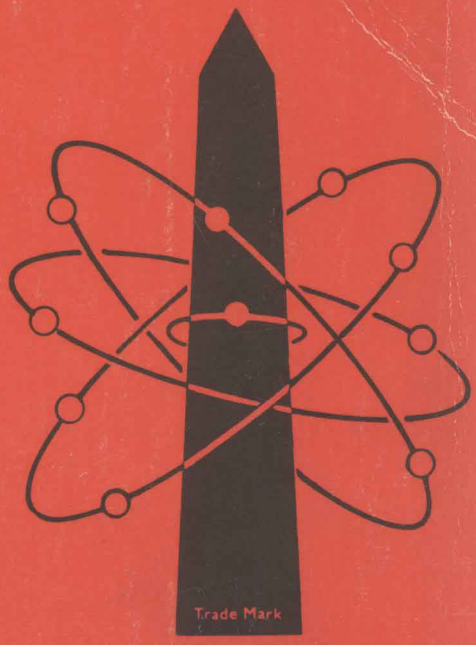
A COMMON CORE BOOK



COMMON-CORE

BASIC ELECTRICITY

Part One

THIRD EDITION REVISED

VAN VALKENBURGH
NOOGER & NEVILLE INC.

Technical Press

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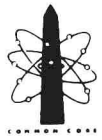

A Series of Basic Training Manuals Developed for

THE UNITED STATES NAVY

by the New York firm of
Technical Education Consultants and Graphiological Engineers
VAN VALKENBURGH, NOOGER & NEVILLE, INC.

Adapted to British and Commonwealth Usage

Third British Edition Revised and Enlarged
under the Technical Supervision of

J. M. CHAPMAN, B.Sc. (Eng.), C. Eng., A.M.I.E.E.,
A.M.I.E.R.E., M.S.E.R.T.

OXFORD
TECHNICAL PRESS
NEW YORK
THE BROLET PRESS

British Library Cataloguing in Publication Data

Van Valkenburgh, Nooger and Neville, Inc.
Basic electricity
Part 1 – 3rd
1. Electric engineering
I. Title II. Chapman, J M
621.3 TK145

ISBN 0–291–39630–5

First Printing – 1980

Printed and bound in Great Britain by
McCorquodale (Newton) Ltd., Newton-le-Willows, Lancashire

PREFACE TO PART 1

EARLIER EDITIONS of the **COMMON-CORE** Series of Manuals on basic electricity and electronics have been tested and acclaimed by more than ten million teachers and trainee technicians throughout the world. Here is now a new edition of the foundation title of the whole Series which represents the most fundamental revision to have been undertaken since publication of the original manuals in Britain more than 20 years ago.

The changes made are important, for as technological progress in electronics continues, so must the degrees of emphasis laid on the fundamentals change also. In the 1950's, for example, the valve (vacuum tube) reigned well-nigh supreme. Today it has been almost wholly superseded by a large and swiftly-growing range of solid-state devices. To keep pace with this progress, up-dated editions of the basic Manuals in the **COMMON-CORE** Series were needed—manuals which lay the foundations for an understanding of such modern electrical and electronic equipment as machine controls (both analogue and digital), instrumentation, computers, telecommunications, lasers and radar.

In this third, heavily revised, edition of *BASIC ELECTRICITY* (Part 1) the topics are presented in more logical sequence. The text has been re-thought, and many of the illustrations re-drawn. But the original format of the books themselves has been retained—*because it has been found to work.* The object remains what it has always been—*to help students teach themselves* the full contents of the Program, thoroughly but at their own preferred pace. The texts therefore contain large numbers of clearly-captioned illustrations, together with periodic blocks of self-testing Review Questions which help students monitor their own progress as they work their way through the Series. This solid framework of methodology has proved consistently effective in teaching students of widely differing basic abilities and backgrounds. It has provided the stimulus for several important improvements in vocational and technical education throughout the world.

The five revised Volumes of *BASIC ELECTRICITY* were originally prepared for a mainly American readership. For his technical and editorial help in making them suitable for students working against a different educational background, THE TECHNICAL PRESS is grateful to MR. J. M. CHAPMAN, B.Sc. (Eng.), C. Eng., A.M.I.E.E., A.M.I.E.R.E., M.S.E.R.T. Mr. Chapman played a large part in the development of the British editions of the COMMON-CORE Manuals over 20 years ago, and has maintained an active interest in the development of the Program as a whole ever since. He is currently Principal of one of the largest Colleges of Further Education in the South-East of England.

THE EARLIER HISTORY of the **COMMON-CORE** Manuals is by now well known. Originally developed for the UNITED STATES NAVY by a distinguished New York firm, VAN VALKENBURGH, NOOGER AND NEVILLE, INC., technical education consultants and graphiological engineers, the text was released in a condensed form to the general public in the United States, where it proved an outstanding success. Civilian students of the COMMON-CORE Program number over ten million, and 12 editions in languages other than English are currently in print throughout the world.

United Kingdom editions of the COMMON-CORE titles began to be published by THE TECHNICAL PRESS from early 1959 onwards—the process of converting the U.S. volumes to British and Commonwealth notation and terminology being supervised by a special Electronics Training Investigation Team working at Training Headquarters of the ROYAL ELECTRICAL AND MECHANICAL ENGINEERS under command of the then Major J. M. Chapman, REME.

Some years later, REME's changing requirements led to the adoption of more strictly equipment-orientated training systems, but the texts to which they had so largely contributed were subsequently revised—some of them more than once—to keep them as constantly up-to-date as possible against the rapidly-changing technological background of the 1960's and 1970's.

Important extensions to the **COMMON-CORE** Program were pioneered in Britain, some of them with the active assistance of Training Command of the ROYAL AIR FORCE and DECCA RADAR LTD. At one time in the 1960's, the *BASIC ELECTRICITY/BASIC ELECTRONICS* Series were adopted by the ROYAL NAVY "for issue on a Fleet basis".

Despite their Services background, the Manuals have proved entirely suitable for civilian use. Their purpose, however, is limited to the training of technicians at the operator level, *NOT* of qualified engineers. They aim to turn out men and women capable of operating, maintaining and carrying out repairs to the equipment described—*NOT* people capable of inventing or improving it.

To the intending electrical engineer, however, the Manuals can be of value in the early stages of training by presenting an easy-to-follow overall view of the subject, sound and accurate within its limits—a framework into which there can be confidently fitted the more detailed and advanced work which must be undertaken later on.

It has been the aim, in short, to present in these Manuals a unique simplification of an ordinarily complex set of subjects; and to ensure that in them *first things come first—and only the essentials come anywhere.*

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§1: WHAT ELECTRICITY IS

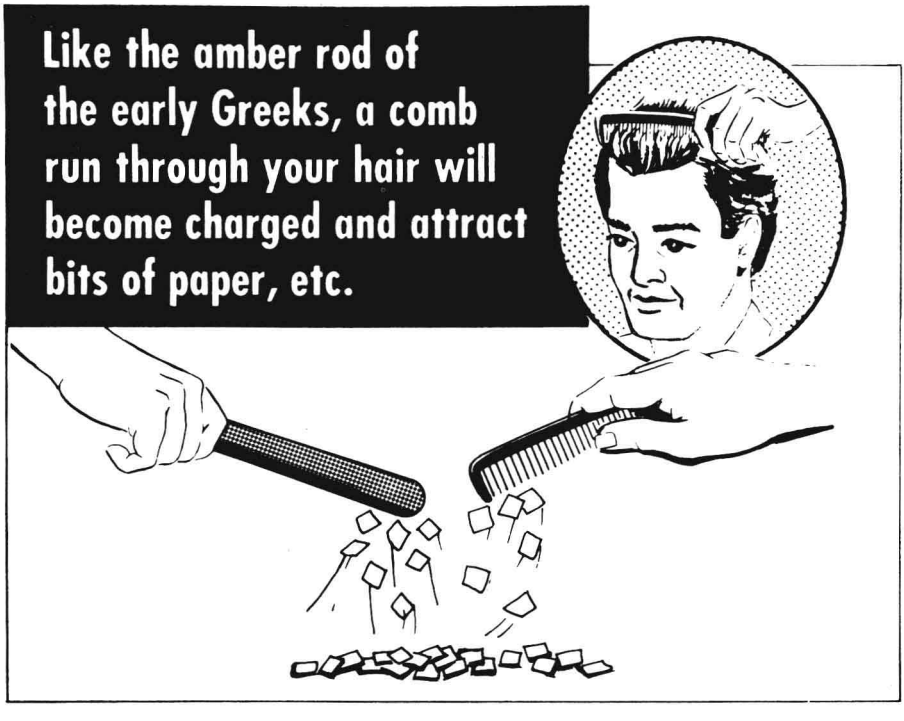
The word electricity comes from the ancient Greek word for amber—*elektron*. The Greeks observed that when amber (a fossilized resin) was rubbed with a cloth, it attracted bits of material such as dried leaves.

Later, scientists showed that this property of attraction existed in other materials such as rubber and glass, but did not exist in materials such as copper or iron. The materials which possessed this property of attraction when rubbed with a cloth were described as being charged with an *electric force*; and it was noticed that some of these charged materials were attracted by a charged piece of glass and that others were repelled by it.

Benjamin Franklin called these two kinds of charges **negative** and **positive**. We know now, as you will learn, that what was actually being observed in these experiments was either an excess or a deficiency in the materials of particles called **electrons.**

Over the years, a series of now-famous scientists found that these electric forces seemed to behave in a constant and predictable way in given situations. They described this behaviour in the form of rules or laws.

These laws now allow us to predict how electric forces will behave, even though we still do not fully understand the precise nature of electricity itself. By learning the rules or laws governing the behaviour of electricity, and the methods of producing and controlling and using it, you will discover how electricity is used to run so large a part of the modern world–and you will have travelled a good way along the road which will qualify you to play your part in running that world.

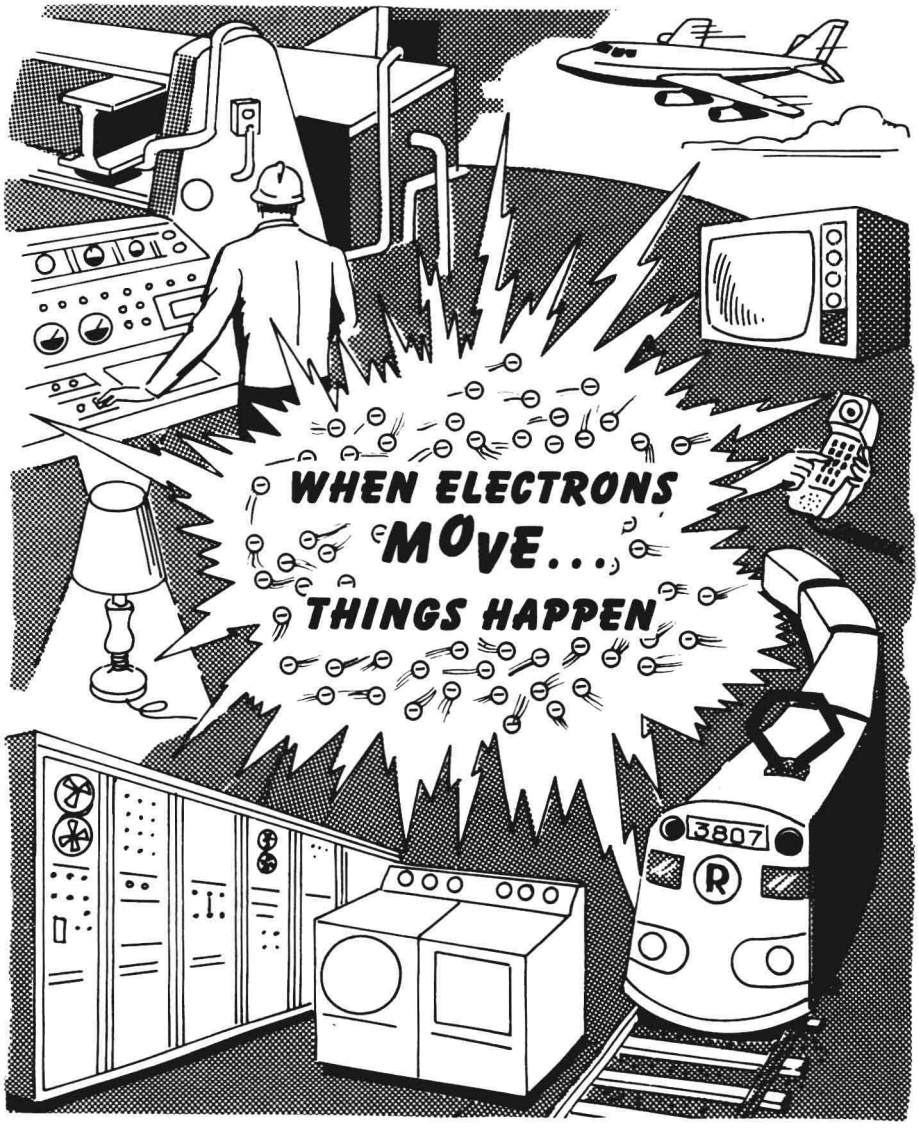


The Electron Theory

All the effects of electricity take place because of the existence of a tiny particle called the *electron.* Although no one has ever seen an electron–and probably never will–electrons have been found to behave consistently in certain ways when subjected to certain forces.

This pattern of behaviour can be explained by what is called the *Electron Theory of Matter.* This theory governs the design of all electrical and electronic equipment. It provides the key to understanding all physical and chemical action; and it is helping scientists to probe into the very nature of the matter of which everything in the Universe is composed.

In short, the assumption that the electron exists, and the knowledge that it always behaves in certain predictable ways, have led to so many important practical discoveries that your first step in learning about electricity must be to grasp the essential points of the theory itself.



The Electron Theory (*continued*)

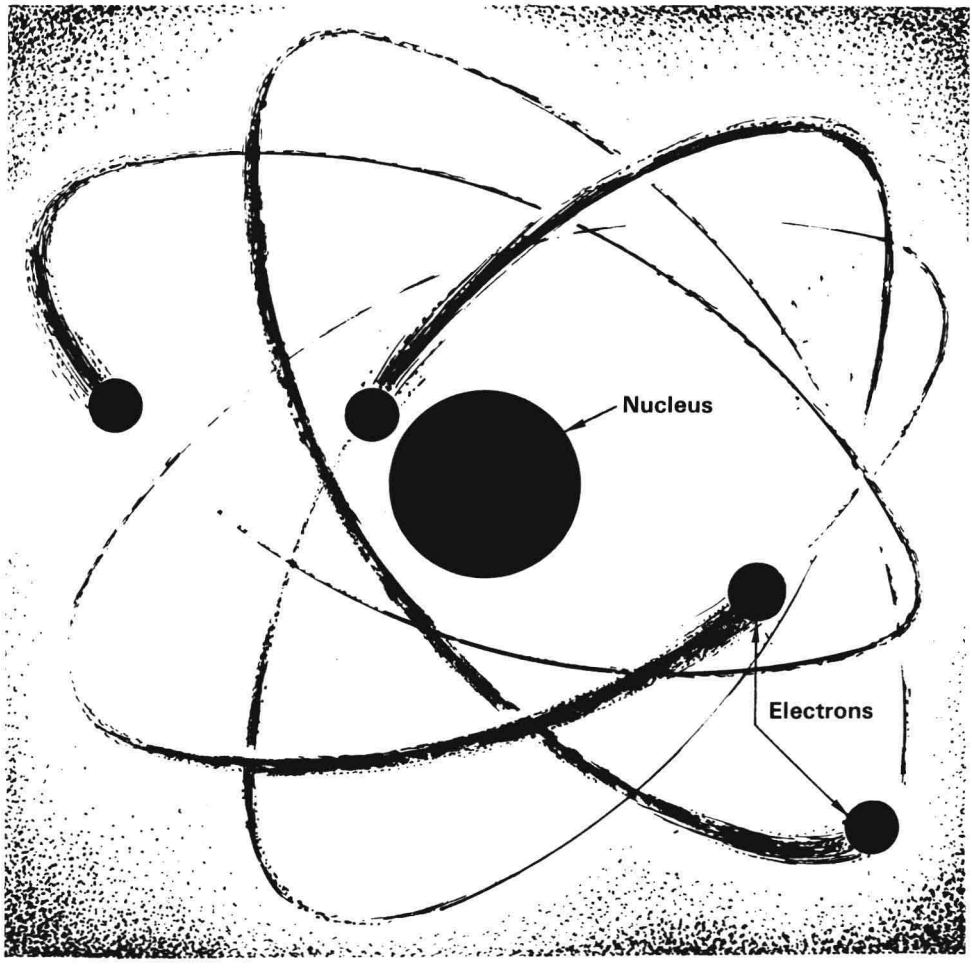
According to the Electron Theory, **all electrical and electronic effects are caused either by the movement of electrons from place to place; or because there exist too many or too few electrons in a particular place at a particular time.**

What, then, *is* an electron?

All matter is composed of **atoms** of many different sizes, degrees of structural complexity, and weight. But all atoms are alike in consisting of a **nucleus** (which differs from atom to atom of the 100-odd chemical elements which either exist in Nature or have been made by Man); and of a varying number of **electrons** which move about that nucleus.

You will get an idea of what the atom is essentially like by looking at the picture below.

THE ELECTRON IS ELECTRICITY



The Breakdown of Matter

Start by examining closely the composition of a drop of ordinary water.

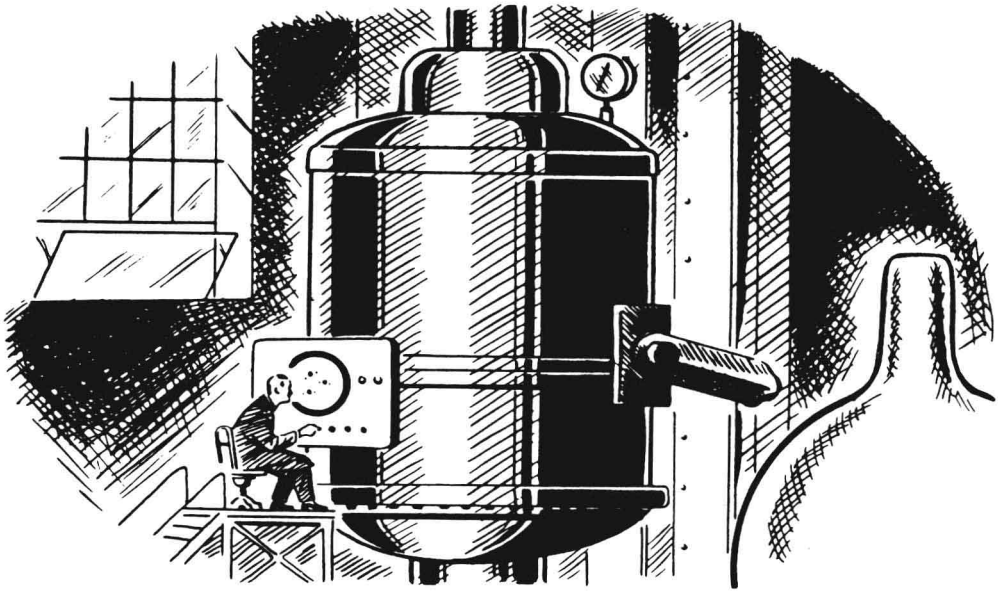
If you take this drop of water and divide it into two drops, divide one of these two drops into two smaller drops and repeat this process about a thousand times, you will have a very tiny drop of water. This tiny drop will be so small that you will need the best microscope made today in order to see it.

This tiny drop of water will still have all the chemical characteristics of water. If it is examined by a chemist, he will not be able to find any chemical difference between this microscopic drop and an ordinary glass of water.

The Breakdown of Matter (*continued*)

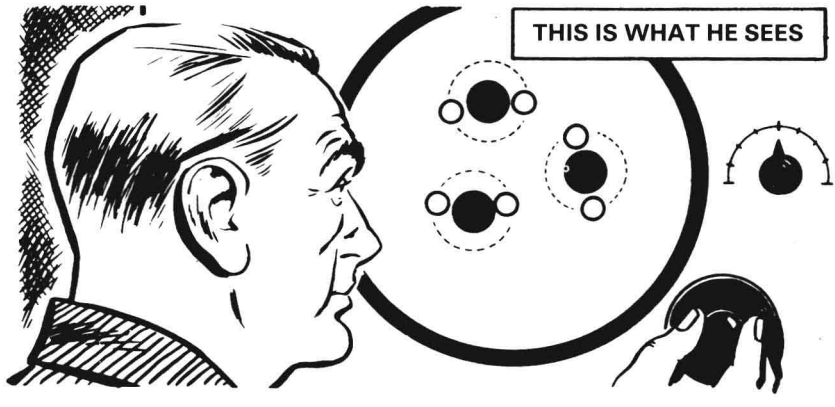
Now if you take this tiny drop of water and try to divide it any further, you will not be able to see it in your microscope.

So imagine that you have available a super microscope that will magnify many times more than any optical microscope at present in existence. This microscope can give you any magnification you want, so you can put your tiny drop of water under it and divide it into even smaller and smaller droplets.



As this happens, even the smallest droplets will still retain all the chemical characteristics of water. But the time will eventually come when you are left with a droplet so small that any further division will cause it to lose the chemical characteristics of water.

This last bit of water is called a **molecule.** A molecule can thus be defined as the smallest unit into which a substance can be divided and still be identified as that substance, and nothing else.

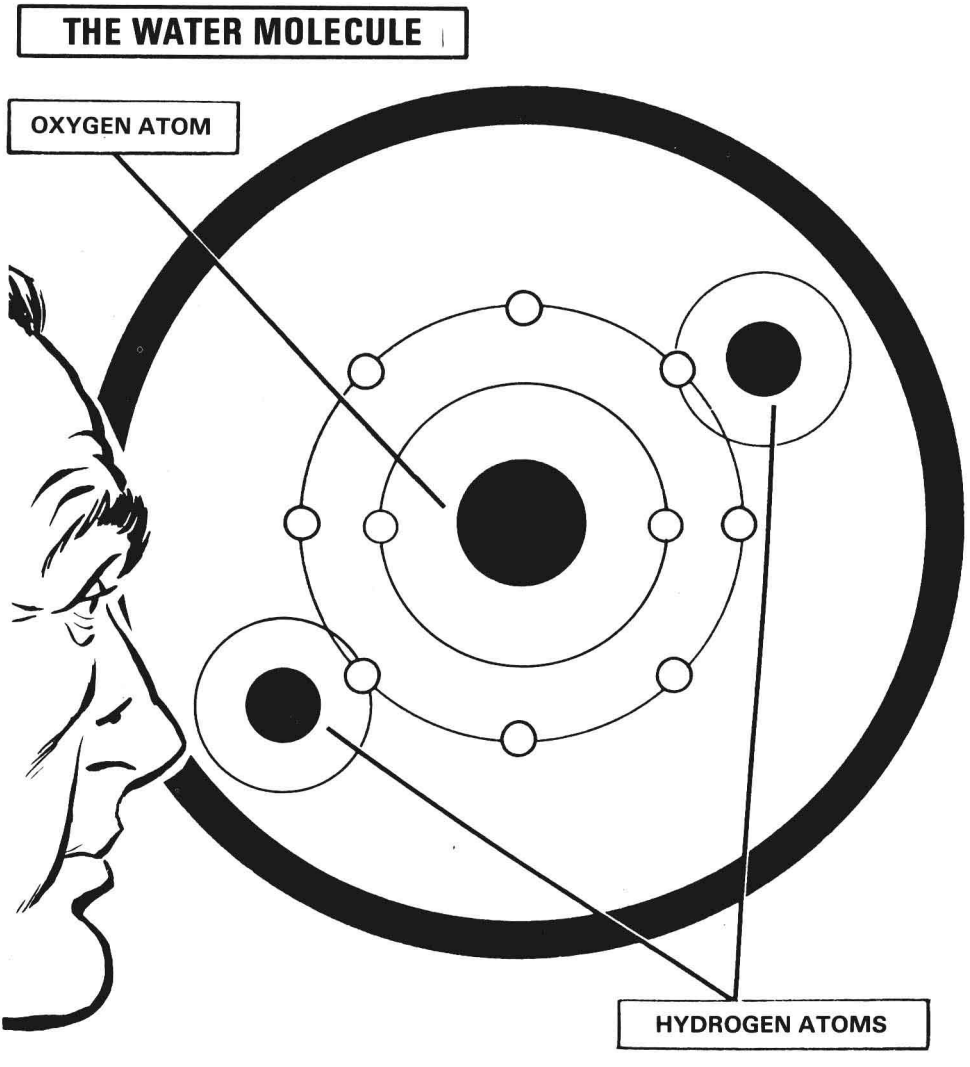


The Structure of the Molecule

If you examined the water molecule under still higher magnification, you would see that it is composed of three parts closely bonded together.

Two of these parts are identical, and are atoms of *hydrogen.* The third is larger and otherwise different from the other two. It is an atom of *oxygen.*

When two atoms of hydrogen combine with one atom of oxygen, you get a molecule of water.



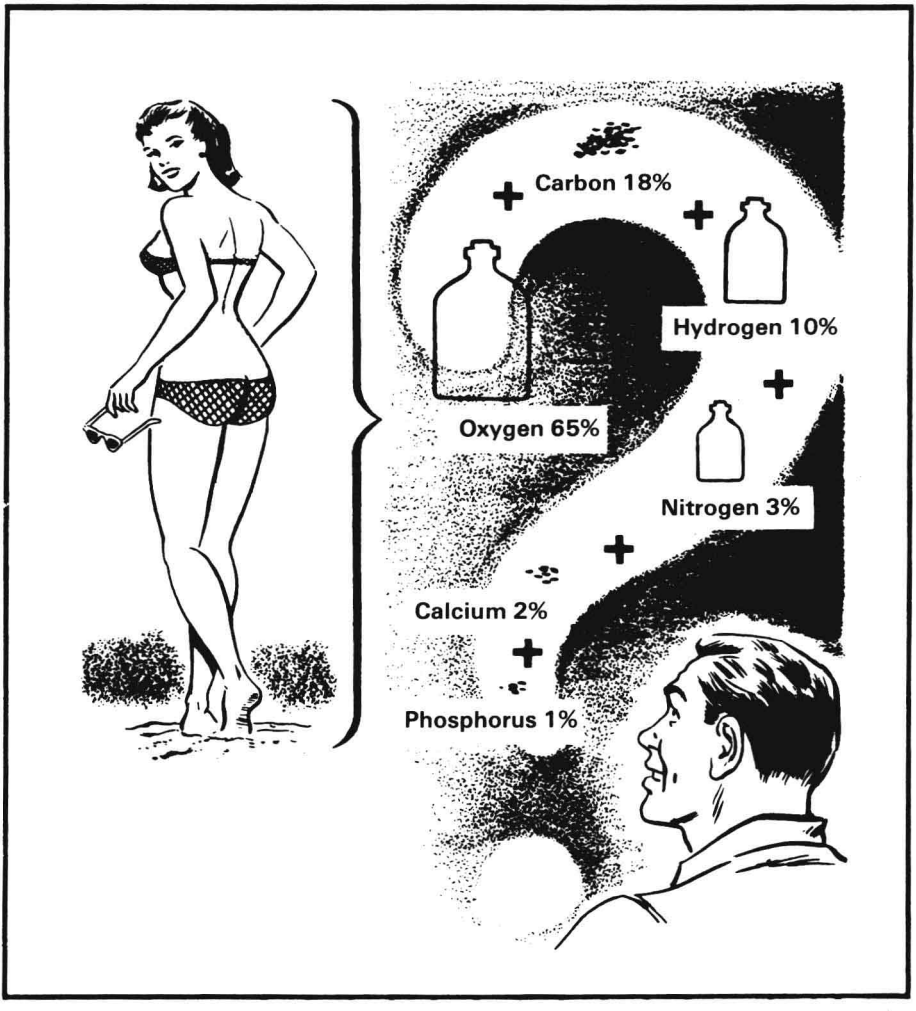
The Structure of the Molecule (*continued*)

While water is made up of only two kinds of atom—oxygen and hydrogen—the molecules of many other materials are more complex in structure. Cellulose molecules, for instance, the basic molecules of which wood is made, consist of three different kinds of atom—carbon, hydrogen and oxygen.

All materials are made up of different combinations of different atoms to form molecules of the materials.

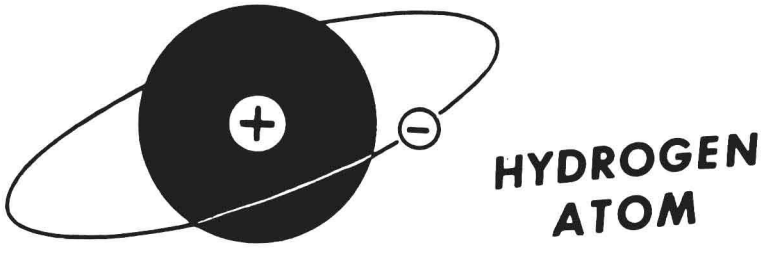
There are just over 100 different kinds of atom. They are known as *elements*. A Table of them all is given on page 1.127. You will see that oxygen, carbon, hydrogen, iron, gold and nitrogen are all elements.

The human body with all its complex tissues, bones, teeth, etc., is almost entirely made up of only fifteen elements, and only six of these are present in any quantity.



The Structure of an Atom

Now take one of the two smaller atoms in your molecule of water. Here is what it would look like under enormous magnification.



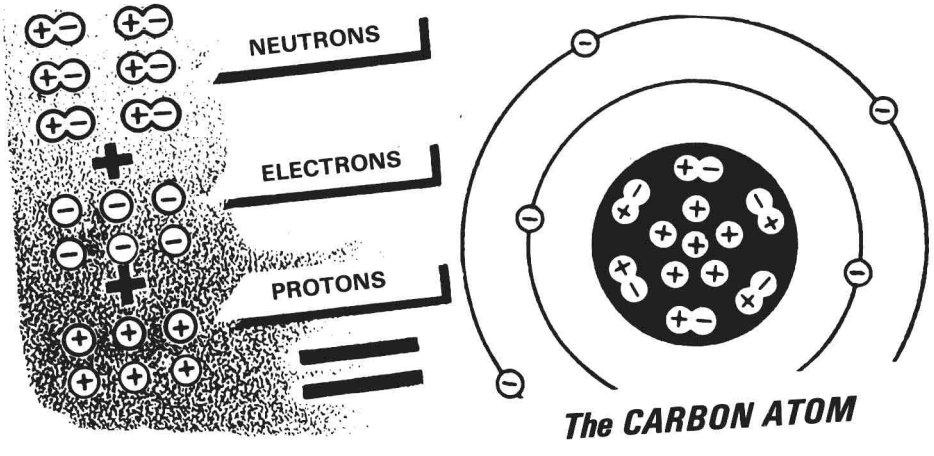
You will see that this particular atom is like a sun with one planet spinning round it. The 'sun' represents the nucleus of the atom, and the 'planet' is the single electron which is all that a hydrogen atom possesses.

This electron carries a *negative* (—) charge of electricity, while the nucleus is *positive* (+) in charge.

In all atoms, the negatively-charged electrons circle round their positively-charged nucleus at distances which are very great indeed compared with the sizes of the nucleus and of the electrons themselves. The result is that most of the bulk of any atom, tiny though that is, consists of empty space. You will get an idea of the scale involved if you think of the nucleus as a ship in the middle of the English Channel, and of the electrons in the outer orbit of an atom as bathers on the beaches of Dover and Calais.

In all atoms, the total number of negatively charged electrons normally circling the nucleus exactly equals the number of positive charges on the nucleus. These positive charges are called *protons*.

Besides the protons, the nucleus also contains electrically neutral particles called *neutrons*, which are like a proton and an electron bonded together. Atoms of different elements contain different numbers of neutrons within their nucleus, but the number of electrons spinning about the nucleus always equals the number of protons (or positive charges) within the nucleus.



Electric Current

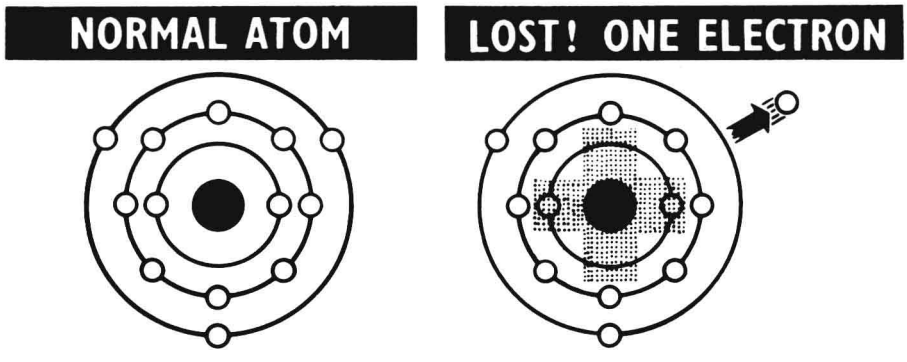
All atoms are bound together by more or less powerful forces of attraction existing between the nucleus and its electrons. Electrons in the outer orbits of an atom, in particular, are attracted to their nucleus much less powerfully than are electrons whose orbits are nearer the nucleus.

In certain materials (they are known as 'electrical conductors') these outer electrons are so loosely bound to their nucleus that they can quite easily be forced away from it altogether, and left to wander among other atoms at random.

Such electrons are called 'free electrons'. **It is the directional movement of free electrons in a conductor which makes an electric current.**

Electric Charges

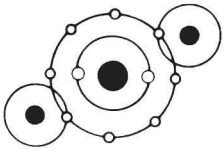
Electrons which have been forced out of their orbits create a deficiency of electrons in the atoms which they leave, and will cause a surplus of electrons at the point where they come to rest. A material suffering a **deficiency** of electrons becomes *positively* charged; and one possessing a **surplus** of electrons becomes *negatively* charged.



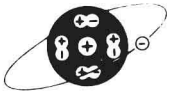
When an atom loses an electron, it loses a negative charge. The part of the atom left behind therefore ceases to be electrically balanced, for its nucleus remains as positive as before, but one of the balancing negative charges has gone. It is therefore left positively charged. This positively charged body is called a *positive ion.*

In solid materials, ions are held in place by the crystalline structure of the material and therefore do not move as free electrons do. In liquids and gases, however, ions can move like electrons and contribute to current flow.

REVIEW of Electricity—What is it



1. ***Molecule.*** **A combination of two or more atoms. The smallest unit into which a substance—such as water—can be divided without losing its identity as that substance.**

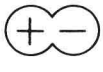


2. ***Atom.*** **The smallest particle into which an element—such as hydrogen—can be divided and still retain its original properties.**

3. ***Nucleus.*** **The relatively heavy positively-charged central part of an atom.**

4. ***Proton.*** **The relatively heavy positively-charged particles in the nucleus.**

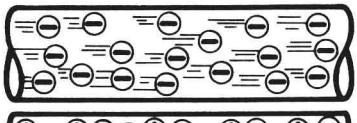
5. ***Electron.*** **The very small negatively-charged particles which, practically weightless, circle in orbits round the nucleus of an atom.**



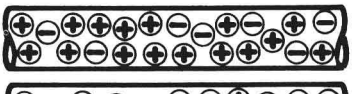
6. ***Neutron.*** **The relatively heavy neutral particles in the nucleus of an atom that behave like a combination of a proton and an electron.**

7. ***Bound Electrons.*** **Electrons held fast in their orbit round the nucleus of an atom.**

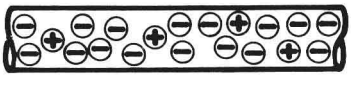
8. ***Free Electrons.*** **Electrons which have left their orbit round the nucleus of an atom and are wandering freely through the material of which they form part.**



9 ***Electric Current.*** **The directional movement of free electrons in a conductor.**



10. ***Positive Charge.*** **A deficiency of electrons.**



11 ***Negative Charge.*** **A surplus of electrons.**

SELF-TEST Review Questions

1. **What is an element?**
2. **What is a molecule?**
3. **What electric charge is there on the nucleus of an atom?**
4. **What electric charge is there on an electron?**
5. **What electric charge is there on a proton?**
6. **What electric charge is there on a neutron?**
7. **What are free electrons?**
8. **What is a positive charge?**
9. **What is a negative charge?**
10. **Define an electric current.**

HOW TO TACKLE SELF-TEST REVIEW QUESTIONS

You would do well to write out your answers to all the Self-Test Review Questions in this book on a sheet of paper. The answers to all of them are contained in the Section you have just studied.

If you find difficulty with any of your answers, go back over the Section, locate the difficult fact or concept, and then write out the correct answer or definition on to your sheet of paper.

In this way, you will begin to LEARN BY DOING — provenly one of the most effective ways there is of retaining in your memory facts which you have first learnt by hearing or reading.

THE NEXT STEP

You have just learnt that an electric current is caused by the flow of a great many free electrons, all carrying a negative charge of electricity and all moving in the same direction when they come under the influence of an electric force.

You must now see what electric charges are — how they are generated, how they behave and how they can be made to move from place to place. You will also learn the very important fact that electric fields exist around a charged body.