Basic Electricity Kit X20

X20 Instruction manual

PHILIPS

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Instruction Manual

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Batteries

Note: No batteries are supplied with the kit. Any 9-volt battery of reasonably large capacity will do, but the EverReady PP4, PP7 or PP9 (or their Berek equivalents) are recommended as these have press-studs which will fit the battery leads provided in the kit.

Spares

Spares price list is available free on application to Radionic Products Limited, ESL BRISTOL, St. Lawrence House, Broad Street, Bristol, BS1 2HF.

Contents

Introduction

This kit will provide endless hours of fun and interest for anyone who can read and follow the simple instructions, even though he knows nothing about electricity. Everything works from a small battery, so that even the youngest enthusiast may safely be left to his own devices. A spanner is the only tool he needs and this is provided in the kit.

Despite its simplicity, the kit will give a quite amazing insight into the science of electricity and magnetism by showing how it is applied in many spheres of life today.

Before starting to build, read the section entitled 'Description and function of components' and physically identify each component in the kit. Then study the section on 'How to build the circuits'. Having done that, you may proceed to the experiments.

For those who wish to probe more deeply into the subject, a booklet is available from Radionic Products Limited called 'Fundamentals of electricity'. This booklet will add to the interest of the experiments and provide an excellent basis for further study.

The science of electricity

The ancient Greeks knew that if amber was rubbed with another material, such as silk, it would attract small particles. They were thus aware of the phenomenon of 'static electricity'. The Greek name for amber was 'elektron' and from this the modern words electron, electricity and electronics are derived.

For centuries knowledge of electricity made little progress. At the beginning of the seventeenth century William Gilbert, Queen Elizabeth's scientist physician, found that quite a number of substances produced static electricity and, in the eighteenth century, it was realised that this was of two kinds, positive and negative. Later a list of such substances was compiled and so arranged that if any two were rubbed together the one higher in the list would be left with positive electricity and the lower one with negative electricity. Such a list is shown below.

1. Rabbit fur
2. Glass
3. Mica
4. Wool
5. Cat fur
6. Silk
7. Cotton
8. Wood
9. Amber
10. Resins
11. Metals (Copper, Silver etc.)
12. Sulphur
13. Metals (Gold, Platinum)

About this time, in 1780, the development of the steam engine by James Watt marked the real beginning of the Industrial Revolution which transformed the world from isolated communities of craftsmen producing hand-made articles into a world of industrial communities producing machine-made articles by the hundreds, thousands or millions. Scientific and technical activity gained momentum and out of this electric power emerged. Mechanical energy could now be turned into electrical energy, sent along wires to where it was needed, and then turned back by electric motors into mechanical energy or otherwise into heat or light. The first public generating stations were established in London and New York in 1882. These generated direct current. Alternating current, which could be distributed over much greater distances because transformers could step up the transmission voltages and so permit the use of thinner wires, came into use some five years later, having been patented in London in 1881. At about this time the internal combustion engine also started to come into use as a readily available local source of power.

Thus, unlimited mechanical power in the hands of man transformed the world in relatively few years into one in which the proverbial wealth of kings now lies within the reach of all. This rich, wonderful world has resulted from an extension of the physical capabilities of man.

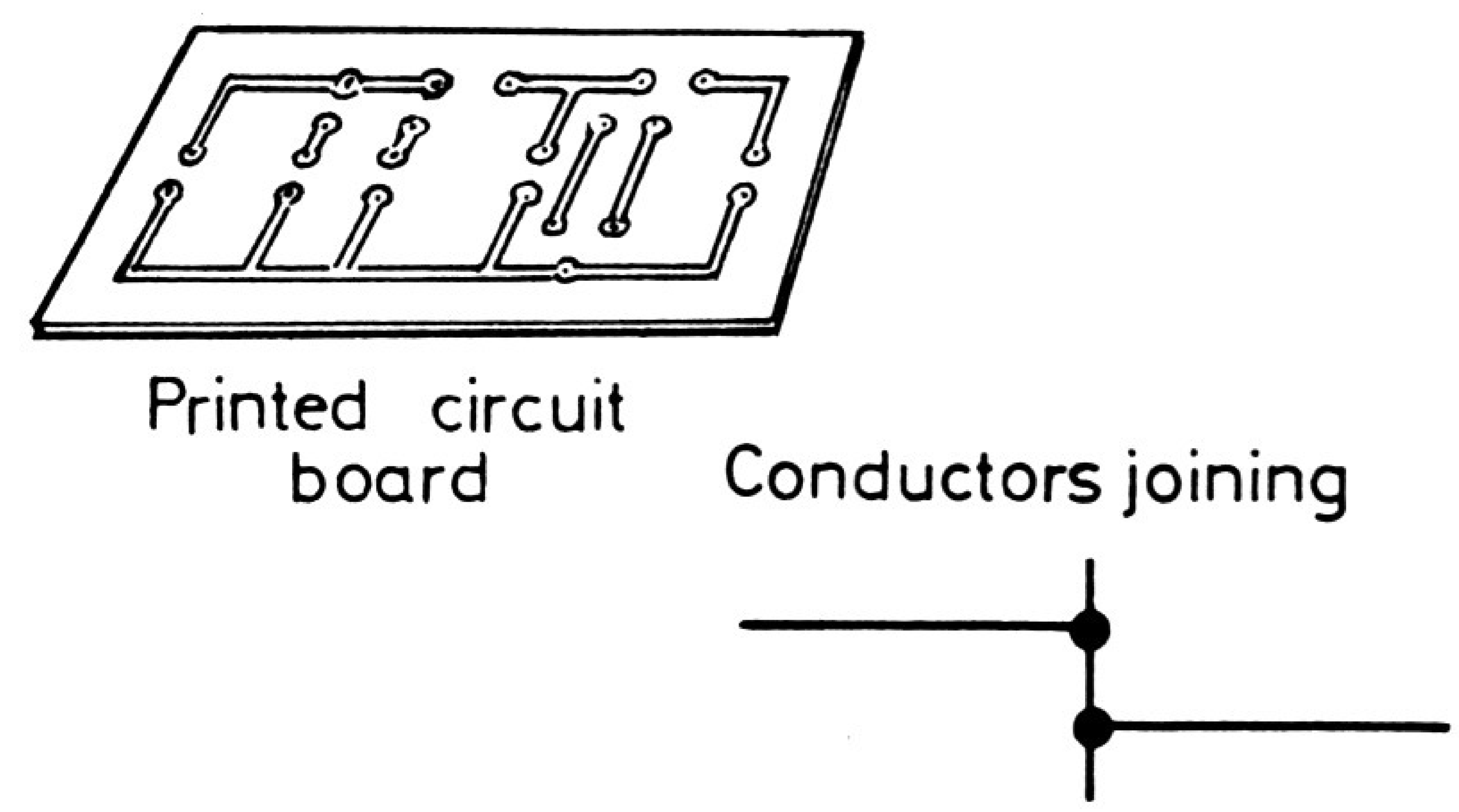
This kit will provide a basic knowledge of electricity and the experiments will reflect some of the excitement felt by the pioneers when they first saw the results of their researches.

Description and functions of components

The components in the kit are listed below. Against each is a brief description of how the component functions, the symbol used for it in theoretical circuit diagrams and a sketch to help in identification.

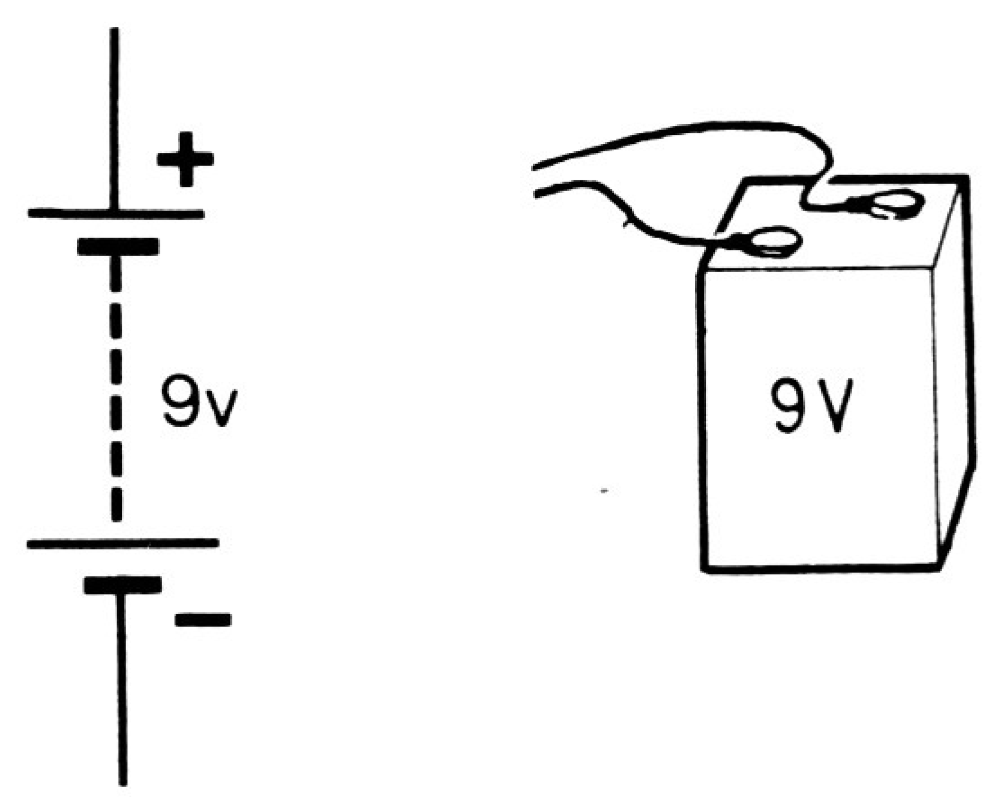
Printed circuit board

The board provides a mounting base for the components and, already etched upon it, the pre-arranged connections for all the experiments described.



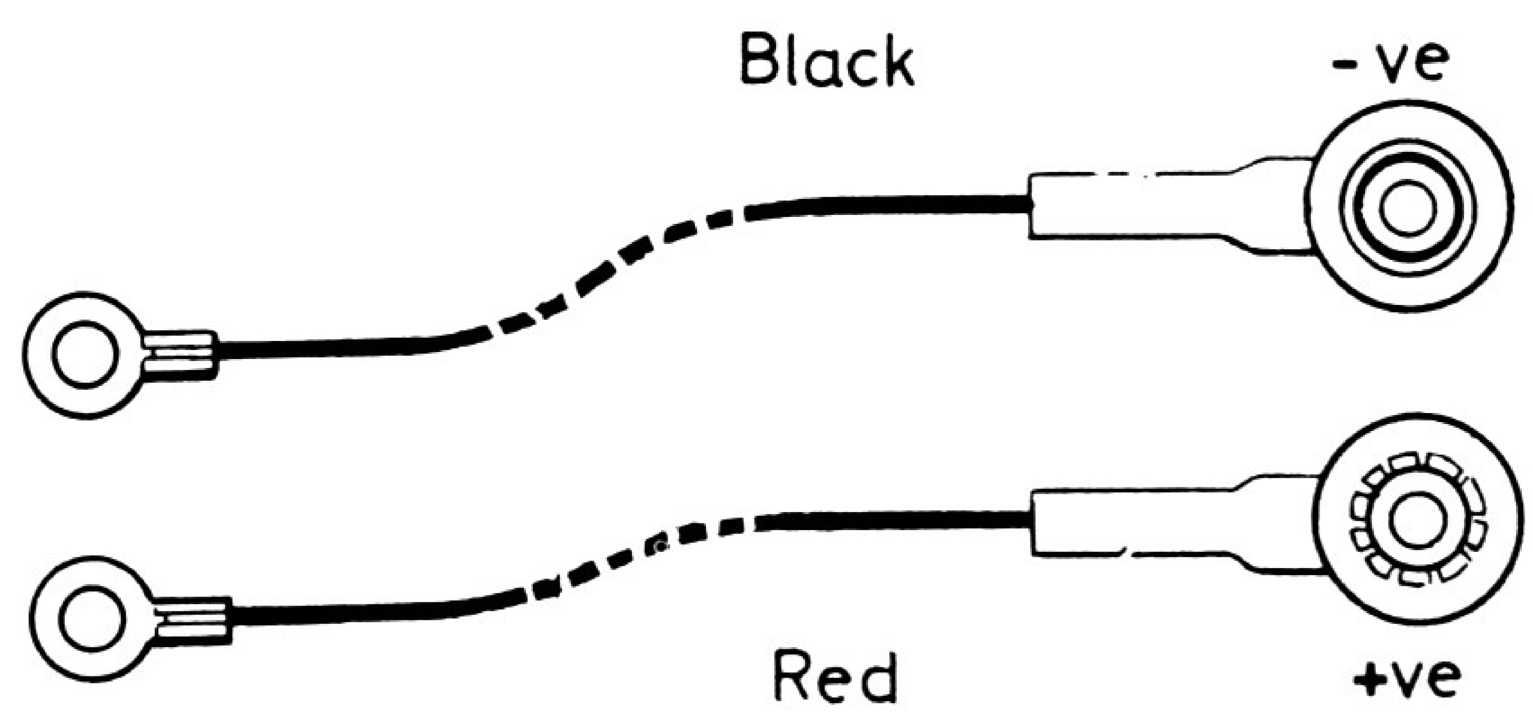
Battery (not included in the kit)

A 9-volt dry battery is used to provide direct current (dc) for the experiments described. Dry cells provide the energy by electro-chemical action, each producing an e.m.f. of 1½ volts. Six such cells are joined together to form a 9-volt battery.



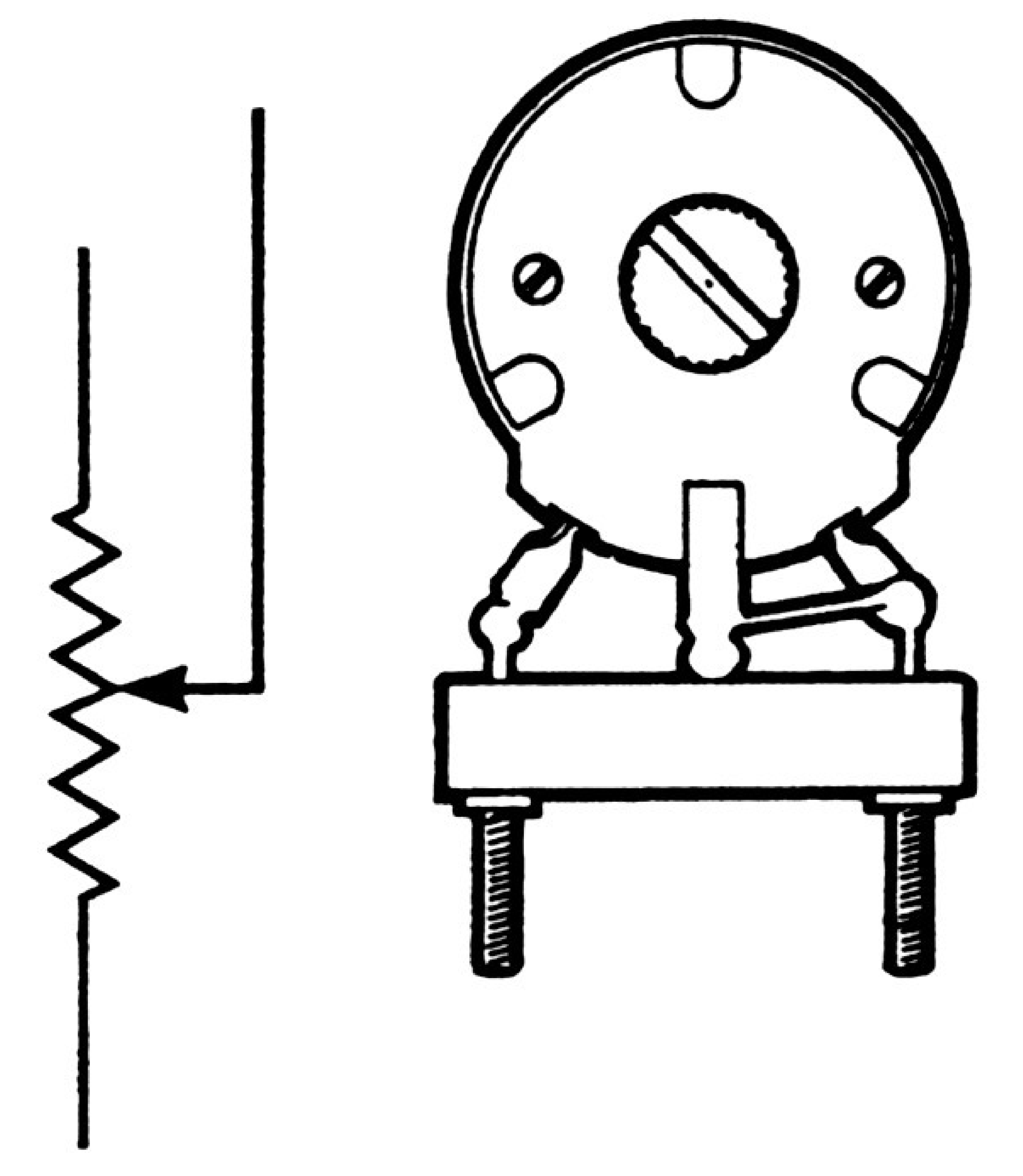
Battery Leads

A pair of leads is provided. Each has a tag on one end which is bolted to the printed circuit board and a fitting at the other end for connection to the battery.



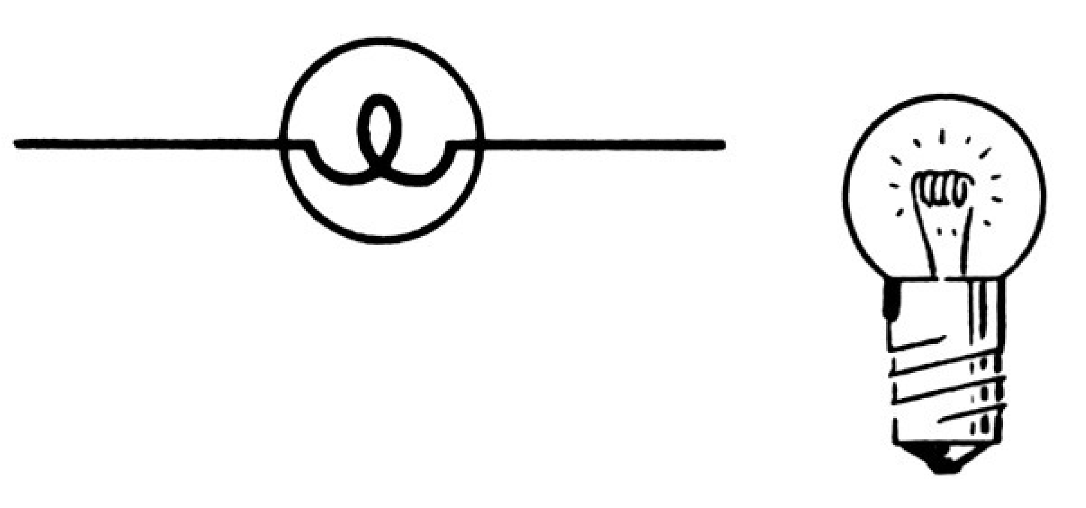
Rheostat (variable resistance)

The rheostat or variable resistance can control the amount of electrical current flowing in a circuit, by resisting the flow of current through it. The greater the resistance, the less will be the electrical current flowing in the circuit. The amount of resistance to current flow is changed in the rheostat by turning the knurled control knob on the top.



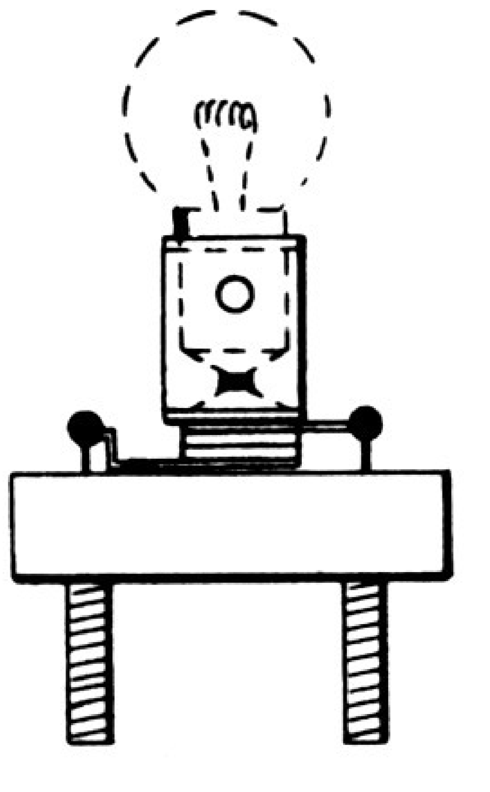
Lamp

The lamp consists of a piece of high resistance wire (the filament) which is sealed in a vacuum inside a glass bulb. The flow of current heats the filament and makes it glow with an intensity dependent on the amount of current flowing.



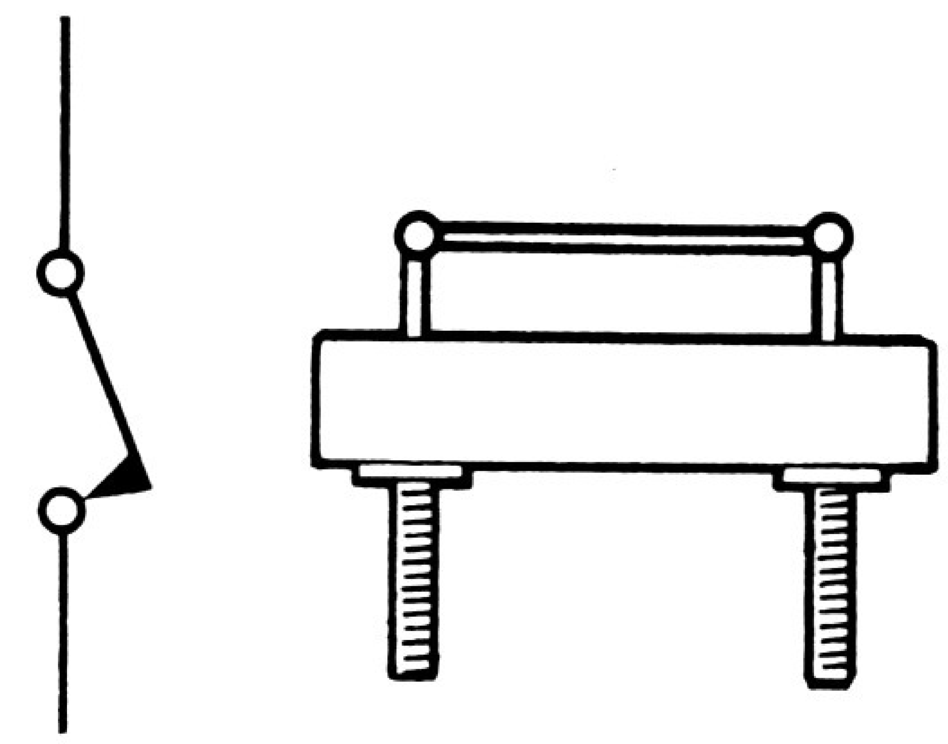
Lamp Holder

The lamp holder is a screw-in socket to hold the lamp and connect it electrically to the circuit board.



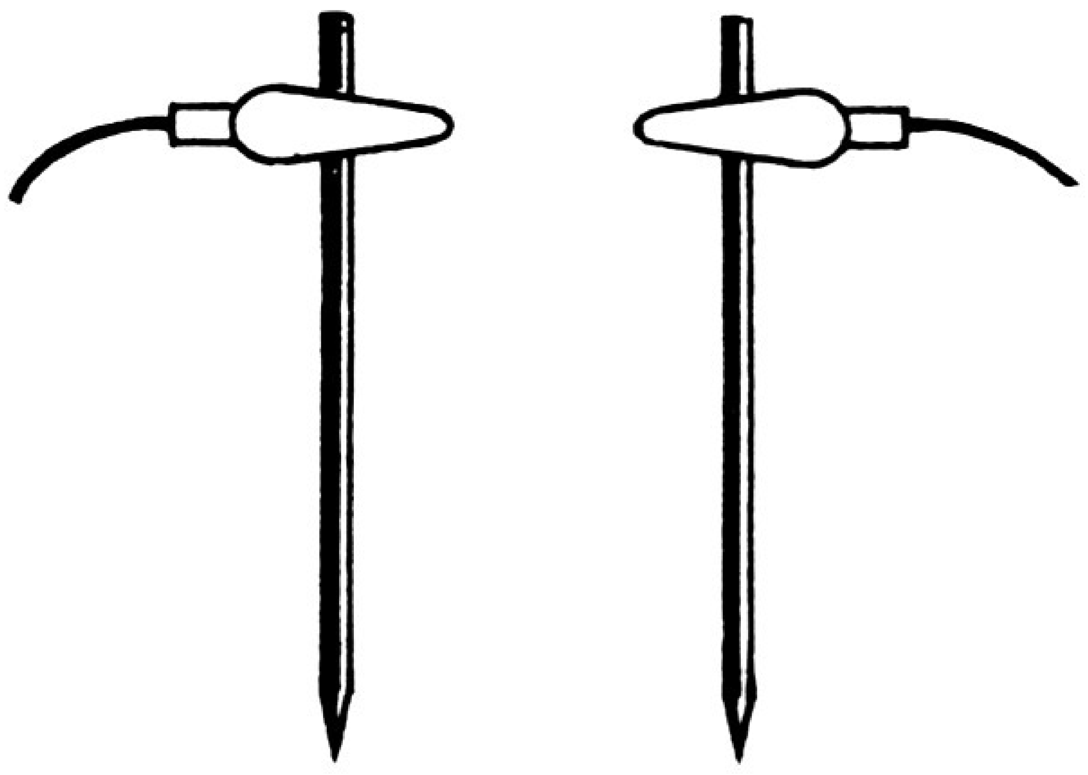
Switch link

The switch link takes the place of the conventional switch. To switch a circuit 'off', the switch link is removed; or to switch 'on' a different part of a circuit, it is moved to a different position.



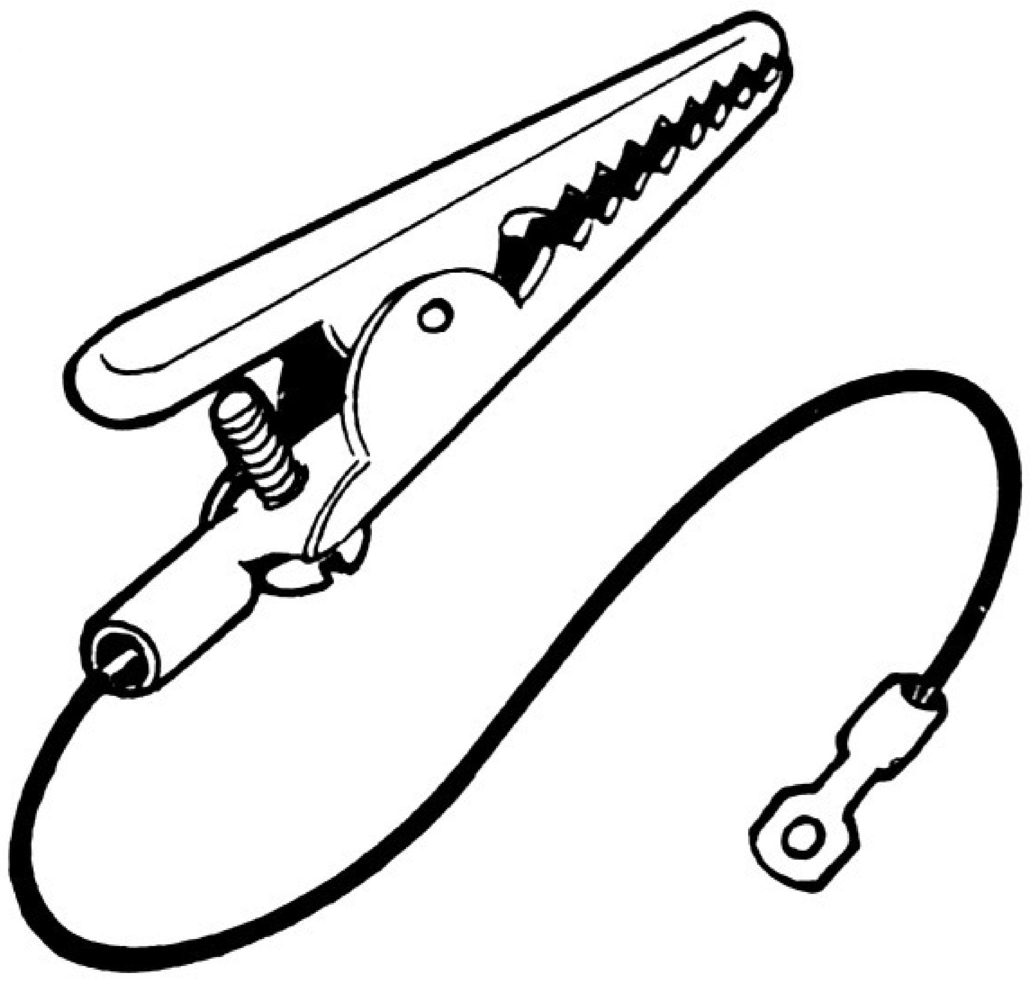
Carbon electrodes

The carbon electrodes are for use when the conduction properties of liquids are investigated. As their name suggests, they are rods made of carbon, the substance that both pencil lead and diamonds are made of.



Crocodile clips and leads

These are used to hold pieces of wire for temporary connections to a circuit or for holding the carbon electrodes, and joining them into an electrical circuit.



How to build the circuits

With the new and unique printed circuit board which forms a basis for this kit, the building of the circuits is extremely simple. At the same time, the building methods are in close conformity with the most modern printed circuit board techniques. Thus, while you may build quickly, you are learning how modern electrical designers lay out and construct the circuits used in modern technology.

Our printed circuit board is unique in two ways. Firstly, no soldering is needed. The components are merely placed in position and secured there with nuts at the back of the board. Secondly, the pattern of the board is not confined to one circuit only, as is usually the case, but is carefully designed to enable all the circuits to be built upon it.

The building procedure is simply as follows:

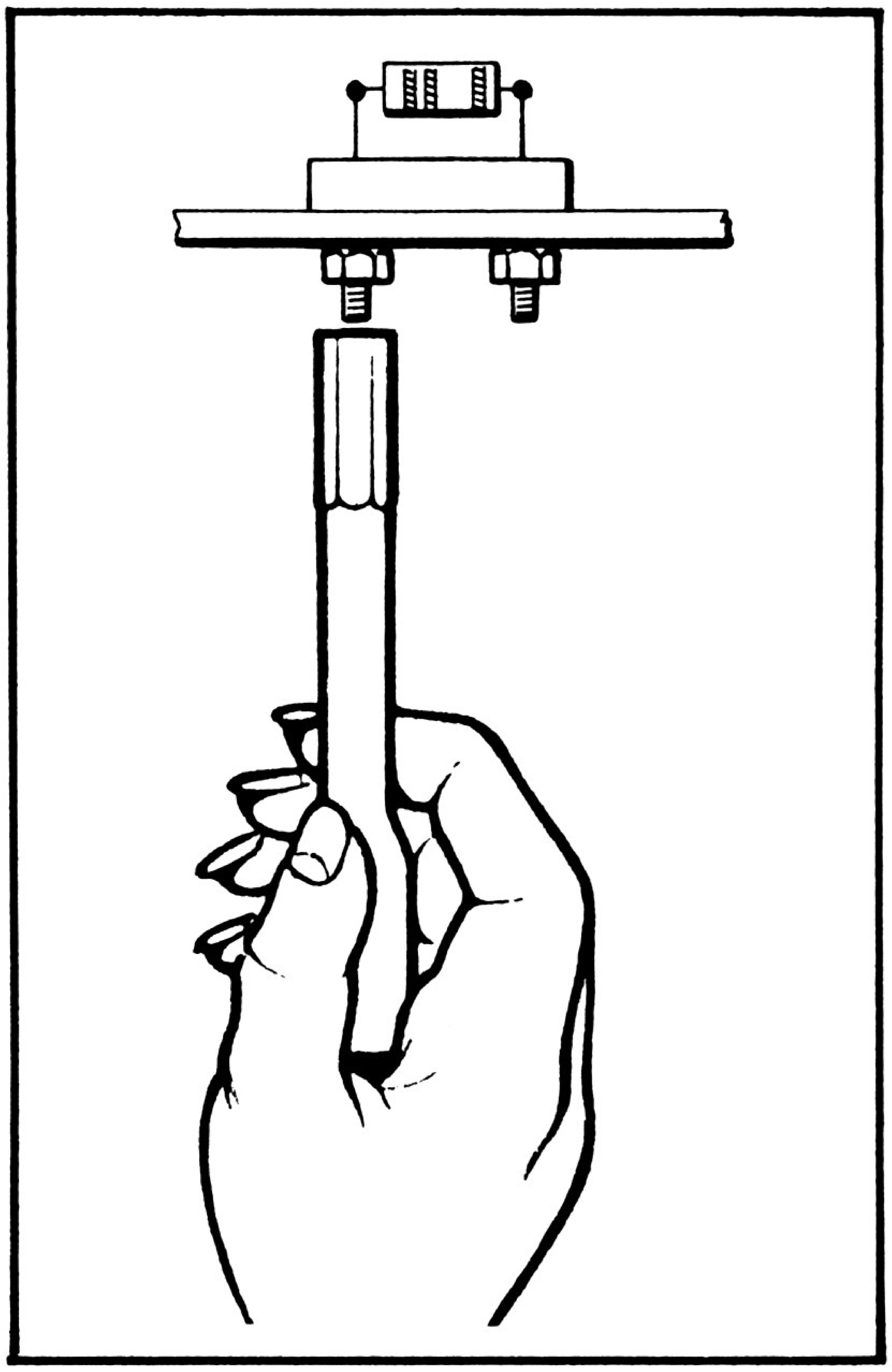
(1) Study the layout diagram for the experiment you are doing. This shows a picture of the board, and the outline of components used in the experiment.

(2) Select from the kit all the components needed for the experiment. These are all marked on the layout diagram.

(3) Place the printed circuit board in front of you with the tinned copper conductors on the *upper* side, exactly as in the layout diagram.

(4) Take the components, one at a time, and position each in the panel using the holes shown in the layout diagram. Do this carefully because an error will prevent the circuit from working.

(5) As each component is placed in position raise the board so that the threads protrude fully through the underside of the board and screw a nut onto each of the threads. One end of the nut is rounded and the other is flat. It is better to put the rounded end towards the board. Tighten up the nuts finger-tight so that the component is fully seated on the panel and then finally tighten with the box-spanner. Do not over-tighten; tighten only to the point where the nut offers a firm resistance.

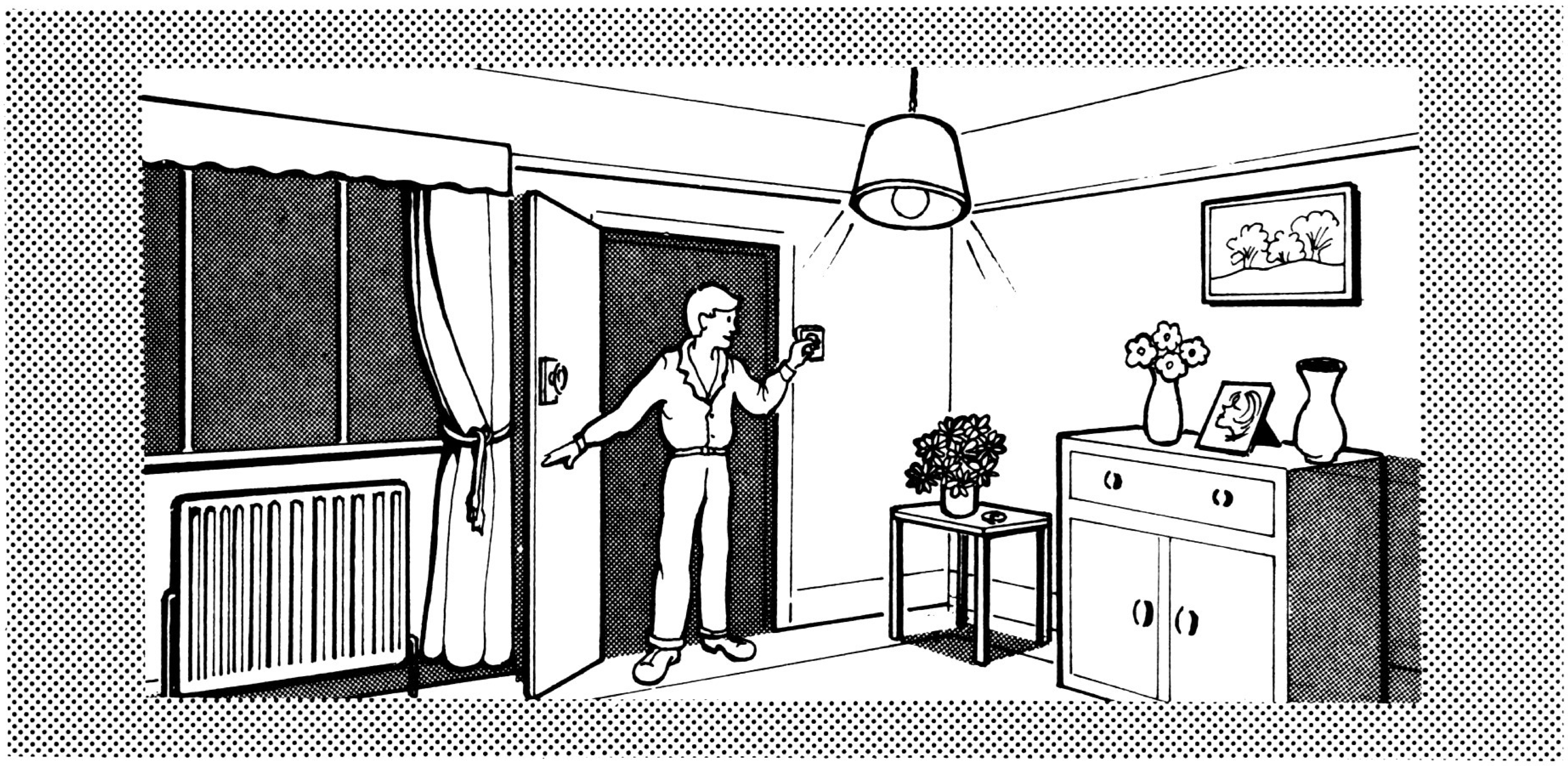


(6) When all the components have been mounted connect up the battery and the circuit will function.

Compare the theoretical circuit diagram with the final layout noting how the connections in the theoretical diagram are in fact effected by the conductor strips on the board.

Experiments 1 to 20

Experiment 1



Making an electrical circuit

Every time you walk into a dark room you switch on the light. The switch is usually quite a long way away from the light bulb and you cannot normally see how the lamp and the switch are joined to each other, because the wires are covered up in the walls.

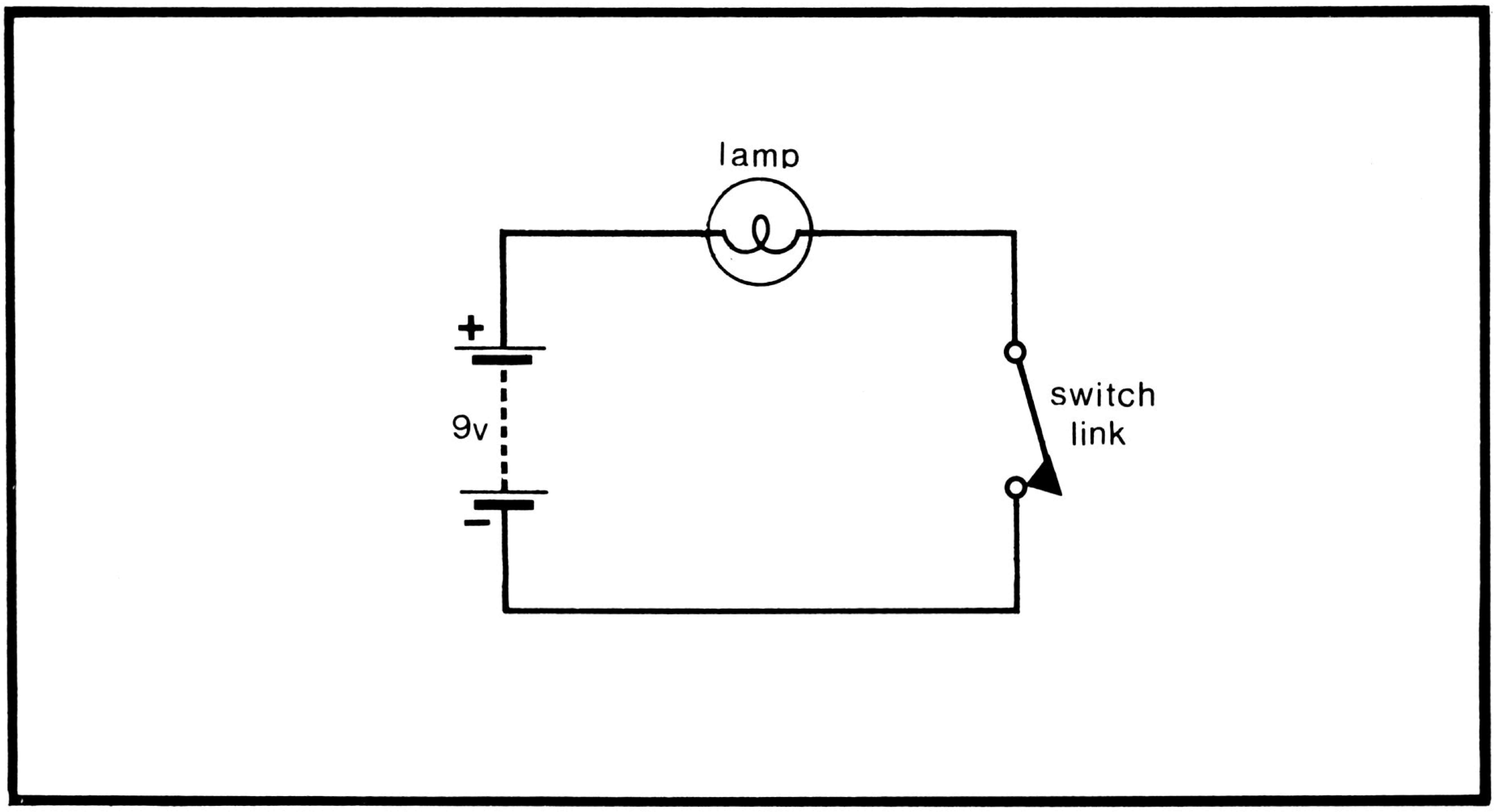
This first experiment shows you how the lights in your house work. You can see on the printed circuit board how the switch is joined to the light bulb and how both are joined to the battery by the metal strips which take the place of the wires used in your house. The battery used in the experiment takes the place of the electricity supplied to your house by an electrical power station. The battery is a very low voltage (9 volts) and so cannot hurt you.

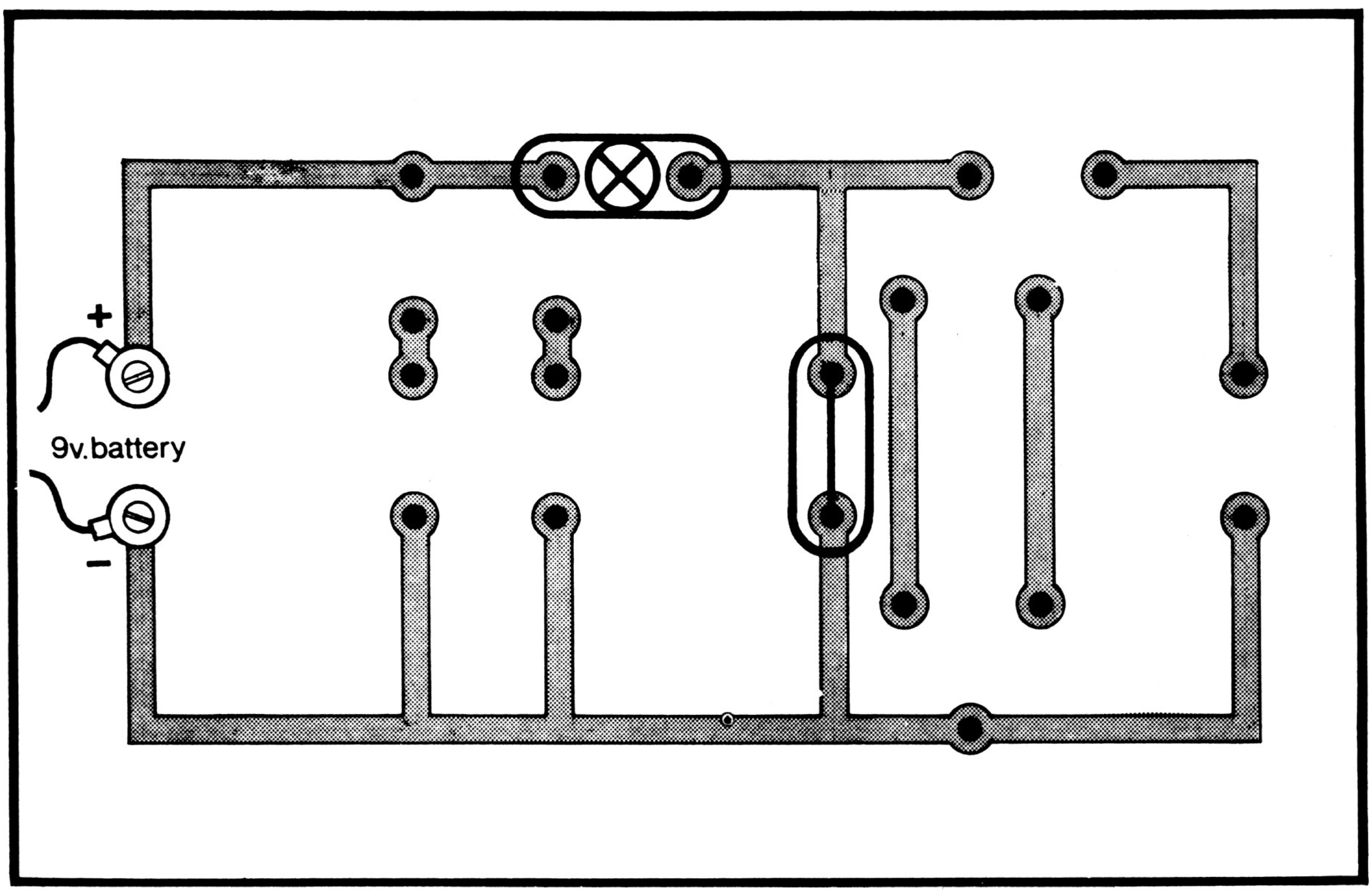
WARNING

You must not ever try to do this, or any of the other experiments in this kit,by joining the printed circuit board to the electricity you use in the house. The house electricity is at a very much higher voltage (240 volts) and can hurt you very badly, or even kill you if you should try to use it in this way.

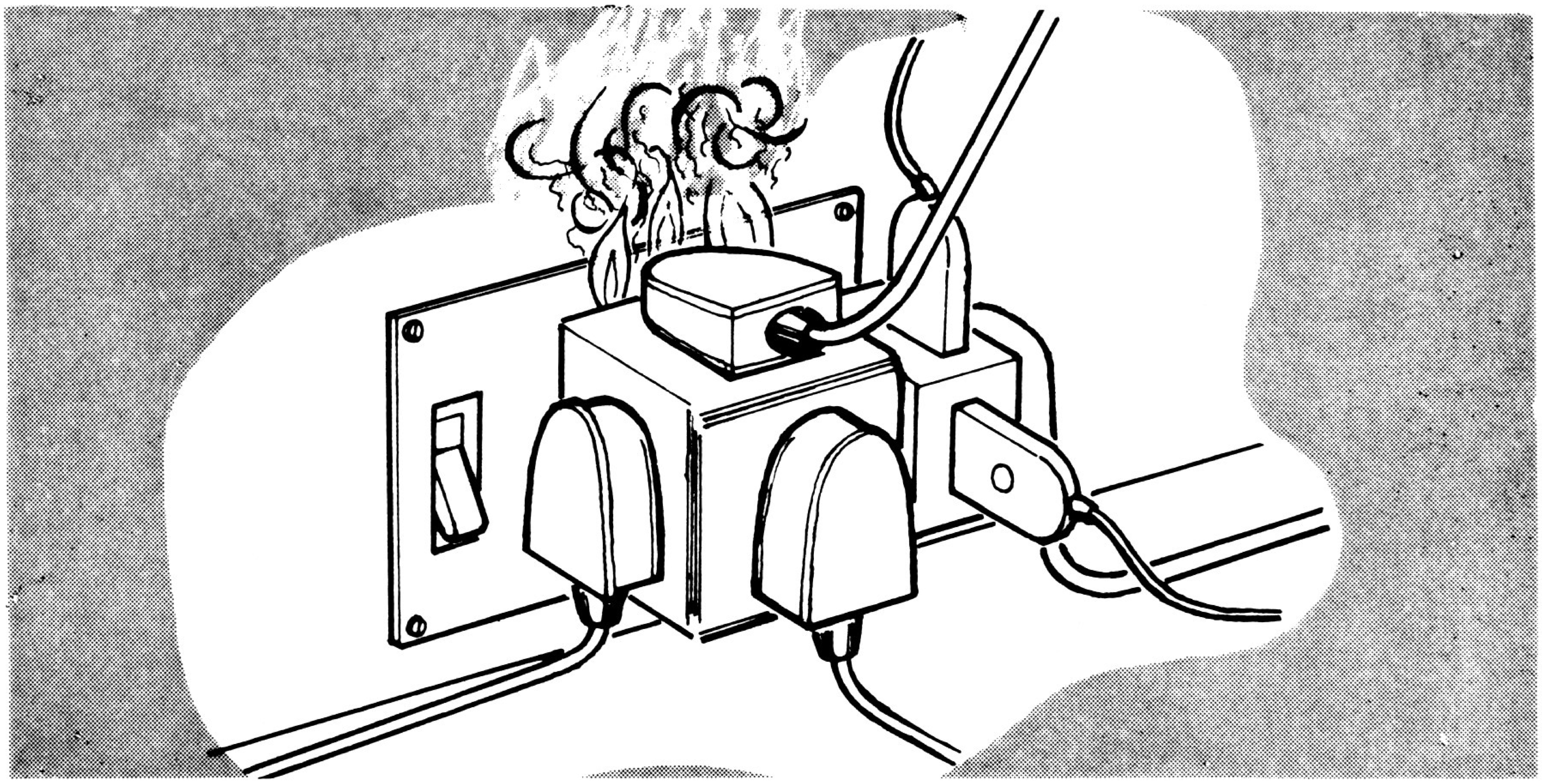
To build this circuit, first put the lamp into the place shown. Connect the battery into the circuit, and finally put in the switch link.

1. Did the lamp light before you put in the switch link?
2. Did the lamp light after you put in the switch link?
3. Remove the switch link. What happens to the lamp?
4. What do you think are the reasons for the results you got?


lamp
+
9v
−
switch
link


+
9v.battery
−

Experiment 2



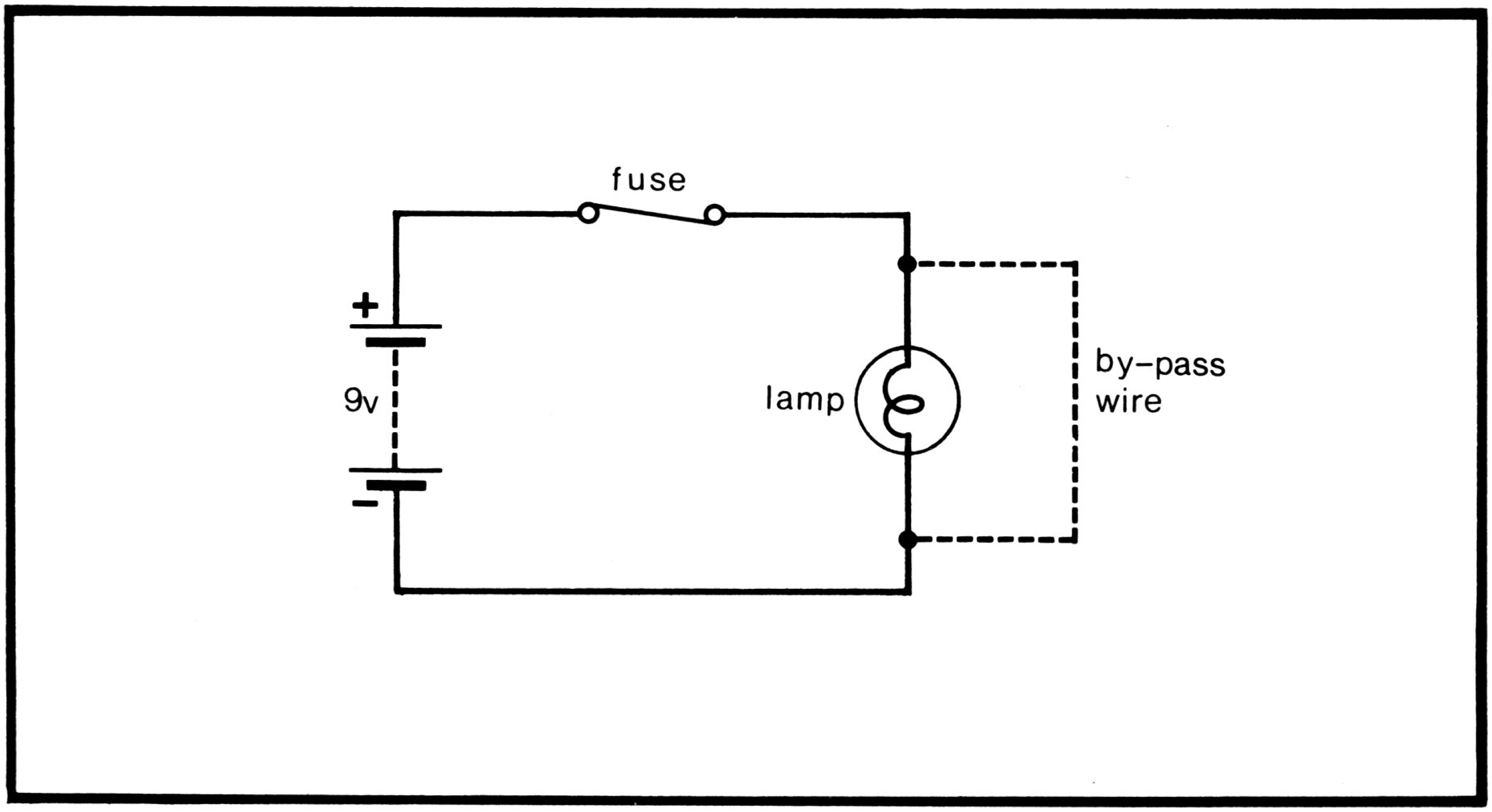
The fuse

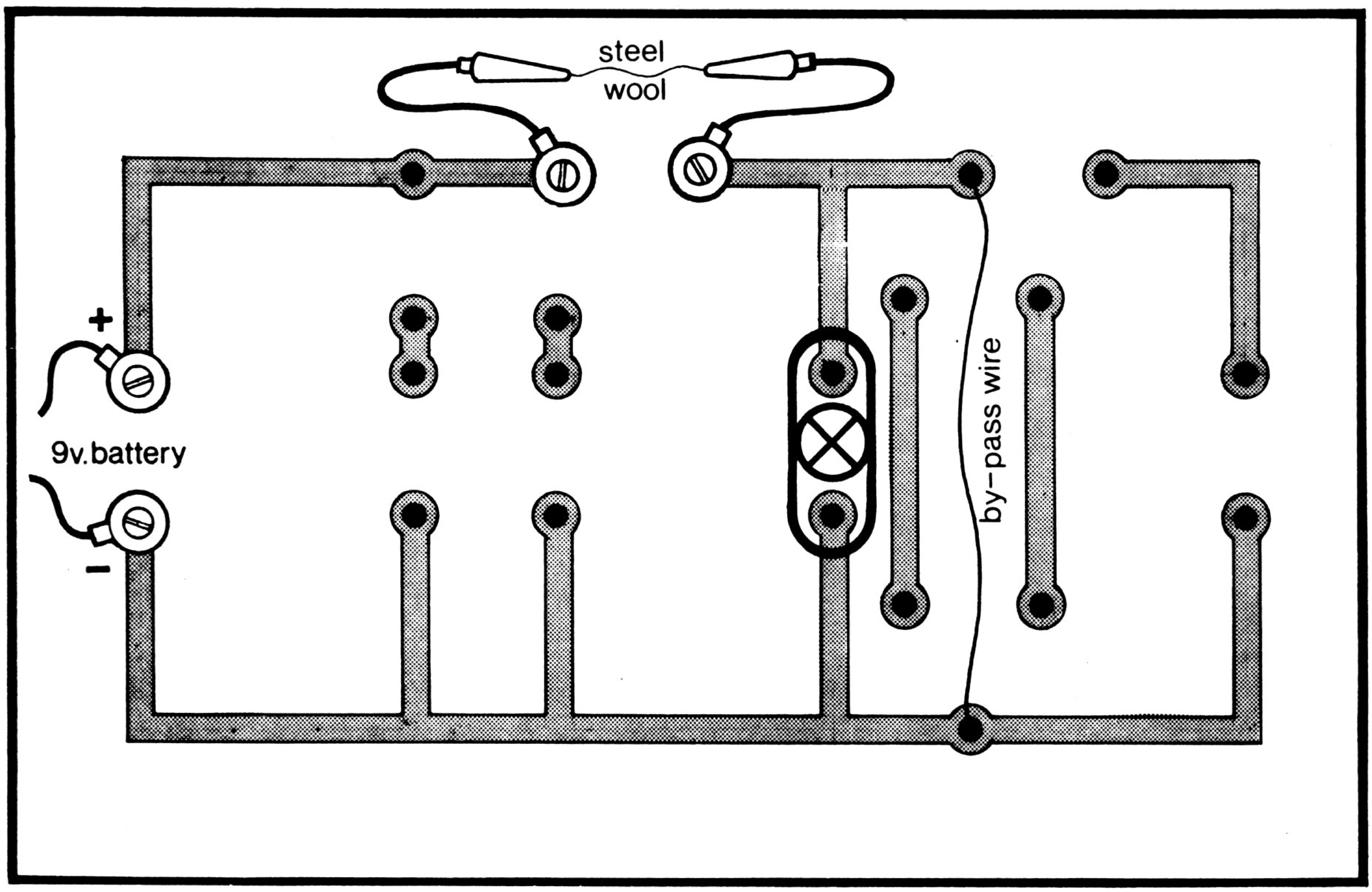
At some time, you may have had all the lights in your house go out at once, even though the switches were still 'on'. The probable cause was that a fuse had blown.

A fuse is made from a piece of wire whose thickness is carefully worked out so that it burns out and breaks if more than a certain value of electric current flows through it. This protects a circuit by stopping too high a current flowing through it. All electrical circuits in a house are normally protected by fuses including each appliance, such as a radio or electric kettle. If a fuse should 'blow' (burn out) in your house, you should make sure that it is replaced by a fuse of the same value, never larger. Also, you should not put more than one plug into a socket like the one shown in the picture above. In such a case, the electrical wiring may burn out instead of the fuse and cause a serious fire in your house.

To build the experimental circuit, first connect a very thin strand of steel wool with crocodile clips to two nuts and bolts put into the holes shown on the printed circuit board. Connect the lamp into the circuit and finally the battery. Note that the lamp lights. By-pass the lamp by placing the bared ends of a piece of copper wire one end each side of the lamp, on the metal strip as shown. The lamp should go out. Note what happens to the strand of steel wool.

1. What happens to the strand of steel wool when the lamp is by-passed?
2. Remove the piece of copper wire which by-passes the lamp. Why won't the lamp light now?
3. A fuse acts under emergency conditions to protect the circuit. What will cause a fuse to blow?


fuse
+
9v
−
lamp
by-pass
wire


steel
wool
+
9v.battery
−
by-pass wire

Experiment 3

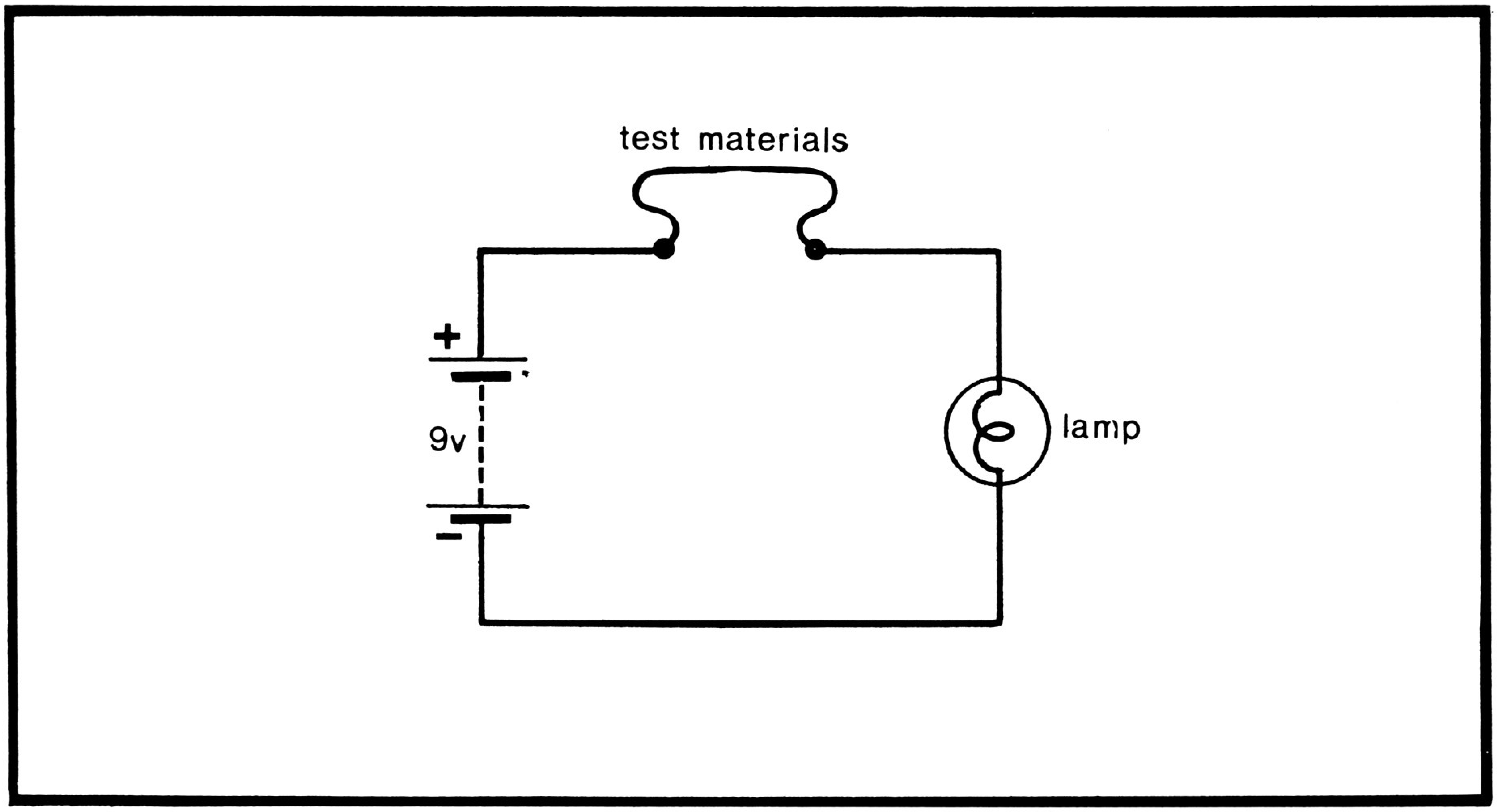
Conductors and insulators

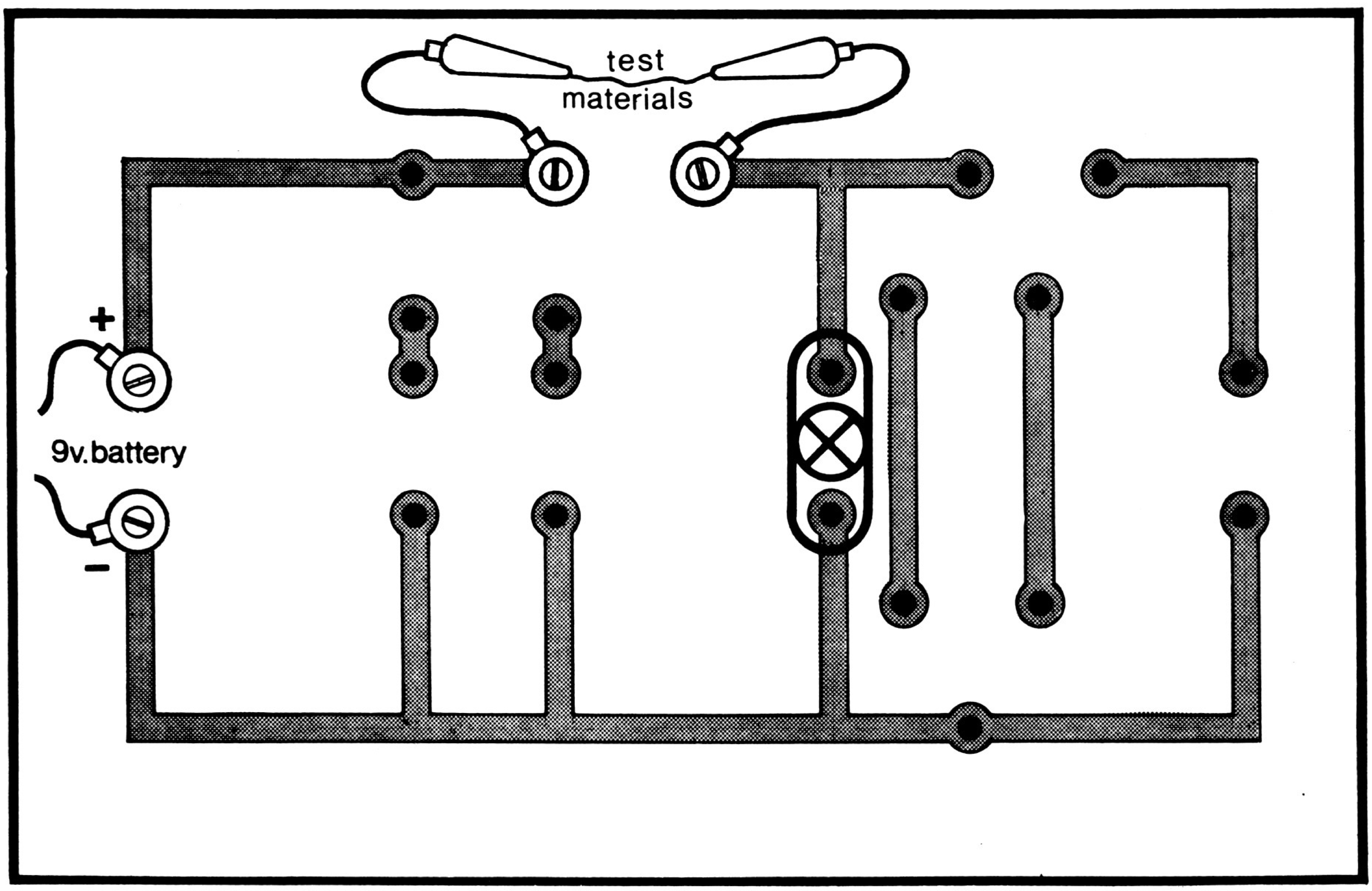
You probably have seen the electricity pylons which carry the electrical power cables across the countryside. The cables going from pylon to pylon carry a very high electrical voltage and yet the pylons themselves carry no voltage at all. The electrical voltage carried by the cables is kept separate from the pylons themselves by china or porcelain discs. The cables are made of copper which allows electric current to flow easily. Copper is a good electrical conductor. The porcelain discs will not allow electric current to flow through them at all. Porcelain is a good electrical insulator.

This experiment is to see what sorts of materials are good conductors and what sorts of materials make good electrical insulators.

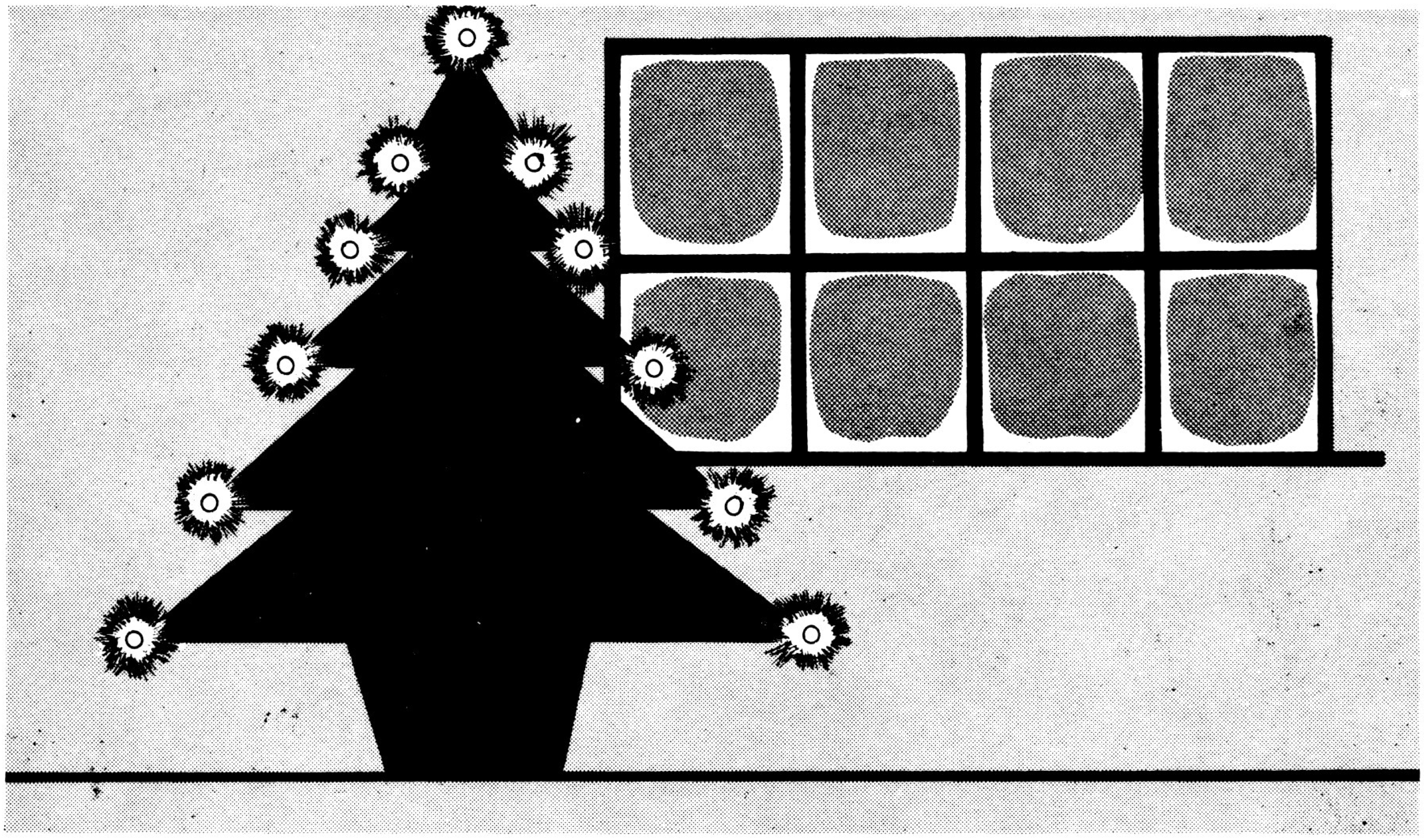
Put the lamp and battery onto the printed circuit board as shown. Collect as many different materials as you can, such as different types of wire, string, nylon thread, cotton and rubber, and cut them all to a length of 6 centimetres. Then connect each in turn to the points shown on the printed circuit board, noting each time what happens to the lamp.

1. What does it show about the material used if the lamp lights brightly?
2. What does it show about the material used if the lamp doesn't light at all?
3. What does it show about the material used if the lamp lights but only very dimly?
4. Why, for instance, can you touch the flex on an electric kettle, without being hurt, even when the kettle is switched on?


test materials
+
9v
−
lamp


test
materials
+
9v.battery
−

Experiment 4



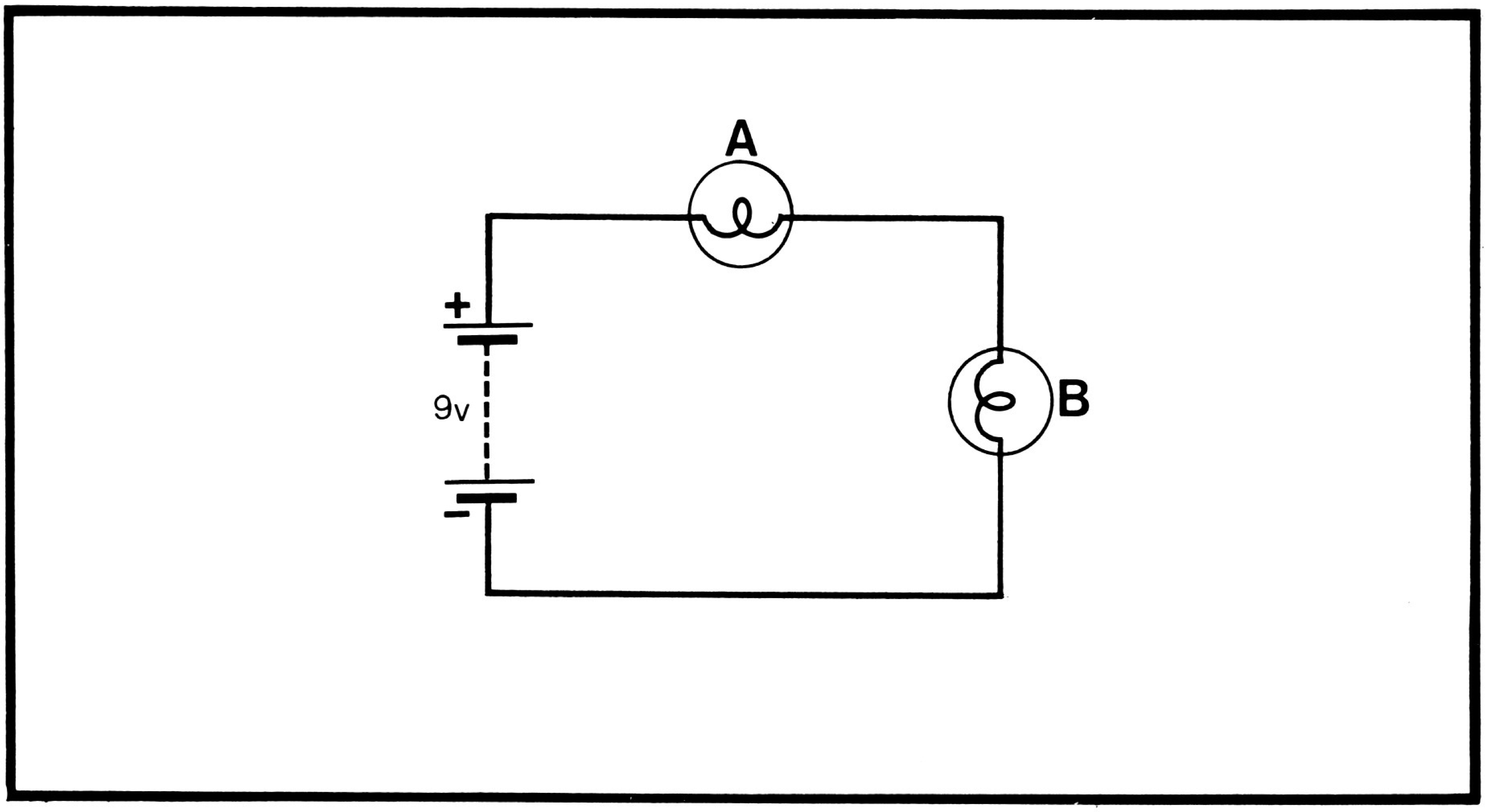
Lamps in series

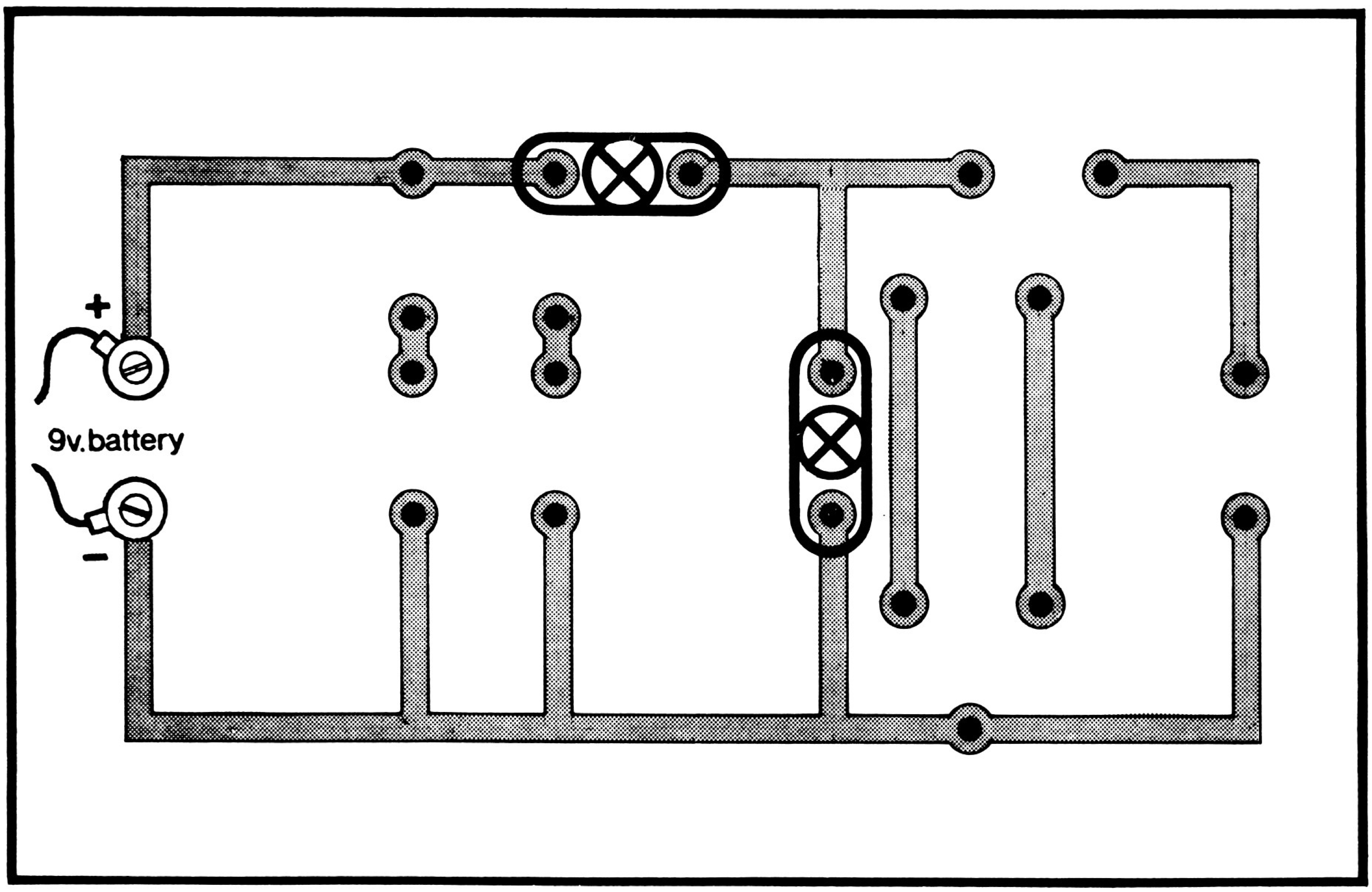
A Christmas tree always looks at its best when there are lights on it. You perhaps have noticed what trouble it causes, however, when the lights go out. It means that one bulb is either loose or burnt out, and each bulb has to be checked in turn until the faulty one has been found and tightened or replaced. Once that bulb has been put right, the lights should come on again unless yet another bulb is faulty.

This experiment is to show why all the lights go out when one bulb is not working.

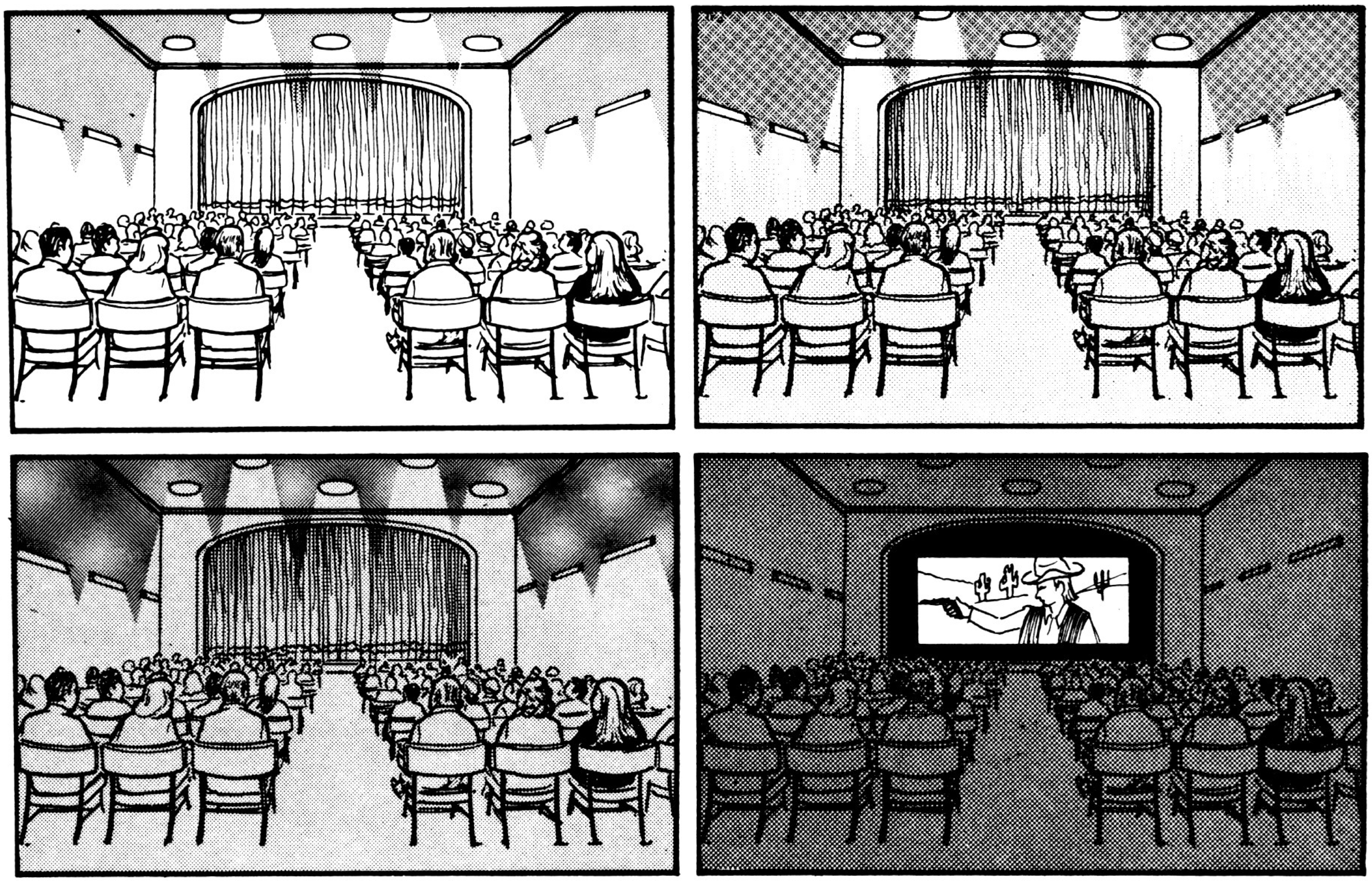
Construct the circuit on the printed circuit board as shown. Remove lamp A and note what happens to lamp B. Replace lamp A and remove lamp B. Note what happens to lamp A.

1. What happens to the lamp which is still connected, when the other lamp is removed from the circuit?
2. Why does this happen to the lamp which is still connected, when the other lamp is removed?
3. What effect would it have if one of the lamps burnt out while still connected into the circuit?


A
+
9v
–
B


+
9v.battery
–

Experiment 5



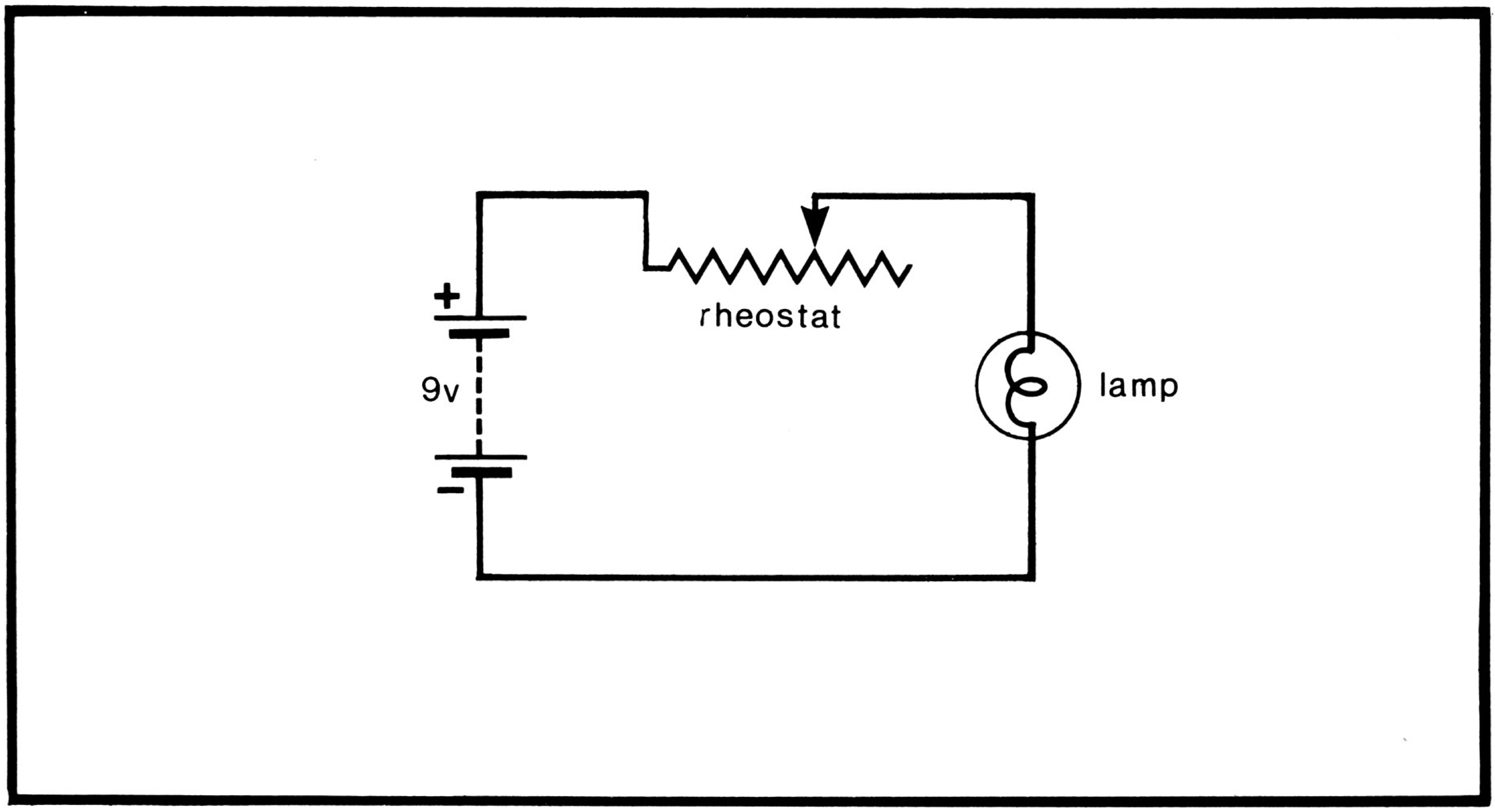
The dimmer switch

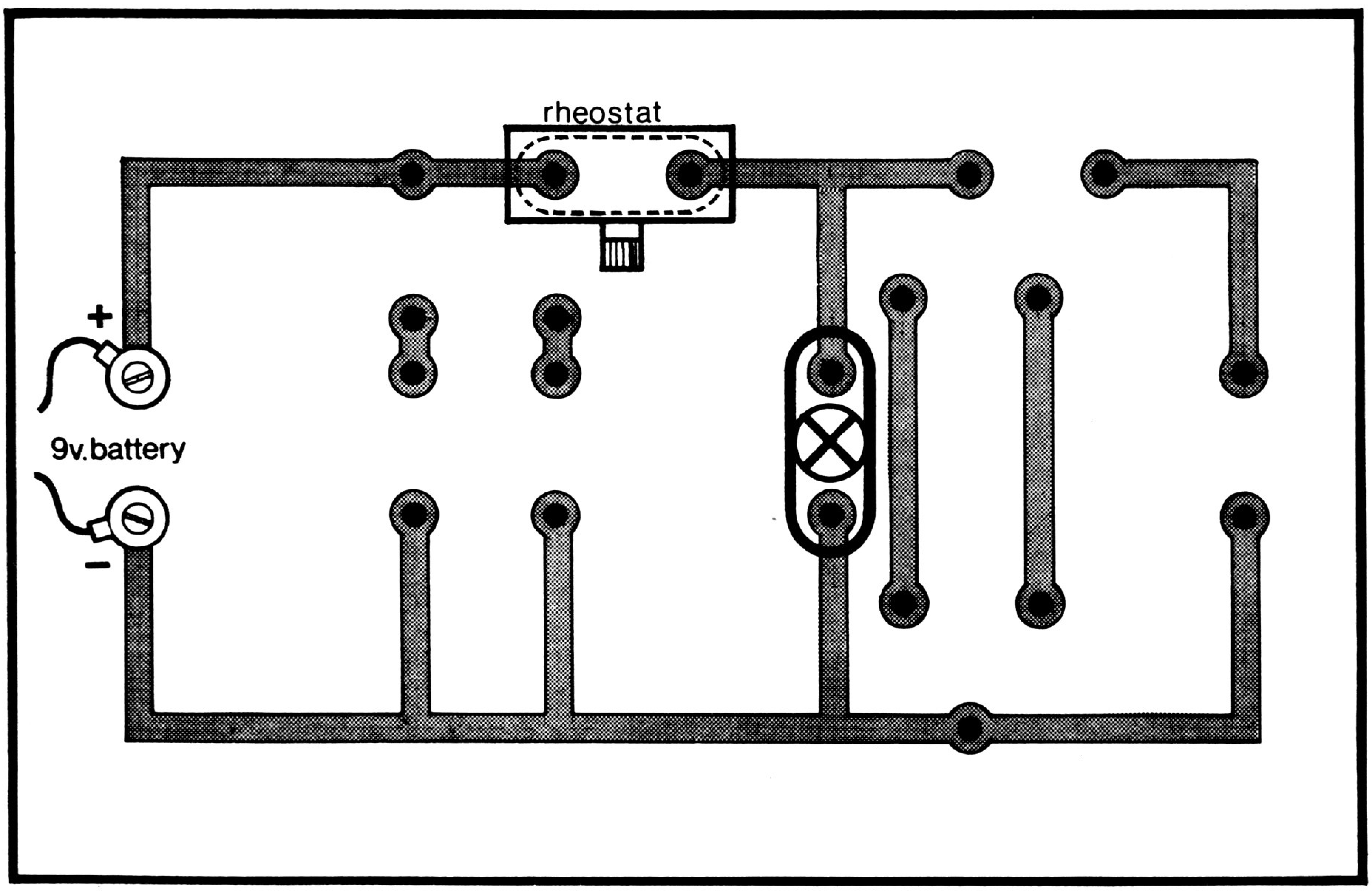
When you have been to the cinema, perhaps you have noted that the lights in the ceiling don't go out suddenly at the start of the film. Instead, they slowly get dimmer before they go out. This effect is produced by means of a dimmer switch.

This experiment shows you how a dimmer switch works.

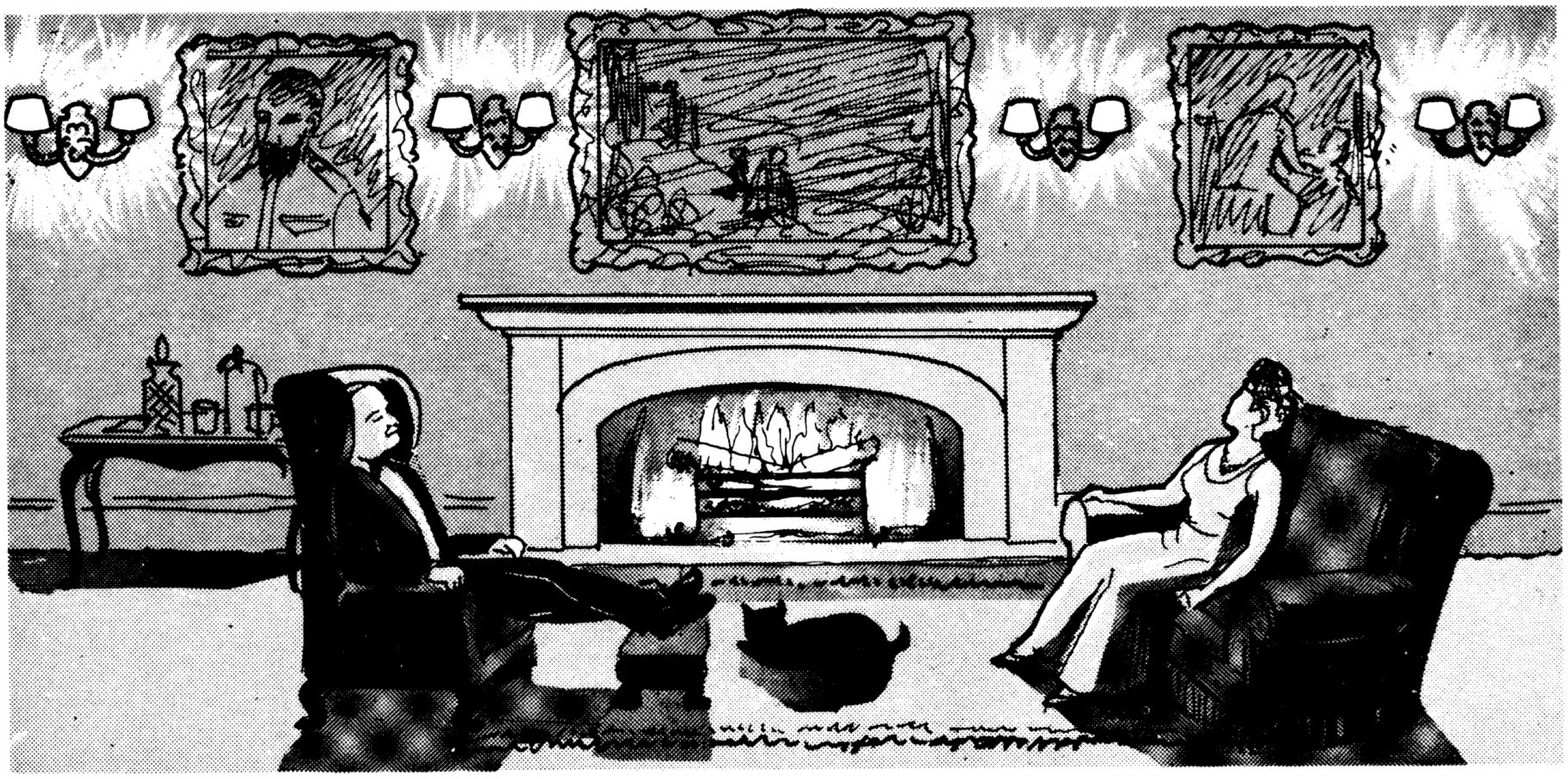
Connect the lamp and the rheostat into the circuit as shown. Make sure that the knob on the rheostat is turned fully clockwise. Connect the battery into the circuit. The lamp should light. Turn the knob on the rheostat slowly in an anti-clockwise direction, watching what happens to the lamp.

1. What happens to the lamp brightness as the knob on the rheostat is turned in an anti-clockwise direction?
2. Remember that the rheostat is a variable resistance. Why do you think the lamp is affected in this way?


rheostat
9v
lamp


rheostat
9v.battery

Experiment 6



Lamps in parallel

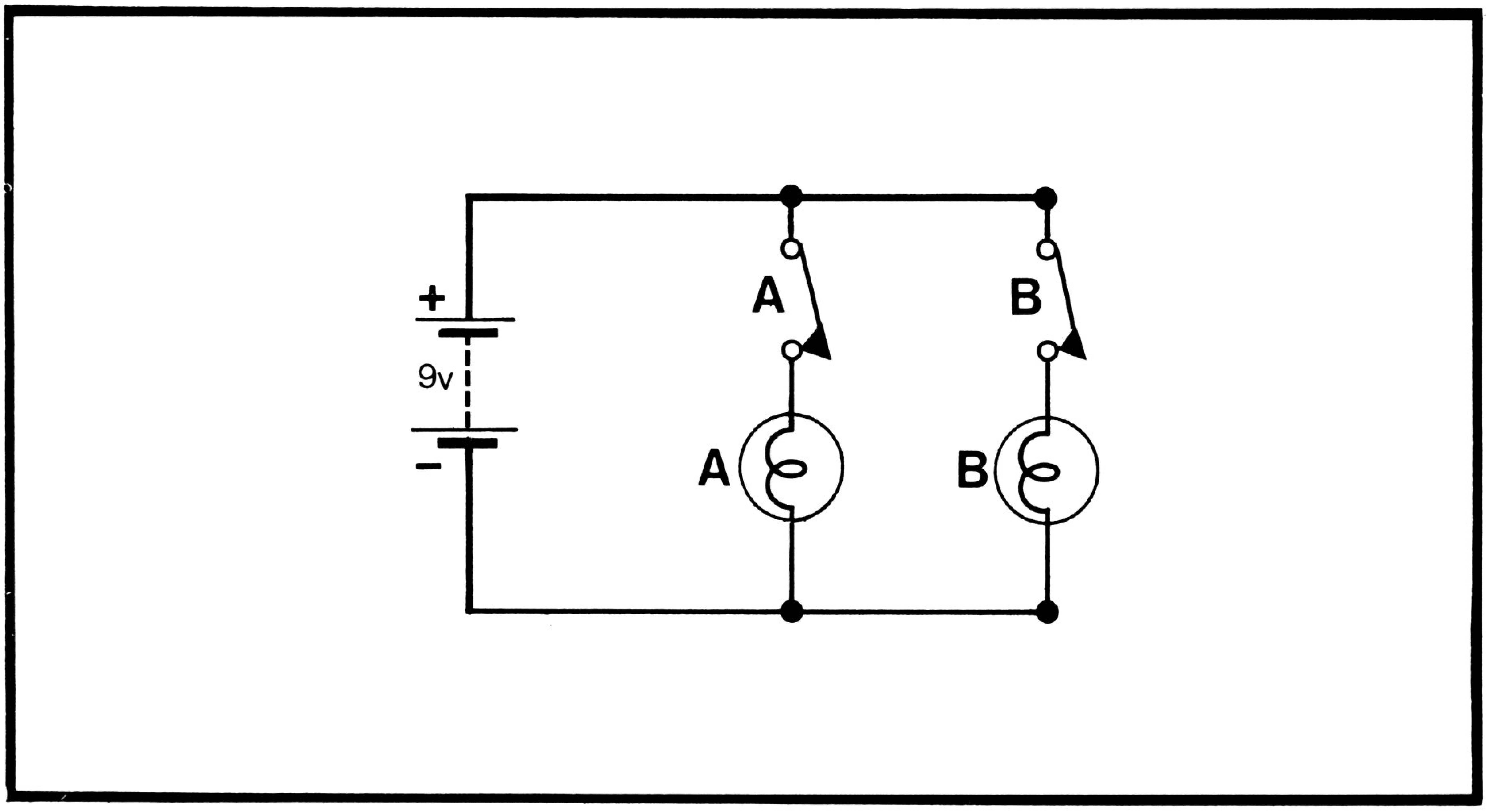
When you switch off a light in your house, it does not affect any of the other lights. Similarly, if one of the lights should burn out, it has no effect on the working of the other lights. You can still turn them on and off as you please, and they will continue to work just the same as before.

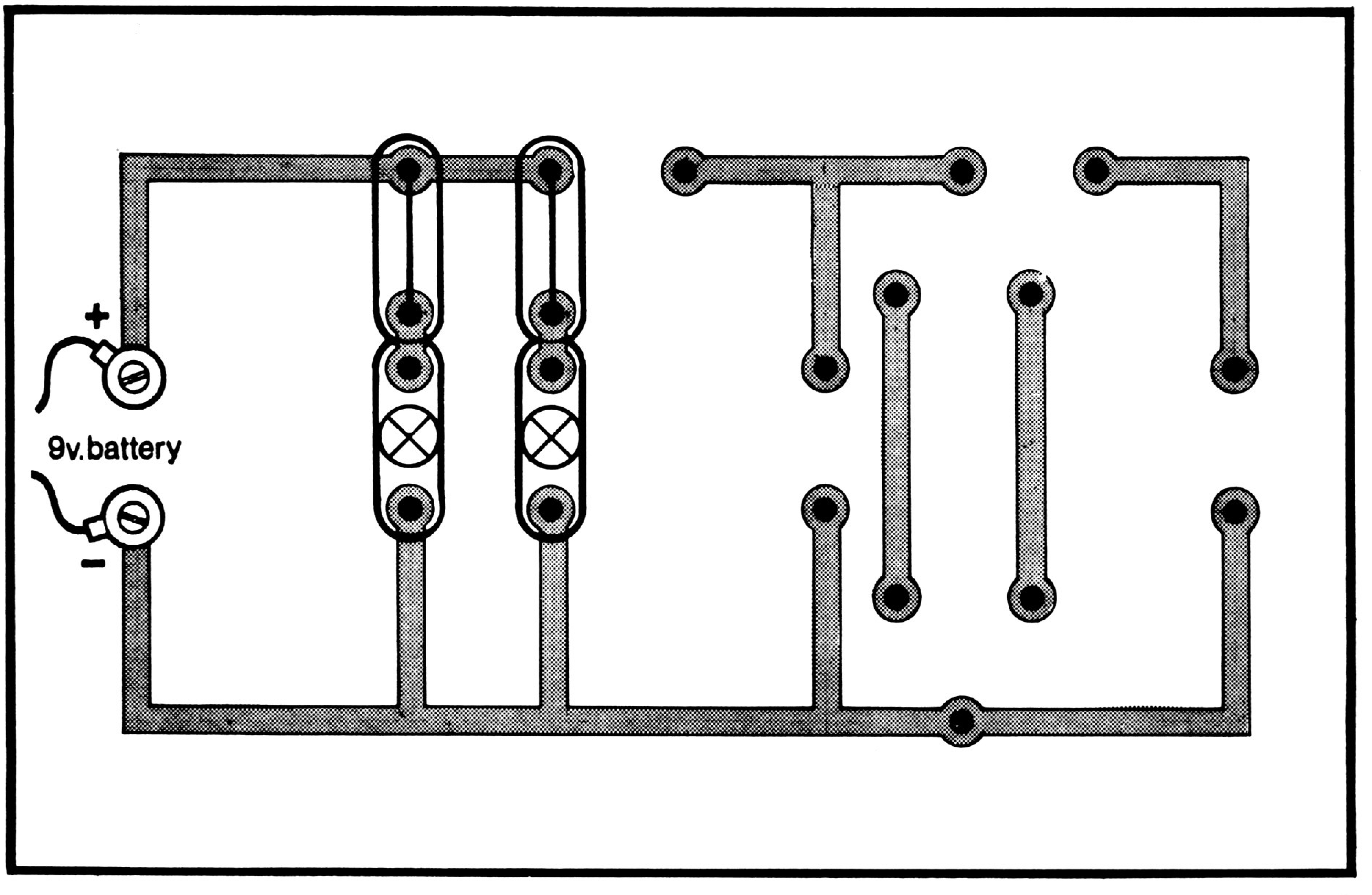
Obviously, then, the wiring to the lights in your house must be different in some way from the wiring used for Christmas tree lights. If one light burns out on the Christmas tree lights all the lights go out, and this does not happen if one of the house lights burns out.

This experiment shows you how lamps can be wired up so that they have no effect on each other.

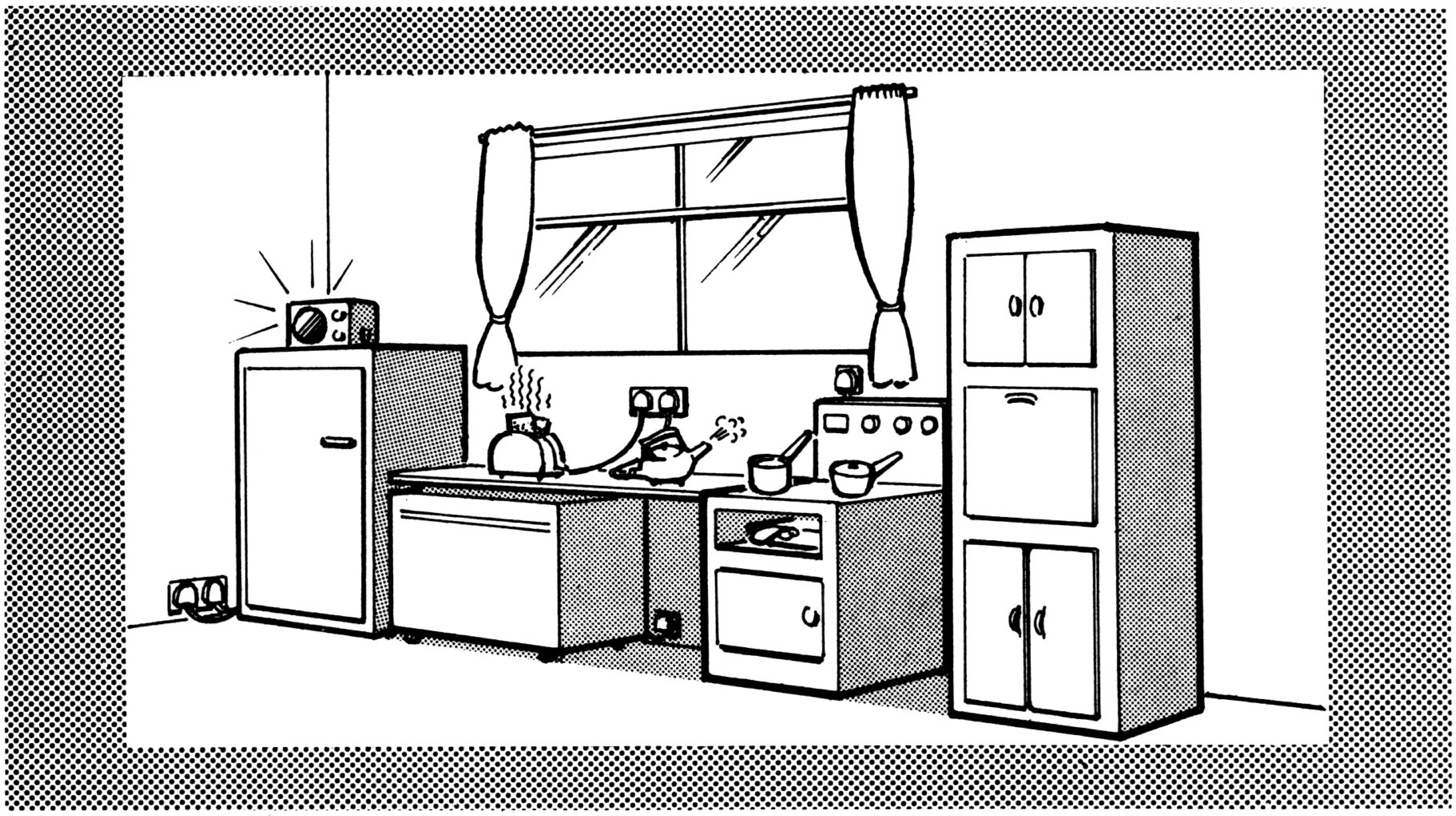
Build the circuit on the printed circuit board as shown, putting in both of the switch links A and B. Note that both lamps are lit. Remove each switch link in turn noting what happens to the lamps. Remove each lamp in turn with both switch links in place, and note what happens to the remaining lamp.

1. What happens to lamp A and to lamp B when switch link B is removed?
2. If lamp A is removed from the circuit, does lamp B go out, or does it remain lit?
3. Trace how many paths the electric current can take in going from one side of the battery back to the other side, when all the lamps and all the switch links are in place. Then turn back to Experiment 4 and do the same thing. What is the difference?


+
9v
-
A
B
A
B


+
9v.battery
-

Experiment 7



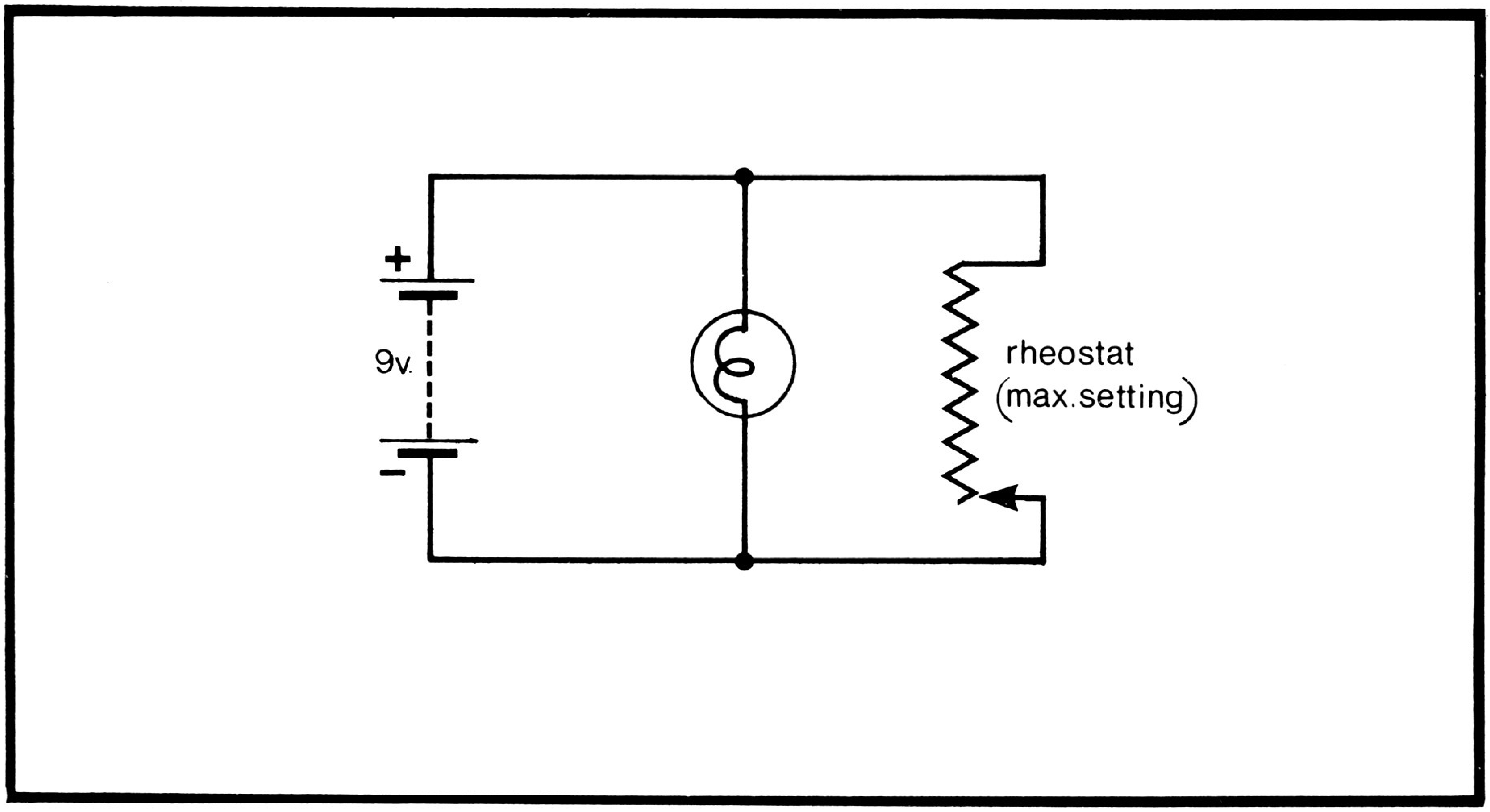
Loads in parallel

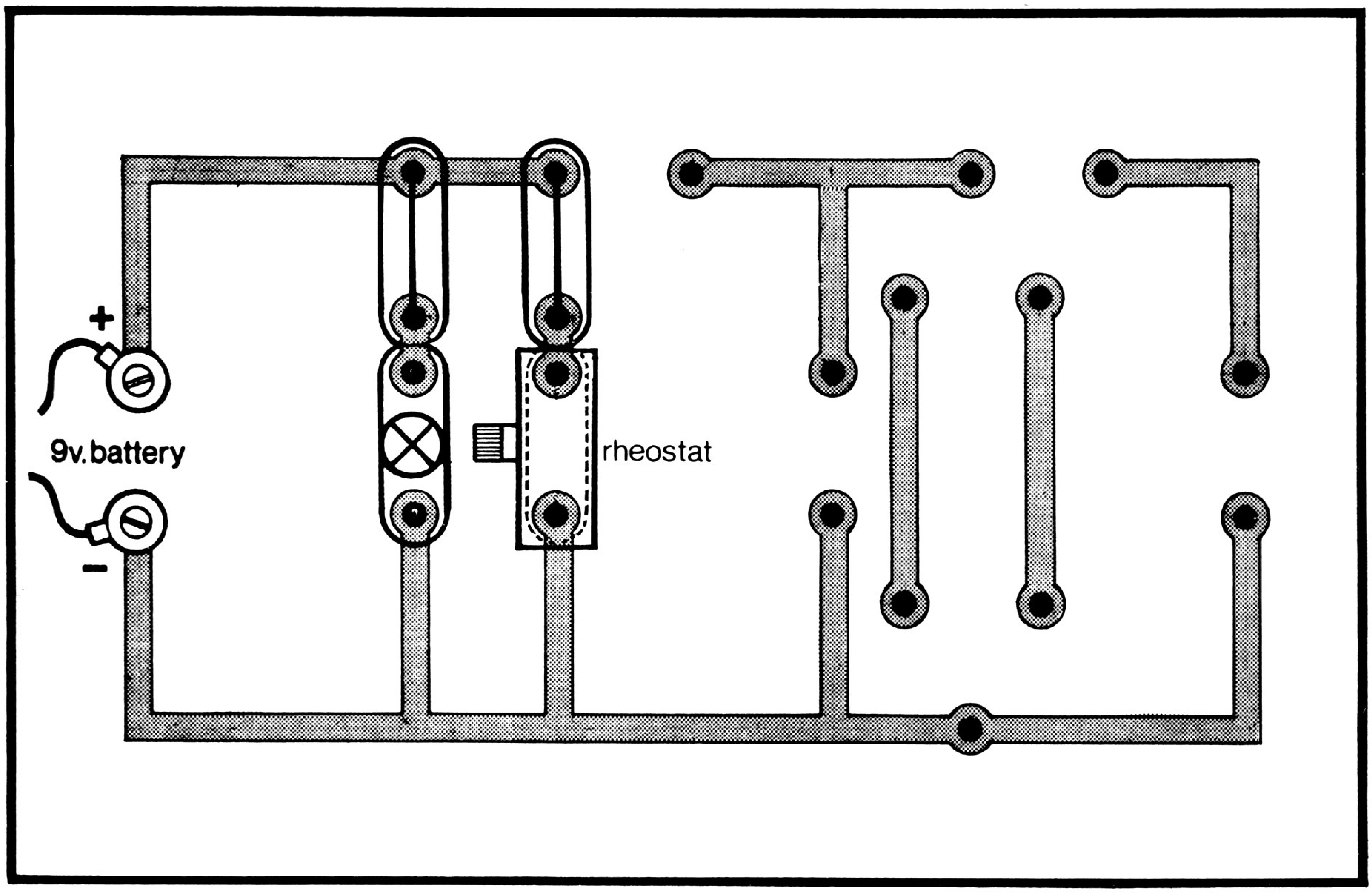
In any house there are probably a lot of electrical appliances, each of which will put a different load on the electrical supply. These appliances may either be on one at a time, or all at once. For example, a washing machine may be in use either on its own, or at the same time as an electric cooker, a T.V. set and an electric kettle. Whatever is switched on, there is no effect on the other appliances already in use. The radio doesn't suddenly go quieter when the cooker is switched on, and it doesn't take any longer for the kettle to boil just because the washing machine has been switched on.

This experiment shows you the type of circuit that is used to prevent one appliance affecting the operation of any others.

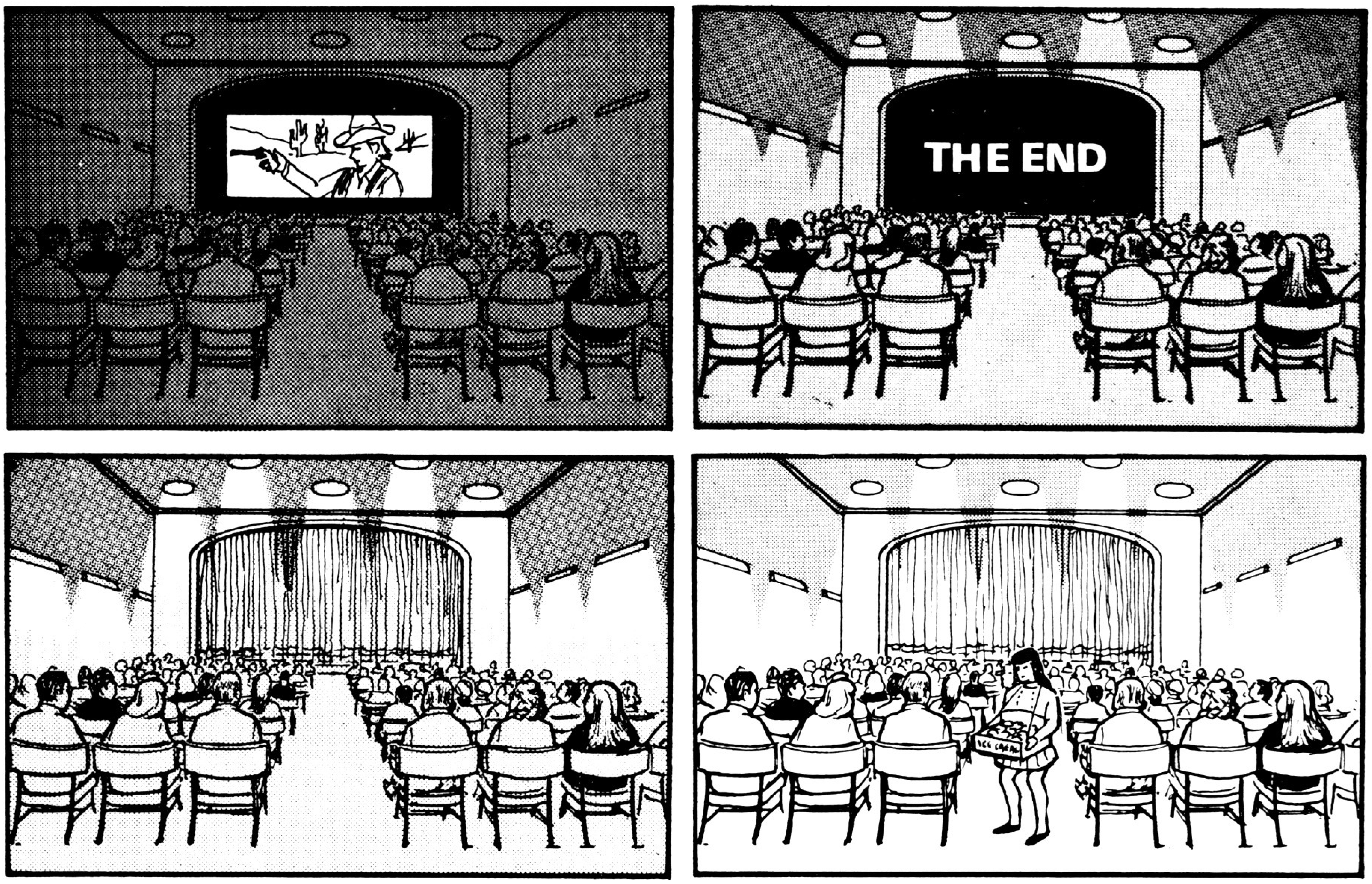
In this experiment, you put the rheostat in place of one of the lamps in the circuit you used for the last experiment. Before you put the rheostat into the circuit, make sure the knob is turned fully in an anti-clockwise direction or you will damage it. With the knob in this position, its resistance to current flow is greatest, 1000 Ohms compared with the 150 Ohms of the lamp. Compare the brightness of the remaining lamp when the rheostat is used as compared with when another lamp is used. Change over between the two components several times so that you can be sure of the result.

1. Does the lamp's brightness alter when the components are changed over?
2. See if you can find out why you get these results.


+
9v.
-
rheostat
(max.setting)


+
9v.battery
-
rheostat

Experiment 8



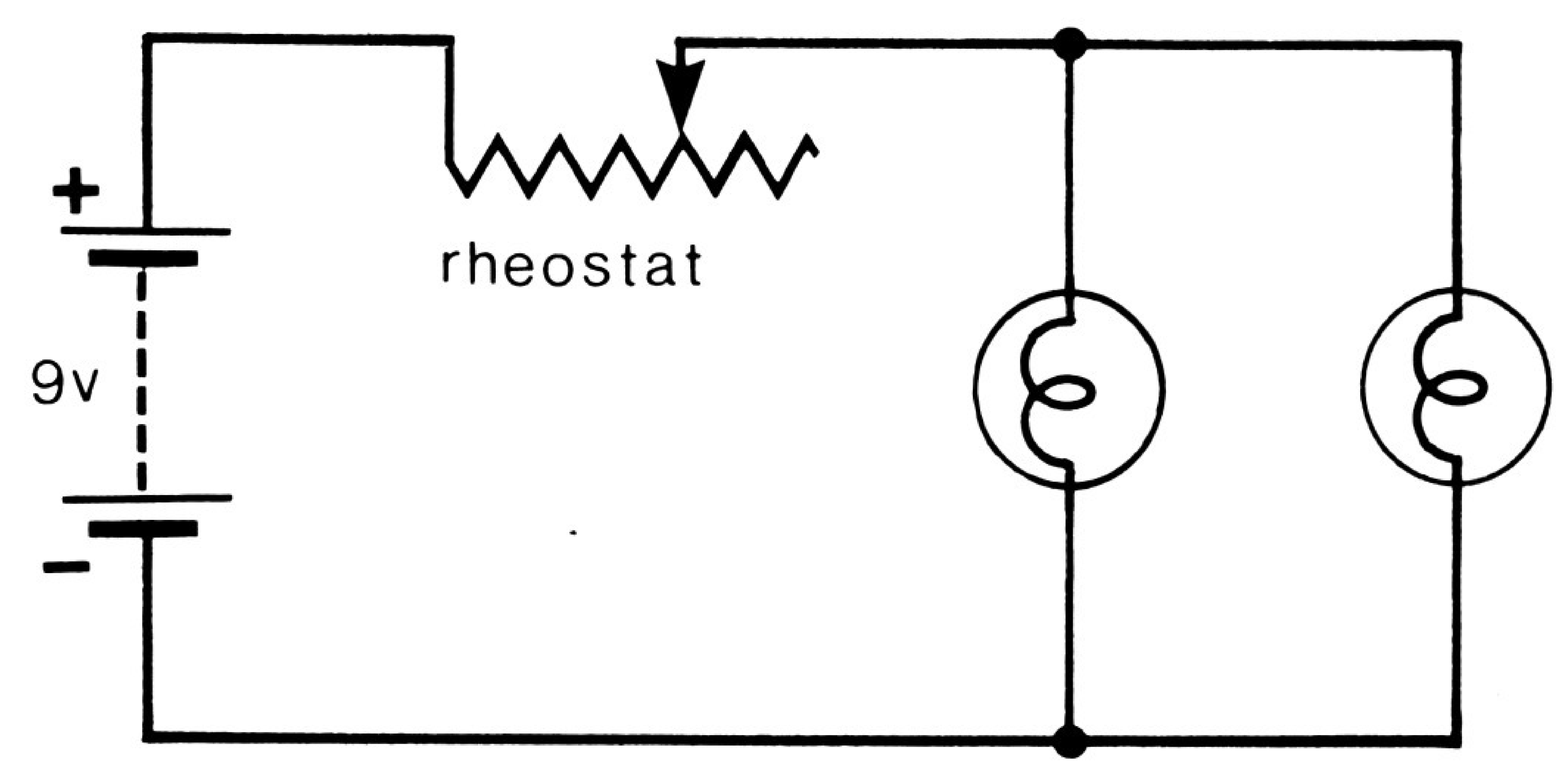
The practical dimmer switch

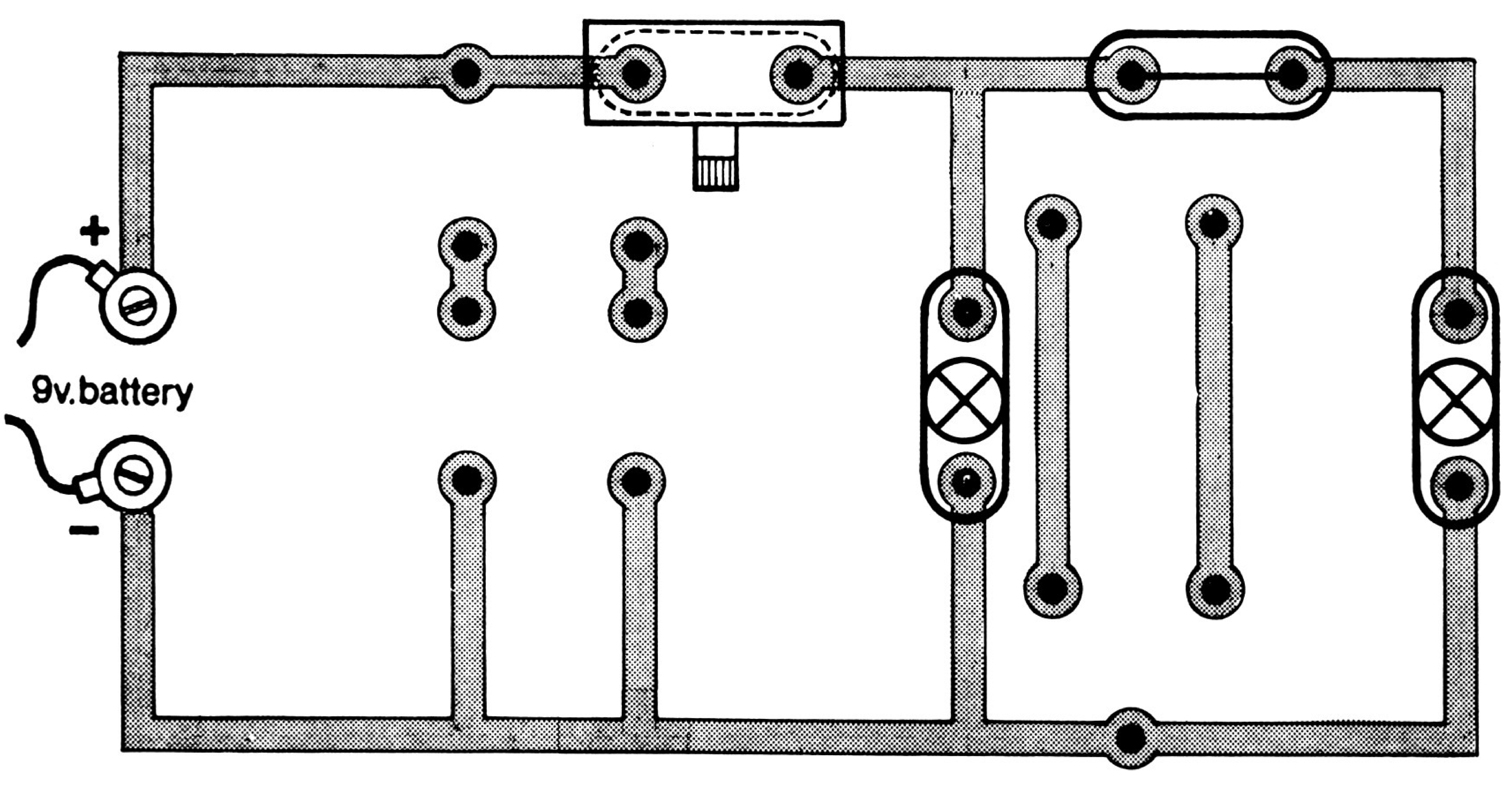
In Experiment 5, you saw the effect that a dimmer switch had on one light. In the cinema, of course, a lot of lights are all dimmed at once. This can still be done by using one dimmer switch. If this was not possible, the operator would have to try to operate twenty to thirty dimmer switches all at once which would be very difficult.

This experiment shows how the one dimmer switch controls several lights at once.

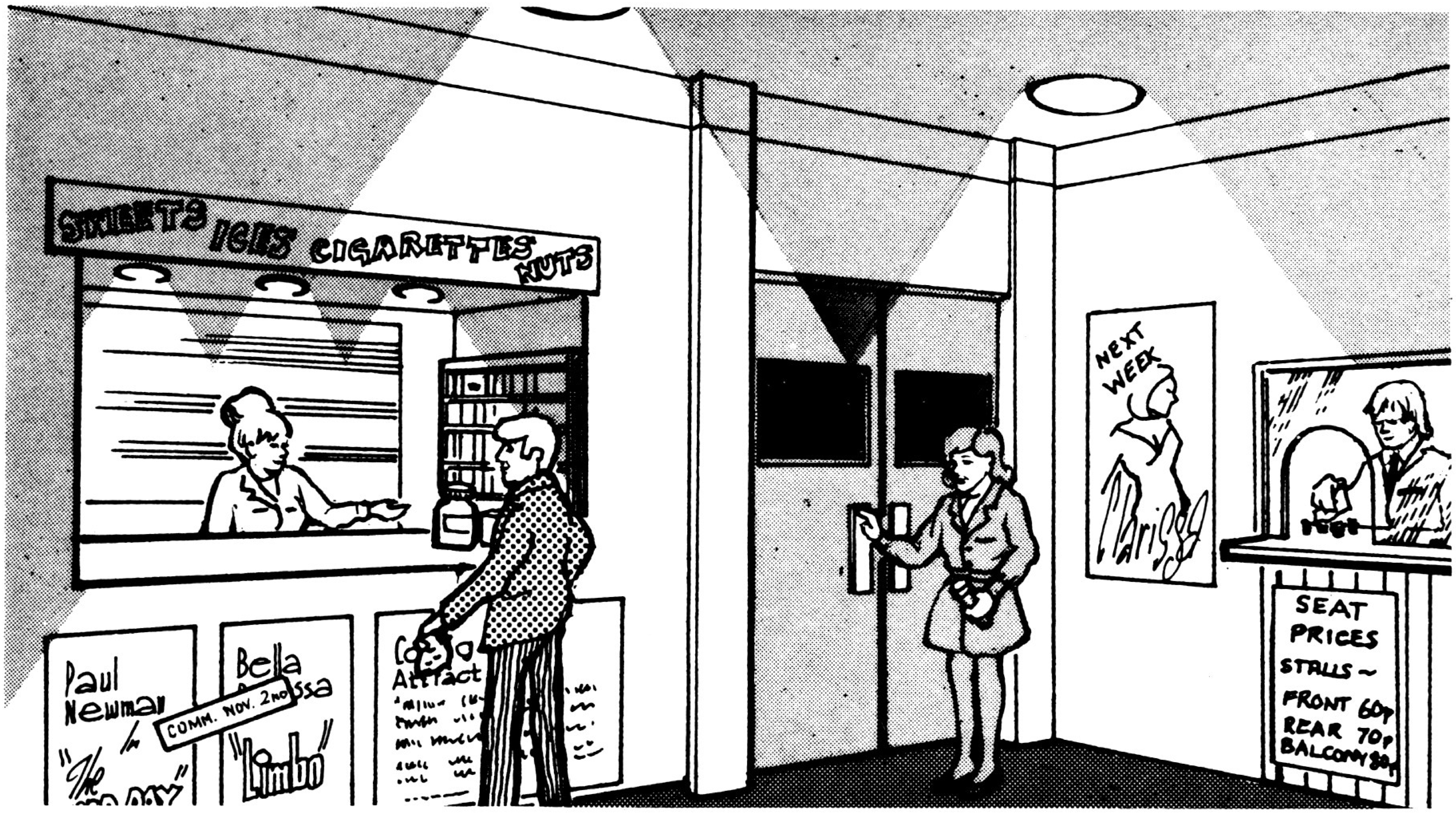
Build the circuit on the printed circuit board as shown. Move the central knob on the rheostat anti-clockwise as before and note the effect on the brightness of both lamps.

1. What happens to the brightness of both lamps as the central knob on the rheostat is turned?
2. Can the electric current from the battery take any path other than through the rheostat?
3. Are the lamps in the circuit connected in series or in parallel?
4. The dimmer switch would still work if the lamps were connected in the other way. Why do you think the lamps are connected in the way they are?


+
9v
−
rheostat


+
9v.battery
−

Experiment 9



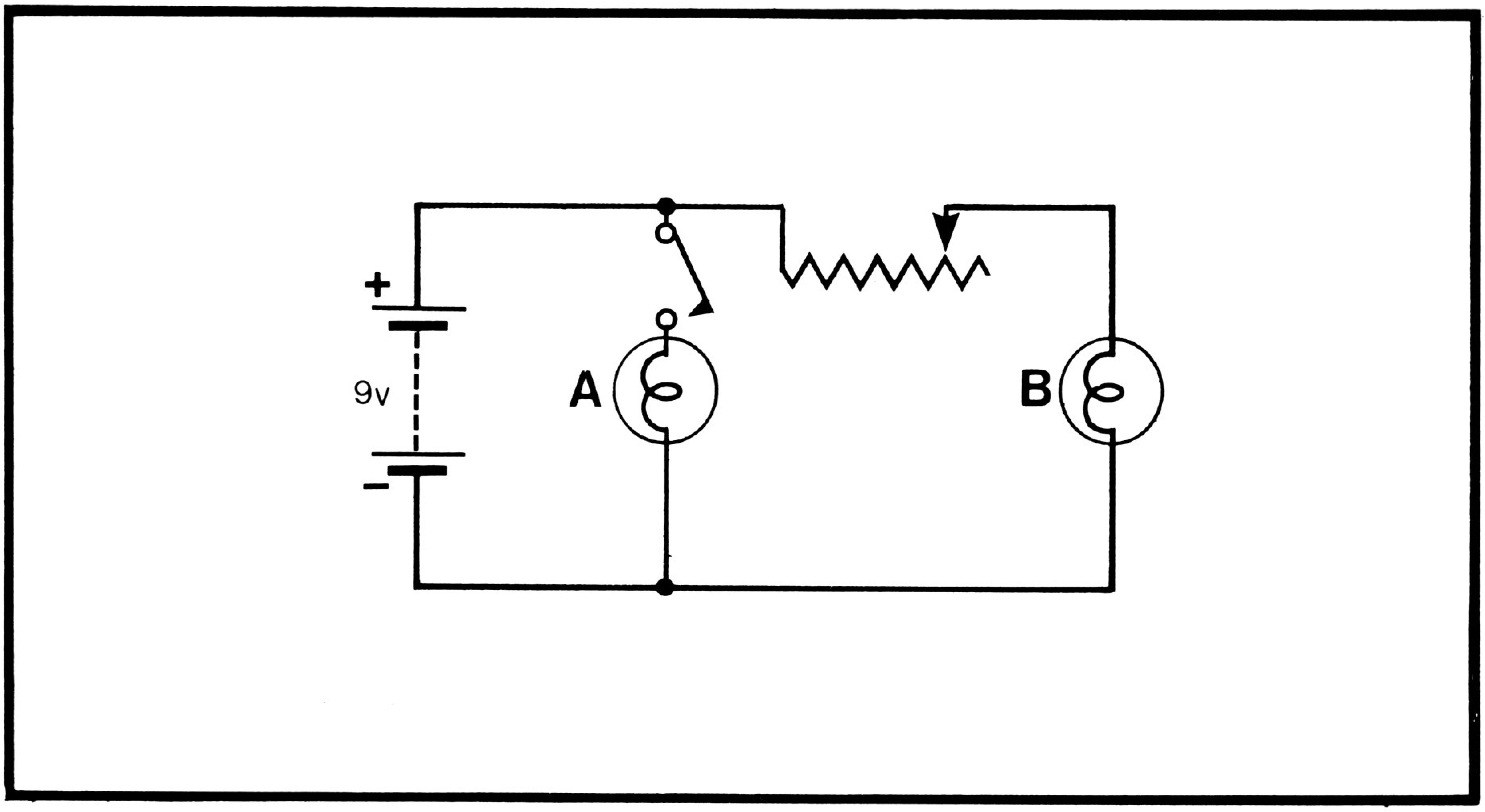
A full lighting circuit with dimmer switch

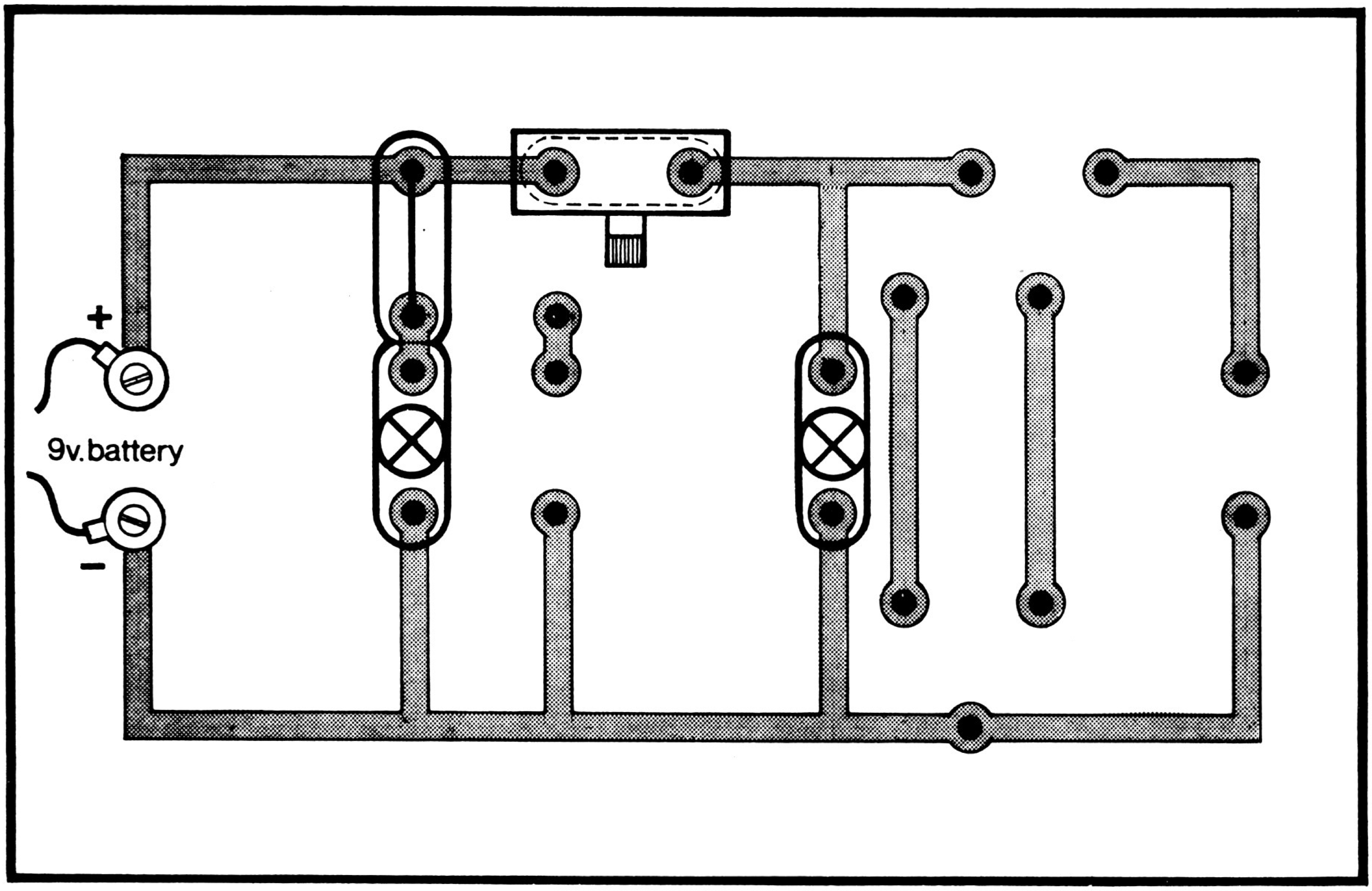
Not all the lights in a cinema are connected to a dimmer switch. If this were the case, the cashier at the pay desk and the attendant in the sweets kiosk would have great difficulty in doing their jobs. Also, the entrance lights would go out as well, so people wouldn't be able to find their way into the cinema.

All these other lights must be separated from the dimmer switch circuit, and this next experiment shows how this is done.

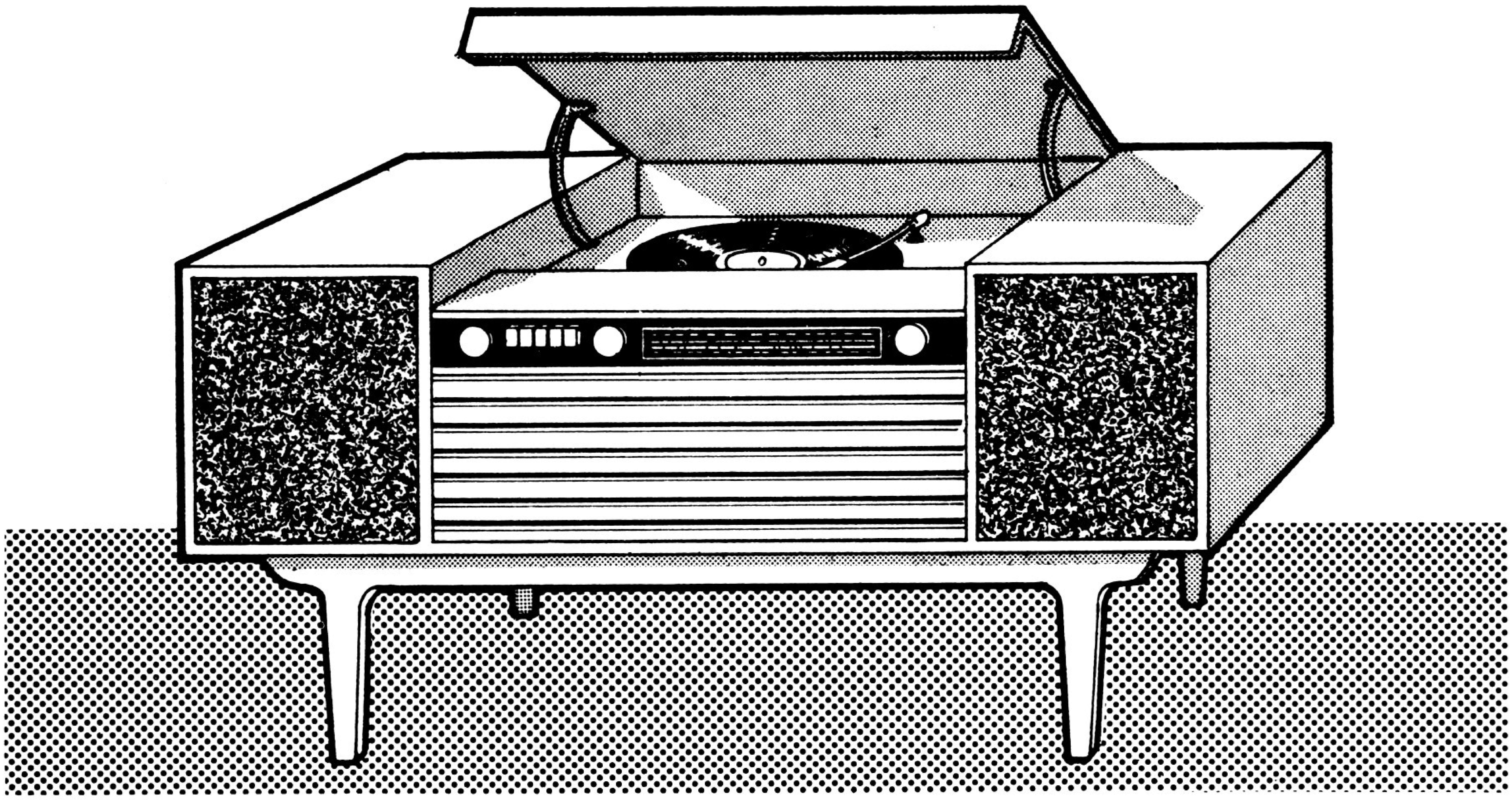
Build the circuit on the printed circuit board as shown. Lamp A represents the lights in the cinema entrance, the cash desk and the sweets kiosk. Lamp B represents the lights inside the cinema itself which have to be dimmed. To do the experiment, vary the resistance of the rheostat by turning the control knob as before. Note what happens to the brightness of both lamps. Remove the switch link to lamp A so that lamp A goes out. Note whether the brightness of lamp B changes.

1. With both lamps lit, what happens to the brightness of both lamps when the rheostat is altered?
2. When lamp A goes out because the switch link is removed, does the brightness of lamp B alter?
3. Are lamps A and B connected in series or in parallel?
4. Are the dimmer switch and lamp B connected in series or in parallel?
5. Are the dimmer switch and lamp A connected in series or in parallel?


+
9v
−
A
B


+
9v.battery
−

Experiment 10

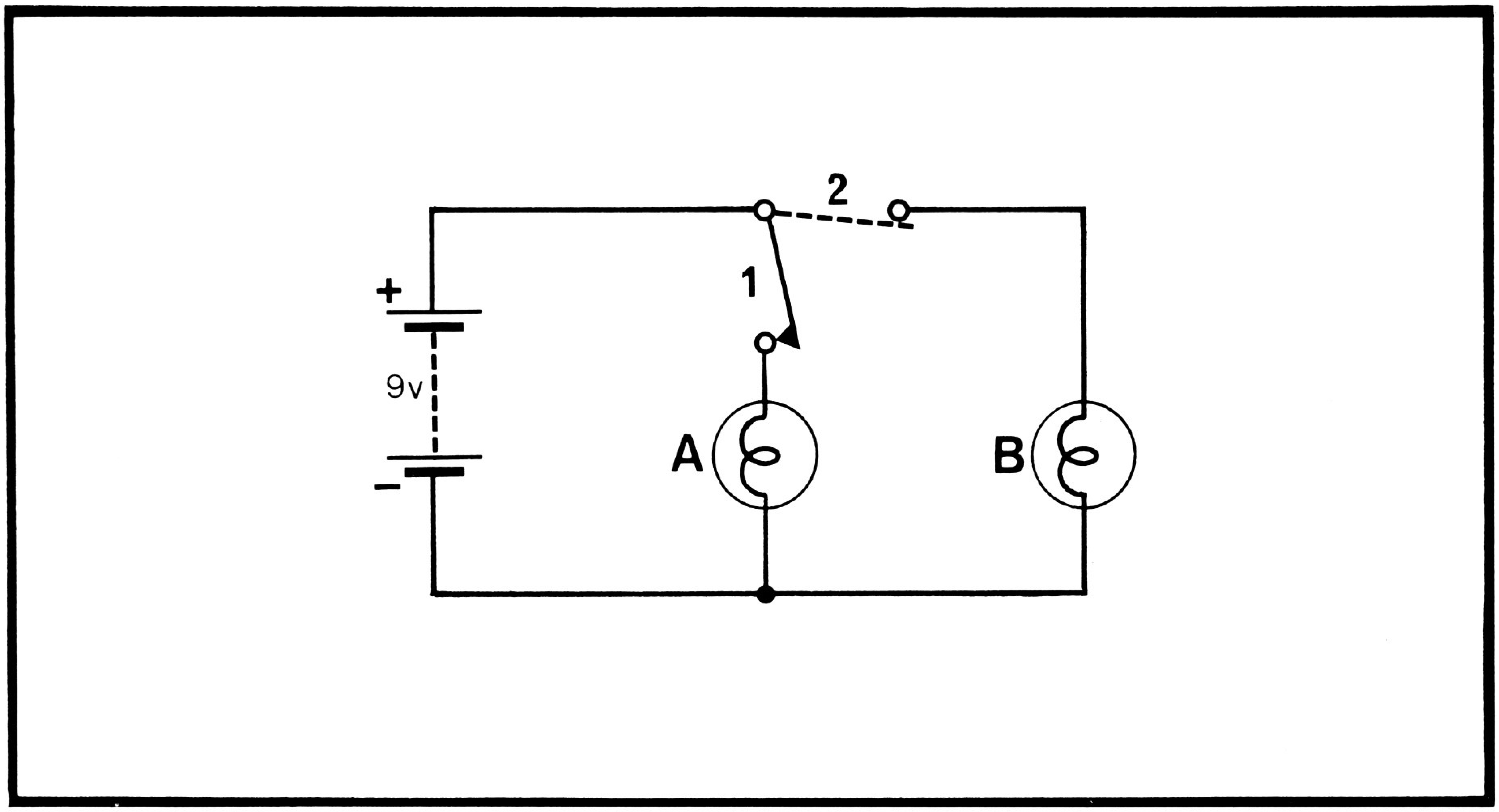


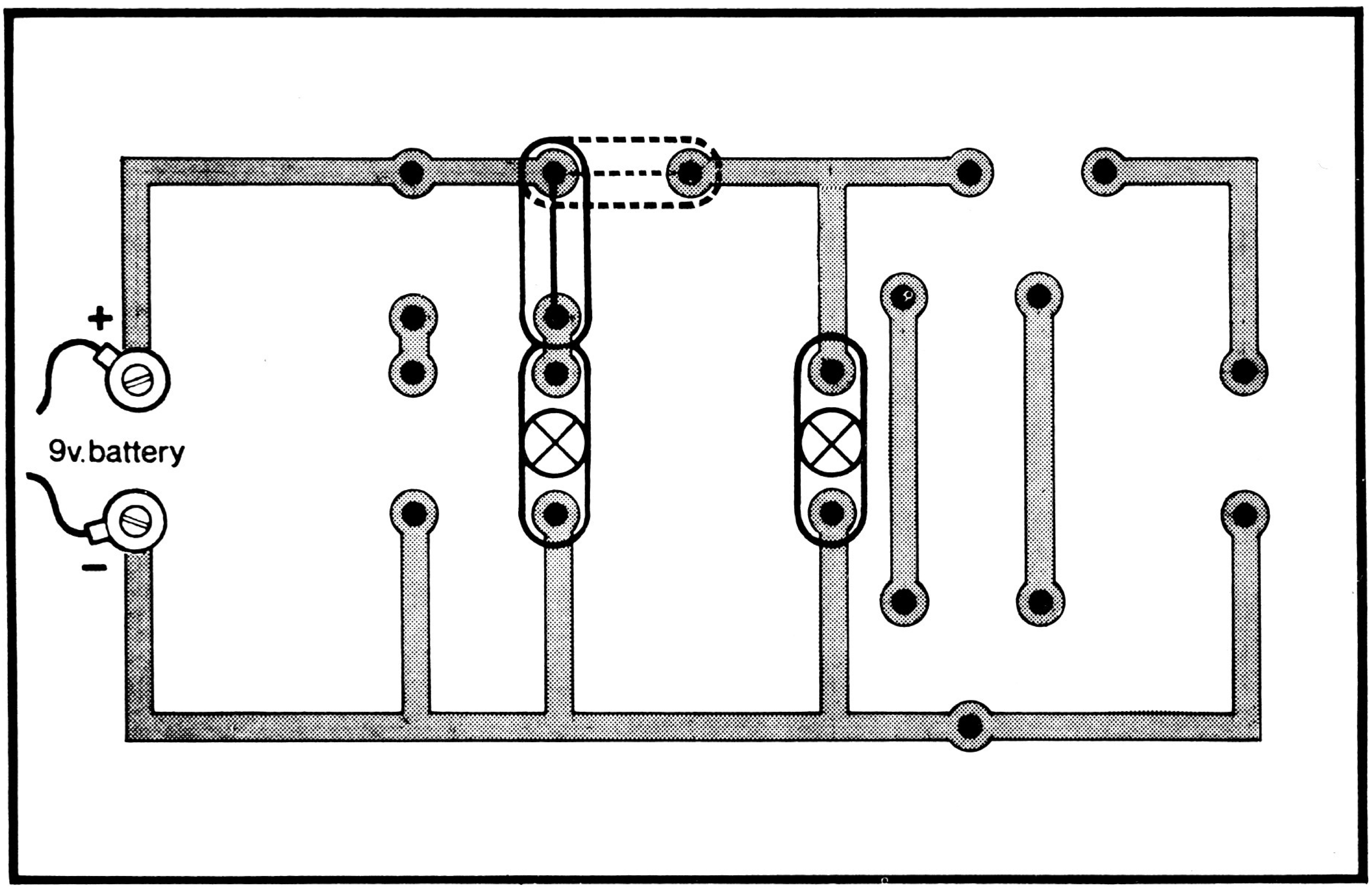
The two-way switching circuit

You have seen how a switch can be used to turn a light on and off. The switch can be used, however, for purposes other than simply to switch something on or off. In a radiogram, for instance, there is both a gramophone and a radio. Obviously, you don't want both of them to be working at the same time; so there must be a way to use whichever one you want at any time. To do this, a switch is put in which can be turned either to 'gramophone' or 'radio'. So whatever position the switch is put in, it turns on either one or the other circuit. For this reason, it is known as a two-way switch.

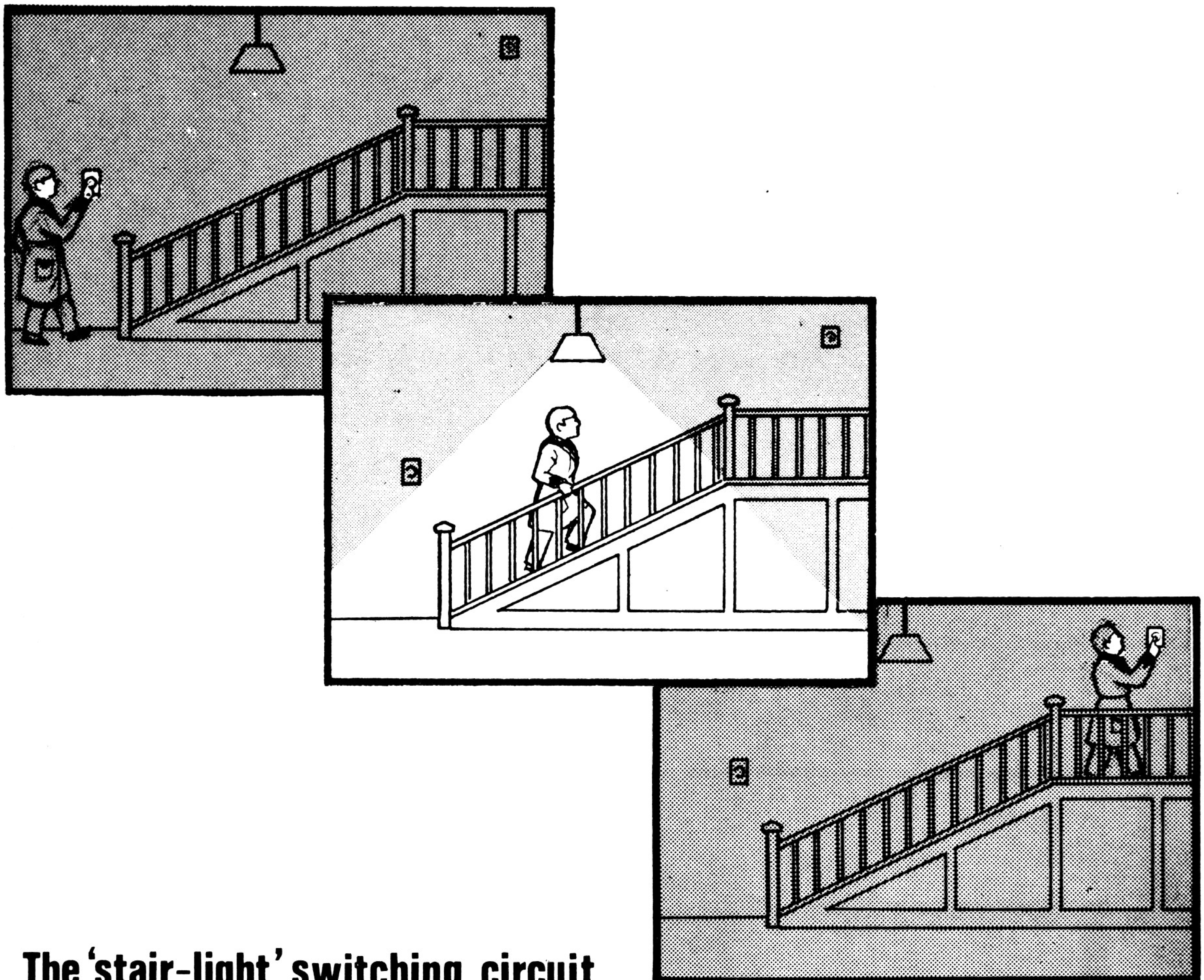
This experiment shows how the two-way switch works. Lamp A represents the gramophone circuit and lamp B represents the radio circuit in a radiogram. Build the circuit as shown on the printed circuit board. Note which lamps are lit. Move the switch link to the position shown as a dotted line on the printed circuit diagram and again note which lamps are lit.

1. Is there any time when both lamps are lit?
2. Is there any time when both lamps are unlit?
3. What is it that decides which lamp or lamps are lit?


2
1
+
9v
−
A
B


+
9v.battery
−

Experiment 11

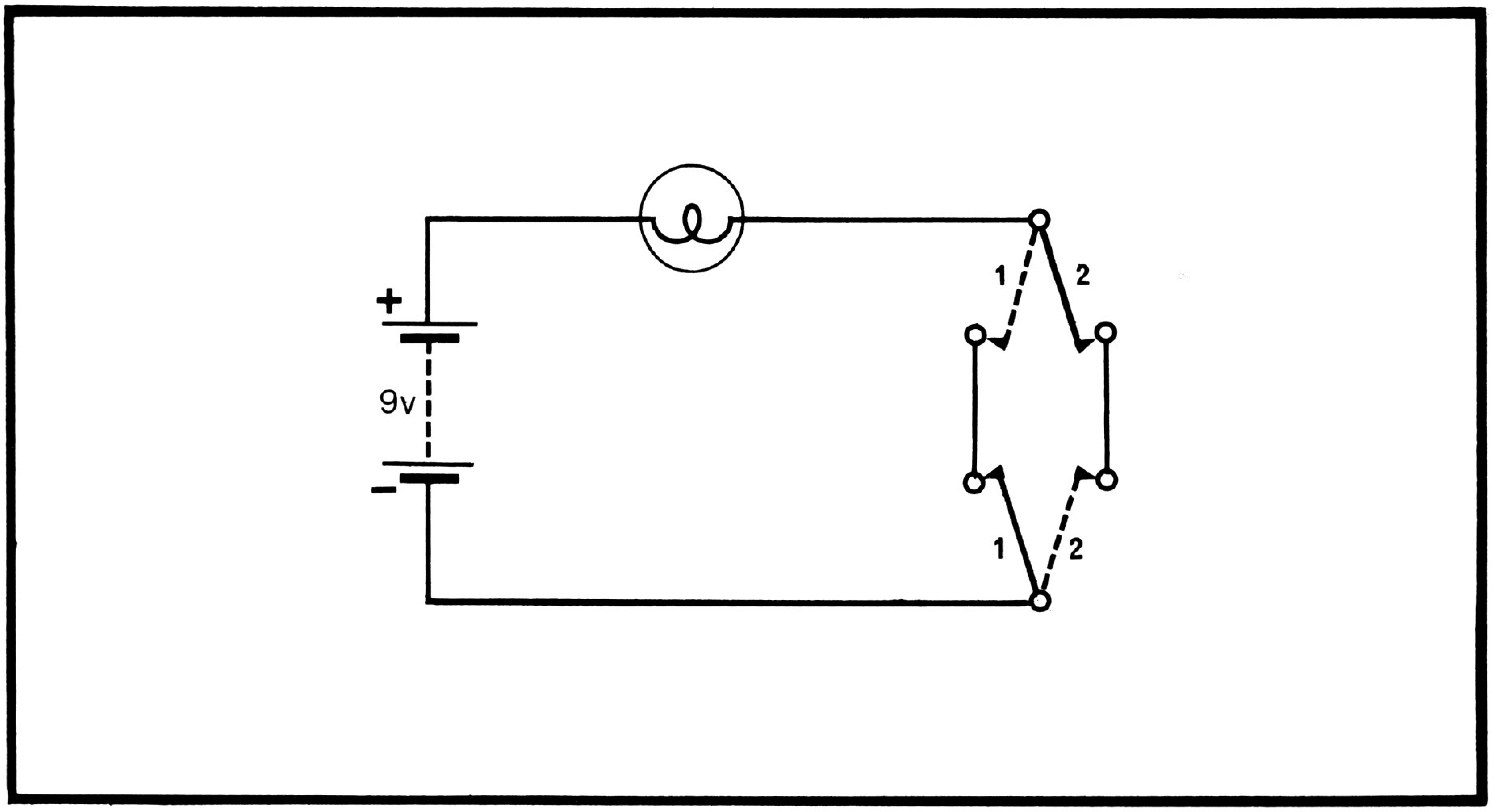


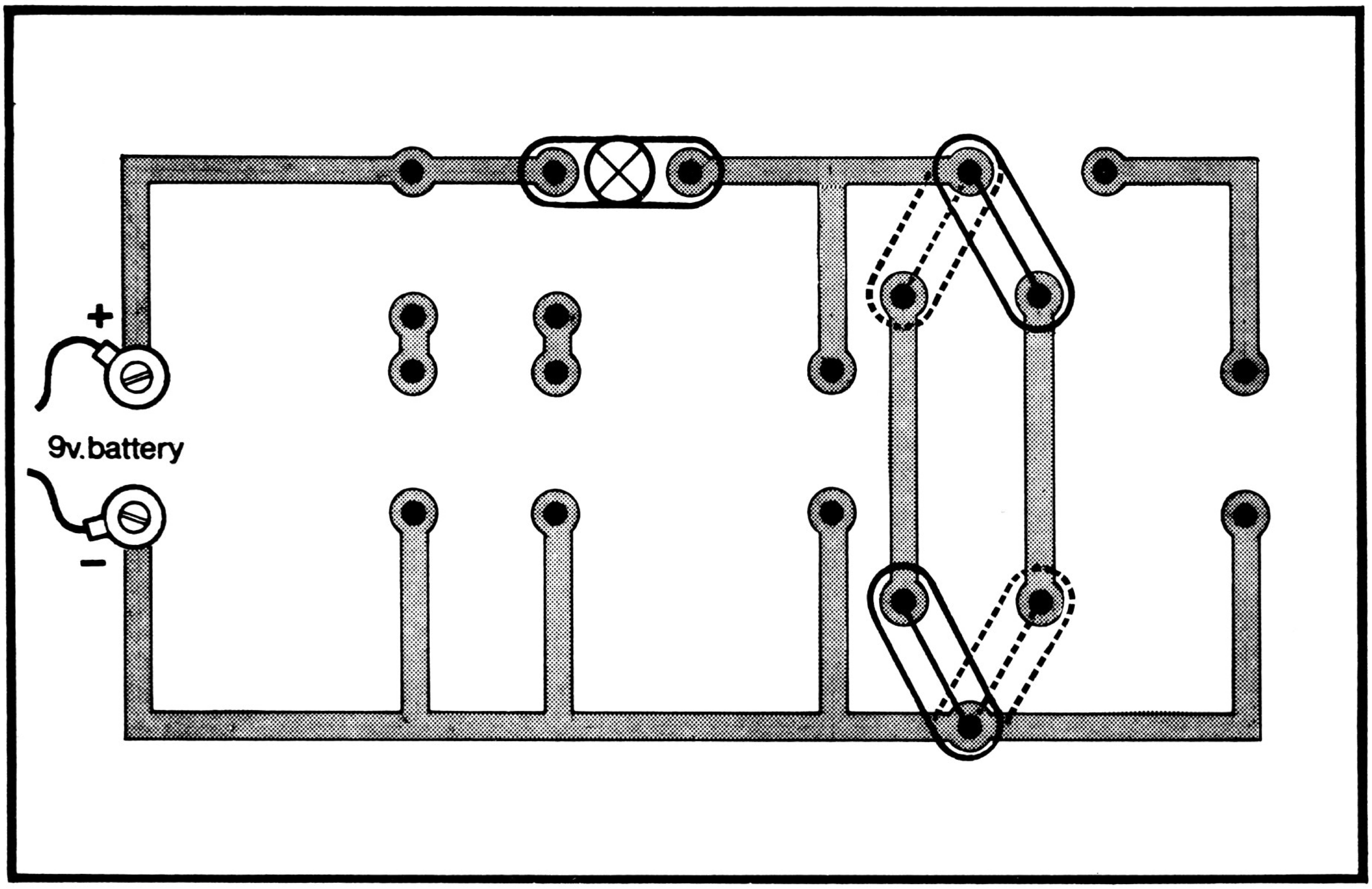
The 'stair-light' switching circuit

Dark stairs in a house can be very dangerous, so it is important that you can put a light on for walking up them and for walking down them. In all modern houses there is a switch at the top and the bottom of the stairs which operate the same light. If the light is turned on at the bottom of the stairs, it can be turned off at the top using the other switch. The same thing can be done when coming down the stairs as well.

This experiment shows you how the switches and light are wired together. Build the circuit as shown on the circuit board, with the top switch link in position 2 and the bottom switch link in position 1. Note whether the lamp is lit. Put the top switch link to position 1 and note whether the lamp is lit. Finally, put the bottom switch link to position 2 and note whether the lamp is lit.

1. What positions do the two switch links have to be in for the lamp to light?
2. What positions do the two switch links have to be in for the lamp to be out?


+
9v
–
1
2
1
2


+
9v.battery
–

Experiment 12

The bar magnet

The properties of a magnet were discovered a long time ago when the Chinese found natural magnets called lodestones in the ground. You may have played with a magnet yourself and discovered some of the special ways in which it acts.

You probably know already that a magnet will pick up some things and not others. For this experiment, collect together as many small objects made from as many different materials as you can. Try picking up with the magnet each object in turn. Make two piles of the objects, one pile of those objects the magnet will not pick up and one pile of those objects the magnet will pick up.

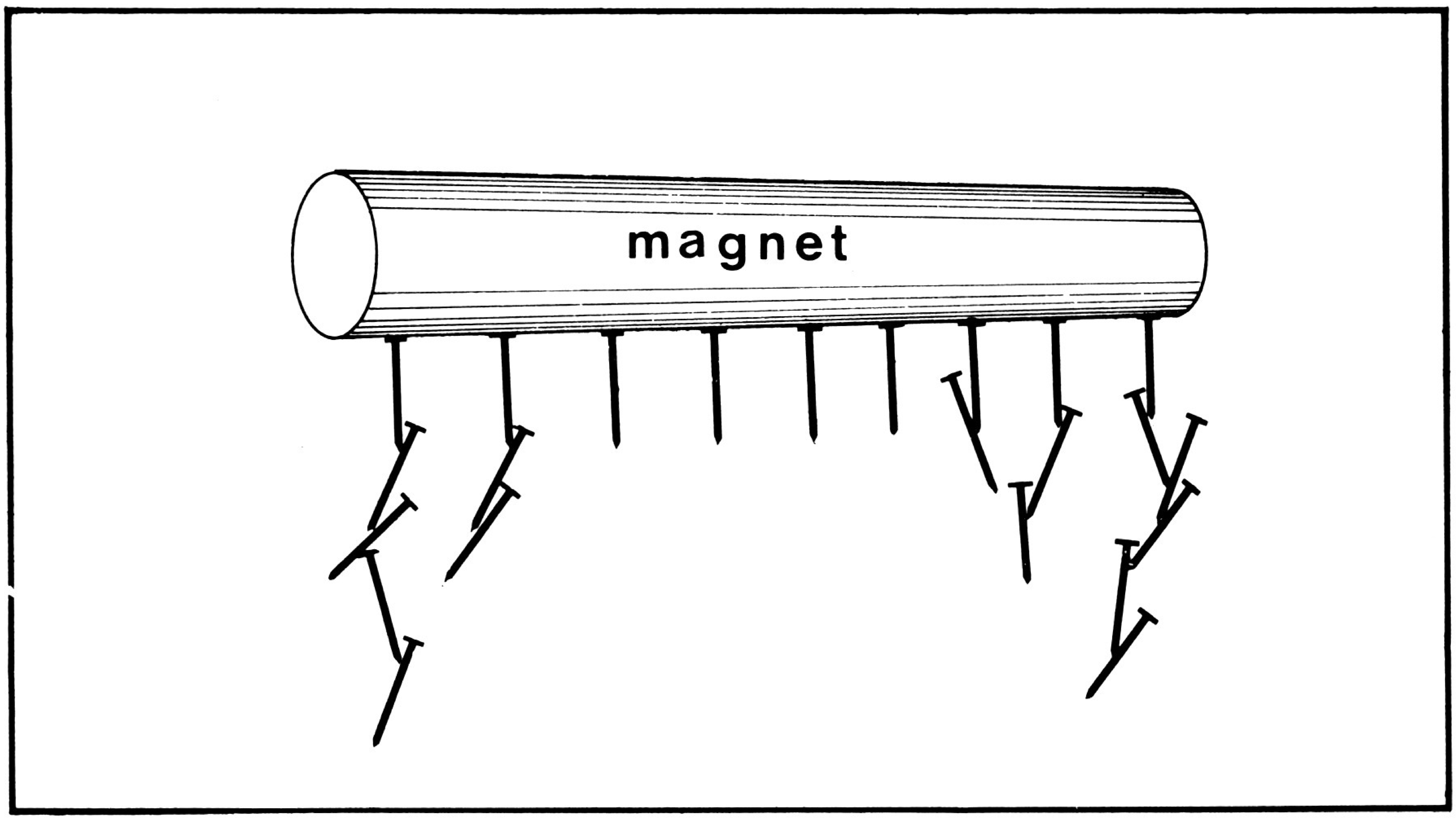
Questions.

1. Will the magnet pick up objects which are not made of metal?
2. Will the magnet pick up all the metal objects regardless of what metal they are made?
3. What metals will a magnet pick up? (If you have difficulty in deciding of what metal an object is made, ask someone).

You have already seen that a bar magnet can exert enough attractive force to pick up small pieces of iron or steel. A bar magnet does not exert the same amount of attractive force from every point on its surface. The points where the attractive force is strongest are known as the POLES of the magnet.

For this part of the experiment you will need some small (half-inch) iron nails.

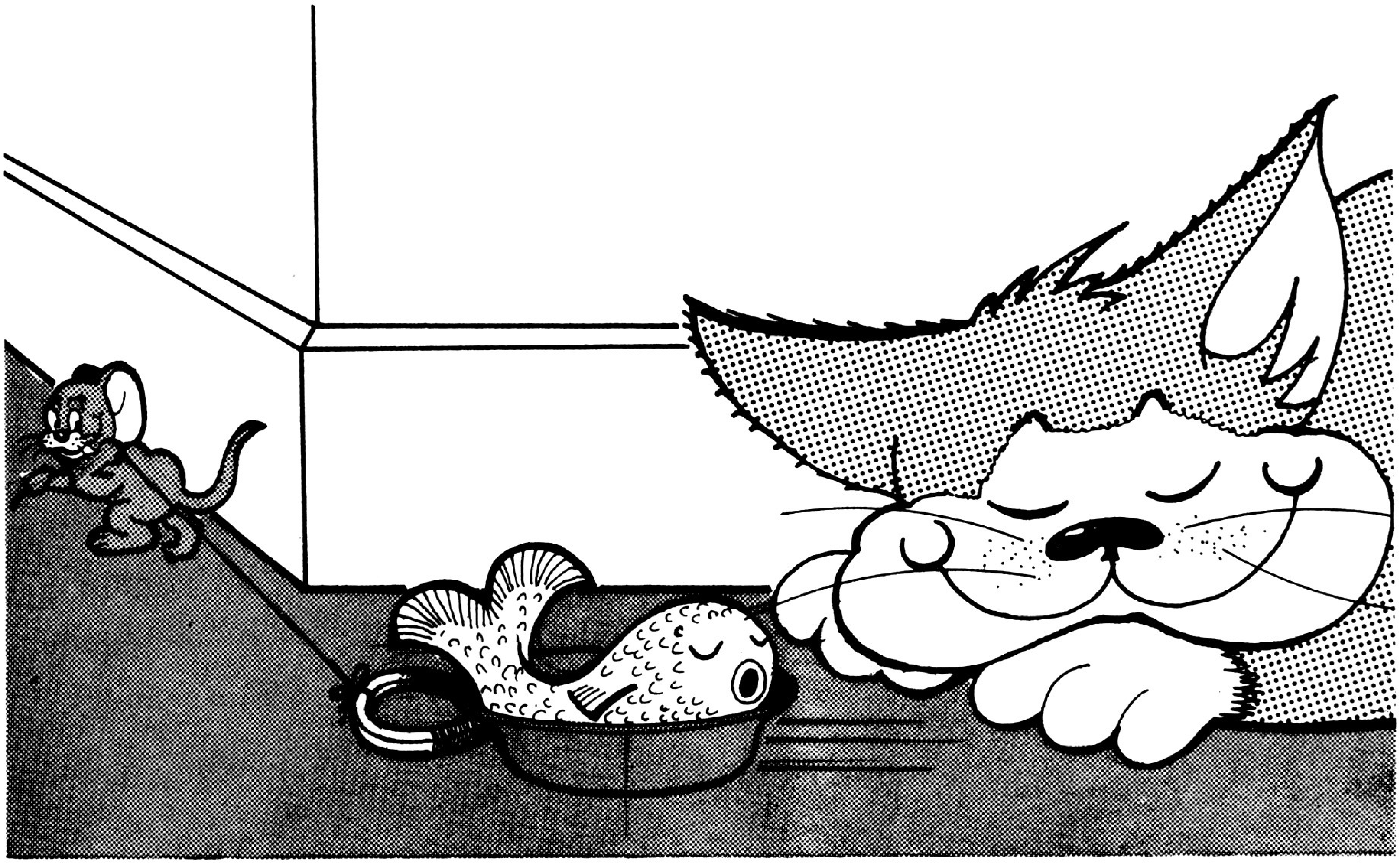
Hold up the magnet horizontally and start hanging nails from it all along its length. Then try hanging more nails from the nails already suspended from the magnet as shown in the picture below, to make chains of nails. Keep on adding nails to each chain until no more nails will stay on.



Questions.

4. Where can you build the longest chains of nails on the magnet?
5. Where is the attractive force strongest in the magnet?
6. Where are the poles found on a magnet?

Experiment 13



Making a bar magnet

If you have one magnet and a piece of steel, you can make the piece of steel into a magnet as well, using the magnet you already have.

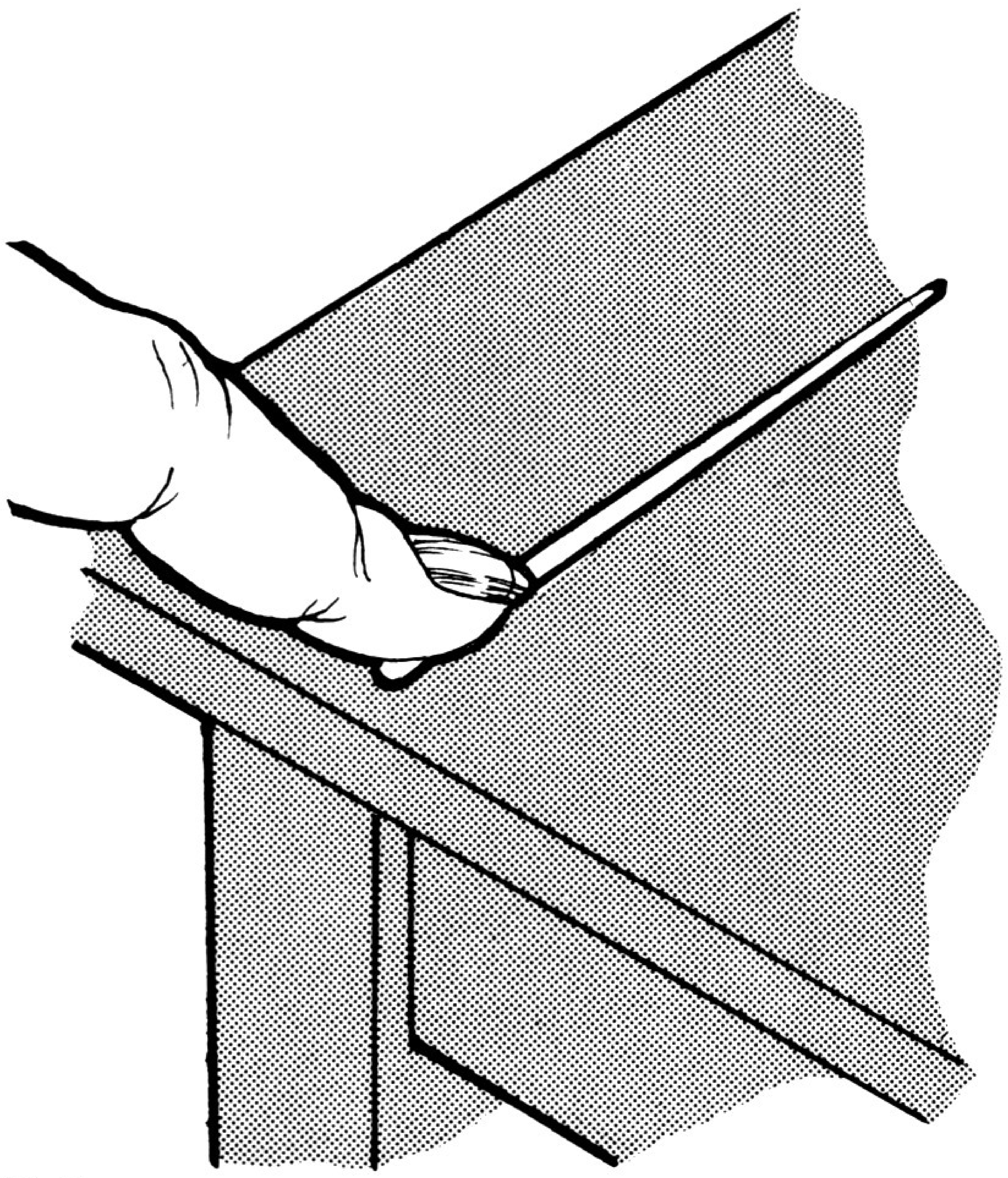
A darning or sewing needle that ladies use for mending is made of steel and so is suitable for making into a magnet. Get a needle and first make sure that it is not magnetised by trying to pick up some half-inch iron nails with it. You should not be able to pick up the nails.

Having satisfied yourself that the needle is not magnetised, place it on a firm flat surface, such as a table top, and hold it down at one end with your finger as shown in diagram 13.1. Make sure that you hold it down firmly.

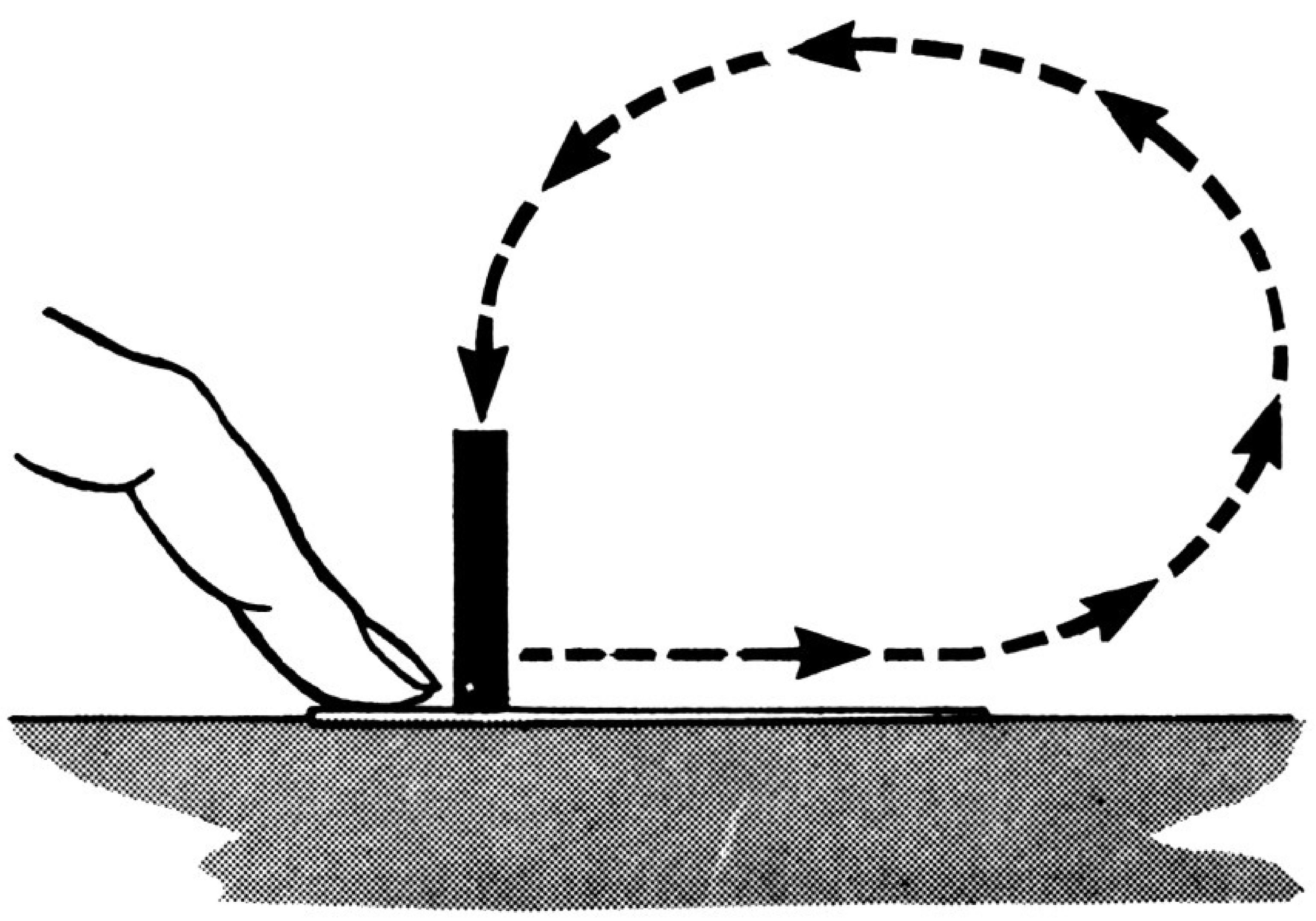
Using the magnet from your kit, run one end of the magnet along the needle from where you are holding it, right to the other end, so you stroke the needle with the magnet.

When you reach the end of the needle, lift the magnet off and return to the end of the needle where you are holding it. The magnet should be lifted well clear of the needle when you are returning it to the beginning, or it will not work so well.

Stroke the end of the magnet along the needle again until the end of the needle is reached, lift the magnet well clear of the needle and return to the beginning. The full cycle is shown in diagram 13.2. You should repeat this cycle for at least three minutes.



13.1

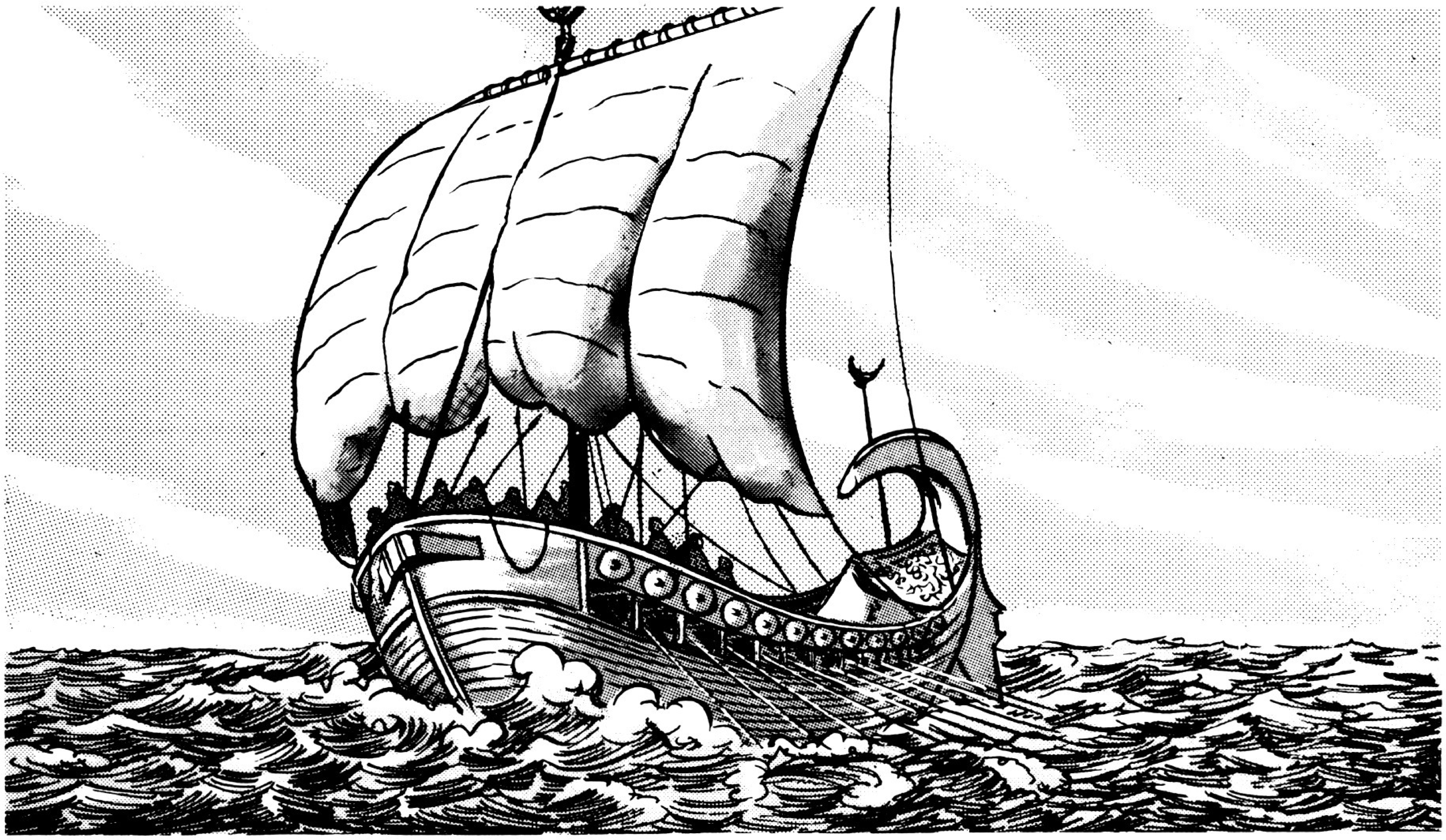


13.2

Put the magnet you have been using well out of the way in the box. Now try to pick up some of the half-inch iron nails with the needle.

1. Will the needle now pick up the iron nails?
2. What does this show has happened to the needle?

Experiment 14

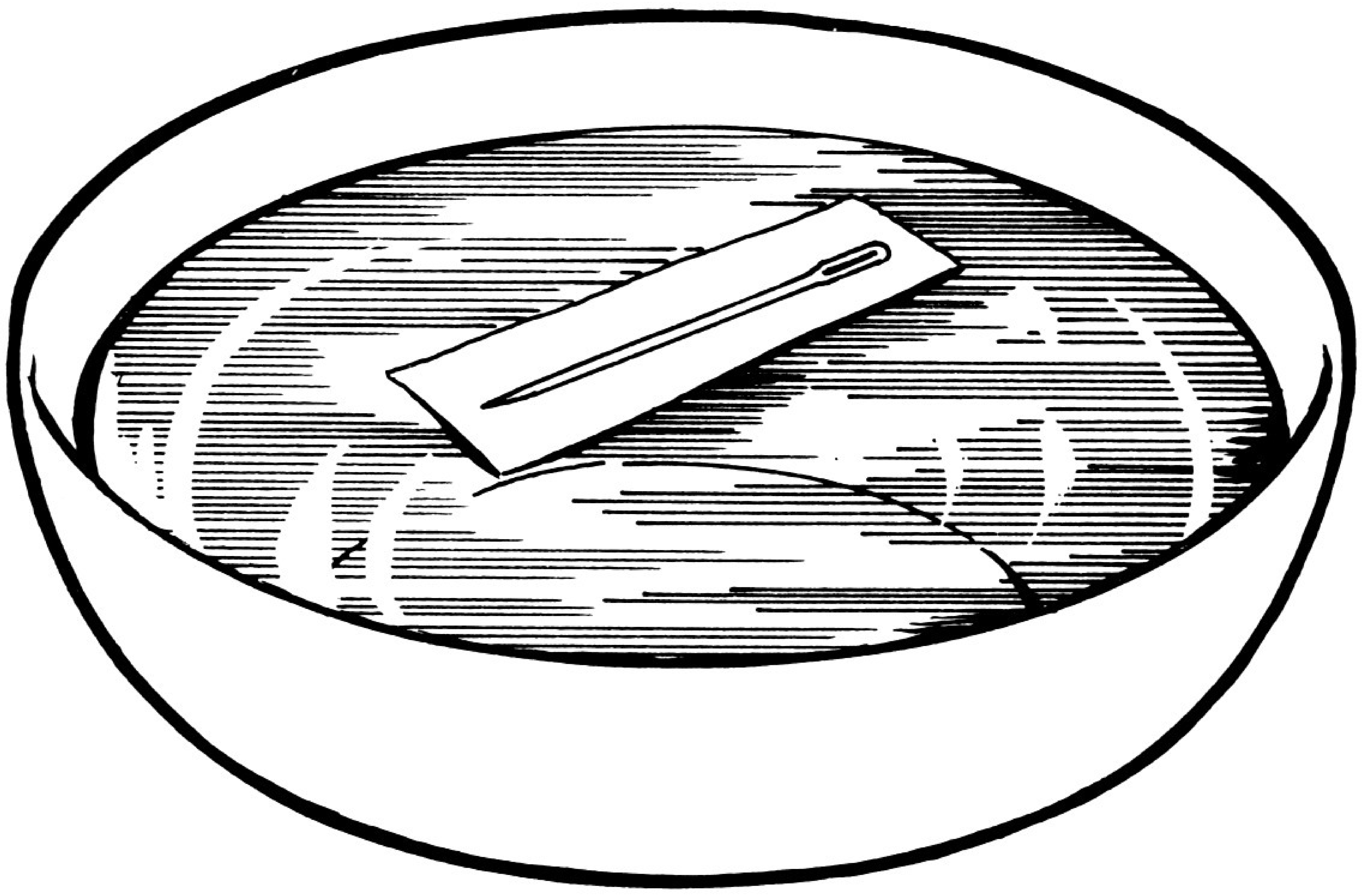


Direction with a magnet

Another special way in which magnets act has been known ever since loadstones were first discovered. Until about 150 years ago, the only practical use for a magnet was through using this special property.

To do this experiment, you will need an un-magnetised needle and the needle you magnetised in the last experiment, together with a dish of water and some thin paper (half a cigarette paper is ideal).

Use the un-magnetised needle first. Float it on the piece of paper on the water in the dish, as shown in the diagram 14.1. Make sure that the surface of the water is absolutely still and let the needle come to rest. Note which way the needle is pointing. Blow gently on the needle in the dish to make it turn and let it come to rest again. Make a note of the direction in which the needle now points. Remember to blow gently as otherwise you may sink the needle. Repeat the experiment several times, making a note each time of the direction in which the needle is pointing when it comes to rest.

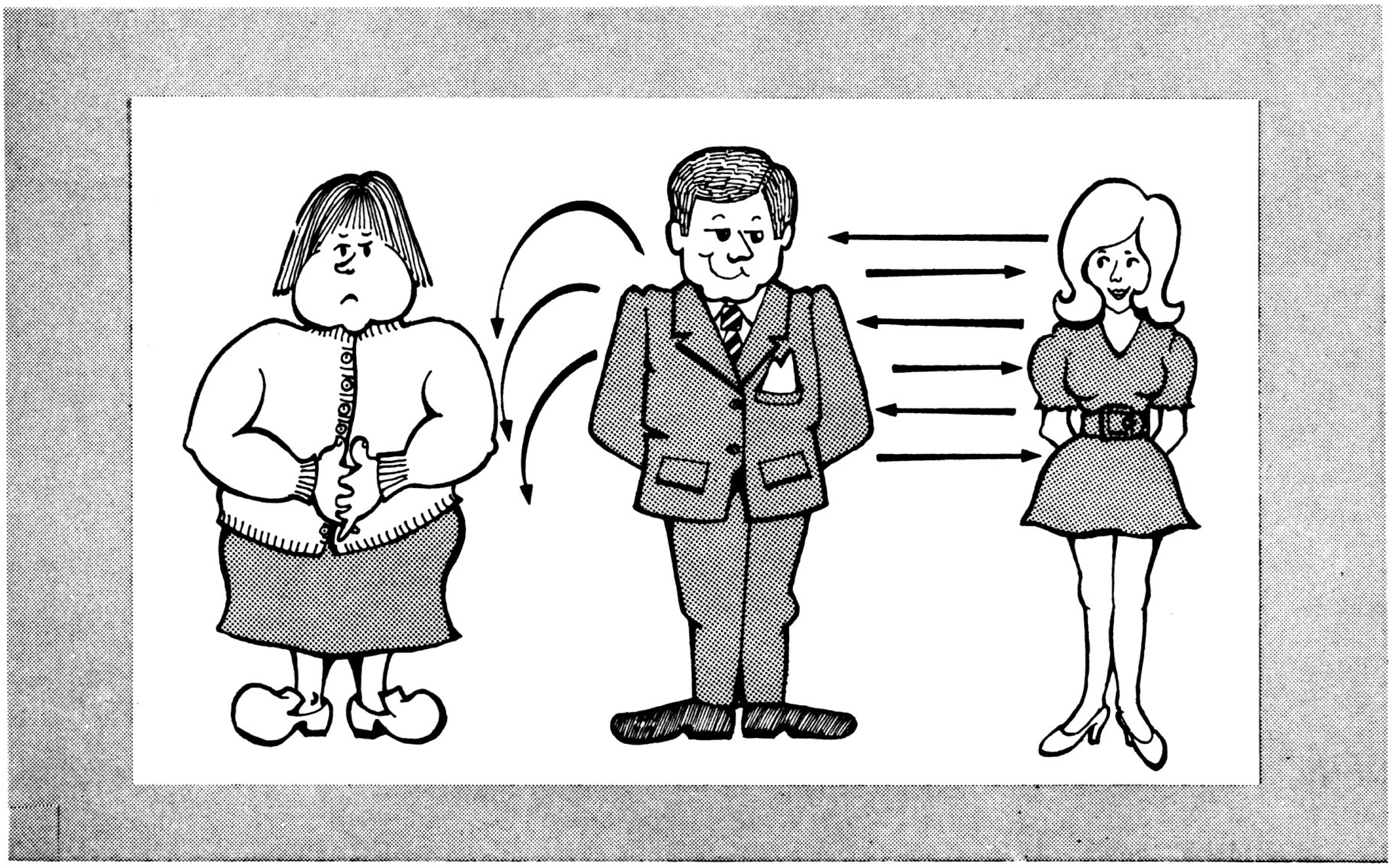


14.1

Replace the un-magnetised needle in the dish with the magnetised one Repeat the experiment, each time making a note of the direction in which the needle is pointing when it comes to rest.

1. When the un-magnetised needle came to rest each time, did it always point in the same direction, or did it point in any direction?
2. When the magnetised needle came to rest each time, did it always point in the same direction or did it point in any direction?
3. What other item in your kit acts in the same way as the magnetised needle?

Experiment 15



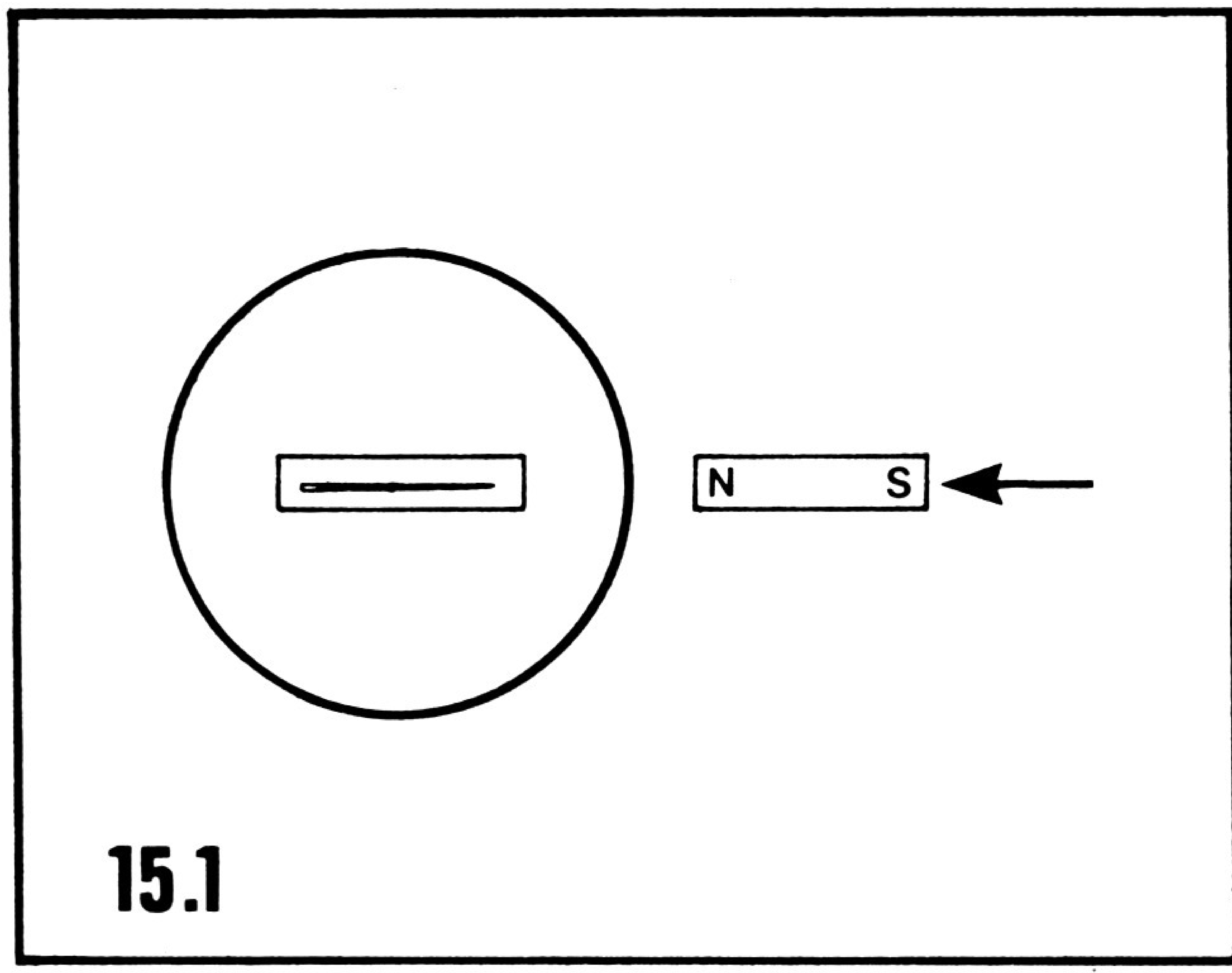
Attraction and repulsion between magnets

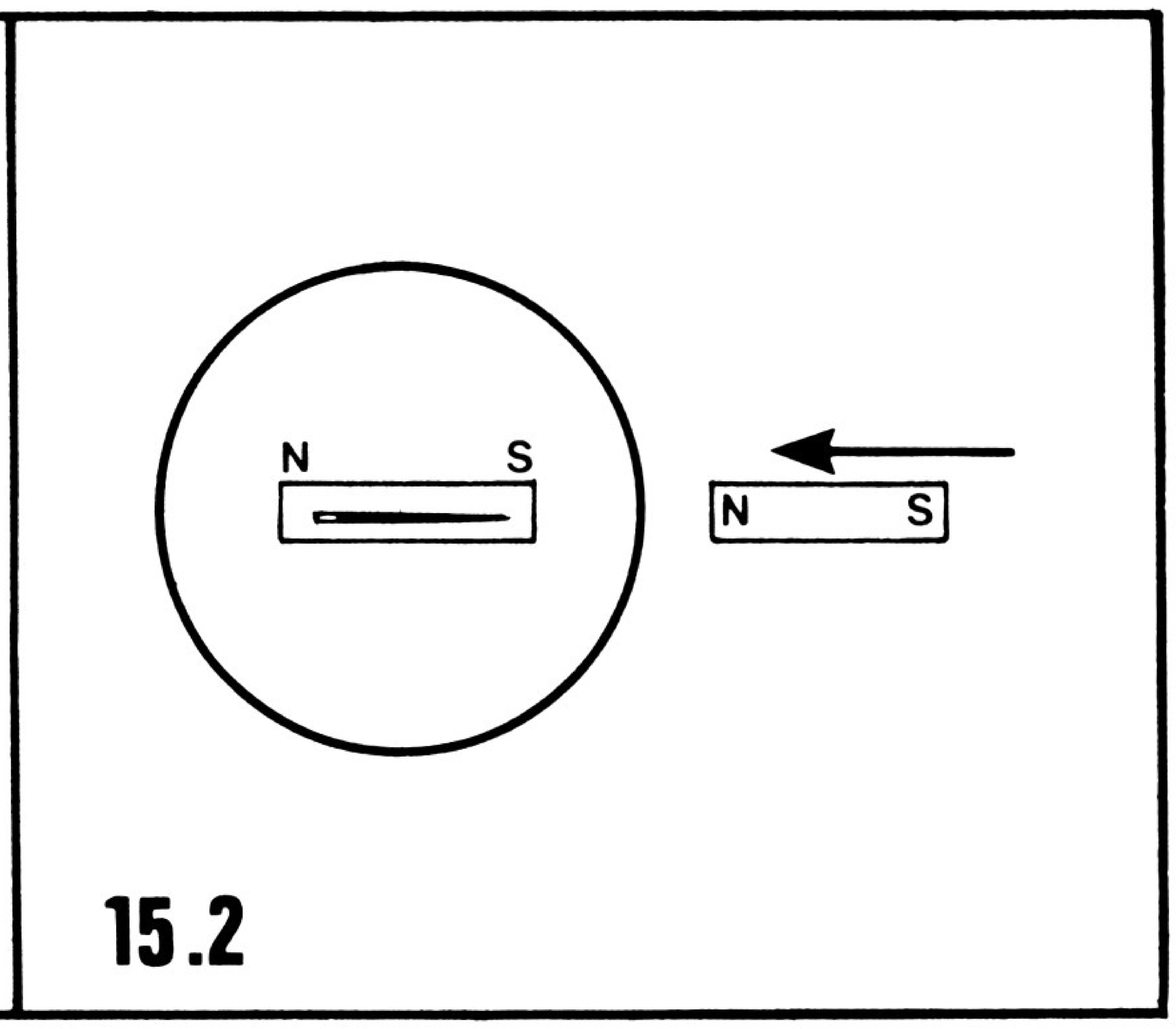
You have seen that a compass is made from a bar magnet, and that one end always points to north, whilst the other end points to the south. The end of the magnet that always points to the north is called the 'North seeking pole' or more simply the 'North pole' of the magnet. The north pole of the magnet in your kit is the painted end.

Float the magnetised needle in the dish of water again and let it come to rest. You can now check to see which is the north pole of the needle (the pointed end or the blunt end) by comparing the direction in which it points with your compass. Make a note of which end of the needle is the north pole.

Replace the magnetised needle in the dish with an un-magnetised one. Make sure that the needle is floating in the middle of the dish. Bring the north pole of the magnet in your kit towards one end of the needle as shown in the diagram 15.1. Make a note of the direction in which the needle moves, either towards the magnet or away from it. Move the needle back to the centre of the dish and repeat the experiment but this time using the south pole of the magnet.

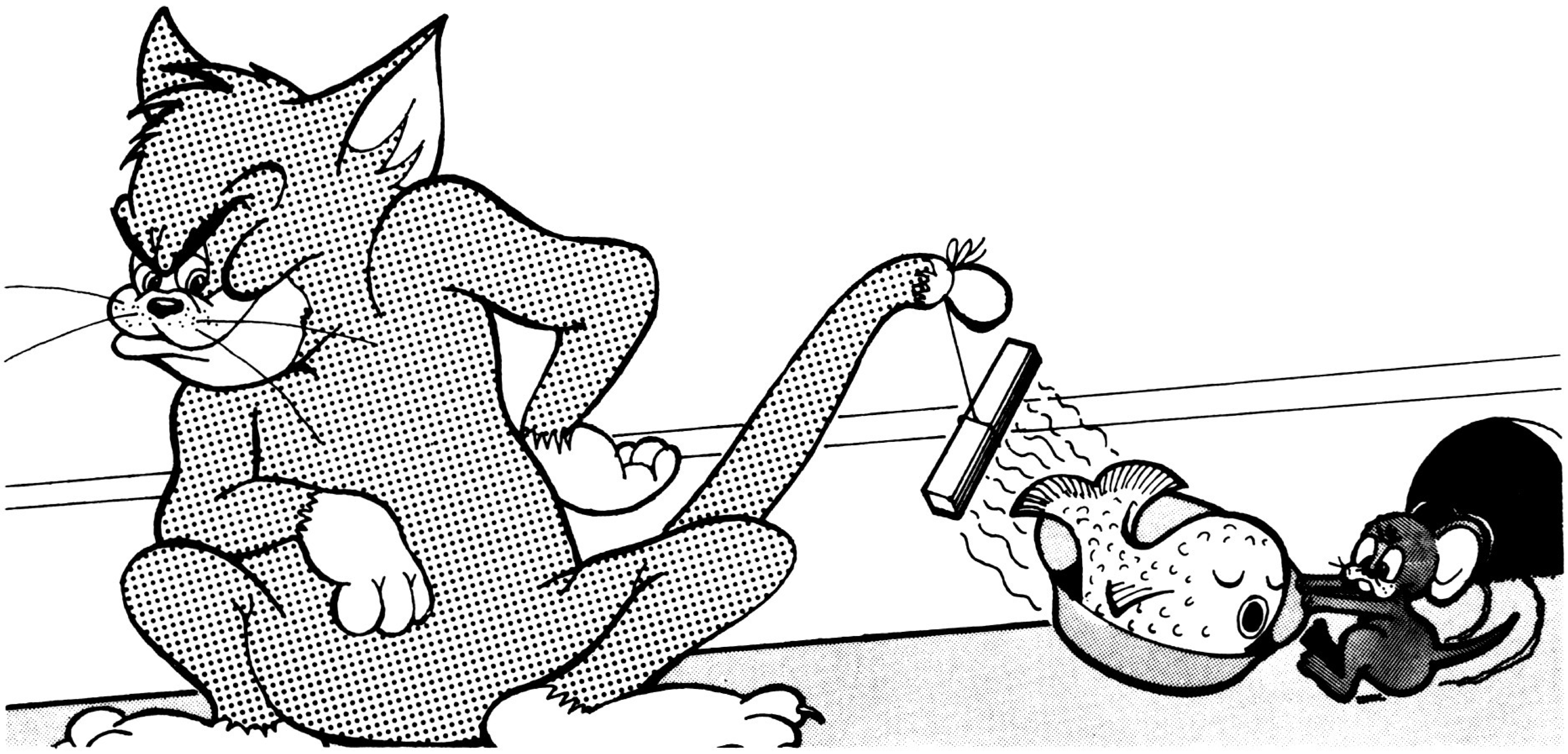
Replace the un-magnetised needle with the magnetised one. Again, let it come to rest in the middle of the dish. Bring the north pole of the magnet towards the south pole of the needle, as shown in diagram 15.2. Note whether the needle moves towards the magnet or away from it. Move the needle back to the centre of the dish. Bring the south pole of the magnet towards the south pole of the needle. Note whether the needle moves towards the magnet or away from it. Repeat the experiment bringing the magnet towards the north pole of the needle.





1. When the magnet was brought towards the un-magnetised needle, how did the needle always move?
2. When the north pole of the magnet was brought towards the south pole of the magnetised needle, or the south pole of the magnet was brought towards the north pole of the needle, how did the needle move?
3. When the south pole of the magnet was brought towards the south pole of the magnetised needle, or the north pole of the magnet was brought towards the north pole of the needle, how did the needle move?
4. If all you had was a magnet and a piece of steel, how could you tell if the piece of steel was a magnet also?

Experiment 16



The field of force around a bar magnet

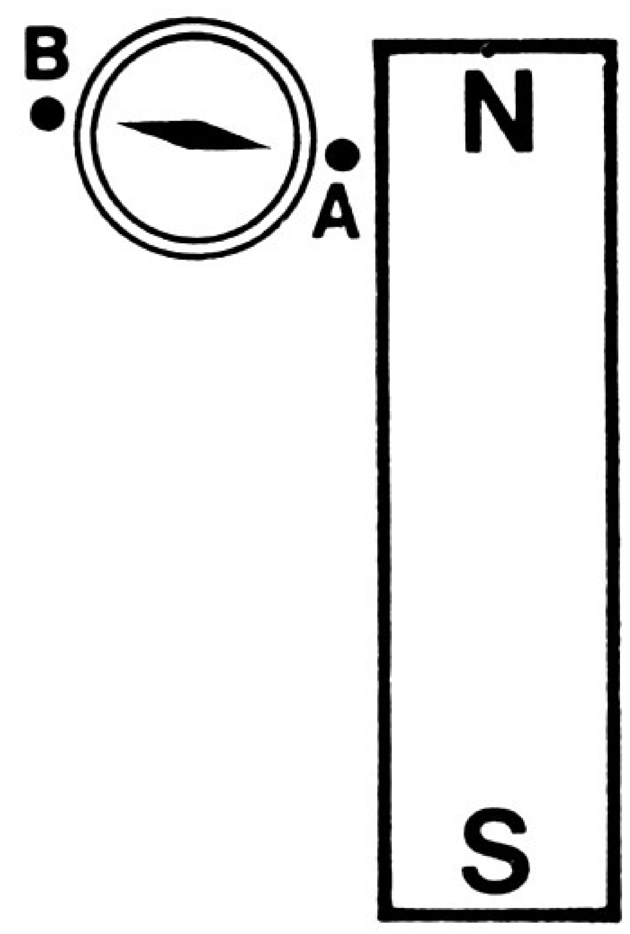
You have seen that the force of attraction is greatest at the poles of a magnet. Also, you have seen that when a magnet is brought close to another magnet, the effect is felt long before the magnets actually touch. Obviously, the force of attraction or repulsion extends outside the magnets as well as being inside them.

In this experiment you will find out how this force of attraction or magnetic force-field fills the space around a bar magnet.

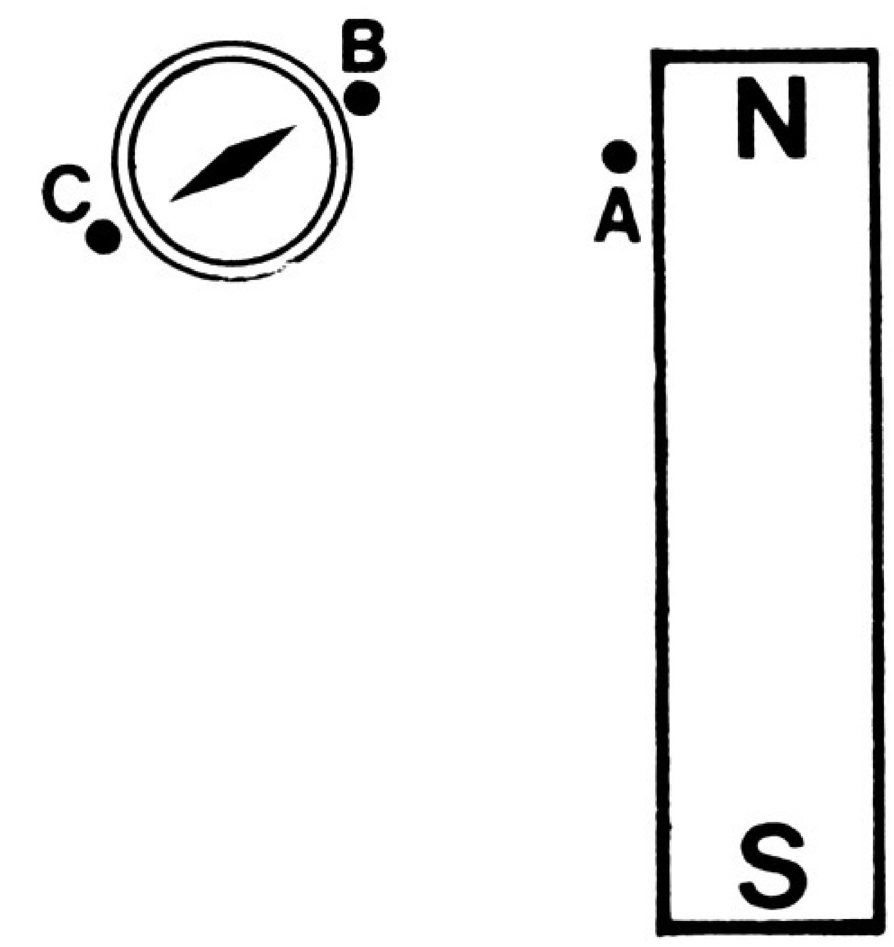
Put a large piece of clean white paper on the table and place the bar magnet from your kit in the middle of it. Place the compass from your kit close to the north pole of the magnet and when the needle comes to rest, mark the direction in which the needle is pointing by making a pencil dot on the paper at each end of the compass needle as shown in diagram 16.1 at the points labelled A and B.

Now move the compass away from the magnet to line up the end of the compass needle that was on point A with point B. Make another mark on the paper to show the position of the other end of the needle (point C in diagram 16.2.).

Continue to plot points on the paper. You will find that the line of dots will lead back to the south pole of the magnet. If you now join up the line of dots you have just plotted, you will have drawn what is known as a LINE OF FORCE. Repeat this experiment several times on each side of the magnet, starting at slightly different points around the north pole of the magnet each time. You will then have a picture of the FIELD OF FORCE surrounding the bar magnet.



16.1



16.2

1. In which direction does the north pole of the compass needle point in relation to the north and south poles of the magnet?

2. Where then can we say that the lines of force start and to where do they go?

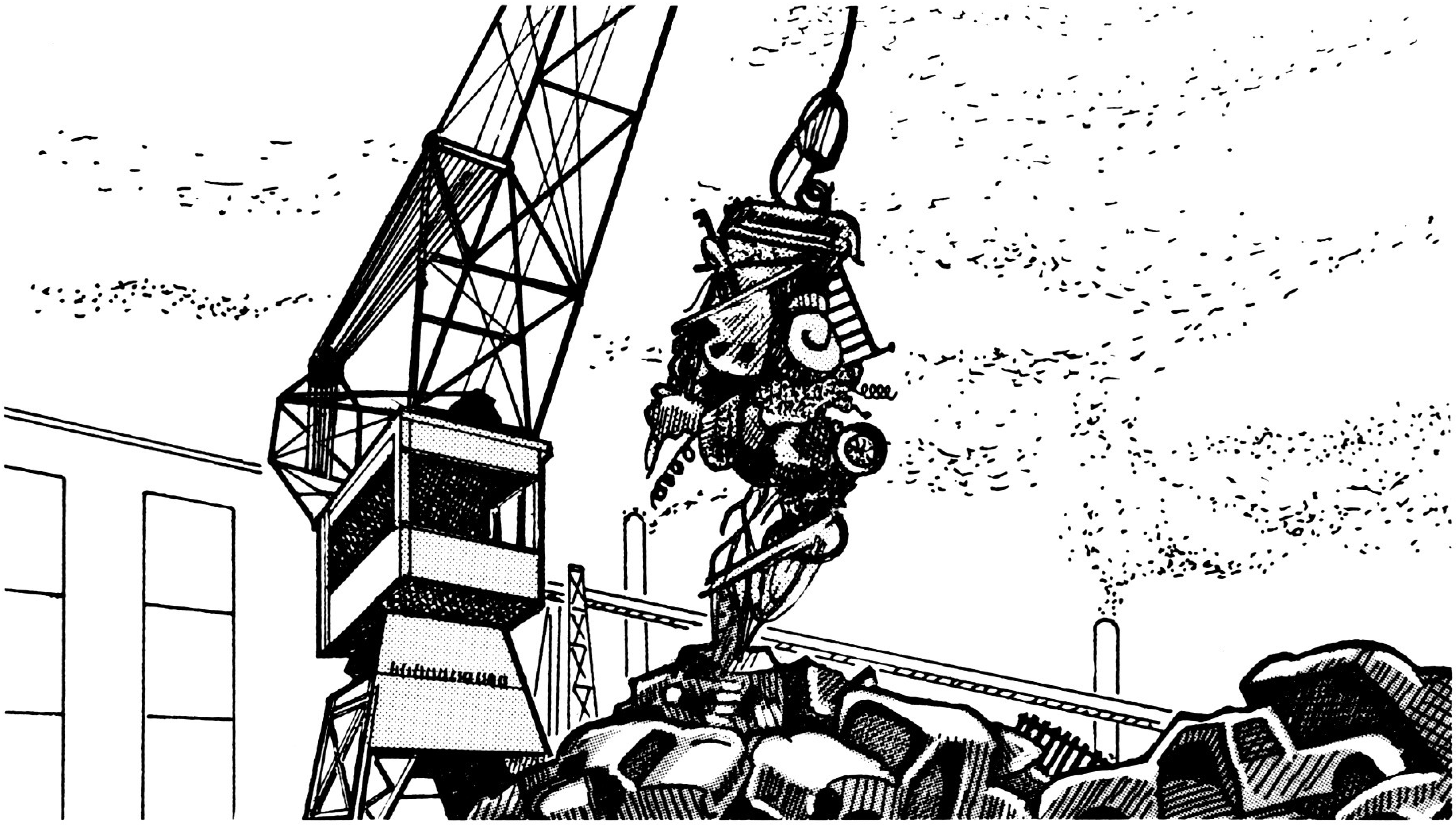
****

You have found that a compass needle, which is a magnet, is affected by other magnets. When there are no other magnets near a compass, it is still affected by something as it always points in a north-south direction. The only way that this can be explained, is to say that the earth itself acts as if it has a bar magnet in its centre (diagram 16.3).

16.3

3. What is the only thing that has an effect on a bar magnet?

Experiment 17

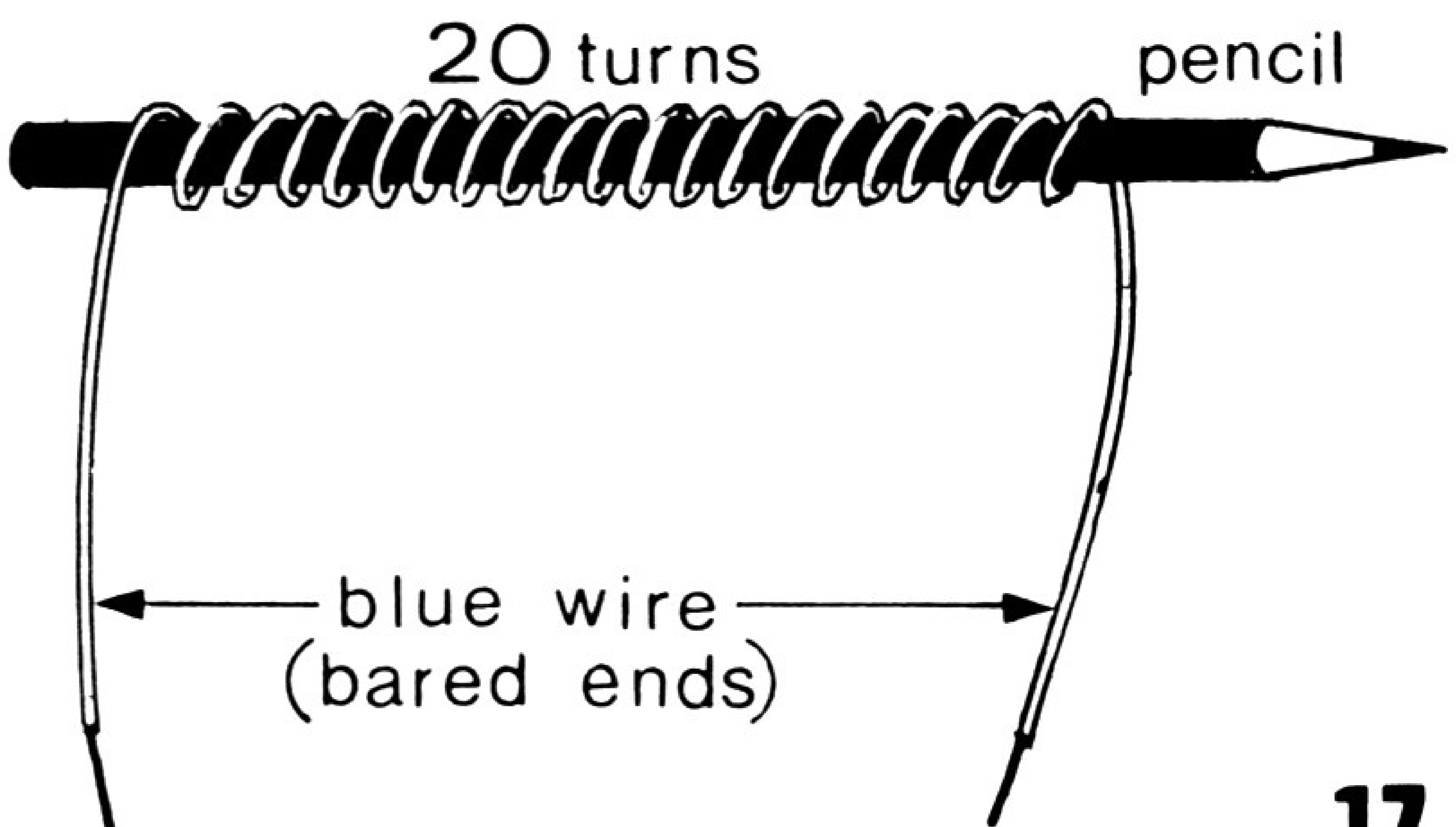


Making a magnet with electricity

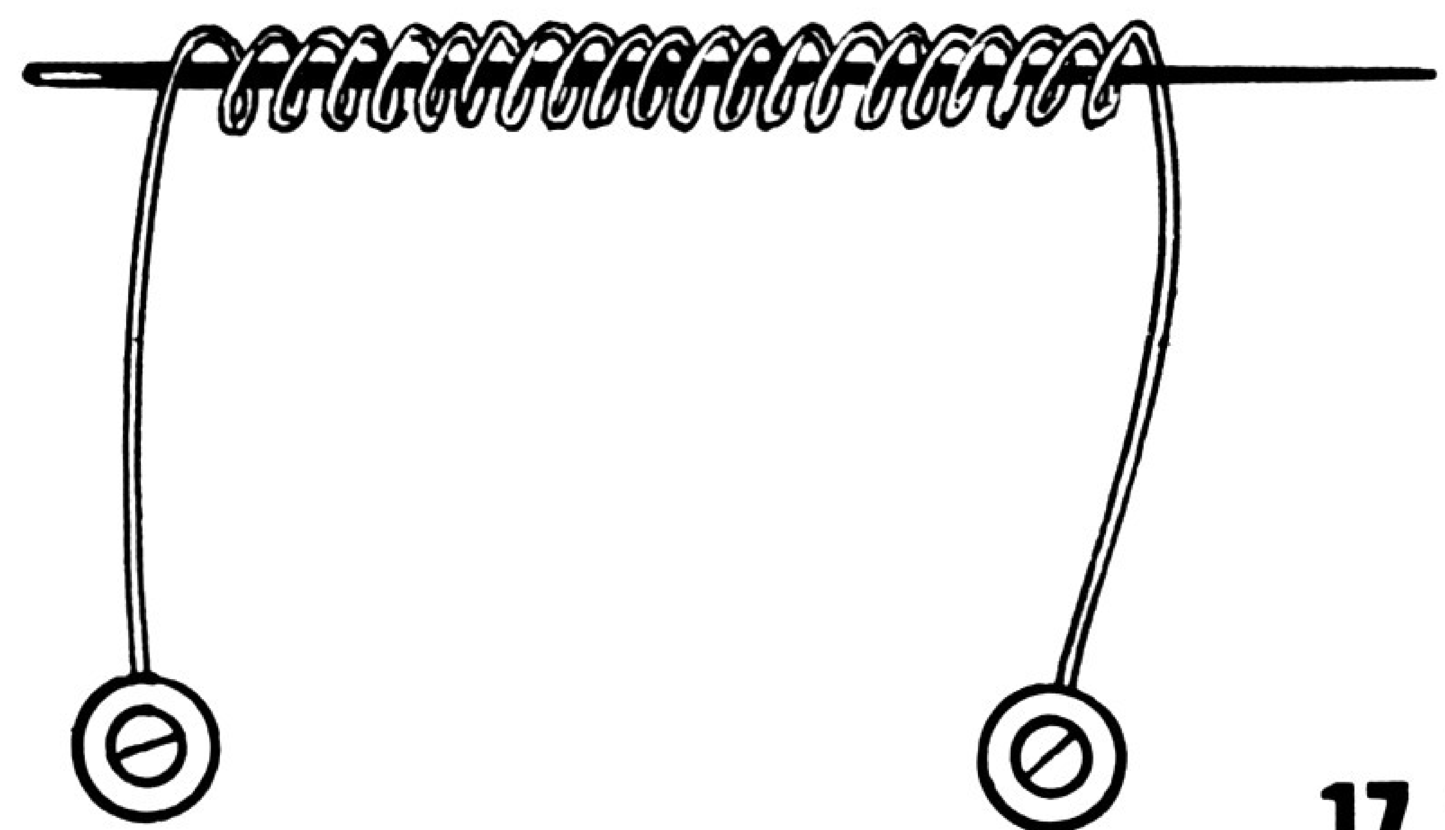
You have made an ordinary sewing or darning needle into a magnet by stroking the needle with another magnet. There is, in fact, a somewhat easier and more practical way of making a magnet.

Wind some of the blue wire (from your kit) 20 times around a pencil so that you make a coil as shown in diagram 17.1. Use sticky tape to hold the coil of wire together, and then remove the pencil from inside the coil. Connect the coil, in series with a lamp, into the circuit as shown on the printed circuit board. Connect the circuit to the battery and make sure that the lamp lights. This is to make sure that the circuit is complete and that an electric current is flowing through the coil. Put an un-magnetised needle inside the coil as shown in diagram 17.2 and leave it there with the circuit switched on for about 3 minutes. Disconnect the battery and remove the needle from the coil. Float the needle in a dish of water as you did in Experiment 15. Using the magnet from your kit, see whether the needle moves towards it or away from it when each end of the magnet is brought close to the needle.

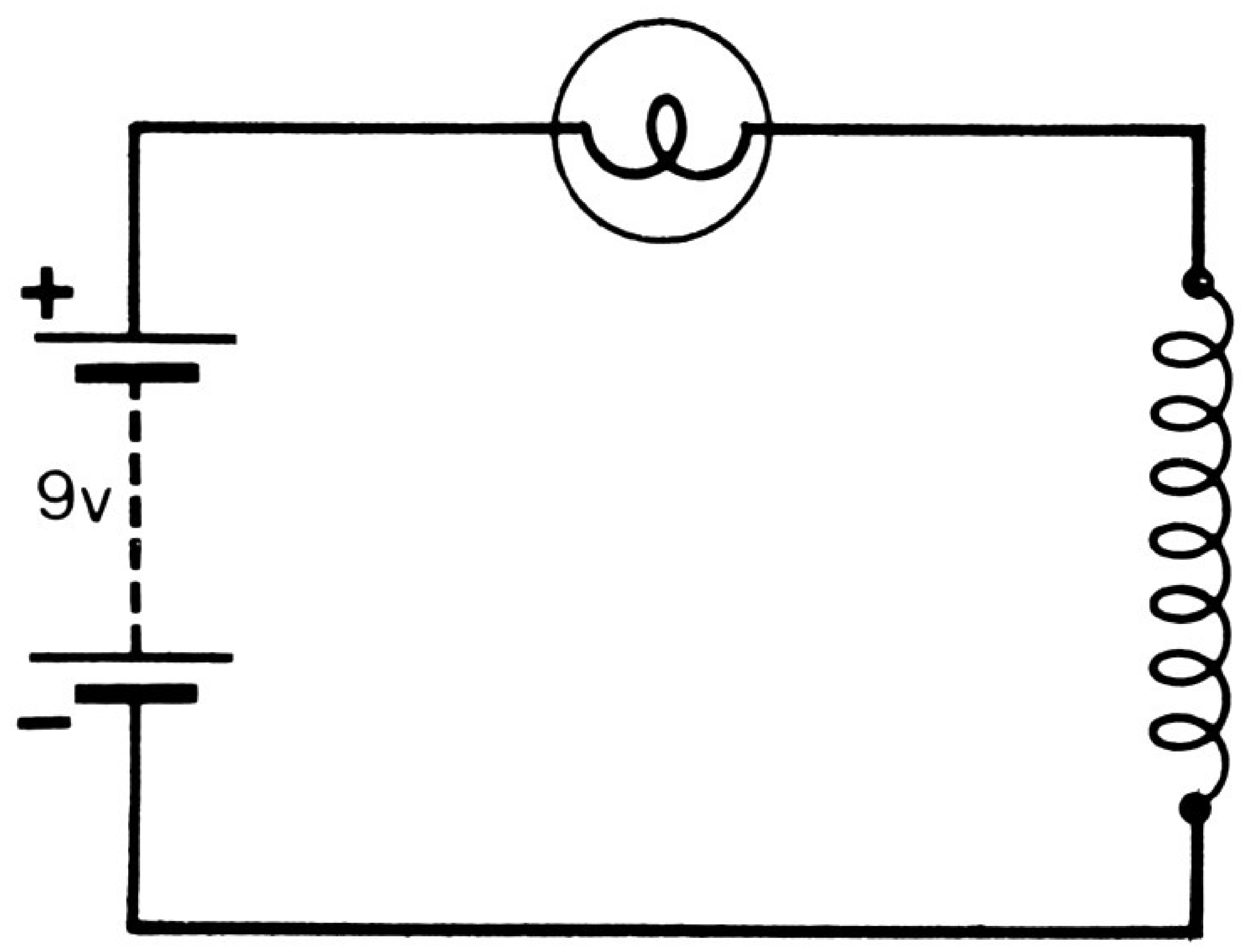
1. Was the needle attracted to the magnet whichever end of the magnet was brought close to it?
2. If the answer to question 1 was 'no', what has been done to the needle?
3. You saw in Experiment 13 that the magnetic field from a magnet could be used to make another magnet. What then do you think surrounds a coil of wire with an electric current flowing through it?

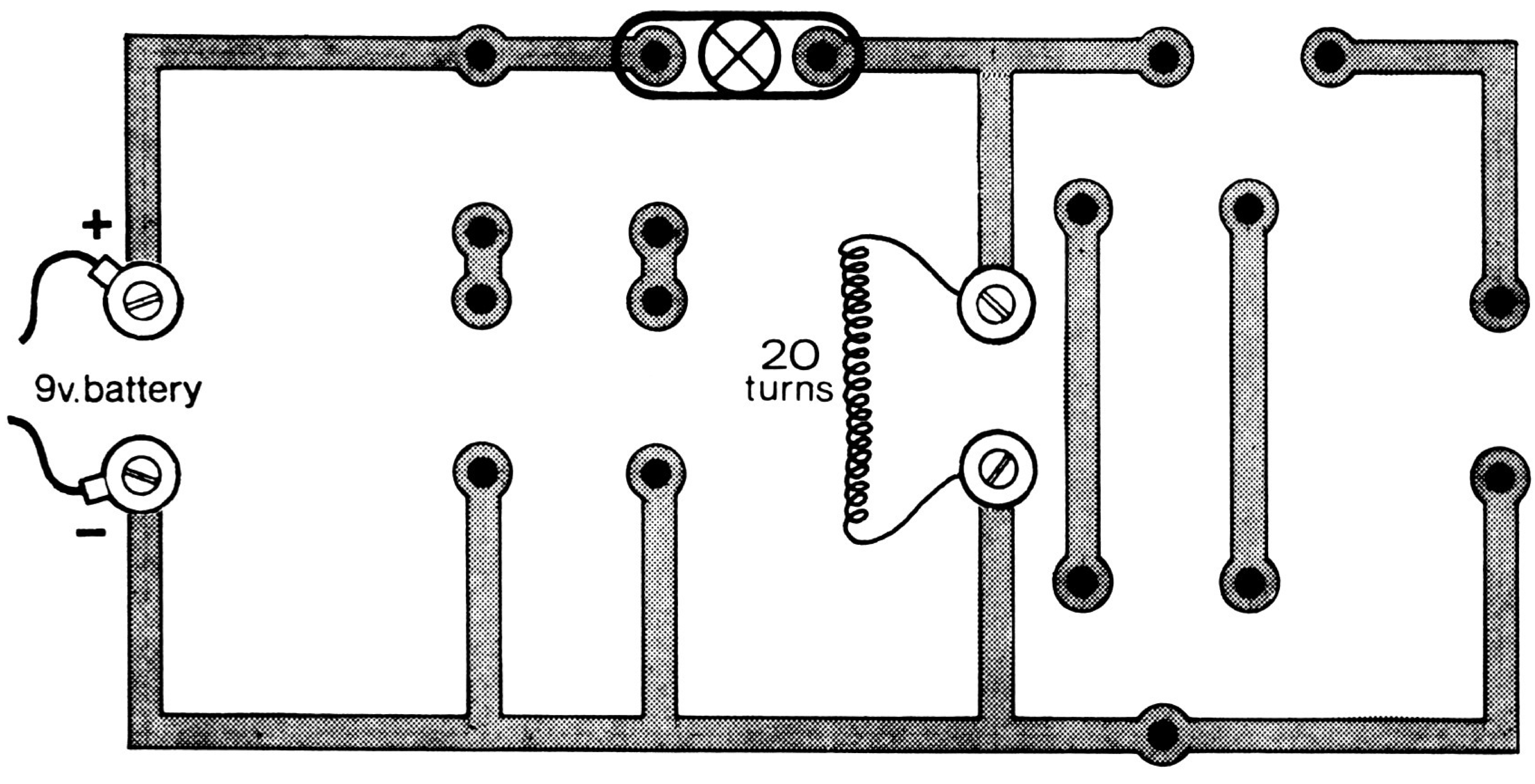


17.1

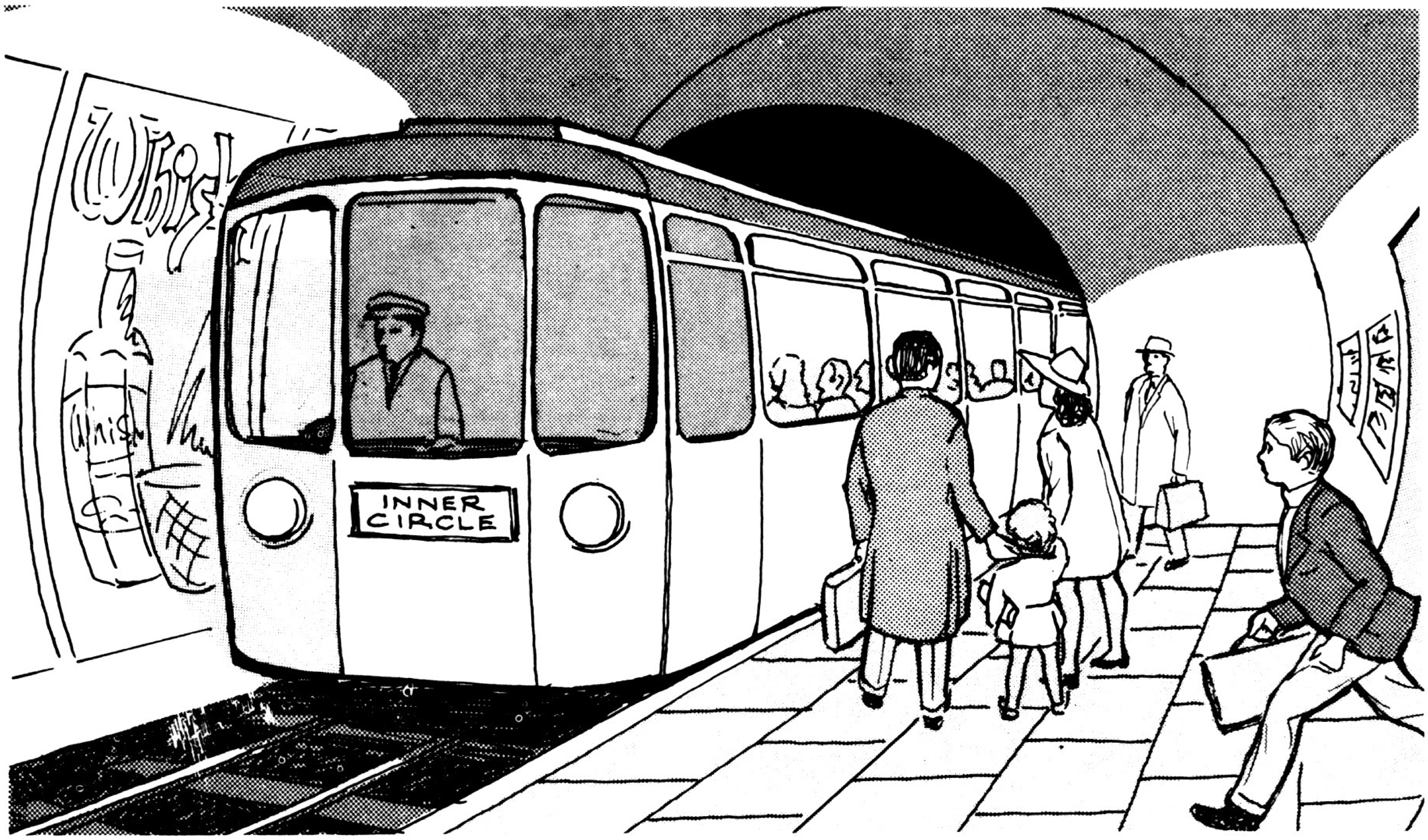


17.2





Experiment 18



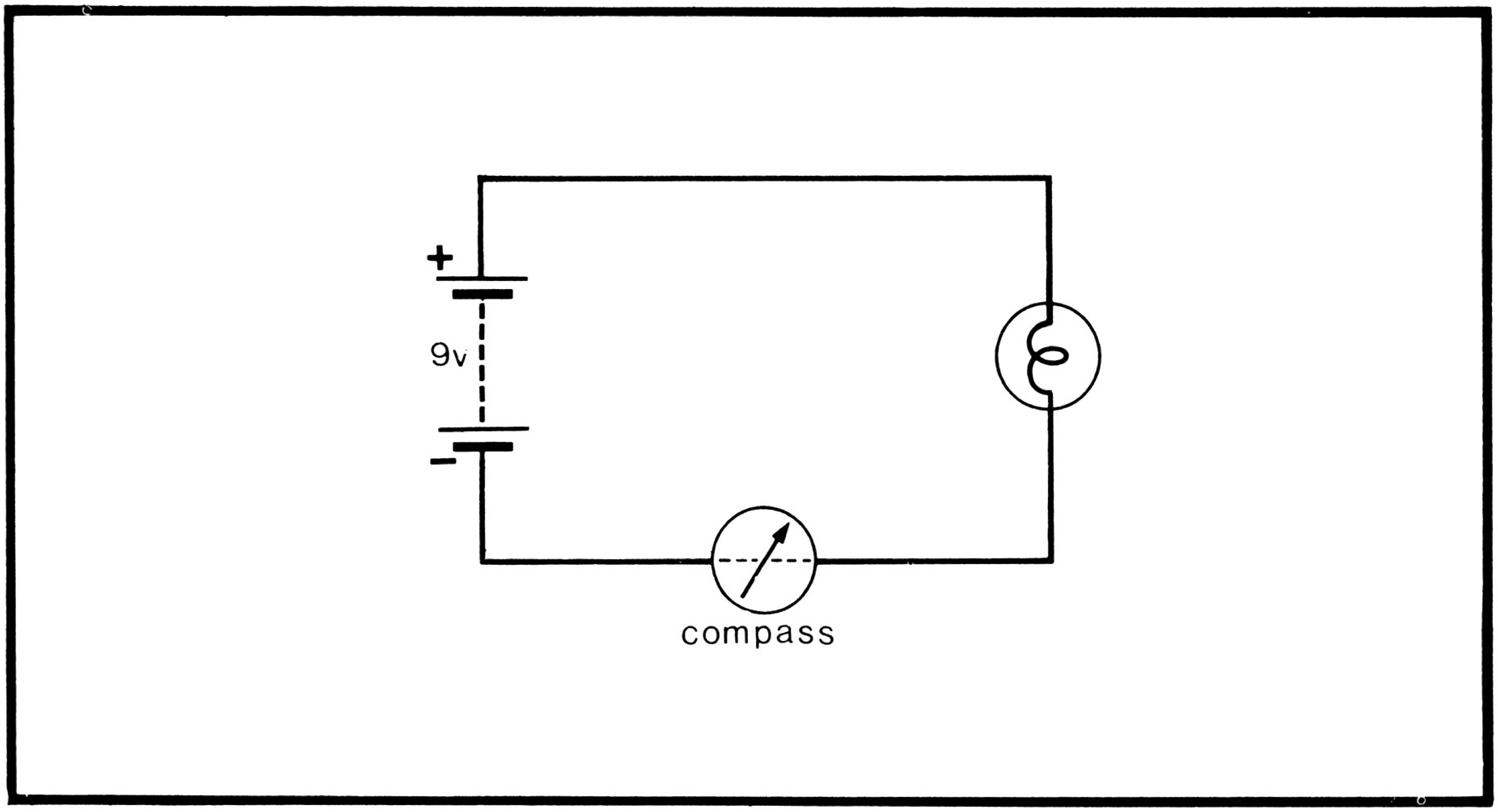
The magnetic effect of an electric current

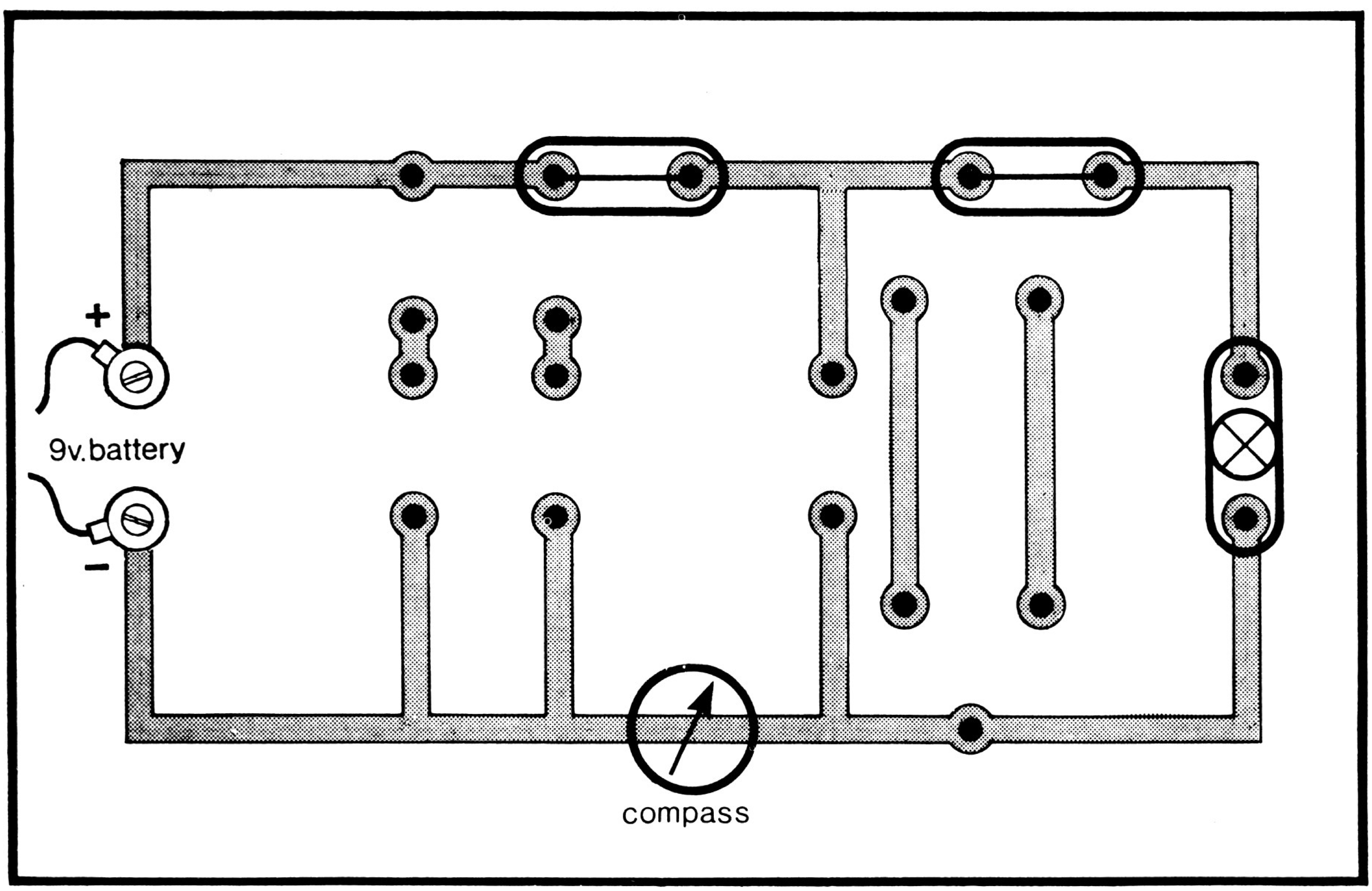
Electric trains use the magnetic effect of an electric current for their braking systems. In this experiment, you will see further proof that when an electric current flows along a wire, a magnetic field is set up around the wire.

Construct the circuit as shown in the printed circuit diagram. The lamp is included so that you can be sure when there is a current flowing in the circuit.

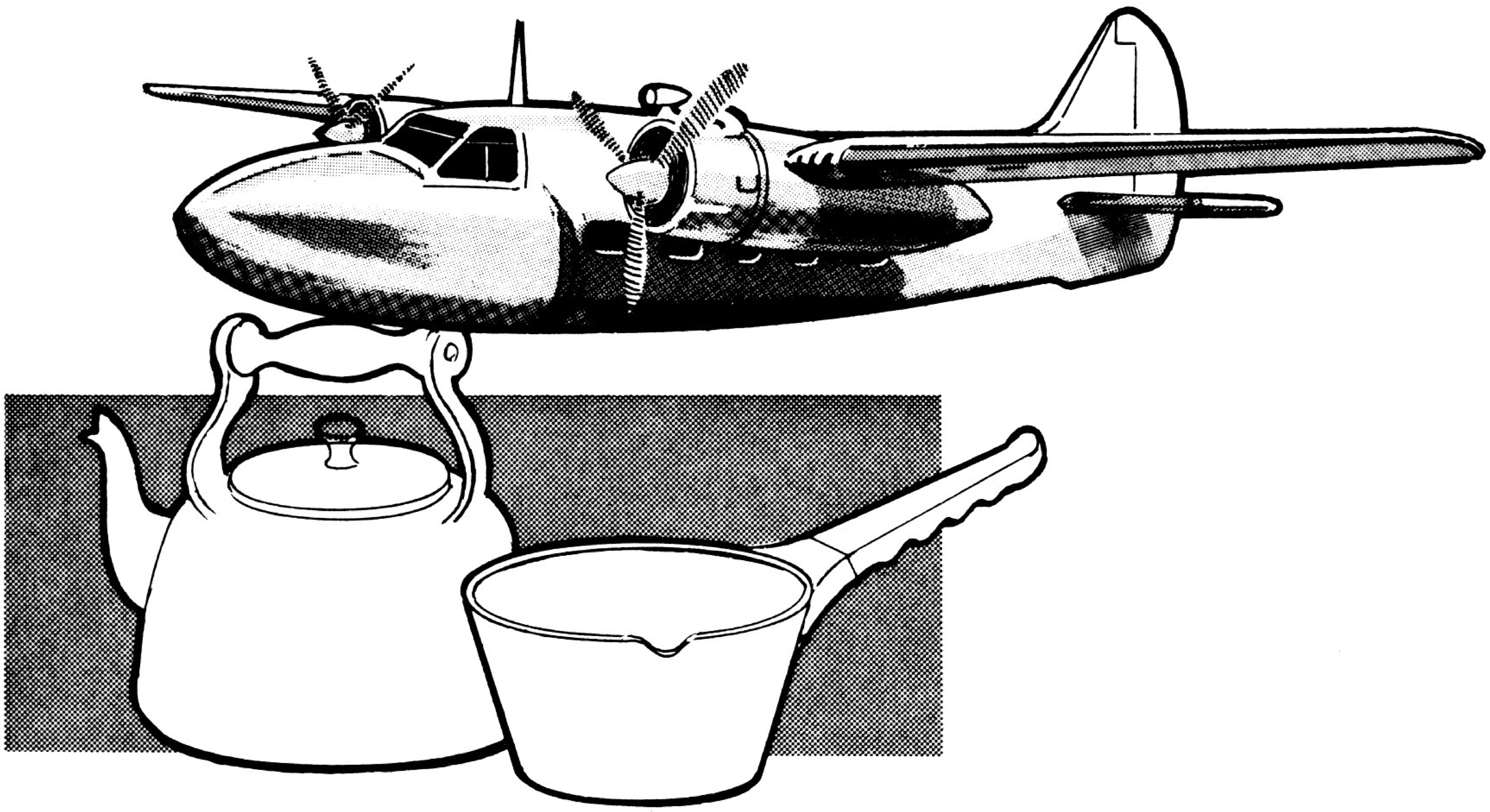
Before you connect the battery to the circuit, place your compass directly over the bottom line of the printed circuit board as shown in the theoretical circuit diagram. Turn the board until the line is pointing in the same direction as the compass needle. Connect up the battery and note what happens to the compass needle. Disconnect the battery again, still watching what happens to the compass needle. Connect up the battery the other way round (you will have to hold the leads in position as they will not clip on) and note what happens to the compass needle now.

1. What happens to the compass needle when the battery is connected?
2. What difference does it make to the compass needle when the battery is connected the other way round?
3. Because of the effect on the compass needle, what can you assume surrounds a wire carrying an electric current?


+
9v
–
compass


+
9v. battery
–
compass

Experiment 19



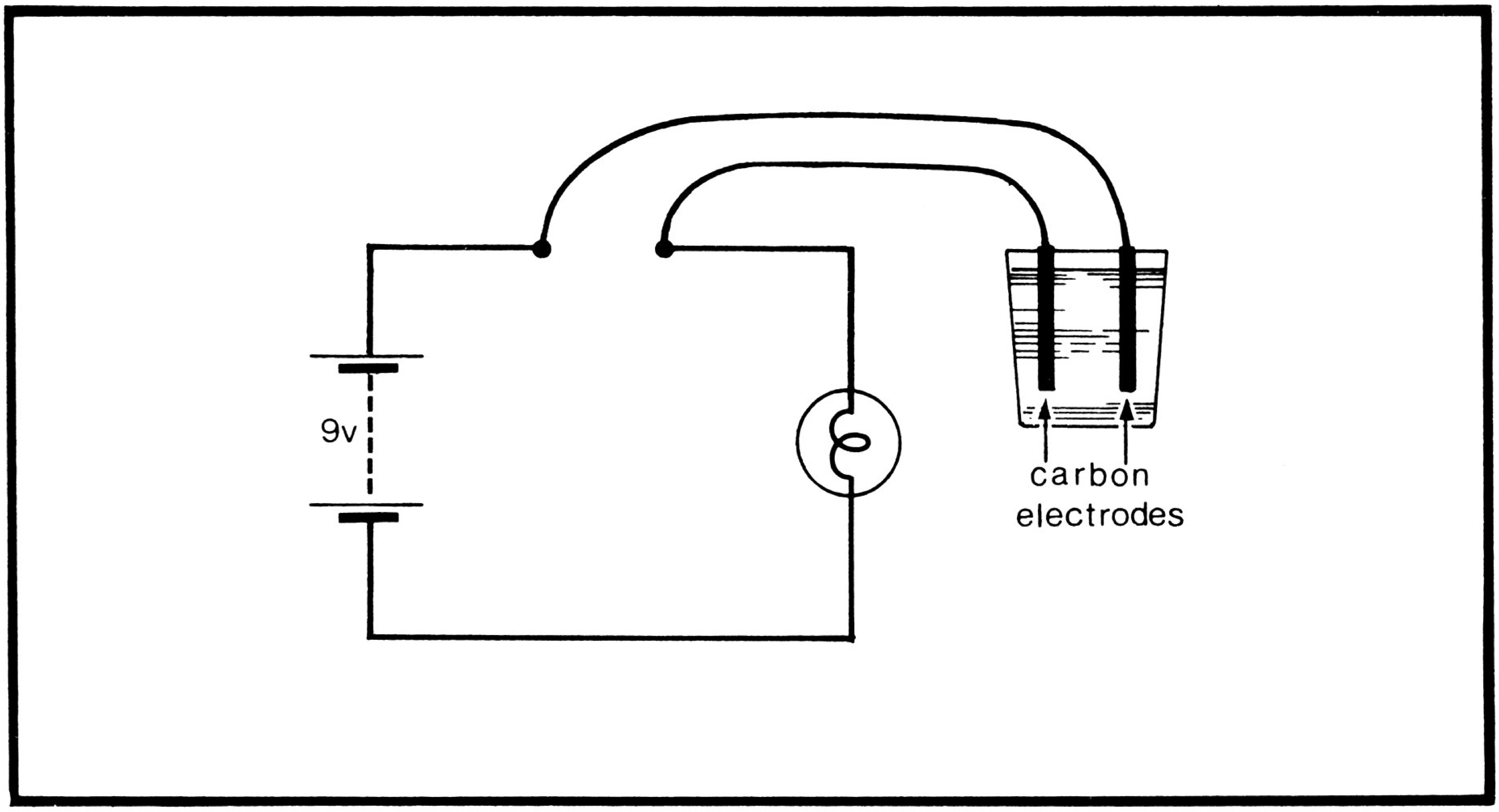
The chemical effect of an electric current

The discovery of the chemical effects of an electric current brought a revolution in industry. One of the important things that this effect is used for is to get the metal 'aluminium' from its ore, cheaply and easily. It is impossible to do this as easily in any other way. As a result, aluminium is now used to make everything from aeroplanes to saucepans..

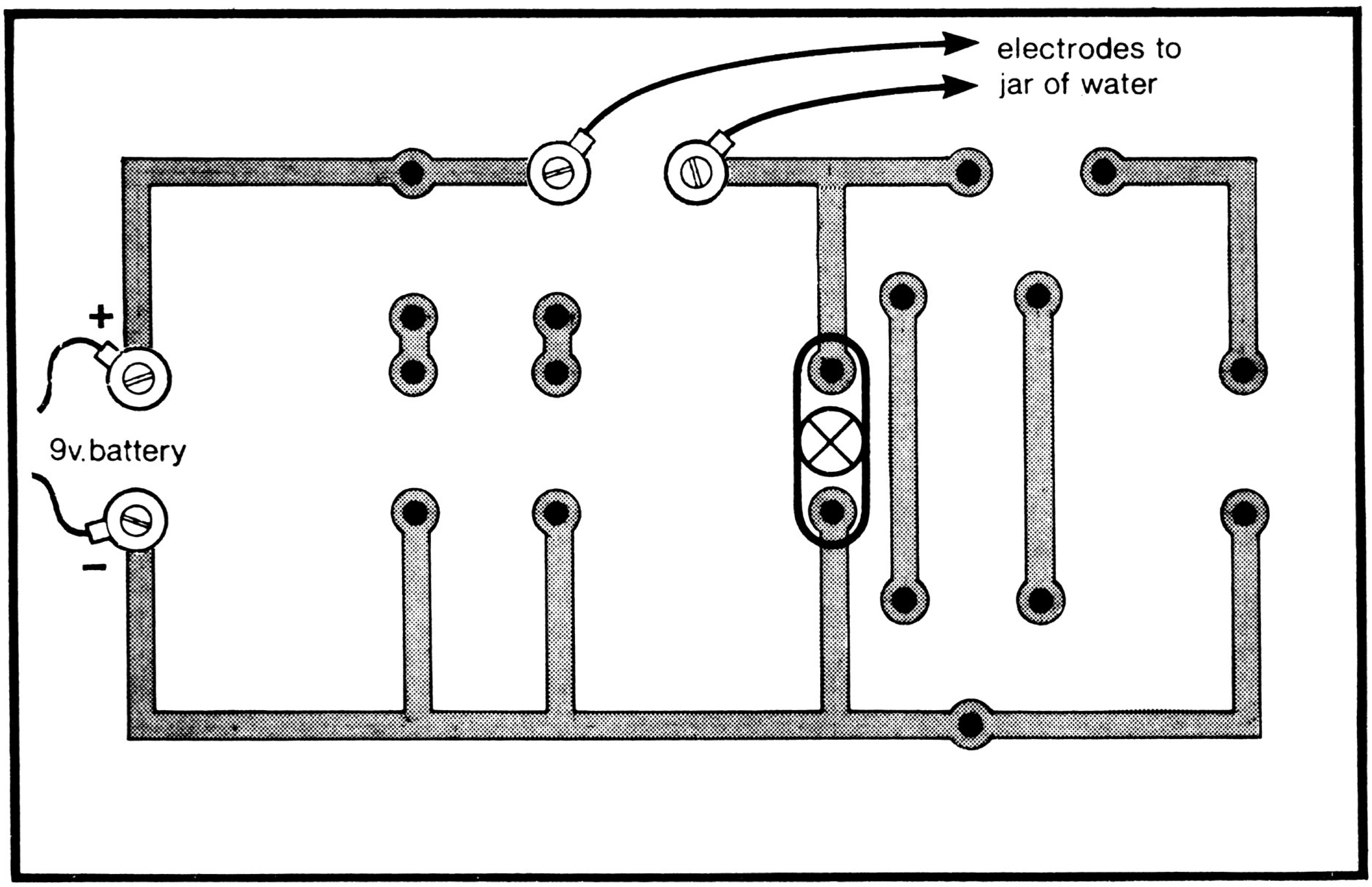
In this experiment, you will see whether liquids can be used to conduct electricity in the same way that a solid does. Build the circuit on the printed circuit board as shown. Fill a glass jar with water and place the carbon rods, called electrodes, in the water so that they do not touch each other. Note whether the lamp lights and whether anything is happening at either one or both electrodes.

Take the electrodes out of the jar and stir a teaspoonful of salt into the water. Replace the electrodes in the jar and again note whether the lamp lights or anything happens to the electrodes.

1. Does the lamp light when the electrodes are placed in tap water?
2. Does the lamp light when the electrodes are placed in salt water?
3. Try and find out why these two results should happen.

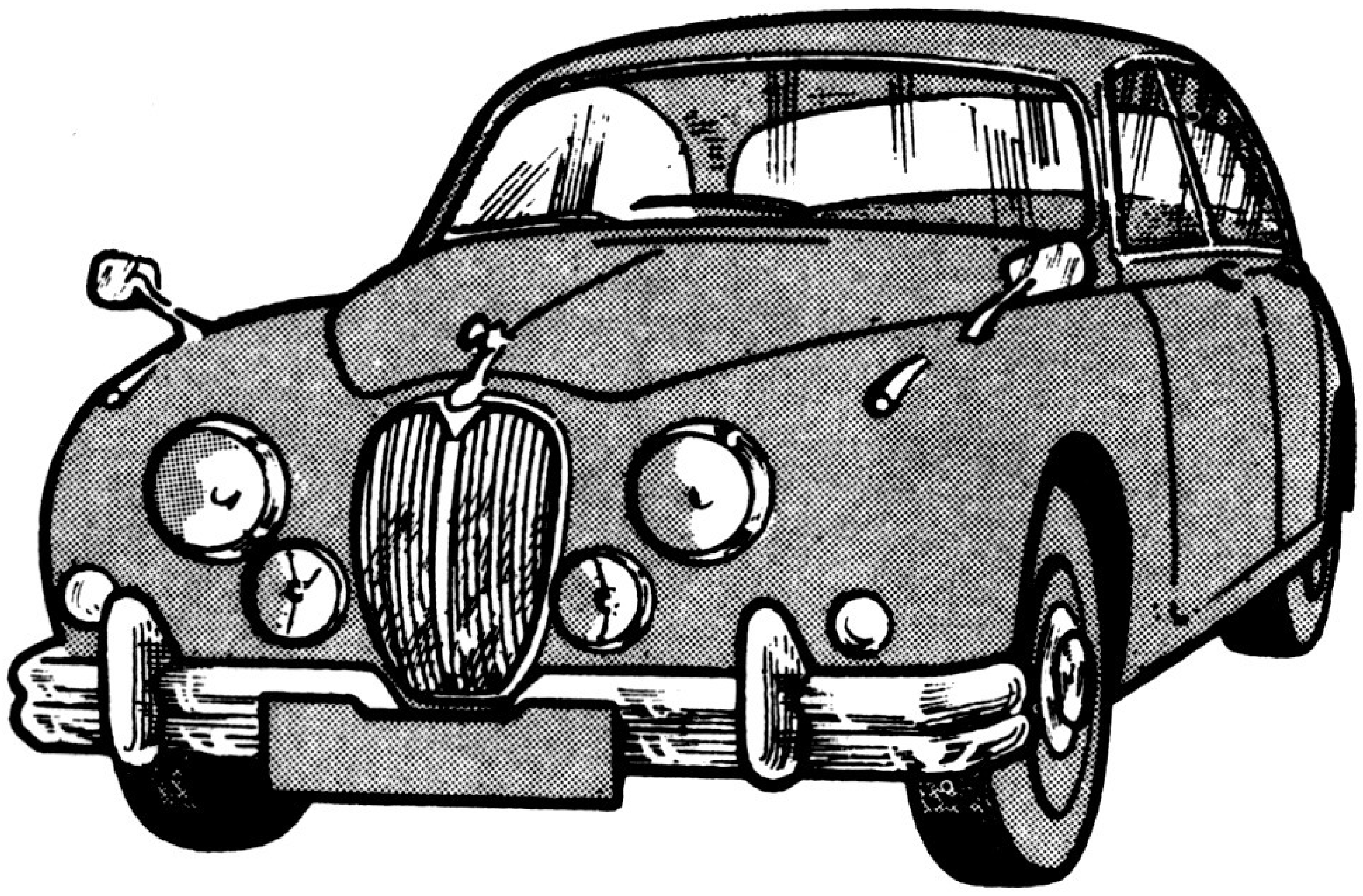


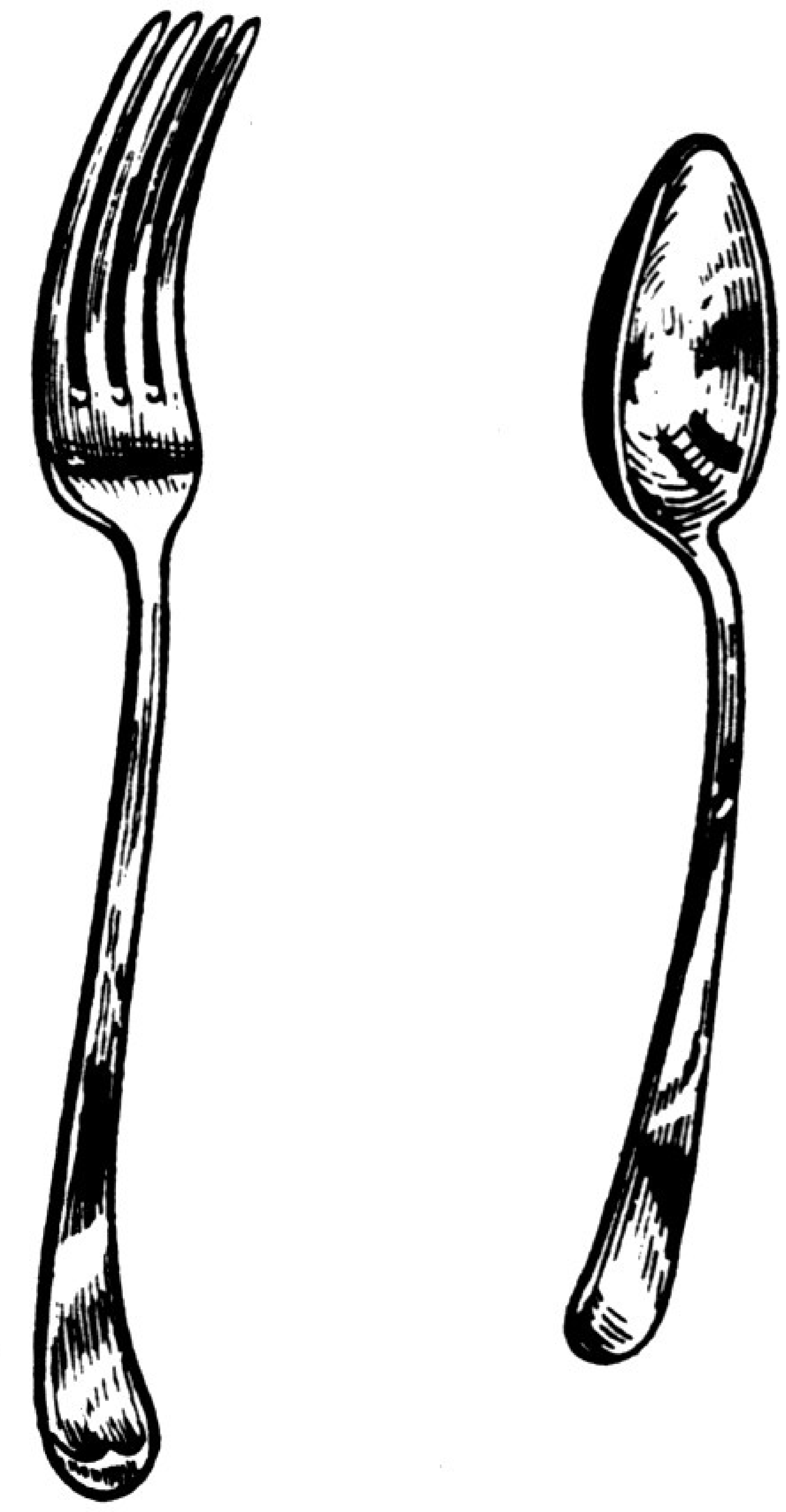
9v
carbon
electrodes



electrodes to
jar of water
+
9v.battery
−

Experiment 20



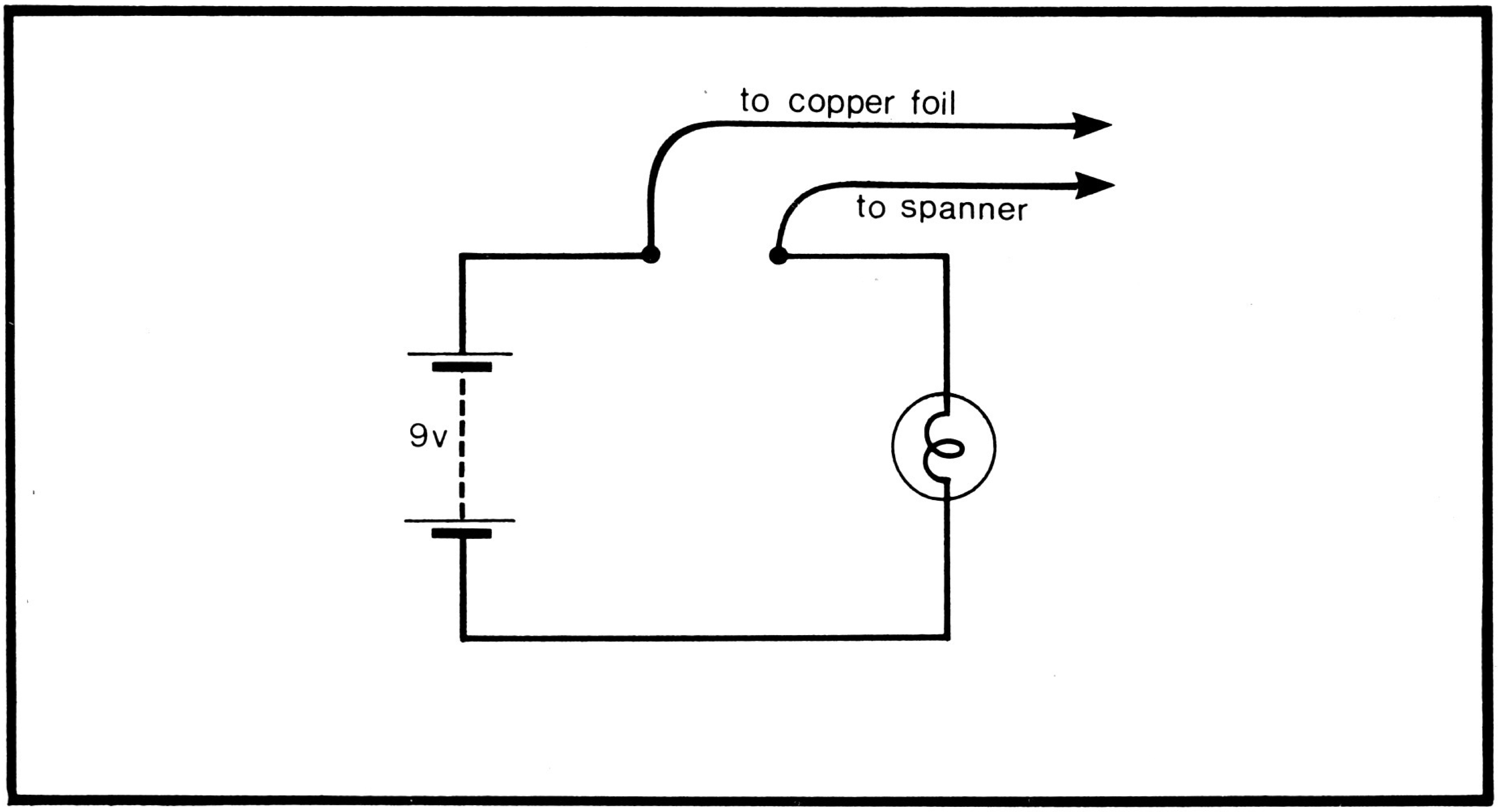


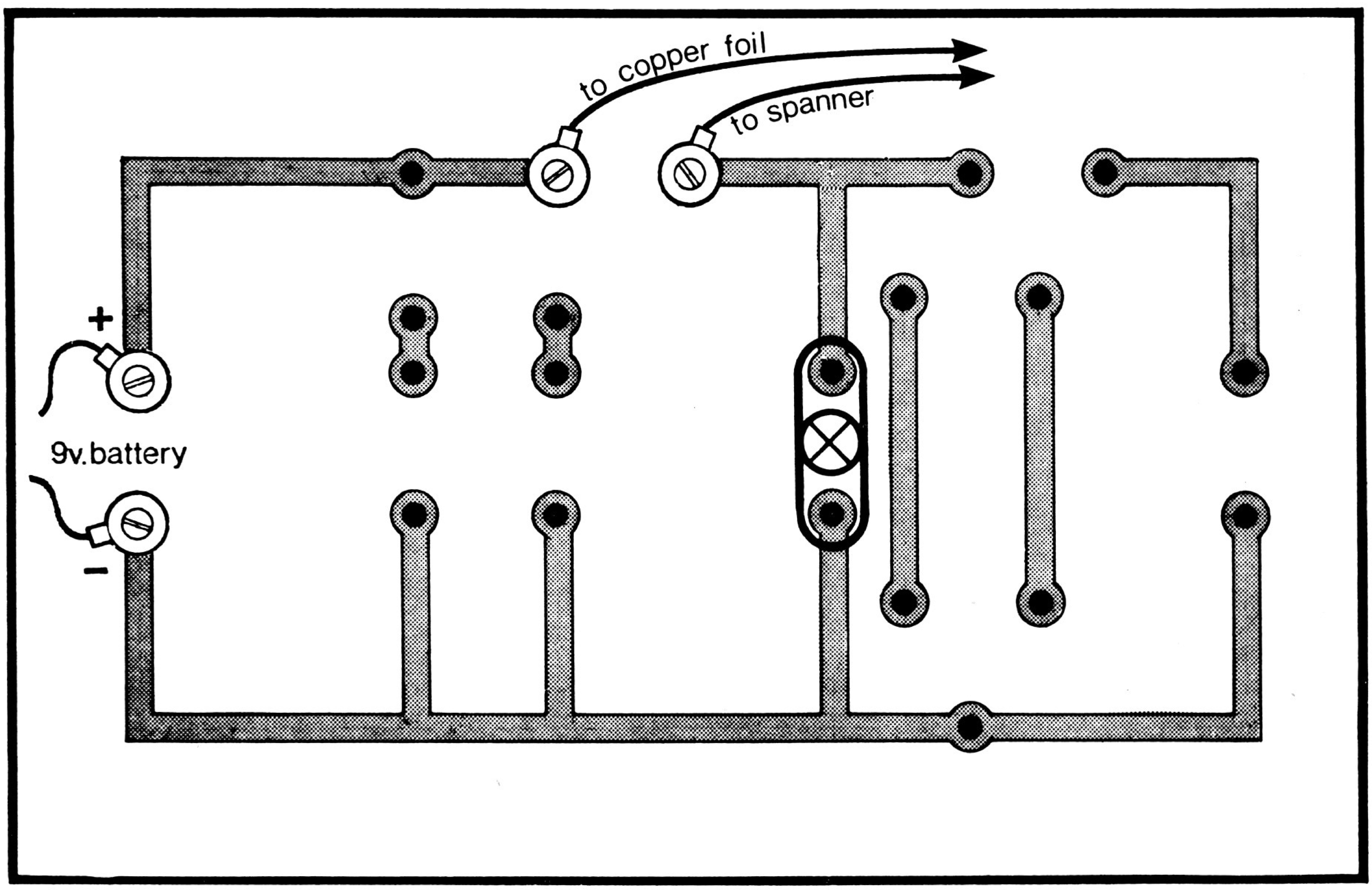
Electroplating

One of the first uses to which the chemical effect of an electric current was put, was electroplating. In this process, a cheap metal is covered with a layer of more expensive metal. This not only protects things, like car bumpers, from rusting so easily, it makes other things like spoons and forks look better and more expensive.

In this experiment you will do some actual electroplating. You use the same circuit that you used for the last experiment, except that you use one copper foil electrode and for the other electrode you use the spanner from your kit. These electrodes replace the carbon electrodes used in the last experiment. The copper electrode should be connected to the circuit on the side nearer to the positive (+) side of your battery. Make sure that both the piece of copper and the spanner are perfectly clean. To clean them, you should scrub them with soap and water and then try not to handle them more than you have to. Finally, wash out the glass jar in which you had the salt solution for the last experiment, fill it with water and put in a teaspoonful of the copper sulphate crystals from your kit. Stir the crystals in the water until they have all dissolved and then put the two electrodes into the solution, making sure that they are not touching. Connect your battery into the circuit and leave the circuit switched on for some time. You will see, after a while, that a coating of copper is forming on the spanner.

You can try this experiment with as many different sorts of metals as you like, but avoid iron and zinc as the copper sulphate solution will discolour these metals even without passing an electric current through them.


to copper foil
to spanner
9v


to copper foil
to spanner
+
9v.battery
−

Appendix A

Basic Electricity Kit X20

List of contents

Sometimes, due to non-availability from the manufacturer, other makes of components of equal or equivalent values have to be substituted. When this occurs an errata slip will appear in the front of the handbook.

Item		Quantity
Instruction manual		1
Printed circuit board		1
Lamp 6V, 40mA		2
Lamp holder		2
Switch link		2
Rheostat 1K		1
Insulated copper wire (length)		1
Crocodile clip		2
Battery leads, pair		1
Carbon electrode		2
Copper foil, piece		1
Copper sulphate crystals, bottle		1
Steel wool, piece		1
Bar magnet		1
Plotting compass		1
Screws 6BA Nuts 6BA Washers 6BA	Packet	1
Box spanner 6BA		1

Appendix B

Answers to questions

Experiment 1

1. No. 2. Yes. 3. The lamp goes out.
4. When the lamp is lit it shows that an electric current is flowing around the circuit. For a current to flow around a circuit, there must be a complete path starting from one side of the battery and going right round to the other side, with no breaks.

Experiment 2

1. The steel wool gets very hot, melts and breaks.
2. Because when the steel wool breaks, the circuit is no longer complete and the electric current can no longer flow.
3. Too high a current flowing through the fuse, which causes it to melt and break.

Experiment 3

1. The material is a good conductor.
2. The material is a good insulator.
3. The material is a poor conductor and a poor insulator.
4. Because the wires that conduct the electric current from the plug to the kettle are covered with a good insulator.

Experiment 4

1. The remaining lamp goes out.
2. Because removing one lamp breaks the complete circuit.
3. The circuit would be broken so the remaining lamp or lamps would go out.

Experiment 5

1. The lamp gradually dims and finally goes out.
2. As the control knob on the rheostat is turned the resistance to the electric current flowing is increased. The amount of current flowing decreases until finally there is not enough to light the lamp.

Experiment 6

1. Lamp A remains lit and lamp B goes out.
2. Lamp B remains lit.
3. In this experiment there are two paths that the current can take, whilst in experiment 4 there was only one.

Experiment 7

1. No.
2. Basically, because the two loads are in parallel, the voltage from the battery (9 volts) is across each load independently as if they were in two separate circuits. The current that flows through each load, therefore, depends only on the resistance of that load and is independent of any other load in parallel to it. The current that flows is only limited by the total current that can flow from the battery, so unless a short circuit occurs, changing the size of one load will not affect the current through any other loads in parallel to it.

Experiment 8

1. The brightness of both lamps alters at the same rate.
2. No. 3. In parallel.
4. If one lamp should burn out or break, the other lamp will remain lit.

Experiment 9

1. The brightness of lamp A stays the same while the brightness of lamp B changes.
2. No. 3. In parallel. 4. In series. 5. In parallel.

Experiment 10

1. No. 2. No. 3. The position of the switch.

Experiment 11

1. Both switches in either position 1 or position 2.
2. One switch in position 1 and the other switch in position 2.

Experiment 12

1. No. 2. No.
3. Basically iron and steel, although a magnet will also pick up objects made of cobalt or nickel which you are unlikely to have among the objects you have tried.
4. At the ends. 5. At the ends. 6. At the ends.

Experiment 13

1. Yes. 2. The needle has become magnetised.

Experiment 14

1. It pointed in any direction.
2. It always pointed in the same direction.
3. The compass.

Experiment 15

1. Towards the magnet. 2. Towards the magnet.
3. Away from the magnet.
4. By bringing each pole of the magnet in turn close to the piece of steel. If the piece of steel is a magnet, one pole of your magnet will repel the steel instead of attracting it.

Experiment 16

1. Away from the magnet's north pole and towards its south pole.
2. From a magnet's north pole, going to its south pole.
3. The magnetic field from another magnet.

Experiment 17

1. No. 2. The needle has been magnetised.
3. A magnetic field.

Experiment 18

1. The compass needle moves from its original direction.
2. The compass needle moves in the opposite direction.
3. A magnetic field.

Experiment 19

1. No. 2. Yes.
3. A current flows when the electrodes are placed in salt water because the salt in the water breaks down into positive and negative ions. The positive ions go to the negative electrode and the negative ions go to the positive electrode. This movement of ions is the same as a current flowing through a solid circuit, so the lamp lights. In tap water, there are only a very small number of ions available from the impurities in the water, so the current flowing is far too small to light the lamp.