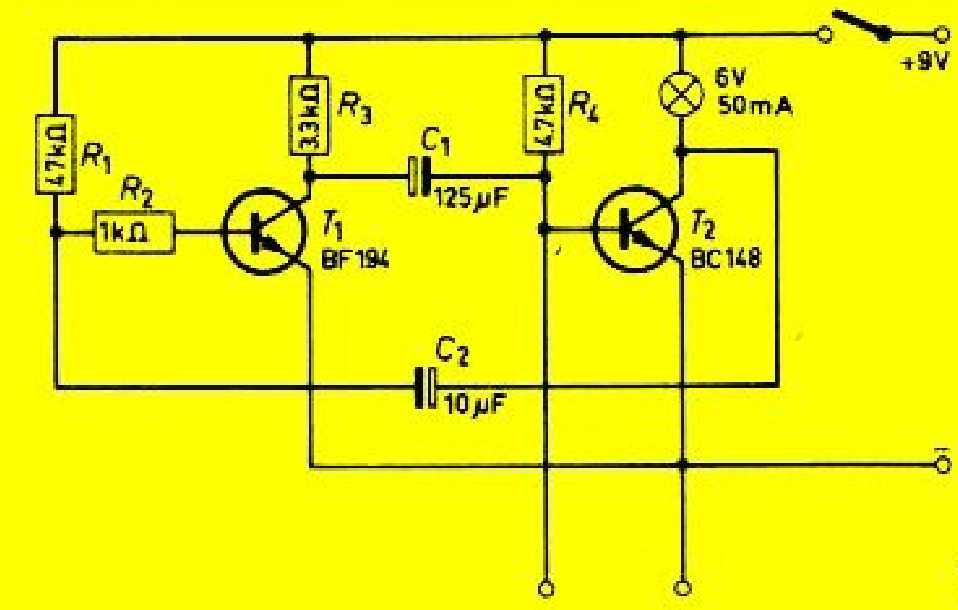
In the technical field and in daily life, a great deal has to be controlled and measured. Both in the elementary school and in the secondary school, to say nothing of technical colleges, pupils are

still plagued with sums in which measurements are carried out. So many pints of water in so many pints of wine, or the container out of which water flows, and what happens when, etc. etc.
With the help of electronics you can measure how much petrol there is left in the tank, what the temperature of an oven is, whether the floor is too damp and, for instance, whether a mixture of two materials is in the proper ratio. When you mix two materials in a machine, it may be possible not only to measure whether the mixture ratio is correct, but also to regulate the taps, in such a way that the correct ratio is automatically maintained.

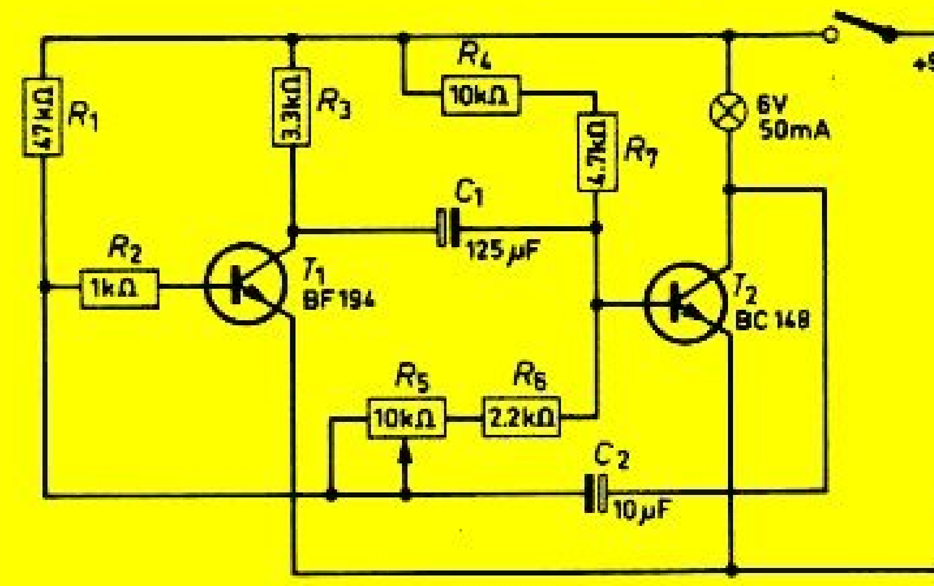
You can use controls to ensure that the temperature in a room remains constant, irrespective of whether it is cold or hot outside. Just think of the refrigerator.
It is also possible to switch on a lamp after a certain period of time, determined in advance. Electronic signalling can also be used as a warning, in the form of a flashing light, that danger is in the offing, or as a smoke detector to warn against fire in buildings or stock rooms. Electronic signalling is therefore extremely useful.
You can no doubt think of many ways to make practical use of the circuits in the kit.

CIRCUIT DESCRIPTIONS AND DATA

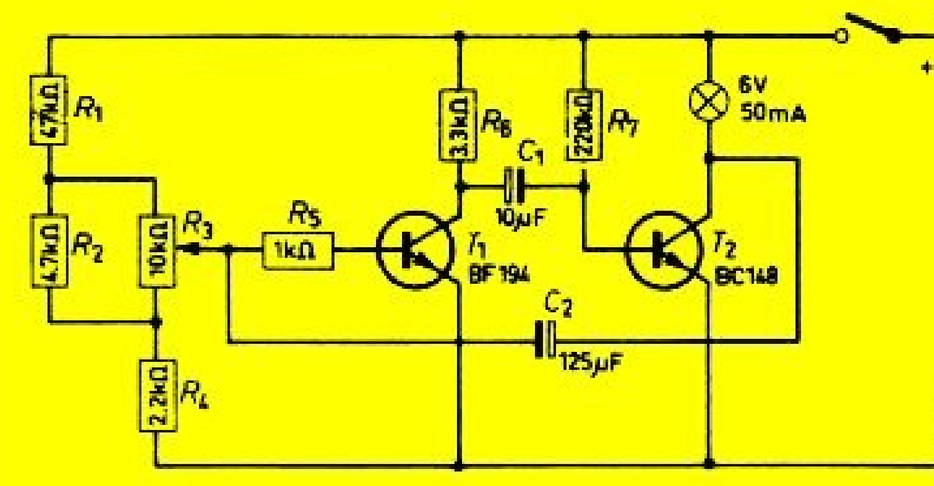
Flashing Lights



1



2



3

Flashing lights are used a great deal in the world of today. They are used for many diverse purposes such as warning lights, direction indicators on cars, traffic lights, aeroplane beacons, obstacle lights, alarms etc. Turning the light on and off can be done in a number of ways. It is often done with the aid of a relay switch, but transistors are used for this purpose more often nowadays, since they have no contacts to burn out and no moving parts to wear out.

Circuit diagram 1 depicts the way transistors are connected up to make an automatic flashing light. The transistor T2 switches the lamp current on and off, while the transistors T1 and T2 together with the resistors and capacitors determine the rate at which this happens. The rate of flashing is not very fast as you will notice. This can be speeded up by replacing the resistor R1 of 47k ohm by a resistor of 10k ohm.

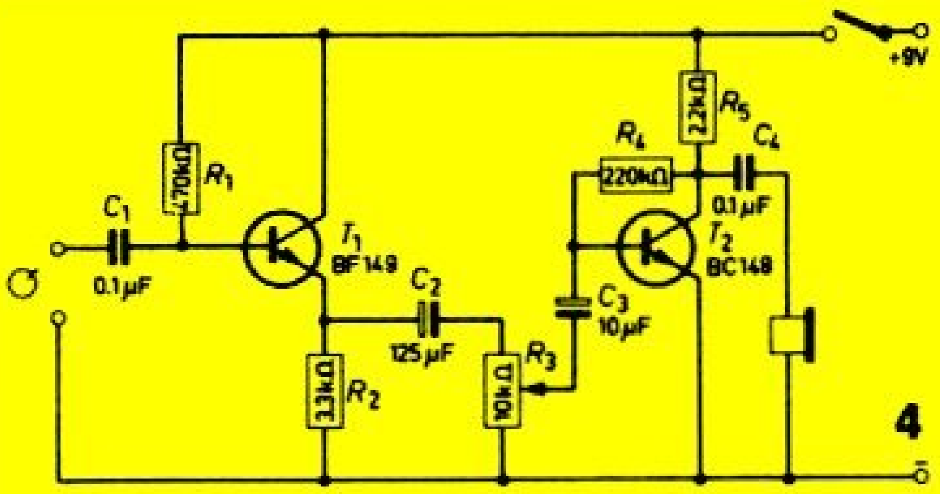
This circuit can also be used to construct a burglar alarm. The two outside contact springs are connected to two metal drawing pins on a doorpost or a window frame. A piece of metal foil on the door or the window makes contact between the two tacks. The light stays off as long as the door or window remains closed. As soon as the door or window opens, the contact is broken and the light starts flashing. Should the intruder be smart enough to cut the wire before opening the door, then the contact is broken any way and the light will start flashing just the same.

The rate of flashing can also be regulated continuously. Such a flasher is shown in circuit 2. The required effect is produced by connecting a variable resistance in series with a fixed resistance between the base connections of the two transistors.

The circuit of diagram 3 provides flashes of short duration, which are used for traffic beacons for instance. The flashing rate can be adjusted with the variable resistor R3, usually called the potentiometer.

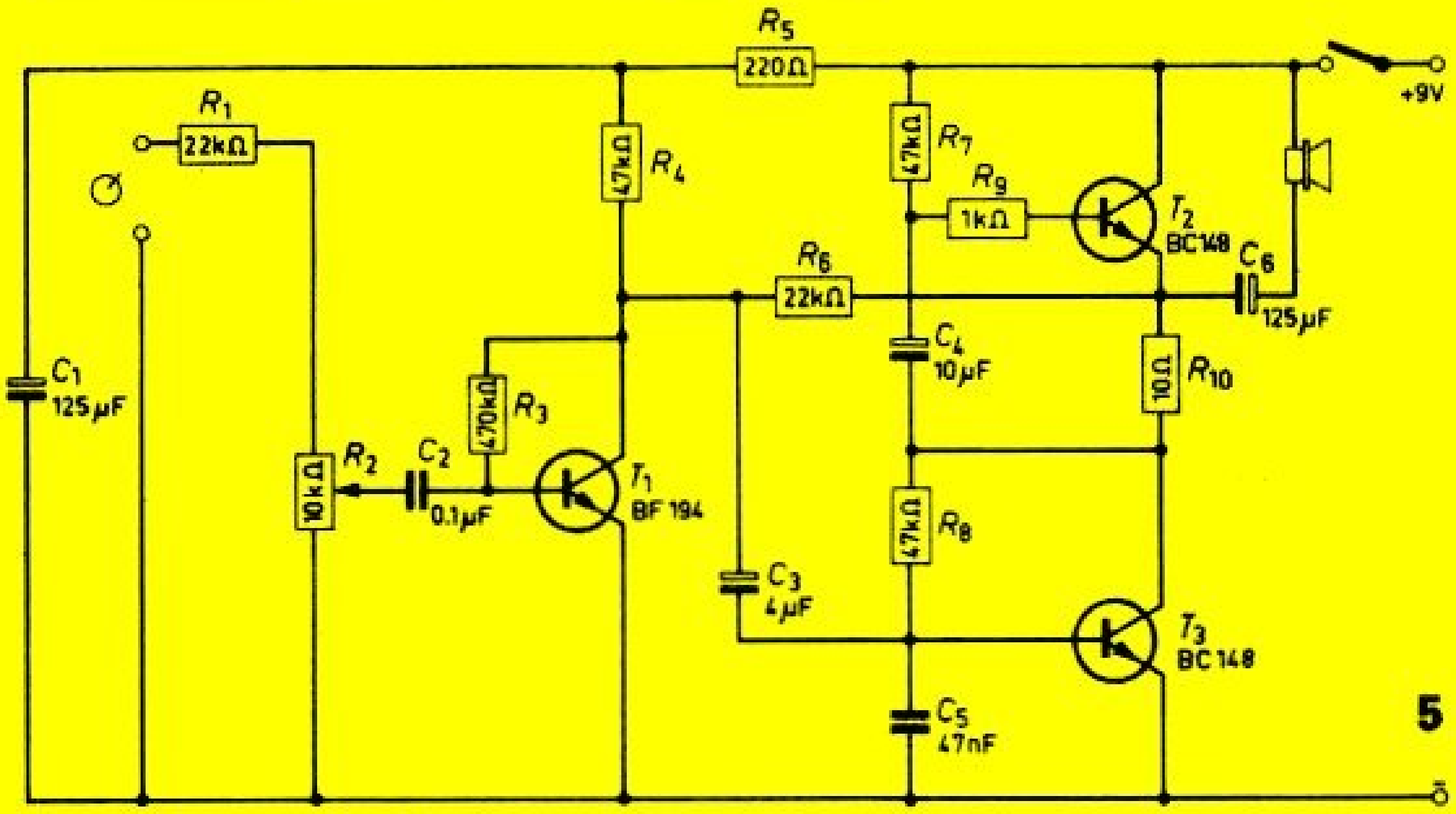
Gramophone amplifiers

Early gramophones were cumbersome affairs, largely due to the fact that to reach a sound level, loud enough to be heard, big horns had to be attached to the pick-up needle. Not only was the sound rather bad, but the effect on the record itself was quite damaging. The electronic amplification of sound has opened up the road to featherlight pick-ups, high levels of sound and the correction of inherent shortcomings of some components to produce sound of as good quality as possible with the available means. A

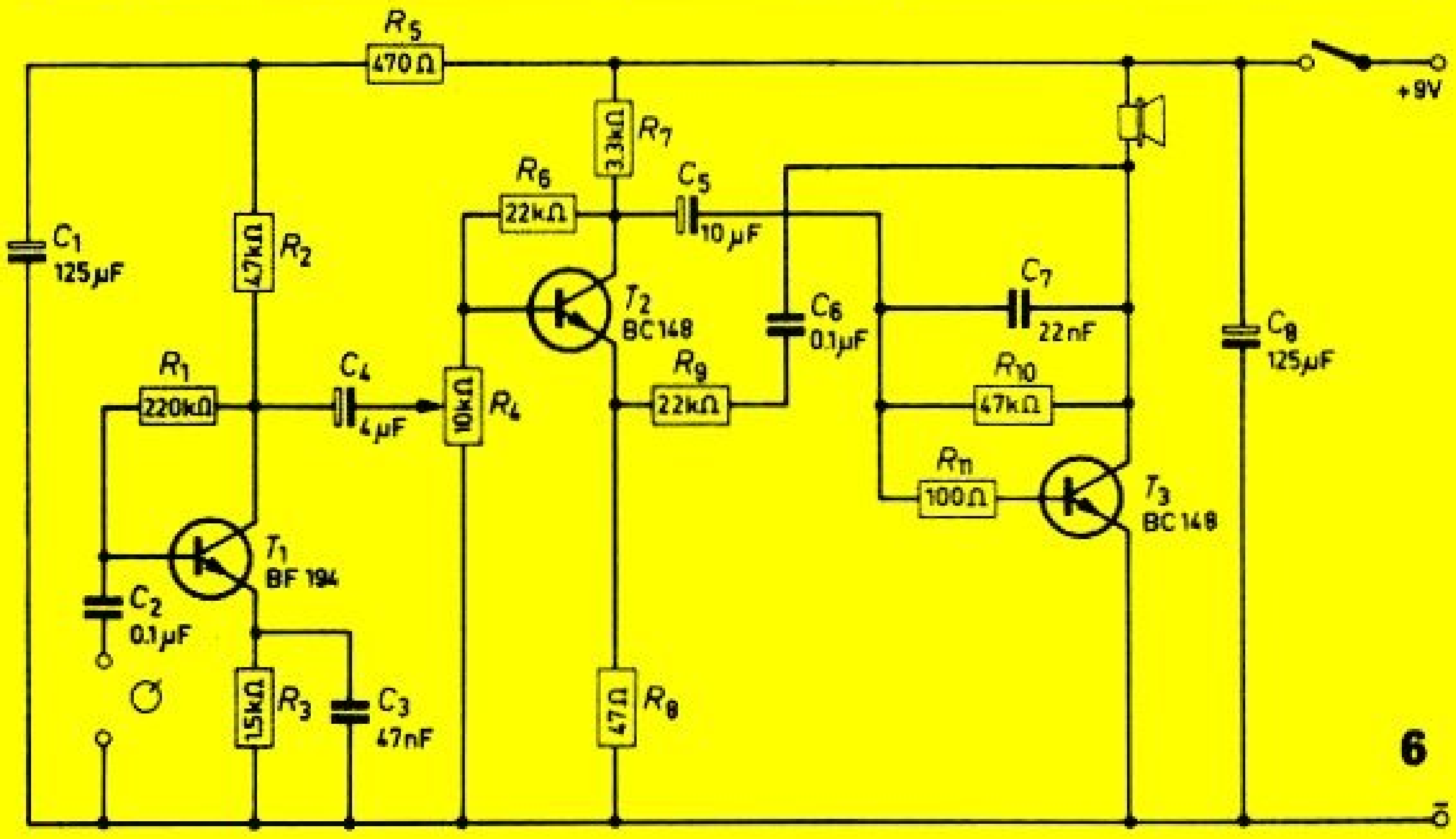


4

Fig. 16



5



6

record player has a screaned cable to connect it to an amplifier. Attach the screen (a) to the minus and the one or two cores (b) to the other connection spring (Fig. 16). Circuit 4 describes a gramophone amplifier for earphone output. The volume is controlled with the potentiometer.

Circuit 5 is a gramophone amplifier with loudspeaker output. The output stage is technically known as a single ended push pull output stage, which is used in many commercially available radios and amplifiers.

Circuit **6** is equipped with the provision to correct the frequency response deficiencies of pick-ups. Where pick-ups tend to reproduce low and high frequencies with less sensitivity than the ones in between, this amplifier corrects this tendency by amplifying these frequencies more than the others. In this way better reproduction of a gramophone record is obtained.

Automatic nightlight or parking light

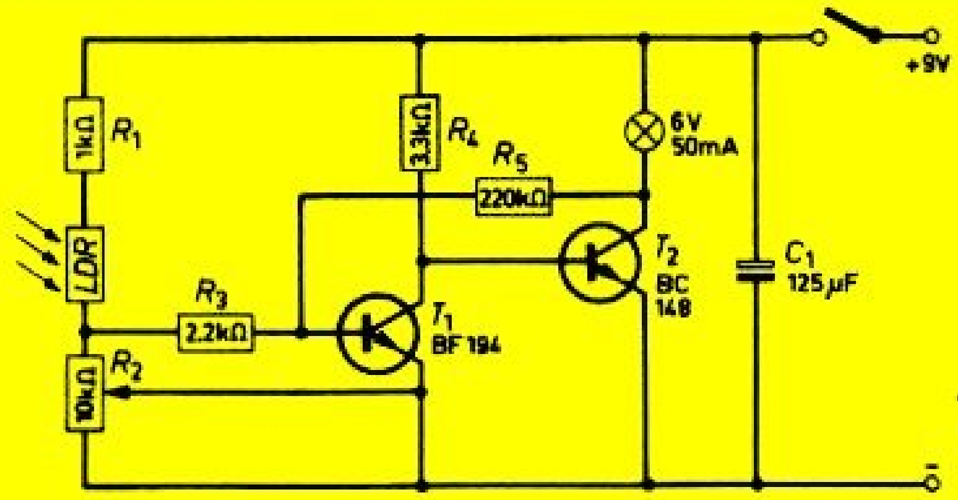
Street lights go on when it gets dark. Does somebody switch them on? No. It is done automatically.
Circuit 7 does the same thing; the light dependent resistor (L.D.R.) senses the change of light and activates the switch made up of the two transistors. With the potentiometer, the level of light at which this happens can be adjusted.
When the L.D.R. receives less light from its surroundings its resistance increases. This in turn decreases the current through transistor T1 and resistor R4. The voltage on the collector of T1 and the base of transistor T2 increases and this makes the transistor T2 conductive. The lamp lights up. The effect of switching over is amplified with the aid of resistor R5 of 220 K ohm.
When the surrounding light comes back on, the opposite effect takes place and the lamp goes out again. Besides street lights, these circuits are used for turning on advertising displays, car parking lights, emergency lights etc.

Moisture indicator

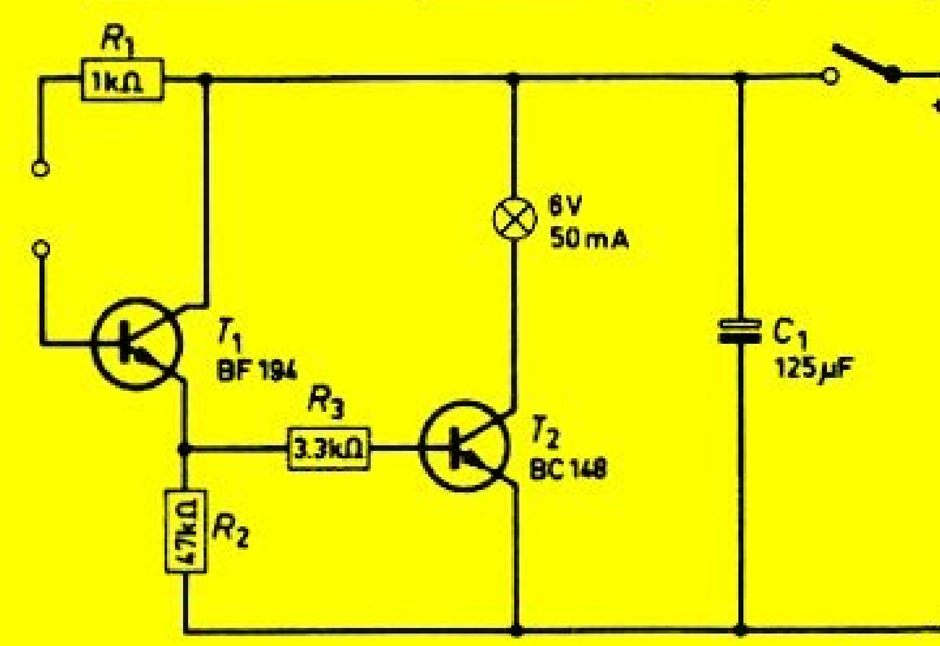
You have undoubtedly heard of the convertible car which automatically closes its hood when it starts raining. How is it done?
Let us take a piece of paper (not the waterproof kind) and tape two bare wires on it at a distance from each other. Dry paper does not conduct electricity if not specially prepared to do so.
Now water, when not in its purest form, does conduct electricity. Therefore when water is absorbed by the piece of paper, the wet paper can conduct electricity.
In circuit 8 this effect is used to turn on a lamp. The current through the wet paper that is connected to the input with the two wires, is amplified in two stages and lights the lamp. In our convertible a motor is switched on which closes the hood.
When the paper dries out again, the lamp goes out.
Two electrodes near the top of a vessel indicate that the vessel is full, when water connects them.

Burglar alarm

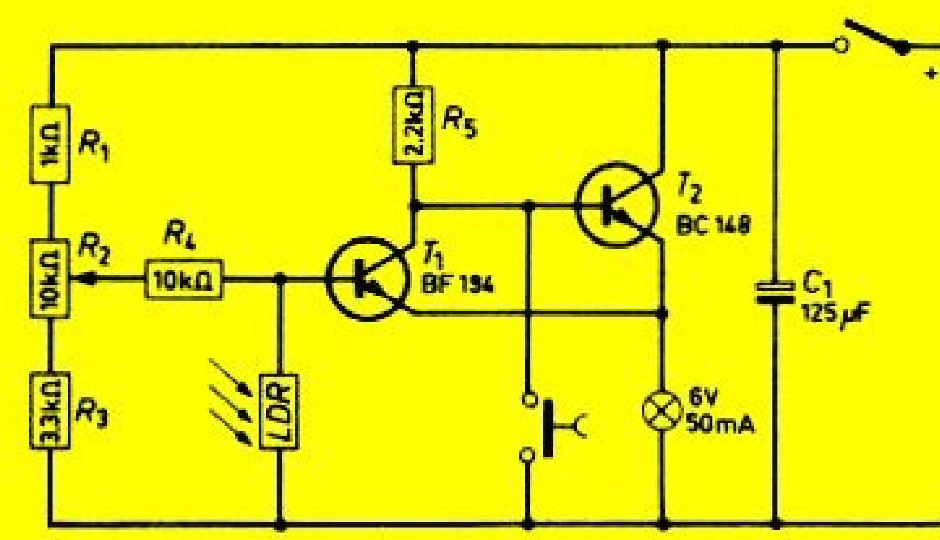
Someone intrudes into a dark room and starts looking around with a torchlight: a burglar. At a distance a warning light flashes on.
Circuit 9 is such a warning installation. When light falls on the LDR its resistance decreases. The voltage on the base of T1 drops and the current through T1 decreases, the voltage on the base of T2 increases and T2 switches on and the lamp lights. Even when the light on the LDR disappears again the lamp remains lit, so that afterwards you can tell that somebody was in. The circuit can be restored to its original state by pushing the reset button. The level of light at



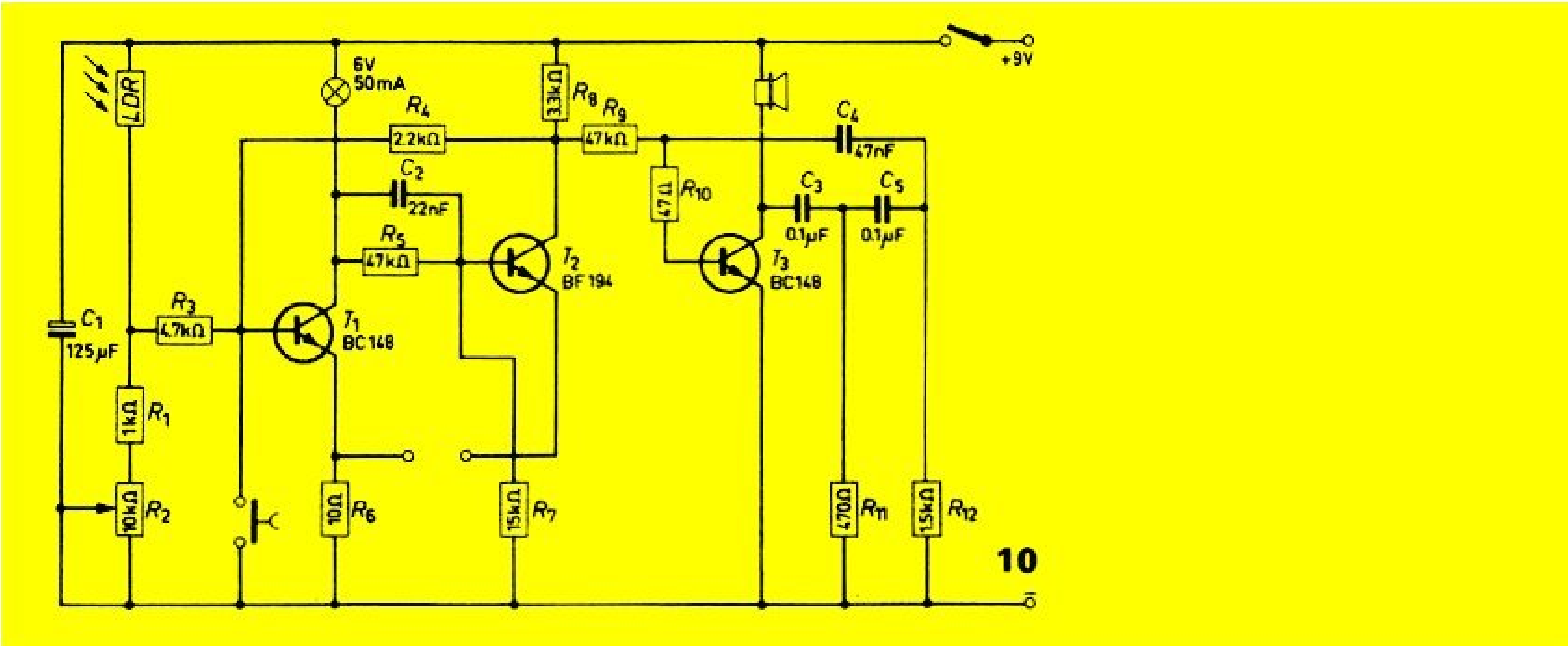
7



8



9



which this alarm operates can be set with the aid of the potentiometer.
Circuit 10 not only reacts to a light on the L.D.R. but also acts on the opening of a door or window, in the same way as described in circuit 1. Besides a lamp that lights up, the alarm also sounds off. It is reset in the same way as circuit 9.

Acoustic relay

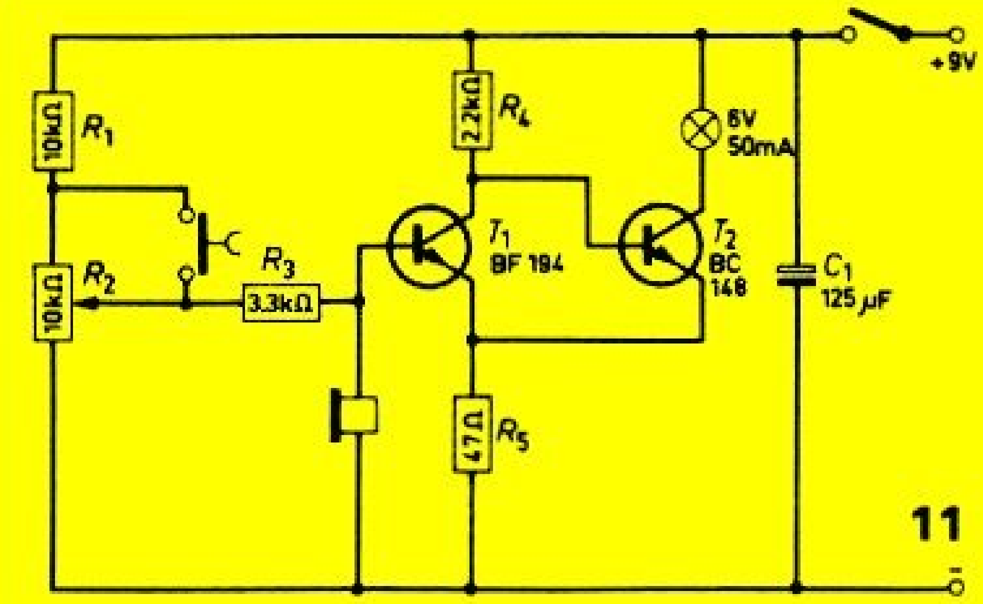
Sound waves can trigger off a circuit just as in the case of the burglar-alarms. In circuit 11 the earphone is used as a microphone. The voltage generated when sound hits the microphone trips the transistor switch and lights the lamp. The sensitivity is adjusted with the potentiometer. This has to be done very carefully to obtain maximum performance. With the button the circuit can be reset once it has been triggered. A very sensitive circuit, and one that also reacts to light is shown in circuit 12. The loudspeaker is used as a microphone and the sensitivity is again adjusted with the potentiometer. A button is also provided to reset the circuit. This circuit is well suited to warn against intruders since it picks up the slightest noise.

Morsecode trainer

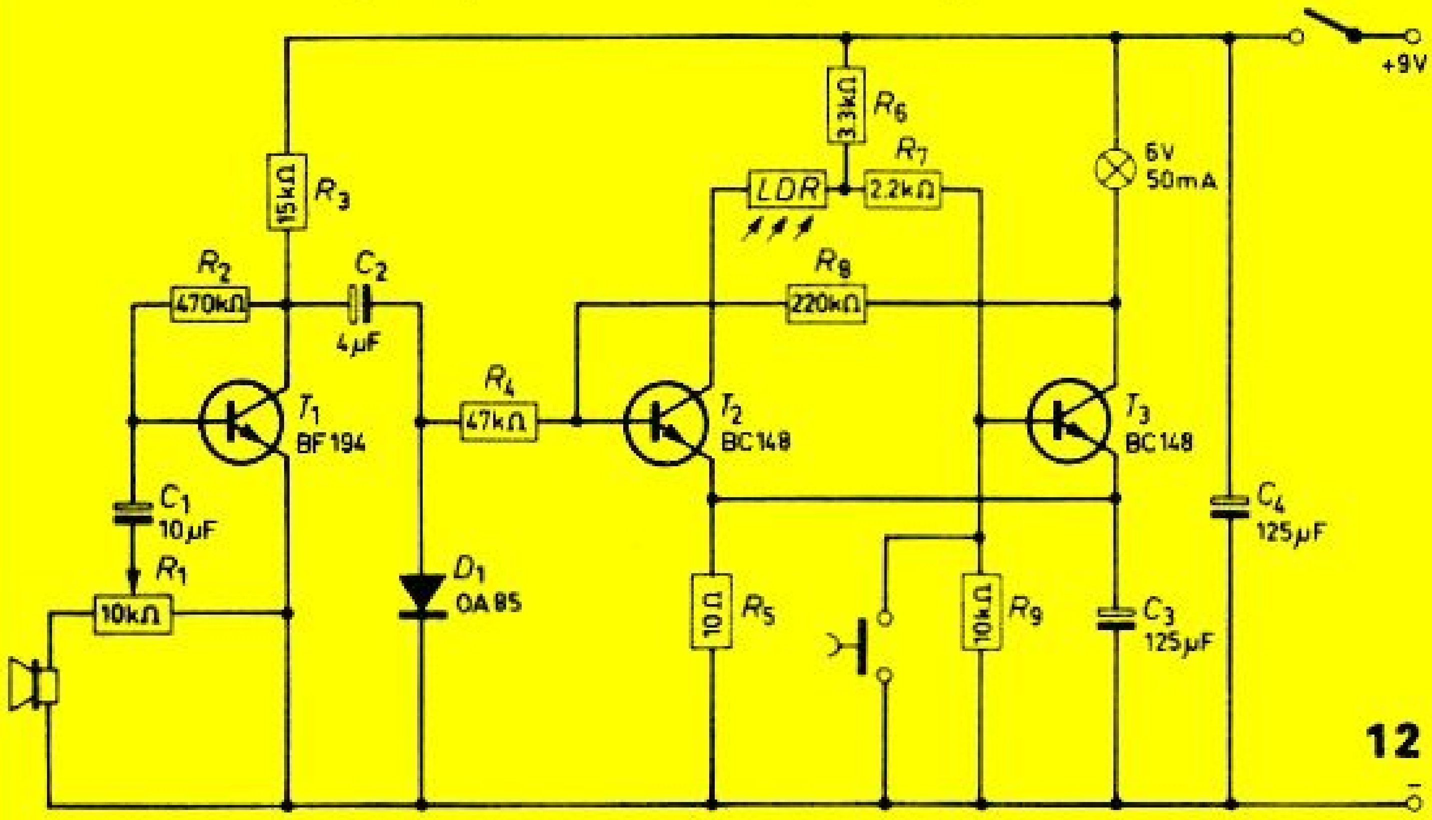
To be able to send messages this way you need a morsecode trainer in order to learn the code. Circuit 13 is such a trainer. Each time the key is depressed the circuit generates a sound which is made audible in the earphone. The volume is controlled with the potentiometer. Circuit 14 serves the same purpose but it is provided with loudspeaker output. In parallel with the push button are two spring connections to connect a real morse key.

Sound

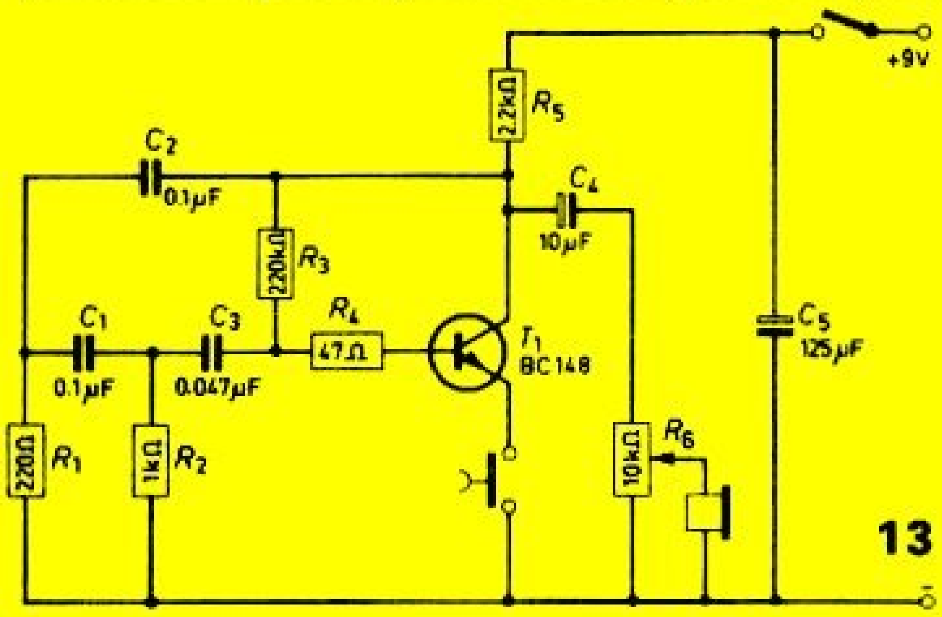
Sound is electronically generated for a great many purposes. One example is the morse code trainer above, but there are also musical instruments whereby the sound is electronically generated for instance in the case of electronic organs. Another field in which sound plays an important role is in the transmission of information from radiosondes, rockets


+9V
10kΩ R1
10kΩ R2
R3 3.3kΩ
2.2kΩ R4
T1 BF 194
T2 BC 148
6V 50mA
C1 125µF
47Ω R5

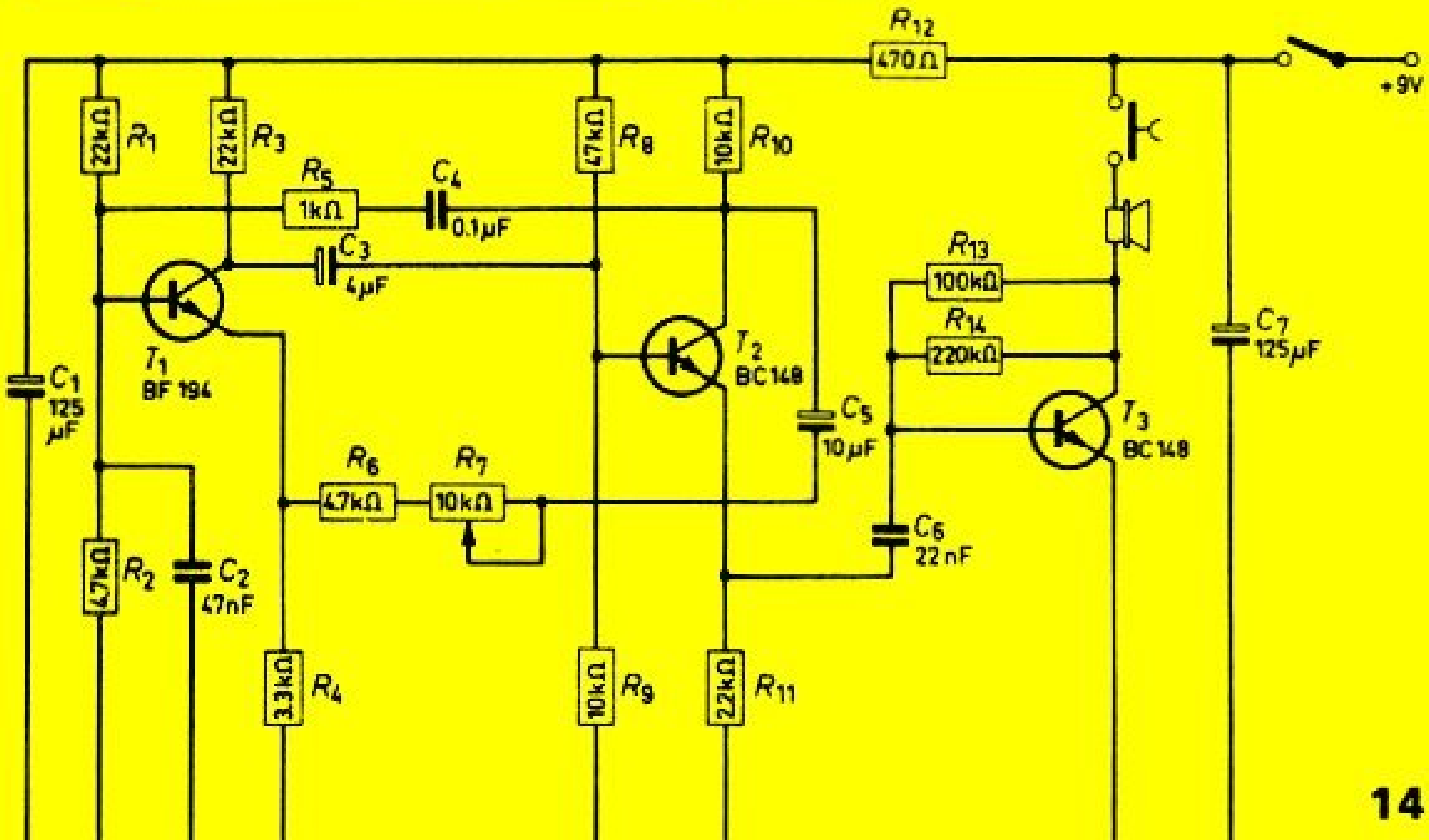
11


+9V
15kΩ R3
R2 470kΩ
C2 4µF
T1 BF 194
C1 10µF
R1 10kΩ
D1 OA 85
R4 47kΩ
3.3kΩ R6
LDR
R7 2.2kΩ
R8 220kΩ
T2 BC148
10Ω R5
10kΩ R9
T3 BC148
6V 50mA
C3 125µF
C4 125µF

12

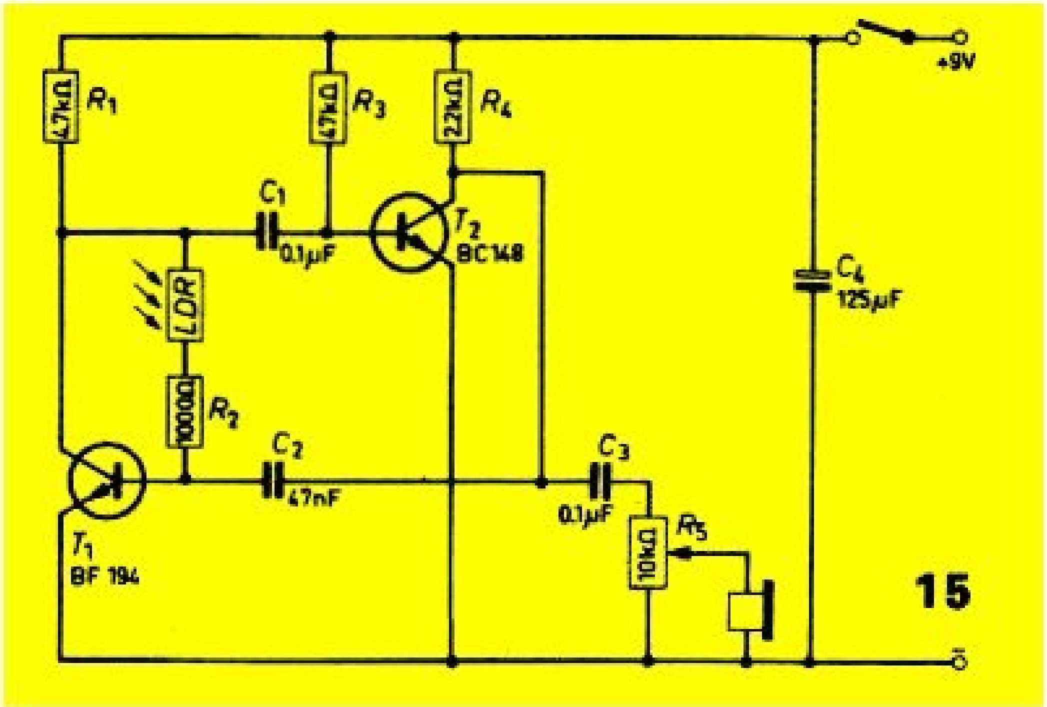

+9V
2.2kΩ R5
C2 0.1µF
220kΩ R3
C1 0.1µF
C3 0.047µF
R4 47Ω
T1 BC148
C4 10µF
220Ω R1
1kΩ R2
10kΩ R6
C5 125µF

13


R12 470Ω
+9V
22kΩ R1
22kΩ R3
R5 1kΩ
C4 0.1µF
C3 4µF
47kΩ R8
10kΩ R10
T1 BF 194
C1 125 µF
T2 BC148
C5 10µF
R13 100kΩ
R14 220kΩ
T3 BC148
C7 125µF
R6 4.7kΩ
R7 10kΩ
C6 22nF
4.7kΩ R2
C2 47nF
3.3kΩ R4
10kΩ R9
22kΩ R11

14

and satellites. One example in which this is done is in circuit 15. The pitch of the sound in this generator is determined by the L.D.R. The L.D.R. changes its resistance under the influence of light changes. Therefore when we connect this L.D.R. across the base and the collector of T1, a change of light will result in a change of pitch. If this sound is transmitted from a radiosonde we know the level of light at the place where the radiosonde is.
This way of measuring at a distance is known as telemetry and besides rocketry and the like, it is also used for measuring in places where it would be impossible for a human being to survive because of heat, pressure, radio activity etc. The sound volume can be regulated with R5.



Variable audio frequency generator

Circuit 16 is a very fine audio frequency generator. In principle two frequencies are generated which are in themselves too high to be audible. These two frequencies are mixed together and the difference can be made audible. By varying either one of the two generators the resultant difference also varies as can be heard through the earphone.
The mixing of the two frequencies is accomplished with the aid of the potentiometer. With little coupling between the two generators the resultant audio frequency is weak. On the other hand a strong coupling results in a tendency of the variable oscillator to oscillate at the same frequency as the other. This results in a zero difference and there is nothing to be heard. The procedure in adjusting this generator is as follows:

1. Turn the variable capacitor all the way to the left.
2. Turn the potentiometer till you can just hear a sound. (Also manipulate the coil on the ferroxcube rod a bit).
3. Adjust the coil on the rod till you hear a very low frequency note. Rotating the variable capacitor to the right makes the sound increase in pich.
4. Turn the potentiometer to the right to increase the sound level. Too much coupling results in a failure to produce the lowest notes. Careful manipulation of the various controls will produce the desired effect.

This type of audio generator is often used in laboratories since it produces a wide range of audio frequencies with a single control.

Ambulance Klaxon

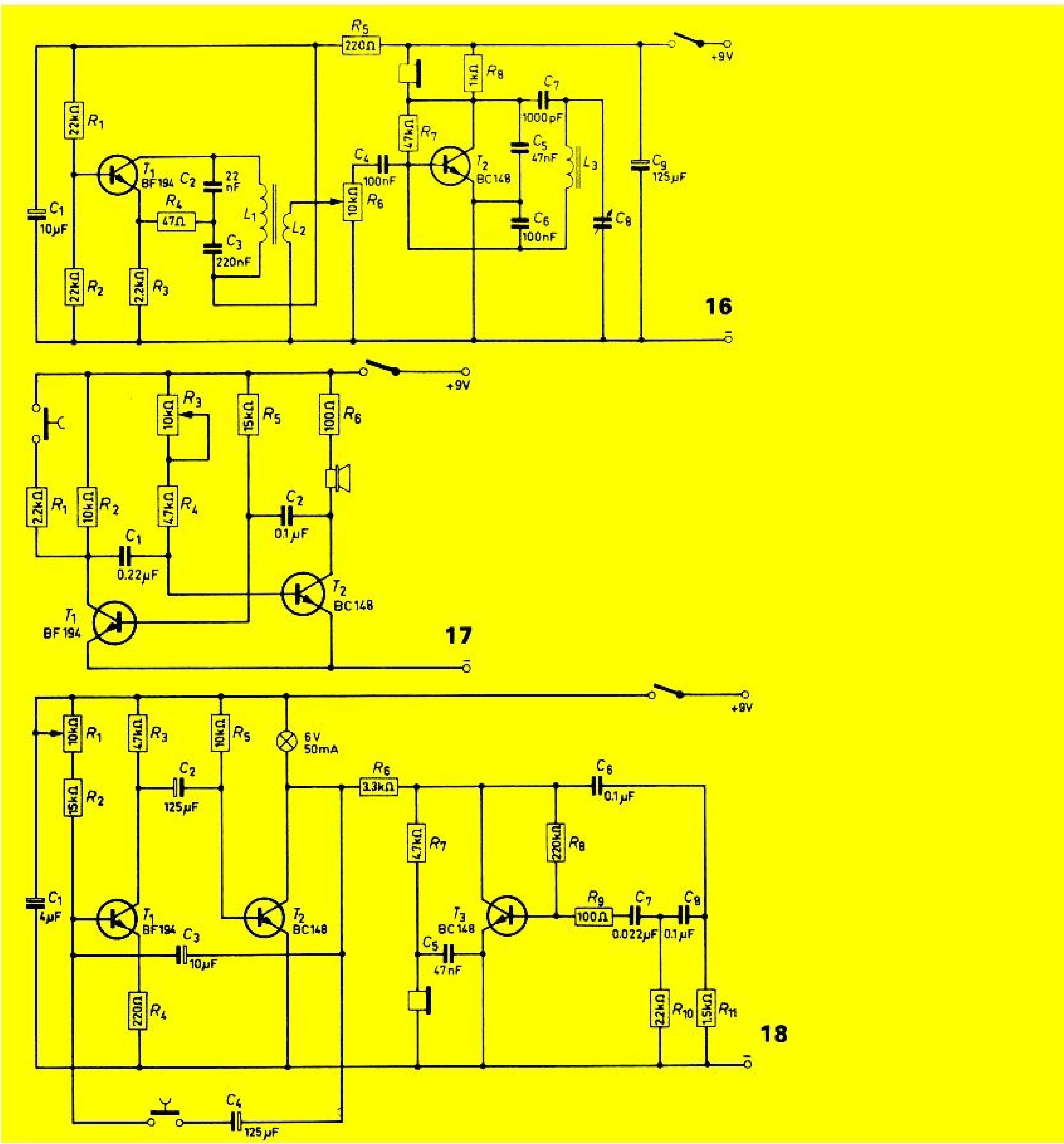
The typical two tone sound of the city ambulance can be reproduced with circuit 17. The pitch can be varied with the potentiometer. With the button depressed the one note is reproduced; with the button released the other one. In fact this circuit is like the one used for flashing light except for the values of the resistors and capacitors. The switching off and on of the transistors goes too fast to be seen with a lamp, but it is now audible through the speaker.

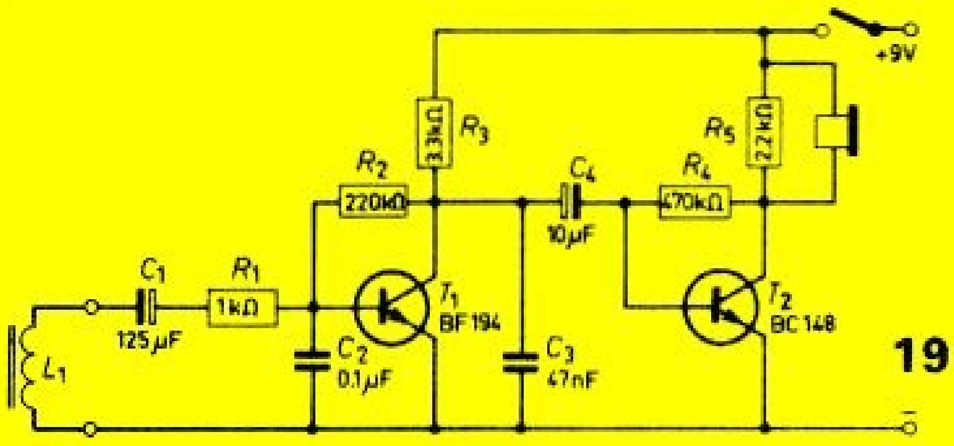
Telephone signal generator

In circuit 18 an installation is described to produce the signals you can hear on the telephone. With the righthand button depressed the calling signal is heard in the earphone. With the button released the engaged signal is heard. In principle the circuit is a flashing light which switches an audio generator on and off. The right pitch can be adjusted with the potentiometer R1.

Telephone pick-up amplifier

Without making any connections to the telephone, circuit 19 can provide you with an extra listening possibility. With the coil from the kit it is possible to pick up the electromagnetic waves which radiate from a transformer inside the telephone. These waves cause a current to flow in the pick-up coil and after amplification this is made audible through the earphone.





19

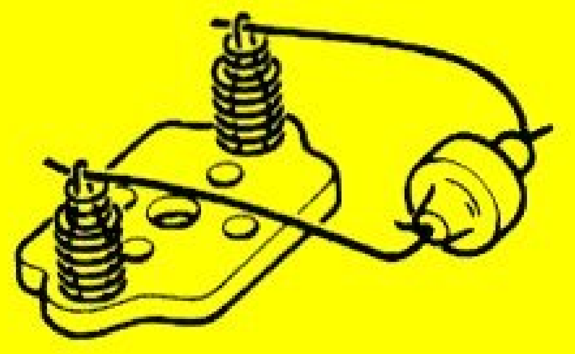


Fig. 17

To find the most sensitive spot on the telephone move the coil around the outside with the phone off the hook till you get maximum value: turning the coil also helps. With a piece of adhesive tape, fasten the coil to this spot. A few metres of wire can be used to connect the coil to the connections on the amplifier. Fig. 17 shows how it is possible to connect the pick-up coil to a cable of a certain length. Keep the wire away from mains leads, since it can pick up hum from them.
Circuit 20 provides loudspeaker output and volume control.
If the telephone microphone is held near the loudspeaker a whistling sound results. In this case either turn the volume down or move the amplifier further away.

Lightmeter

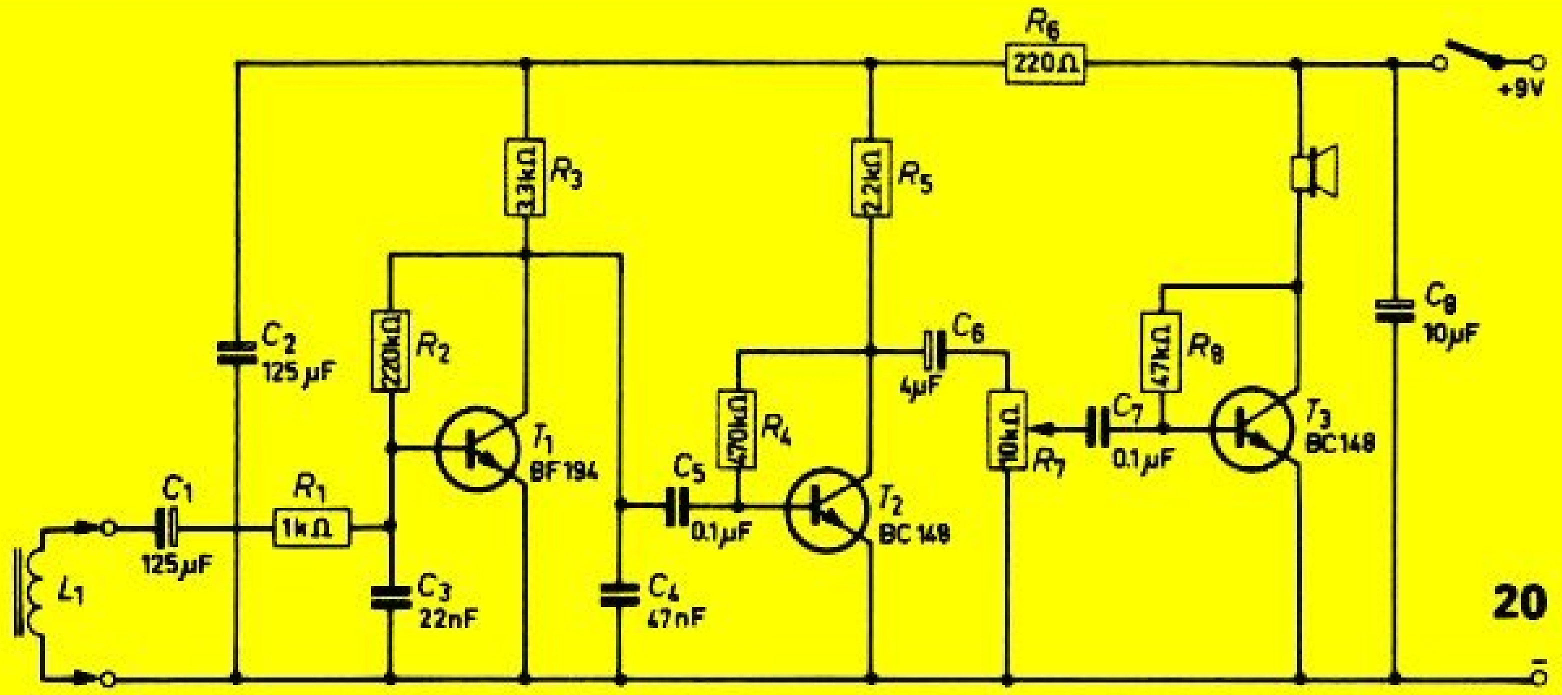
The light dependant resistor in the kit makes it possible to construct a lightmeter. The one in diagram 21 uses a transistor switch with a lamp and potentiometer to determine the light value at the L.D.R.
For each light value a position of the potentiometer can be found whereby the lamp is just on the verge of switching on or off.
For different levels of light the potentiometer must be set at different positions. The position of the potentiometer is therefore a measure of the amount of light falling on the L.D.R.
Modern photography would be unthinkable without lightmeters. Poor lighting results in bad work in industry and therefore lighting plays an important part in the design of modern factories. Lightmeters are indispensable in the architecture of such buildings.

Time switch

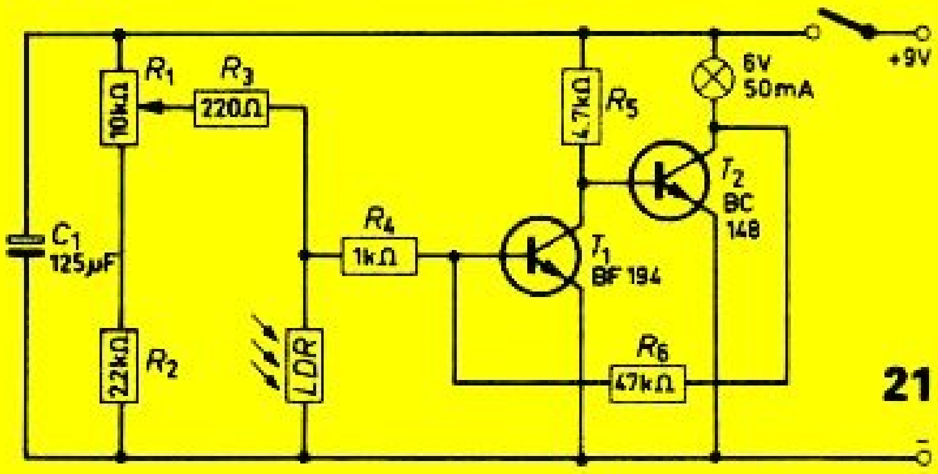
The control of automatic processes frequently calls for a switch, to determine the time in which a particular function is performed. Think, for instance of the fully automatic household washing machine in which each phase of the washing process is timed.
In photographic darkrooms, light sensitive materials are exposed for a carefully controlled time.
Circuit 22 is a time switch which lights the lamp. The time during which the lamp is off, is determined by the value of C1, and the voltage set by the potentiometer. The higher the voltage, the shorter the time before the lamp goes on.

Radio

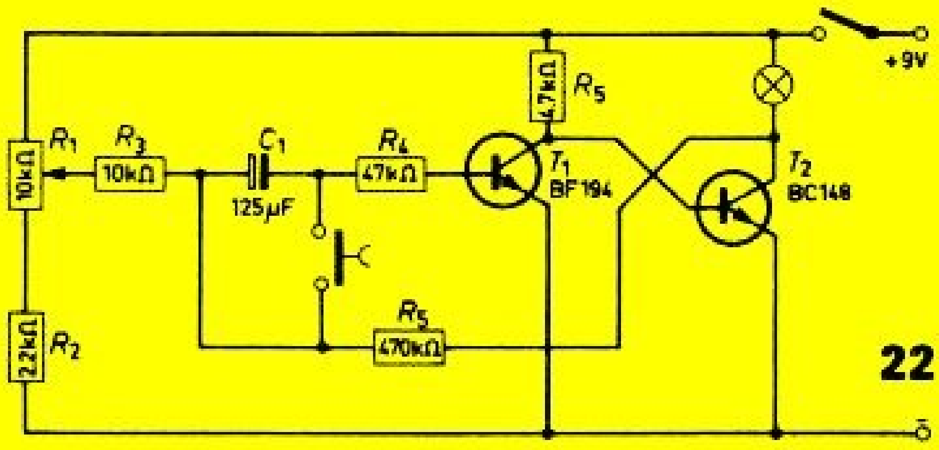
With circuits 23 and 24, one of the most attractive and also the most complicated possibilities of this kit can be built. Since the components are all very close together special care has to be taken to prevent short circuiting. The result will be a radio, receiving stations transmitting in the medium wave range.
To obtain maximum sensitivity with the components available a so-called reflex circuit has been chosen which means that transistor T1 is used first for amplification of the high frequency signal and after detection for amplification of the audio frequencies.
The pointer of the knob is adjusted by turning the variable capacitor all the way to the right and with the pointer on the


R6 220Ω
+9V
R3 3.3kΩ
R5 2.2kΩ
C8 10μF
R2 220kΩ
C2 125μF
C6 4μF
R4 470kΩ
R8 47kΩ
T1 BF194
C7 0.1μF
R7 10kΩ
T3 BC148
C1 125μF
R1 1kΩ
C5 0.1μF
T2 BC148
L1
C3 22nF
C4 47nF

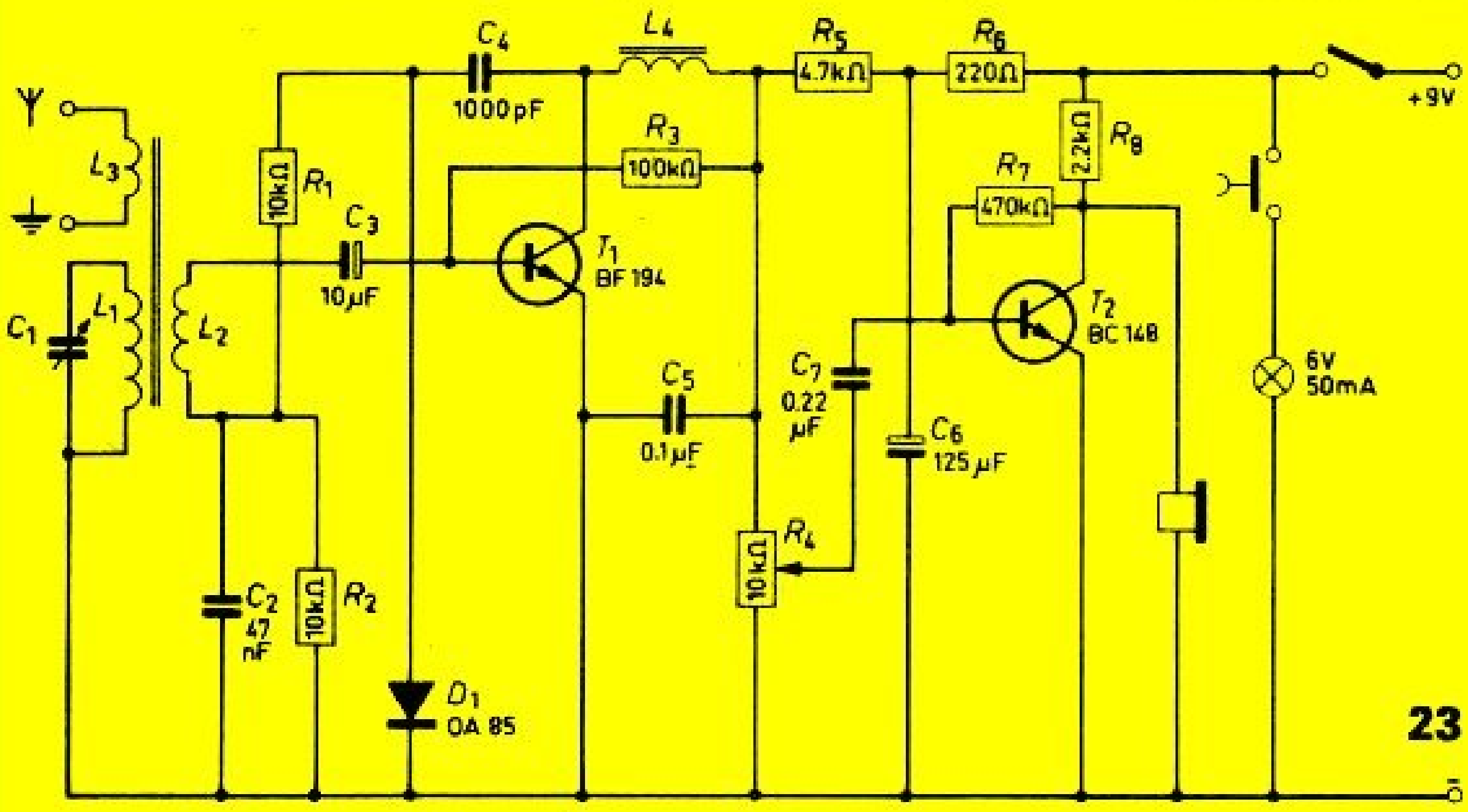
20


+9V
R1 10kΩ
R3 220Ω
R5 4.7kΩ
6V 50mA
T2 BC 148
C1 125μF
R4 1kΩ
T1 BF194
R2 2.2kΩ
LDR
R6 47kΩ

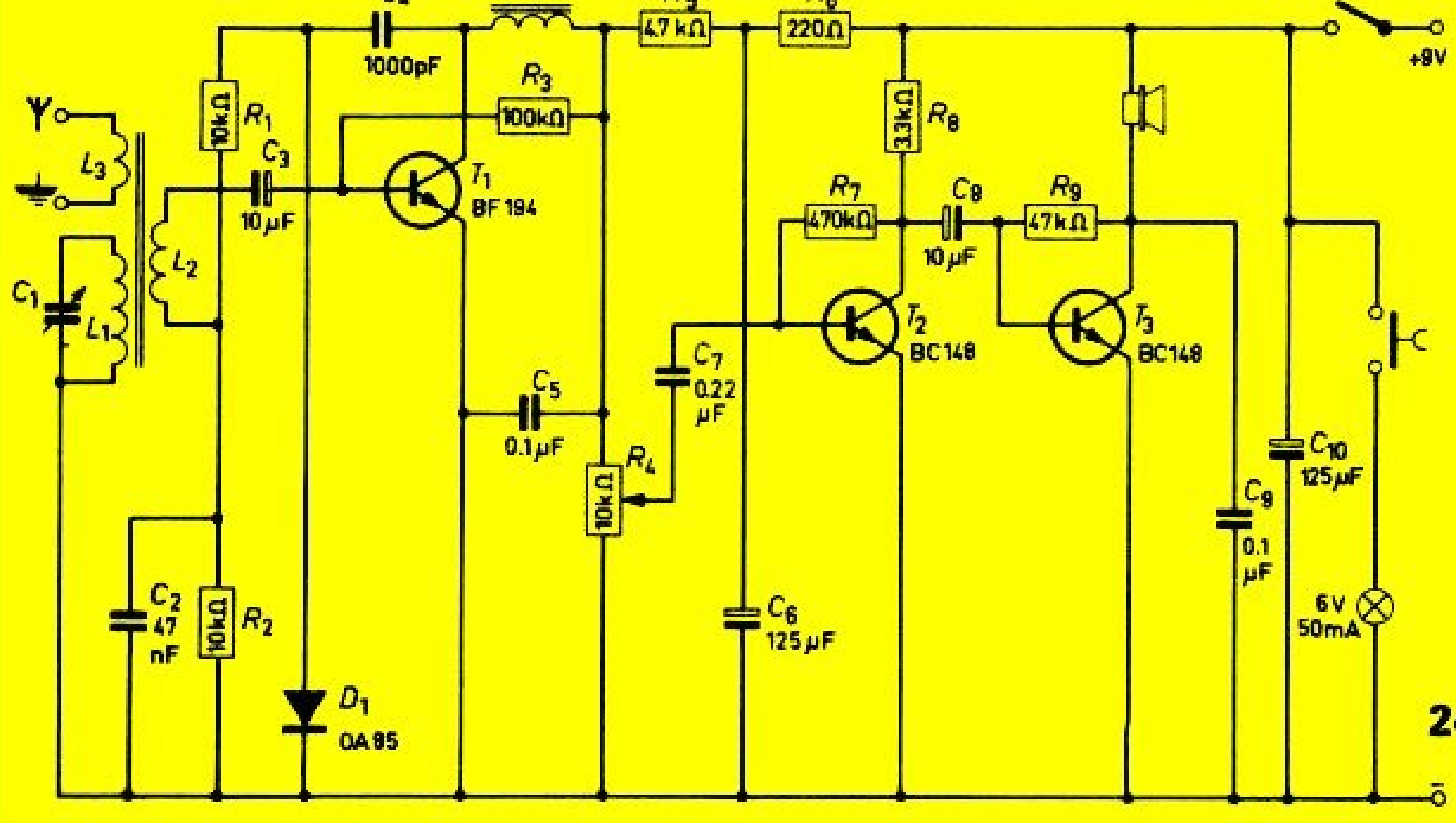
21


+9V
R5 4.7kΩ
R1 10kΩ
R3 10kΩ
C1 125μF
R4 47kΩ
T1 BF194
T2 BC148
R5 470kΩ
R2 2.2kΩ

22


C4 1000pF
L4
R5 4.7kΩ
R6 220Ω
+9V
R3 100kΩ
R8 2.2kΩ
L3
R1 10kΩ
C3 10μF
R7 470kΩ
T1 BF194
C1 L1 L2
T2 BC148
C5 0.1μF
C7 0.22 μF
6V 50mA
C6 125μF
R4 10kΩ
C2 47 nF
R2 10kΩ
D1 OA 85

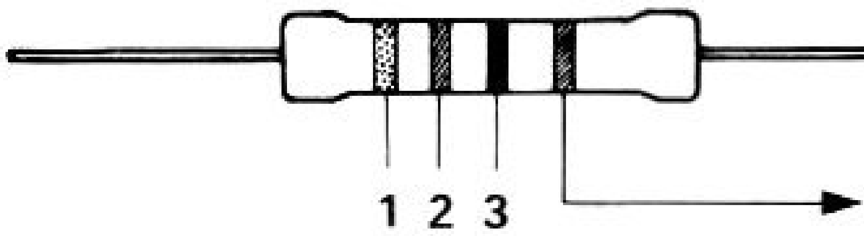
23


C4 1000pF
L4
R5 4.7kΩ
R6 220Ω
+9V
R3 100kΩ
R1 10kΩ
R8 3.3kΩ
L3
C3 10μF
T1 BF194
R7 470kΩ
C8 10μF
R9 47kΩ
C1 L1 L2
T2 BC148
T3 BC148
C5 0.1μF
C7 0.22 μF
R4 10kΩ
C10 125μF
C9 0.1 μF
C2 47 nF
R2 10kΩ
C6 125μF
6V 50mA
D1 OA85

24

line indicated by P the set screw is fastened. Both sets have a volume control and circuit 24 also features loudspeaker output. Since the set is equipped with a direction sensitive aerial it must be turned for optimum reception. The great advantage of this aerial is that it is less sensitive to interference from other directions. The set is also equipped with dial lighting which only works when the button is pressed, in order to save batteries. By making the inside of the knob white the dial lighting is made more effective.

COLOURCODE FOR RESISTORS AND CAPACITORS



Colour	1st band (1st digit)	2nd band (2nd digit)	3rd band (factor)
black	0	0	x 1
brown	1	1	x 10
red	2	2	x 100
orange	3	3	x 1000
yellow	4	4	x 10,000
green	5	5	x 100,000
blue	6	6	x 1,000,000
violet	7	7	
grey	8	8	
white	9	9	

Resistors

10 ohm	brown black black
47 ohm	yellow violet black
100 ohm	brown black brown
220 ohm	red red brown
470 ohm	yellow violet brown
1000 ohm	brown black red
1500 ohm	brown green red
2200 ohm	red red red
3300 ohm	orange orange red
4700 ohm	yellow violet red
10.000 ohm	brown black orange
15.000 ohm	brown green orange
22.000 ohm	red red orange
47.000 ohm	yellow violet orange
100.000 ohm	brown black yellow
220.000 ohm	red red yellow
470.000 ohm	yellow violet yellow

Capacitors

1000 pF	brown black red

3122 106 19701

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